



EPOC 2018

BRIJUNI, CROATIA

CONFERENCE PROCEEDINGS

Conference Agenda

EPOC 2018 – Engineering Project Organizations Conference

Date: Monday, 25/Jun/2018

2:00pm	Opening EPOC 2018: Opening Ceremony Location: ROOM VERIGE		
2:15pm	Chair: Prof. Anita Ceric, Faculty of Civil Engineering, University of Zagreb, Croatia		
2:15pm	Early Career Location: ROOM VERIGE		
3:15pm	Chair: Prof. Carrie Dossick, University of Washington, United States of America		
3:15pm	Break		
3:45pm	Session_1A: Innovation&Growth Strategies Location: ROOM VERIGE		
3:45pm	Session_1B: Life Cycle Value & Governance Location: ROOM SALINE	Session_1C: Project Networks Location: ROOM GRADINE	
5:25pm	Chair: Dr. Paul W. Chan, The University of Manchester, United Kingdom	Chair: Prof. Amy Javernick-Will, University of Colorado Boulder, United States of America	Chair: Dr. Vedran Zerjav, UCL, United Kingdom
	Biased? Biased? Everything is Biased! Unpacking Ontological and Epistemological Perspectives in CEM Research <u>Fred Sherratt</u> , Robert Leicht	Avoiding Failure: The Use of Qualitative Comparative Analysis to Identify Pathways to Successful Sanitation Interventions <u>Allie Davis</u> , Amy Javernick-Will, Sherri Cook	Public Private Partnership Field Evolution Viewed Through a Strategic Niche Management Perspective <u>Amritha John</u> , Ashwin Mahalingam
	Investigating Collaborative Challenges on a Large International Joint-Venture Construction Project <u>David Christopher Oswald</u> , Fred Sherratt, Simon David Smith	Is "Being Green" Rewarded in the Market?: An Empirical Investigation of Decarbonization and Stock Returns <u>Soh Young In</u> , Ki Young Park, Ashby Monk	Revisiting the Relationship between Contract Governance and Contractors' Opportunistic Behavior in Construction Projects Yu Wang, Yongqiang Chen, <u>Wenqian Wang</u> , Yuting Chen, Mengxia Jin
	Learning Effects in Contractual Design in Construction Projects: An Empirical Investigation <u>Yu Wang</u> , Yongqiang Chen, Shuibo Zhang, Wenqian Wang	Operationalizing Prototyping as a Design Method for Sustainable Infrastructure Projects <u>Miguel Andres Guerra</u> , Tripp Shealy	Rethinking Roles and Responsibilities in the Context of the Public Private Value Shift from a Client Perspective <u>Lizat Kulter</u> , Leentje Volker, Marteen. H. Hermans
	Incorporating Stakeholder Interests: What is the Role that Material Artefacts Play in Public Engagement Settings? <u>Vivien W. Y. Chow</u> , Roine Leiringer	Understanding Who is the Client in Megaprojects <u>Juliano Denicol</u> , Stephen Pryke, Andrew Davies	Project Capabilities and Leadership: A Mixed-Methods Systematic Literature Review <u>Francesca Vinci</u> , Vedran Zerjav, Andrew Davies
7:00pm	Welcome drink: & Dinner after 20:00		

Date: Tuesday, 26/Jun/2018

7:30am	Breakfast		
8:30am			
9:00am	KEYNOTE LECTURE: "The National Ignition Facility: A Paradigm for Managing Risk in High Technology Projects", Edward Moses, Ph.D. Longview Consulting, Inc. President Location: ROOM VERIGE		
9:45am	Chair: Prof. Anita Ceric, Faculty of Civil Engineering, University of Zagreb, Croatia		
10:00am	Session_3A: Innovation&Growth Strategies Location: ROOM VERIGE	Session_3B: Life Cycle Value & Governance Location: ROOM SALINE	Session_3C: Project Networks Location: ROOM GRADINE
11:15am	Chair: Prof. Carrie Dossick, University of Washington, United States of America	Chair: Prof. Irem Dikmen, Middle East Technical University, Turkey	Chair: Dr. Bryan Franz, University of Florida, United States of America
	Boundary Spanners in Learning Temporary Organizations <u>Natalya Sarogayeva</u> , Jens Roehrich	(Re)Assessing Public-Private Partnership Governance Challenges: An Institutional Maturity Perspective Carter Boon Casady, <u>Kent Eriksson</u> , Raymond E. Levitt, W. Richard Scott	Building a Cooperative Culture through the Construction Supply Chain <u>Magnus Hellström</u> , Gerli Hannås, Grethe Friesli
	Examining 'Technology Transfer' on Construction Projects: Insights from a SCOT Enquiry. <u>Kwadwo Oti-Sarpong</u> , <u>Roine Leiringer</u>	Built Back Better? An Analysis of Perceived Performance of Post-Disaster Housing <u>Castle Venable</u> , Amy Javernick-Will, Abbie Liel	"It's Just Paint, Right?" An Empirical Examination of Institutional Mismatch, Bureaucratic Coordination, and Social Management <u>Brittany Nikole Montgomery</u>
	Collaborative Skills and Digital Technologies in Teaching And AEC Practice – A Comparative Study <u>Iva Kovacic</u> , Theodora Spyropoulou, Michael Filzmoser, Therese sulzer	Mapping Regulatory-Related Interactions of Stakeholders for Temporary Accommodations: A German Case Study <u>Miriam E. Hacker</u> , Jessica Kaminsky, Kasey Faust	Community Investment: Addressing Principal-Agent Issues during Local Infrastructure Delivery <u>Kathryn Elizabeth Gasparro</u>
11:15am	Break		
11:45am			
11:45am	Session_4A: Innovation & Growth Strategies Location: ROOM VERIGE	Session_4B: The New Project Manager Location: ROOM SALINE	Session_4C: System Integration Location: ROOM GRADINE
1:00pm	Chair: Prof. Kent Eriksson, Stanford University, United States of America	Chair: Prof. Steve Rowlinson, Hong Kong University, Hong Kong S.A.R (China)	Chair: Prof. Iva Kovacic, TU Wien, Austria
	Rotating Leadership to Build Relational Capital and Enhance collaboration in project alliancing. <u>Tingting Cao</u> , Lianying Zhang	Owner Commercial Capabilities in Chinese Construction Practice <u>Sujuan Zhang</u> , <u>Roine Leiringer</u>	Building Information Modelling, Data - and Stakeholder - Management Framework for Material Passports <u>Melita Horic</u> , Iva Kovacic, Helmut Rechberger
	The First Cracks in the Mirror: A Conceptual Overview of the Ongoing AEC Industry Reorganization <u>Daniel Hall</u>	Success Factors for Cross-Functional Teams in the Construction Industry: A Literature Review <u>Joseph Olopade</u> , <u>Bryan Franz</u>	Legitimization of the Inclusion of Cultural Practices of Displaced Persons in the Planning of Water and Sanitation Services in Accommodation
	Engaging Public Bodies as Intermediaries for Durable Innovation: A Case of Opening up Innovation in the Nuclear Decommissioning Sector <u>Paul W. Chan</u> , Kate Lawrence	Factor and Actor Networks: Alignment of Collaborative Water Partnerships in Ethiopia <u>Kimberly Pugal</u> , Amy Javernick-Will, Jeffrey Walters, Karl Linden	Affordability and Sustainability: The Context of Technology <u>Michael Puddicombe</u> , Peter Lalime, Charles McAuley

Date: Wednesday, 27/Jun/2018

7:30am - 9:00am	Breakfast		
9:00am - 10:15am	Session_5A: Innovation & Growth Strategies Location: ROOM VERIGE Chair: Dr. Sinem Mollaoglu , Michigan State University, United States of America	Session_5B: Life Cycle Value & Governance Location: ROOM SALINE Chair: Dr. Ashwin Mahalingam , IIT Madras, India	Session_5C: The New Project Manager Location: ROOM GRADINE Chair: Dr. Eleni Papadonikolaki , University College London, United Kingdom
	Contradictions in Project Based Learning: A Qualitative Study of Three City Development Projects Ljzet Kuljeri , Thijs Willems, Leentje Volker, Marleen Hermans, Alfons van Marrewijk	Determining Resource-Needs in Refugee Camps: A Study of Refugee Camps in Greece Michael Robert Ward , Cristina Poteacovschi	Using the Case Method in Teaching Project Management at Graduate Level: Early Lessons Tiendung Lo , Dallas Wingrove
	Horizon 2020 Transcended: The Redesign of the AEC Organization Robert C. Pouliot , Constantine John Katsanis, Alexander Katsanis	Worker Engagement on Construction Sites – Time for a New Look Steve Rowlinson	Designing Project Management for Next Generation Project Managers Louis Lousberg , John Heintz
	Boundary Spanning and Knowledge Brokering for BIM Innovation in Firms Eleni Papadonikolaki , Ammar Azzouz	Building in Uncertainty: Dilemmas That National Leaders Face in Resolving Competing Agendas of Project Sponsors Michael Hannaken	Assumption-Based Thinking for Project Risk Assessment Irem Dikmen , M. Talat Birgonul
10:15am - 10:45am	Break		
10:45am - 12:00pm	Session_6A: Project Networks Location: ROOM VERIGE Chair: Prof. Mladen Vukomanovic , University of Zagreb, Croatia	Session_6B: System Integration Location: ROOM SALINE Chair: Prof. Andrew Edkins , UCL, United Kingdom	Session_6C: The New Project Manager Location: ROOM GRADINE Chair: Dr. Michael Puddicombe , Norwich University, United States of America
	Collaborative Delivery Practices, Goal Alignment, and Performance in Architecture, Engineering, and Construction Project Teams Anthony Sparkling , Sinem Mollaoglu	Intentions and Behaviors Toward Fecal Sludge Management in Rural Communities James Harper , Angela Bielefeldt, Amy Javernick-Will	Building Project Management Skills in University programs: Conceptualisation of an Embedded System Simulation (RES-SIM) Sillimont Kanjanabootra , Jason Von Meding, Vanessa Cooper
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BIASED? BIASED? EVERYTHING IS BIASED! UNPACKING ONTOLOGICAL PERSPECTIVES IN CEM RESEARCH

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BIASED? BIASED? EVERYTHING IS BIASED! UNPACKING ONTOLOGICAL PERSPECTIVES IN CEM RESEARCH

Dr Fred Sherratt¹ and Dr Robert Leicht²

ABSTRACT

Methodological debates are nothing new in CEM research. However, when the consequences (and at times even the content) of such debates are considered, what often emerges is both a superficiality and inconsistency in the way research methodologies are understood, mobilised and used to judge the rigour and value of empirical work. CEM research seems reluctant to engage with the nature of reality, the nature of knowledge, or indeed with any philosophy at all. This paper explores and considers the influence, or lack of influence, that ontological and epistemological positioning has on much of our CEM research, and what that means for the findings we generate. With an explicit focus on bias, and the approaches taken within a volume, 173 manuscripts, of the *Journal of Construction Engineering and Management* are examined. We argue that multi-methodological perspectives on a problem should be adopted where possible, able as they are to generate more holistic understandings and more comprehensive illuminations of phenomena in practice, and thereby support the development of a more mature CEM research discipline, both in terms of academic scholarship and relevance to practice.

KEYWORDS

Bias, Epistemology, Methodology, Research Paradigms

INTRODUCTION

Methodological debates are nothing new in academia, and the field of construction and engineering management (CEM) is no different. From the flurry of articles published in the pages of *Construction Management and Economics* in the mid-1990s (Seymour et al 1997; Runeson 1997; Seymour et al 1998 etc.), to the special issue on methodologies published by the *Journal of Construction Engineering and Management* in 2010 (Taylor and Jaselskis 2010), researchers continue to question

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and challenge how we do what we do, and whether it is, all things considered, the best way to be doing it.

However, when the content and consequences of such debates are considered, what often emerges is both a superficiality and inconsistency in the way research methodologies are understood, mobilised, and used to judge the rigour and value of empirical work, particularly by construction engineering and management (CEM) researchers. Whilst the grounding of much of our research within schools of science and engineering has to some extent inevitably cast our footings within realist ontological and positivistic epistemological paradigms, these are now as much beneficial supporting structures as they are the ties that bind.

It is our intention within this paper to reveal the contemporary methodological state of our discipline, to expose the ontological and epistemological foundations that are currently underpinning our work through an empirical review of publications in the *ASCE Journal of Construction Engineering and Management*, focusing on the 2017 issue. Through this process the influence, or lack of influence, that this philosophical positioning has on much of our CEM research is revealed. We have chosen to highlight one consideration of academic quality within our discussions: that of bias. Bias is a highly revealing term within any academic research, as it is often only through the positioning of bias within empirical work that underlying methodology is revealed. It is also the methodological positioning of the work that determines the criteria by which bias should be evaluated, accepted or eliminated, and so judgements of quality made from this perspective should be made using fundamental philosophical understandings. Problems occur when such assessment is made absent philosophy or even methodology, for example, to judge constructionist work (grounded in a relativist ontology) by positivistic (grounded in a realist ontology) criteria would inevitably bring challenges of bias due to the involvement of the researcher in the research despite the fact that no claim to objectivity is, or even is ever made from within this paradigm. The ultimate impact of these shortcomings in understanding and presenting bias in research is the degradation of the quality of CEM research through either neglect or ignorance of the ontological and epistemological foundations upon which the research is intended to build.

Furthermore, we seek to challenge the notion that positivistic research can even itself ever be truly free from bias from both ideological and practical perspectives, given the very nature of CEM research, and suggest that perhaps that too should also be more clearly acknowledged in the research we undertake.

CONTEXT

We must firstly dispel the notion that this paper is a championing or derogation of one research methodology over another. We fully support the argument that multi-methodological perspectives on a problem should be adopted where possible and practicable, able as they are to generate more holistic understandings and comprehensive illuminations of phenomena in practice (as proposed by Edum-Fotwe et al, 1997; Seymour et al, 1997; Dainty, 2008 among others). This argument seems to have gained a general acceptance, as evidenced by, for example, the 2010 *Journal of Construction Engineering and Management* special issue (Taylor and Jaselskis, 2010) and generating research that seeks to draw on a variety of methodological perspectives.

However, the engagement of CEM researchers with methodology, as it defines itself, still seems problematic. As a field, we still seem reluctant to accept that, as Green et al (2010:125) stated at the very end of their contribution to the JCEM special issue: “all research methodologies operate on the basis of underlying assumptions about the nature of reality and the ways in which it can be accessed.” Yet dalliances with the nature of reality, the nature of knowledge, or indeed with any philosophy at all, still remain a rare find within our research outputs.

For example, within the same CEM special issue Abowitz and Toole (2010) provide an excellent reminder of the need for rigorous and robust considerations of sample, operationalisation of indicators, and testing of empirical data, but these are not themselves philosophical concerns. Despite the authors’ use of the term ‘methodology’ within the paper, they actually present discussions about the validity and reliability of various methods as mobilised within a realist ontology and positivistic epistemology, a methodology which itself remains unacknowledged. Whilst these discussions are certainly most welcome, given the many weaknesses in research of this kind as it is frequently executed, it is the unspoken adoption of positivism as *the* default methodological position that has further consequences for CEM research overall, including those around the concept of bias.

A NOTE ON QUANTITATIVE AND QUALITATIVE DATA

Another commonplace, and potentially much more problematic example, is the notion that there are such things as quantitative and qualitative ‘methodologies.’ This is a conceptualisation that emerges frequently in CEM research, and one that should be robustly challenged: they are simply different types of data (i.e. numbers or words) and nothing more. *How* you collect and analyse that quantitative or qualitative data, within the accepted practices and protocols of your stated research paradigm and its parameters of validity, reliability and generalisability, to ultimately support the claims then made - *that* is methodology. However, statements such as ‘quantitative and qualitative methods are rooted in particular ontological and epistemological positions’ (Zou et al 2014:320) can be found within CEM methodologically-focused papers (the example of Zou et al 2014 specifically focuses on methodologies as associated with health and safety research within construction), despite the fact that qualitative data can be, and indeed frequently is, treated as positivistically as quantitative data in many cases. Indeed, this means that the assumption that one can use ‘research methods as a proxy for research methodologies’ (ibid 2014:322) is spurious at best. Although there may indeed be ‘traditional’ associations, the use of ‘qualitative research’ (a label which is itself methodologically meaningless) does not reflect methodological diversity in and of itself, despite claims to the contrary (Fellows and Liu 2008). In fact, the straightforward adoption of ‘social science approaches’ to CEM research was always unlikely to bring significant methodological change as despite more widespread use of qualitative data much of sociology, psychology and other disciplines within this field remain highly positivistic in terms of their underlying realist ontology (Augoustinos et al, 2006). We have, in many cases, simply adopted more of the same approaches, yet methodologically claimed otherwise.

HAVEN'T WE BEEN HERE BEFORE? HOW BIAS CAN HELP

Such struggles with methodology are perhaps unsurprising within CEM research outputs, given that it is a field that sits at the intersection of physical and social sciences (Love et al 2002), and as noted these struggles have been explored before. However, this does not mean we should consider such debates and discussions 'done with', particularly when the consequences of such methodological ossification continue to have ongoing repercussions for current research direction and the shape of CEM research as a whole.

We now continue to develop our discussions of methodology around the aspect of bias. Bias, quite simply, is "any tendency which prevents unprejudiced consideration of a question," (Dictionary.com, 2018). As bias involves the introduction of a systematic error within empirical work by selecting or encouraging one outcome over another (Merriam-Webster, 2018), it can therefore significantly affect the validity of the work. Bias is particularly important as its use, or misuse, enables the labelling of 'good' or 'bad' research, and as such can be considered a significant contributor to the outputs and shape of our research field. Bias is here explored from ontological perspectives, the level of methodological grounding which sets out what Green et al (2010) encouraged us to evaluate: the assumptions about the nature of reality itself.

BIAS WITHIN REALIST (AND RATIONALIST) ONTOLOGY

Realist ontology asserts that there is a real world 'out there', an objective reality that exists independently of those who inhabit it (Runeson and Skitmore, 2008). This acceptance in turn prescribes that there are ways to determine the 'rules' that govern this reality and dictate how variables will interact therein: as articulated through positivist epistemology. Realist ontology forms the foundations of what is often considered to be 'true' scientific enquiry – and the laws of physics, chemistry, engineering, etc. all ground themselves within this paradigm.

Developed from realist foundations are notions of post-positivism (Love et al, 2002), an epistemological position which grounds itself in a rationalist ontology which is more accepting of the 'complexities' of reality, particularly those that involve people and social phenomenon. Rationalism proposes that social representations are underpinned by an objective reality and, although there is an acceptance that such representations may not necessarily be 'true', the understanding remains that through positivistic explorations of such representations, drawing on the notion of the 'mind as a mirror' (Rorty, 2009) which accurately reflects the world as it is (Gergen, 1999), knowledge can still be gained about reality.

Yet in order to maintain an approach which seeks to empirically verify a real world, scientific considerations of control, standardisation and objectivity are required and so bias is something to be clearly acknowledged, avoided and eliminated. It is something to be designed out of studies, through the precise and considered collection of appropriate data, using appropriate methods, from representative samples and ensuring the carefully managed interactions of researchers with their participants (Oppenheim, 1992). As previously noted, Abowitz and Toole's (2010) paper is itself grounded within a realist ontology and so also, quite rightly, they make a clear evaluation of bias from within this paradigm, specifically highlighting issues of individual bias in self-reported data as well as bias inadvertently introduced during

the data collection process by the design of the data collection tool or the researcher themselves.

When qualitative data is sought from within a rationalist ontological perspective, management of bias is just as critical, as the same quality measures remain as valid as if the data were quantitative. For example, when qualitative data is sought through interviews, researcher bias can be introduced in myriad ways including inadvertent changes in question structure, intonation, body language, and even the researcher themselves – their gender, race or age also has the potential to be influential in the responses given depending on the composition of the sample (Kvale, 2007).

Bias unarguably has a significant role to play in research grounded in a realist or rationalist ontology, and a lack of attention to bias can easily make the difference between ‘good’ and ‘bad’ research. The way in which biases have been controlled within any research study should be clearly explicated, and as recent missives on the CNBR network have shown, noting issues such as bias in sampling (Holt, 2018), generalisation, response rates, methods of analysis and use of literature to support the researchers’ own bias (Edwards, 2018), this remains an ongoing concern in our field.

BIAS WITHIN RELATIVIST ONTOLOGY

Relative ontology asserts that even if the external world of realism should exist, it is completely inaccessible. All that can be accessed are the representations themselves, as set out within the rationalist position, but rather than accepting such a ‘frame’ in order to access reality, relativism instead argues that such representations cannot be judged or evaluated for their validity or accuracy (Burr, 2003). In challenging the concept that knowledge is a direct perception of reality, the only realities become those which are constructed by individuals or societies in specific contexts (Gergen, 1999). They are therefore in constant flux; there is no such thing as an objective reality or fact (Burr, 2003), instead within a relativist paradigm there are multiple realities and therefore multiple truths (Taylor, 2001).

Such an approach does not negate the validity or utility of research grounded in this paradigm. Commonplace within social sciences, research grounded in relativist ontology has been used to develop different practices and interventions to produce change and solve problems in various social contexts (Gergen and Gergen, 2004; Wiggins and Potter, 2007), including developing recommendations for training and the design of work environments and equipment (Taylor, 2001), and UK Government reviews of child abuse within society (Stainton-Rogers and Stainton-Rogers, 1999).

This ontological position naturally also has consequences for bias. As noted, from within a relativist paradigm there is no single truth, no one ‘reality’, and we cannot go ‘beyond’ the representational data to make interpretations or seek ‘facts’; therefore bias in this context differs significantly in its conceptualization from bias as it affects methodologies grounded in realist or rationalist ontologies. For example, bias within the data as collected is inevitably mitigated by the collection process, as naturally occurring data which has not been generated by the researcher for the purposes of the research is prioritized, and therefore has no researcher bias associated with it (Potter and Mulkay, 2007). Where data is elicited, for example through interviews, the approach is also very different as the role of the interviewer within the interview has to be considered and so the interaction is analysed as a whole, considered as an interactional and active engagement (Potter and Hepburn, 2005; 2007) in which the

researcher is as important as the interviewee. Once the notion that interviews can reveal ‘the truth’ is abandoned, then there is no need for complex approaches to attempt to remove issues of bias, and interviews can instead be used to explore the participants variable interpretive practices they employ to construct their versions of the social world through conversation (Potter and Mulvey, 2007).

Within the relativist paradigm researchers cannot extract themselves from the research, it is simply considered impossible, and this has therefore led to the inclusion of reflexivity within the research process (Taylor and Bogdan, 1998; Gibbs, 2007). Any account of a social phenomenon will inevitably reflect researchers’ partial understandings or special interests in the situation (Taylor, 2001) as well as be influenced by their cultural, social, gender, class and political position (Creswell, 2007). Therefore, reflexivity is a necessity, and researchers should clearly position themselves in the project – clearly stating and reflecting on their own motivations, background and therefore ‘biases’ (Denzin and Lincoln, 2005) as may affect the research and the research process. Indeed, the need for reflexivity has been called for from within CEM research itself, where qualitative research is still being undertaken from an alleged objective and bias-free perspective (Dainty, 2008).

Such open and explicit acknowledgement of bias within relativistically-grounded research means that no claim is made to ‘objectivity’, as that would be nonsensical, and so instead trustworthiness, credibility and dependability are put forward as suitable replacements for validity (Lincoln and Guba, 1985), demonstrated through clear explications of method, analysis and discussion. Findings are not seeking ‘truth’ but instead trying to find ‘fit’ with shared understandings, a process validated by ‘member-checking’ (Creswell, 2007) with those who experience the phenomenon under scrutiny on a regular basis.

Yet despite the fact that ontological positioning has such a significant influence on bias, the lack of understanding and acceptance of this philosophical fundamental within the CEM research does at times lead to the same challenges as raised by Runeson (1997), who claimed that any alternative approach to research from realist ontological perspectives would be ‘anti-scientific’, and that such traditional methods were the ‘...best insurance against bad research’ in CEM. To claim that research which seeks opinion as ‘subjective’ and ‘biased’ (Runeson, 1997) simply does not address the wider methodological paradigm that may have been mobilised, and does not acknowledge that there are equivalent standards of rigour and quality that should be met within such approaches (Seymour et al, 1998). To judge research grounded in a relativist ontology by the standards of that grounded in a realist ontology, standards that it has not set for itself, will, where bias is concerned, always be found wanting.

BIAS INHERENT IN CEM RESEARCH

The function of CEM research is often considered to be ‘... to improve the effectiveness and efficiency of the construction industry’ (Lucko and Rojas, 2010:127). We are an applied field, and therefore our research should be relevant and useful (Edum-Fotwe et al, 1997). If our outputs are not useful, then ‘... research may fail to inform the development of approaches which resonate with practice perspectives’ (Zou et al, 2014:316).

However, this arguably creates bias within the field in a number of ways. Bias towards research that has the ability to add commercial value through action-oriented

outcomes (Edum-Fotwe et al, 1997:450) inevitably means our research is perhaps not asking the awkward and challenging questions it should on behalf of the workers to improve their lot, rather than the lot of the shareholders (Sherratt, 2017). That CEM workers are also hard to access, and do not have email, or spend much of their day sitting at desks with time to spend answering questionnaires or phone interviews, further skews CEM research as a whole, particularly in terms of sample compositions.

Bias is also generated by the need for ‘industry engagement’ and the perceived need to ‘...collaborate with industry practitioners to establish credibility’ (Lucko and Rojas, 2010:127), which in turn adds bias to which phenomena are deemed suitable or prioritized by industry for examination. Indeed, as Edum-Fotwe et al (1997:451) note ‘there is therefore an evolving situation whereby research in construction management has to rely on the partnership with industry not only for its relevance, but also for part or all of its funding’.

It would also probably not be too bold a statement to suggest that the construction and engineering industries do not care, or even want to care, about ontology. They want to support and fund research that proves things, that determines things, that can tell them that if you do (a) and (b) then (c) will follow, and so bring positive change to your organisation and its projects. Generalisability is therefore prioritised, as is a quest for ‘facts’ and the ‘truth.’ Yet this generates a clear bias in the methodological design used in CEM research, as research grounded in a realist ontology will allow you to do just that, rather than present the more nebulous, yet equally valid, conclusions that can be drawn from relativist work.

However, as noted in the introduction, doggedly adhering to a realist ontology may not always be the ‘best way to do it.’ The requirement for CEM research to also consider the social are well noted, as is the argument that we should perhaps move away from the inevitable predisposition to measure people and their social world as if they were steel beams and superstructures, utilising ‘scientific’ methods to do so (Love et al, 2002). People are inconsistent, changeable, and awkward (Sherratt et al, 2012), they behave, and respond to questions or observations variably, depending on context, on who they are with, what they have been tasked to do, or even if anyone is watching them – in often highly discernible ways (Donaldson and Grant-Vallone, 2002). Therefore, applications of scientific approaches to people often prove pointless (Midgley, 2001). As Abowitz and Toole note, surveying people through positivistically developed constructs is a challenge, and that there are some constructs that simply cannot be measured directly (2010:111), even when using robust approaches from within that particular paradigm.

The fact that we are an applied field should make us all the more reflexive in the research we carry out, no matter where we have philosophically grounded ourselves. Not only should we continually make open and critical evaluations of what research we are doing, and why, and perhaps importantly who is paying for it, but also acknowledge the ways in which this influences our methodological approaches. The latter certainly has the potential to specify and perpetuate the dominant ontological paradigms within our field, and is likely to be a contributor to the self-perpetuating definitions of what makes ‘good’ CEM research and how it should be evaluated.

SUMMARY: EVERYTHING IS BIASED?

Here we have suggested that yes, perhaps everything is biased. There is bias within our dominant ontological paradigm of realism, and there is also bias within

research carried out from a rationalist perspective. In both cases there are ways to eliminate, mitigate or acknowledge such biases and it is the effectiveness of these actions should be used to judge the quality of the work, by the standards each paradigm sets itself. What is lacking in contemporary CEM research is perhaps the knowledge to make such judgements of ‘good’ and ‘bad’ research from within these different paradigms, as the continued assertion that ‘qualitative research’ is somehow inevitably methodologically different to ‘quantitative research’ appears to demonstrate.

That we are so reliant on industry engagement will also add bias to our work, in terms of what we study, how we are able to access such phenomena, and what research methods are deemed appropriate by those funding our work. Although many social sciences are highly accepting of the fact that people are variable and changeable and so realism is not the best foundation for their evaluation, industry demands actionable research. It still holds to the dream that ‘...all evils can be cured by appropriate technological steps’ (Berlin, 2001:52), which was imposed on society by the political misapplication of scientific game theory in the 1990s, and has led to the development of a target driven system that is currently failing, as people are simply not controllable in this way (Curtis, 2007).

Bias is therefore something that has the potential to influence the field of CEM research in a number of ways. It has the potential to define and shape our discipline, to set acceptable standards of ‘good’ and ‘bad’ research in terms of what and how we research. However as this paper suggests, everything is biased, and we are at risk of methodological ossification if we do not start to grasp methodology, philosophy and our understandings of reality with much more rigour. We now look to the current canon of work, and seek to evaluate the extent of this phenomena within our field.

THE STATE OF PLAY

METHOD

To provide some evidence of the current state of methodology, a review of current literature was undertaken. Considering the special ASCE Journal 2010 special issue on research methodologies, the most recent complete volume of JCEM was reviewed to explore the influence this special issue had on the field. All 173 research papers from 2017 were collected and reviewed with an emphasis on the language used to explicate the research design. The manuscripts were coded into a spreadsheet to capture common elements related to the research undertaken.

The process of reviewing a volume of JCEM manuscripts, out of necessity, required some procedural steps and guidelines to ensure consistency and reliability of the results. After collecting the full volume, each manuscript was coded into an excel spreadsheet to capture key factors - authors, number of authors (range of one to six authors, with a median of three), primary type of data (quantitative, qualitative, or mixed), and explicit reference to methodology. This was a simple requirement of whether the text used the word ‘methodology’ as the descriptor to define the research approach. In addition to reviewing each of the abstracts for the topic and approach, each manuscript was reviewed with a focus on the research process undertaken. While there was typically a specific section within each script, often titled ‘methodology’, ‘research process’, ‘research design’, or ‘research methods’, among

several other terms, many of the papers delved directly into the data collection or analysis without such a section preceding it. The papers were also reviewed to capture if their research design explicitly addressed methodology, or focused exclusively on the methods or techniques.

Beyond exploring the methodology, explicit references to epistemological viewpoints were sought, references to ontological positioning, and in particular the discussion of bias in any form. This was done first, by performing a review of the relevant research design sections and results, discussion and conclusions. To ensure the topics were not missed, an additional text-based search was conducted, focusing on these key terms and appropriate derivatives (methodology, epistemology, ontology, and bias) to attempt a complete capture of papers exploring explicit discussions of ontological or epistemological discussions.

FINDINGS

What are we doing?

To begin, a brief overview of the topics explored in a single volume of JCEM will help to provide suitable context for the positioning of the researchers, as well as the range of bias discussions that were, or were not, undertaken in the presentation of their research findings. The broad topics touched upon are highlighted in Figure 1, ranging from Safety (28%) as the most common topic, to materials applications (4%) and scheduling analysis (3%), with approximately 20% of the topics grouped under ‘Other’. This ‘Other’ categorization was needed to capture topics that were focus of papers but only occurred in one or two of the published manuscripts. The topics ranged from knowledge management, to quality, to international market share by contractors, to prefabrication, and culture. One of the elements that emerges from reviewing the topics, is more than 50% of the papers address social topics in some manner, from the safety of people on construction sites, to organizing or procuring project teams. Even amongst topics that could be identified as commonly fitting into realist, positivistic paradigms, such as economics, estimating, and technology, forays into human aspects such as assessing risk in project costs or financing, bid strategy, and factors affecting the adoption of technology were also often the focus of the research.

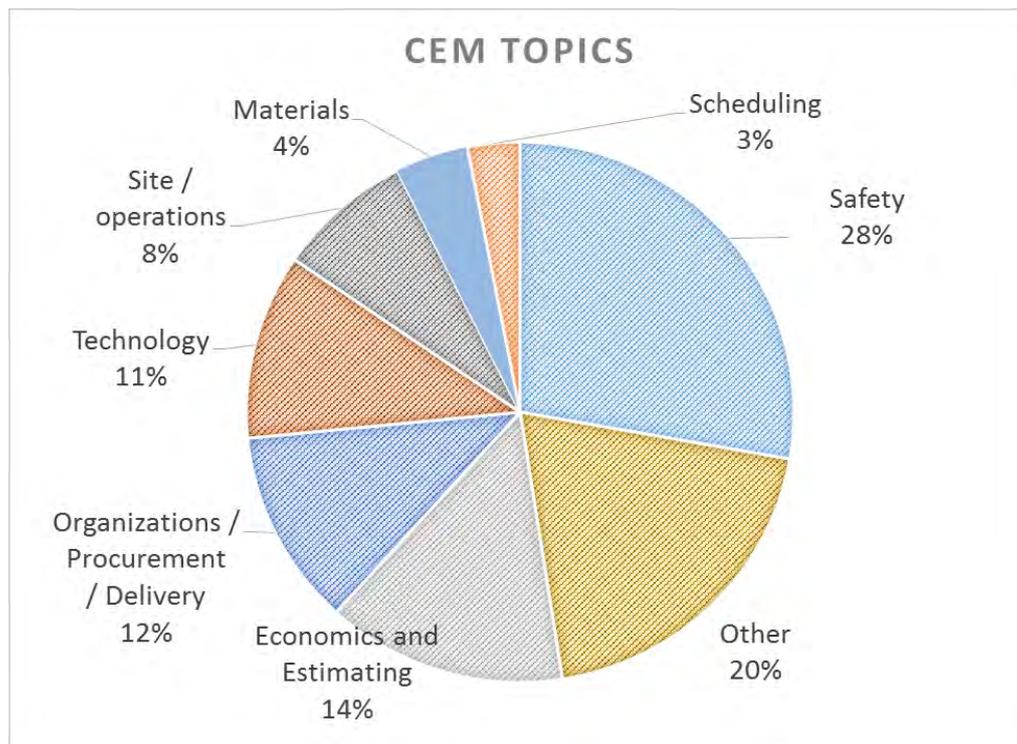


Figure 1: Topics addressed in the 2017 Volume of the *ASCE Journal of Construction Engineering and Management*

How are we doing it?

While methodology was explicitly referenced in 47% of the papers (excluding bibliographic citations), epistemology as an explicit term only occurred in two papers, and ontology in four. As Zou et al (2014) also found, many papers simply do not state a methodological position, but this can be determined through the method used, and claims made around reliability, validity, generalizability and also bias. In the volume analyzed, nearly half (47%) of the studied papers used the term methodology. However, less than five papers actually explicitly mobilized this methodology and linked it to theoretical and epistemological perspectives of the studied topics. The majority of papers simply assumed a positivistic epistemology and focused on analyzing quantitative data. 74% of papers used primarily quantitative data in the presented analyses, with another 18% using mixes of both qualitative and quantitative data. Even amongst the mixed methods papers presented, they frequently began with qualitative data, most often interviews, and moved to surveys or related methods to collect larger pools of quantitative data.

For many, a positivistic perspective and quantitative data were arguably very appropriate to the topic under examination. For studies that compare methods for compaction of soils (Karatai et al, 2017), computer modelling of the performance of asphalt or other materials (Imran et al, 2017), or the differentiation of empirical methods of schedule analysis (Ballesteros-Perez, 2017), positivism provides a highly appropriate lens for the analyses undertaken. However, less than 20% of the papers

focused on these type of studies, primarily in scheduling, estimating, or material-related research. In the remainder of the manuscripts, the epistemological position should be at the very least identified in order to clearly enable evaluation of the research itself, even if this is positivistic and not a theoretical lens we (the authors of this nihilistic treatise) would perhaps suggest as an alternative.

What of Bias?

Building upon this limited consideration of philosophical framing, across all of the papers less than 1/3 (28%) even raise the concern of potential bias in the research as part of their explicit discussions. Even amongst that 28%, four only mention bias in the context of the literature review or problems with bias identified in previous studies, without discussion of bias as present in their own work. Two papers note bias, without actually explaining the source or concern at all, much less how this potential bias was potentially mitigated or removed. Additionally, with the focus on quantitative data and analytical modelling, eight of the papers discussing bias focus on bias introduced in forecasting values using specific methods. These typically focused on bias introduced by selection of variables used to model forecasted values, such as cost estimates (Shrestha et al, 2017) or in a specific variable, such as timing of business cycles (Kapelko and Abbott, 2017).

The most common discussion of bias related to survey data collection, either in the selection of the respondents (8 papers), potential self-selection bias in the participants that respond (6 papers), and most commonly bias in the responses by the survey respondents (14 papers). In many cases, these discussions were reasonably well situated to highlight how bias was a concern regarding the topic selected, and the attempts made to mitigate or remove the bias in the approaches taken. For example, in Sunindijo's and Kamardeen's (2017) study of work stress on gender diversity, the researchers explicitly discuss their realist framing, employ a thoughtful survey design along with sampling and data collection process that Abowitz and Toole (2010) would applaud. Despite all of their efforts, they also include an explicit discussion of bias that highlights how the self-selection of the respondents could introduce bias into the sample simply through motivation to participate or that the subject matter might appeal to a specific audience. This reflexive element within the presented research provides a good example of the type of bias that perhaps needs to be better explicated in other CEM research.

At the other end of the spectrum, Leung et al (2017) in their study of stressors and performance in expatriates also employ a survey for data collection. However, they do not discuss their epistemological or ontological framing, and in their conclusions, state, "However, remedial actions have been taken to address the potential risk of common method bias...therefore, the final result of current study is reliable." This lack of discussion is challenging because the research process undertaken was well designed, employed purposive sampling, and applied appropriate analytical techniques to draw reliable conclusions. Building upon the concerns raised by Sunindijo and Kamardeen (2017), the self-selection of the respondents could have skewed the population toward either those who felt strongly about the topic, or due to its sensitivity, could also have skewed it away from participants that were themselves unduly stressed. In addition, while the conclusions are intriguing, the context of the

respondents, or the chosen location (Hong Kong) of the targeted expatriates could influence how the results are transferred to other regions.

Of the 50 or so papers even mentioning bias, very few actually identify bias as a concern to be raised as an element of the research process design, or as unique elements of the research topic and approach studied. An example of a paper that does examine bias is that by Karakhan and Gambetese (2017), which explores the potential for sustainable design to introduce safety risks in construction. The authors identify researcher bias in the evaluation of the safety risks associated with specific LEED points. In an attempt to eliminate the potential bias, the risks were verified through technical reports or publications linking the sustainable element associated with the LEED point to the safety risk. In a different approach to studying the effectiveness of safety, Marin and Roelofs (2017) identify the potential bias introduced by surveying participants immediately following safety training. To help combat this influence, the researchers performed time-lagged follow-up surveys six months after the training. Additionally, they point out the potential self-selection bias of the respondents that choose to participate in the lagged survey. These manuscripts stand out due to their identification of unique ways in which the researchers and the process could introduce bias to the specific research questions, and the authors demonstrate how they have attempted to remove or mitigate the bias through their research process.

What do we do about Bias?

Beyond the consideration of bias as an element to be considered in research design and selection of both methodology and methods, the approach to biases when raised was disconcerting. The over-reliance on Cronbach's alpha as the sole mechanism for demonstrating a lack of bias could be considered both alarming and disappointing. Originally developed in the context of psychometric tests in the 1950s, such as the five-factor model, Cronbach's alpha is generally used to determine the relation of a set of different measures or questions as an estimate of the average correlation for measuring a consistent construct (Nunnally, 1978). It has grown in use within the social sciences as an element of internal consistency for reliability of test scores – inter-correlations among test items should be maximized if the questions posed are measuring the same construct. However, there are numerous studies that show that Cronbach's alpha can take on high values even when measuring unrelated constructs (see for example Green et al, 1977; Schmitt, 1996). Even considering these limitations, there are multiple stages of the research process in which researcher bias can be introduced both before and after the data collection that would not be indicated in the measure.

Despite the limited explication of bias and philosophy amongst the pool of JCEM papers, there are several papers that are both well founded within theory and develop thoughtful research designs, e.g. Poleacovschi and Javernick-Will (2017) study how 'expertise' is assessed in the area of knowledge exchange within engineering firms. The authors take collect extensive qualitative data and quantitative data to pursue a hermeneutic methodology to the space that leads to both interesting and insightful considerations for how we frame the expertise of our colleagues. The authors explicitly note the use of 'reflective memos' as an element of the interview process. In the research design, the importance of the context and contextual sensitivity in the interview processes undertaken is explicit and considered in the analysis. The authors

further employ reflections of the interviews to build upon the best practices emerging from the methodologies employed in relativist interpretations that lend themselves to the question of how different individuals interpret ‘expertise.’ However, despite the well designed and executed study, the authors do a disservice to the CEM community by limiting their discussions of the issues of bias that are implied in the approach taken, and so they are unfortunately not explicated for the benefit of the wider community.

DISCUSSION AND CONCLUSIONS

There are several challenges that arise from such limited discussions of bias (and, of course, other benchmarks for research ‘quality’ that have not been explored here), and the underlying epistemological and ontological positioning of any research project.

Firstly, and perhaps most concerning, is the publication of research that contains critical flaws with relation to bias inherently within its design. For example, one paper presented research seeking to explore the relationship between cultural dimensions of the Hispanic construction workforce as an element of higher injuries and fatalities rates of Hispanic workers. The research design presents no information about the methodology employed and dives directly into the survey development process, focusing on testing the clarity of the questions and the survey distribution. When designing the actual data collection, the authors survey English-speaking managers, rather than the Hispanic workers to understand safety behavior. The authors then rely on these responses to interpret cultural challenges. In particular, the authors introduce bias in their expectation of culture as an explanation, and then wholly ignore more mundane explanations, such as the language barrier, that are also likely factors in the behavior observed by the managers that responded to the survey, serving as the sole source of data presented. As noted by Alsamadani et al (2013) – single language work crews have significantly higher safety performance than multilingual construction crews. It must also be noted that the authors of this initial paper did develop their work through another paper that helps address our areas of concern, by employing methods to engage the Hispanic workforce directly, in a different context (offsite) that explores their perceptions first-hand, however the fact remains that the first paper was published as a stand-alone submission.

However, it is surely the role of editors and reviewers (i.e. all of us within the CEM community) to ensure that benchmarks are in place to avoid such flaws, and to request more explicit discussion of research design within the methodology section of any submission. Perhaps the dominance of the positivistic paradigm has enabled and even supported a lack of attention to the fact that the potential for bias exists within it in a wide variety of ways, including those clearly set out by Abowitz and Toole (2010). Bias should therefore be explicitly addressed in positivistic research design, beyond simple Cronbach’s alpha testing, and we suggest reflections on bias should also take into consideration the funding of the research and its ultimate aims – be they interventions, process developments or other organisational changes.

As the prevalence of research of the people in construction grows, the ability to effectively design such research, as well as engage in meaningful analysis and discussion of the ontology and epistemology underpinning it, needs to be engendered in the CEM research community. This is perhaps not helped by the lack of clarity in how we articulate underlying research philosophy in our presented work; we do not

clearly set out the acknowledged quality benchmarks, and consequently what claims to validity, reliability and generalisability can actually be made, and so how they should be evaluated by our peers. Indeed, as Mahoney (1977) found, academics can be very strongly biased against research that reports results or findings that contradict their own theoretical perspectives, and so when a realist meets a rationalist, bias within our own peer-review processes is something of a predictable phenomenon.

Closer to home, EPOS needs to define what is important to the community – methodologically. ‘Social science informs the human context in which projects are completed’ (Chinowsky 2011:7), so where is the social science? Are we effectively conducting meaningful research within the EPOS community, and more importantly are we spreading the values, understanding, and proper conduct of research out into the broader community? But what will be accepted? Will unfamiliar methodologies be welcomed by editors and reviewers, or will they be judged by inappropriate benchmarks and so deemed bad research? Indeed, how do we combat the perpetuation of primarily positivist and realist paradigms in research when those are the dominant perspectives accepted for publications, that industry ‘understands’ and so funds, and which are therefore those measured for tenure or academic advancement?

BUT ARE WE NOT BIASED?

Of course we are! And so is this paper.

We selected ASCE JCEM as the primary venue for analysing lack of ontological and epistemological variety, knowing in advance that it was lacking. This was partly intentional, to highlight the extent to which the problem persists even within a community that, at least partially, recognizes its own limitations as noted by the 2010 Special Issue, yet seven years on things do not seem to have significantly changed.

We should also clearly position ourselves, the authors, within this research.

Fred Sherratt is a social constructionist, her work is firmly grounded in a relativist ontology and her research on safety explored how people construct this concept on construction sites, revealing it to be fluid, highly changeable and not at all as measurable as safety climate surveys may suggest. She has faced a lot of criticism of her work over the years, which apparently is not representative in terms of sample, not generalizable, and therefore ‘weak science’. These are all criticisms that she is very happy to accept if you are going to insist on judging her work on positivistic terms, but she would really rather you didn’t.

Rob Leicht is a construction engineer and recovering empirical positivist, having developed and published a number of studies that would clearly fit into the default CEM research paradigm. While having explored and pursued alternative methods over the years, such as one of the manuscripts in the JCEM special issue related to observational studies, he has only recently endeavoured to explore the paradigms and philosophical framing that give meaning to the data we collect and analyse.

This study is, perhaps surprisingly, grounded in a realist ontology and positivist epistemology. The empirical work involved counting, measuring, and the quantification of qualitative data (the papers) into statistics for analysis. Bias here was controlled by the method employed, keyword searches mechanising the process

and therefore removing researcher bias. But this was of course a highly appropriate, effective and insightful way to approach this phenomenon and our data, and that is our fundamental point. As noted, the sample carried bias in selection, but was purposeful given the noted special issue in the same journal several years before – partially to see how the results had been adopted into the community. In addition, we attempted to demonstrate examples of both alternative methodologies and well developed research designs that appropriately consider bias were present, though sparser than we would like (again – we’re biased).

We are ultimately advocating for multi-methodological approaches and well-designed research processes appropriate to the approach. Although we must acknowledge our inherent concern whenever positivist and realist perspectives are brought to bear on social topics within the CEM research community, There are a variety of topics in which this has and can continue to provide value, and it would be folly to advocating abandoning them wholly. However, we wish to see an increase in alternative approaches where appropriate paradigms are mobilised and even combined to provide a holistic evaluation of the phenomenon under scrutiny. Yet, for that to become a reality, we need to develop our understandings of what and how alternative methodological paradigms should be mobilised within their own definitions of validity, reliability, generalizability and, of course, bias. We therefore hope this paper is able to stimulate debate, but also champion tolerance and reflexivity in all that we do, and so support the development of a more mature and relevant CEM research discipline, in terms of both academic scholarship and applicability to practice.

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INVESTIGATING COLLABORATIVE CHALLENGES ON A LARGE INTERNATIONAL JOINT-VENTURE CONSTRUCTION PROJECT

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INVESTIGATING COLLABORATIVE CHALLENGES ON A LARGE INTERNATIONAL JOINT-VENTURE CONSTRUCTION PROJECT

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ABSTRACT

Construction project managers face complex challenges when trying to deliver best value to their clients. International joint venture (IJV) projects can be particularly complex due to differences in political, social, legal, economic, language and cultural expectations between the partners. To provide greater insight in to the realities of these challenges, a case study investigation on a large IJV construction project (+£500m) in the UK was undertaken. As part of a wider three year ethnographic study, the researcher visited the construction site between one and three times a week for three years, and utilised participant observation as the main research tool. Data was collected through site walk-arounds, attending meetings, and informal discussions with employees. The findings revealed that the IJV partners had to try and overcome the following challenges: (i) employee loyalty and motivation towards their own companies rather than the IJV (ii) conflict and confrontation, (iii) alignment of all stakeholders to common goals, (iv) avoiding hierarchical confusion (v) creating effective communication and (vi) a lack of resource and knowledge sharing. Insights into these challenges could help project managers to better prepare for future joint-venture construction projects.

KEYWORDS

Collaboration, international, joint-venture, ethnography.

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INTRODUCTION

Construction project management continues to evolve and present new challenges to both established and new practitioners (Fewings 2013). The management of international joint venture (IJV) projects is a complex challenge that has not received the same attention in construction as it has in other industries (Ozorhon, et al. 2007; Girmscheid and Brockmann, 2009). Since the 1970s, IJV business projects have become increasingly common (Harrigan 1986; Anderson 1990; Beamish and Delios 1997); and in construction they are often complex and dynamic, as they are formed to build large-scale engineering projects (Girmscheid and Brockmann 2009). Examples of IJVs include the channel tunnel between the UK and France, the Øresund links in Denmark, the high-speed railway in Taiwan, and the Three Gorges Dam in China. IJVs are not the easiest forms of organisation to manage and operate (Minja, et al. 2012) and are frequently associated with poor performance and high degrees of instability (Parkhe 1993; Makino and Beamish 1998). This failure rate amongst IJVs is typically higher than are those for domestic joint ventures because IJVs usually face greater challenges (Ozorhon, et al. 2007). Considering this poor performance, the challenges IJVs face for success deserves further attention.

Inter-firm collaboration is a crucial component of the pursuit of international competitive advantage (Ozorhon, et al. 2007). In this bottom-up ethnographic study, recurrent collaborative challenges were identified as a key emergent theme on a large international JV civil engineering project in the UK (+£500m) and were prioritised for examination. The findings and discussions are presented in two sections: ‘collaboration between the IJV partners’, and ‘collaboration between the IJV partnership and other stakeholders’

IJV CONSTRUCTION PROJECT MANAGEMENT

Construction project management has been around for a long time, but has not always delivered the value that clients have been promised (Fewings 2013). Ball (2014) claimed that virtually no client seems happy with their final product; as construction projects typically take too long, cost too much, do not meet the user requirements, fail to last the design life, and often require extensive remedial work. The growing scale and complexity of construction projects has prompted organisations to create joint ventures (JV) to utilise resources of partners as a solution to bid for projects that are beyond the capacity of a single contractor (Zhao, et al. 2013). JVs can be defined as temporary arrangements or agreements between two or more parties to jointly carry out projects. If the parties come from different countries, these become an International Joint Venture or IJV. Research on IJVs in the construction industry is not as extensive as other industries, such as manufacturing; but where undertaken have focused on: performance factors (Sillars and Kangari 2004; Ozorhon, et al. 2007, 2010), risks (Bing and Tong 1999; McIntosh and McCabe 2003), and management issues (Luo, et al. 2001; Chan and Suen 2005).

Within IJV partner agreements risk allocation, dispute resolutions, distribution of profits and the rights and responsibilities of individual parties should be detailed (Gale & Luo 2004). However, there is no single standard agreement document

template as there can be a range of characteristics, and therefore the arrangement is usually made through a complex legal document that is the product of extensive negotiations between the parties (Minja, et al. 2012). The agreement between the IJV partners and the client is also of great importance, as the IJV will benefit if the contract between the client and the IJV partnership is unambiguous and the duties, responsibilities and liabilities of the parties are clearly stated from the very beginning of the project (Ozorhon, et al. 2010).

Yet arguably the complexity only begins with these arrangements, as often partner organisations are from different cultures, and may actually be competitors as well as collaborators (Janger 1980; Killing 1983). Organisations should consider their choice of partners very carefully, as those with cultural similarities are observed to perform better, since they share common values and practices, which reduce the risk of conflict during the formation and operation of the IJV (Sillars and Kangari 2004; Ozorhon, et al. 2010). Shaughnessy (1995) argued that it is very important for parties in the joint venture to also share the same objectives and goals. He identified five key factors:

- communication goals: interpersonal relationships and conflict management
- performance goals: shared goals are identified and developed
- dispute resolution: consideration is given to the need for timely resolution of disputes
- evaluation: both parties agree a continuing evaluation of the team's performance during the length of the contract
- commitment: to a partnering agreement that embodies the spirit of collaboration and which is separate from the venture contract

IJVs in construction are complex to: arrange contractual partner agreements, to manage different cultures throughout the construction phase and to complete in an uncertain environment. While there may be additional challenges, there is also no doubt that there are benefits as well. For instance, Norwood and Mansfield (1999) highlighted advantages of IJVs including: enhanced capabilities in terms of scope and size of work that can be carried out; improved access to local markets; access to new areas of the world with less risk; broadened expertise; and an ability to maintain an international workload. However at present, these advantages are currently being outweighed by disadvantages, as there has been failure to overcome the additional challenges that are inherent within these complex projects that have resulted in poor IJV performance.

RESEARCH METHODOLOGY

Ozorhon, et al. (2010) found that project-specific factors are highly associated with IJV performance, which suggested that each construction project is unique and that appropriate strategies should be developed to handle the particular risks and problems associated with individual projects. This raises questions about the appropriateness of attempting to generalise research findings on IJV performance. Ethnography - a method of studying a specific group in their natural setting usually through

participant observation (Phelps & Horman 2010) - is a research approach that focuses on the particular, rather the general (Shipton 2013). Thus it is argued to be an appropriate and alternative method for understanding IJV projects in construction, and has been adopted in this case study.

Ethnography is emerging as part of the repertoire of approaches to understanding the construction industry, and can offer new routes to knowledge (Pink, et al. 2013). Proponents of ethnographic research argue that it allows for deeper understanding of the setting in question (Harper 1998), accounts for uncertainty of social life, provides detail of social action and acknowledges the researcher-researched interaction in the production of social knowledge (Pole & Morrison 2003). The ethnographic data presented here is drawn from a wider three year study. The ethnographic researcher was a member of the Health and Safety (H&S) department on a large multinational UK construction project (+£500 m) and attended the project between one and three times a week for almost three years. The IJV on the project had been created between four organizations based in Europe and North America.

The H&S advisors each had a different physical space on the site, and the researcher used them as 'gatekeepers'. Gatekeepers can ease the passage of the researcher's entry by introducing the researcher to other informants. They can also make the research environment and context more visible through their explanations and interpretations of the social world (Pole and Morrison, 2003). Data collection involved combinations of: site walk-arounds, attending meetings, and informal discussions with employees. Informal conversations with various participants throughout the different IJV partners and organisations were the primary source of data. Wolfringer (2002) explains that ethnographers frequently choose to record a particular observation since it stands out. The observations that stood out were recorded; and while the wider research study focused specifically on H&S, there were recordings that could be clearly identified as relating to collaborative project challenges. Hence, 'collaborative project challenges' emerged as a theme, able to make a relevant contribution to the existing body of knowledge on IJVs. The data collection and analysis were a concurrent process (Silverman 2013), and was collected and analysed until a point of saturation was reached (Kumar 2005).

DISCUSSION OF ETHNOGRAPHIC FINDINGS

Collaboration means to work jointly with others. In an IJV construction project stakeholders including the partners, client, designers and subcontractors should cooperate and assist each other in working towards project goals and objectives. The ethnographic findings are presented here under themes, which summarise and reflect the key challenges that emerged between and amongst the IJV relationships on the case study project.

While some of the challenges discussed could also be applicable to JVs, international JVs can create additional challenges including: communication barriers and cultural differences and expectations; misunderstanding and unfamiliarity with the host countries rules and regulations; partners working off-shore that may have different

priorities; and preference to employ their own company employees particularly when the company is primarily operating in another country with economic downturn. All the recurrent identified challenges are discussed in the following sections.

COLLABORATION BETWEEN THE IJV PARTNERS

Collaboration is a crucial success factor in any project, but when dealing with partnerships it is particularly important (Vaaland 2004). IJV partners come together temporarily but still remain affiliated to their respective companies. This can be problematic as employees can keep stronger loyalties with their own companies rather than the IJV, which make it more challenging to create a collaborative environment:

H&S advisor: *‘In a IJV it’s harder to be loyal [to the IJV] because when the job ends and your time as an IJV ends.’*

JVs also temporarily merge strategic assets that they can use together in a collaborative manner to satisfy a client's needs (Walker & Johannes, 2003). However, complexity can arise out of the potentially diverse motivations of various partners (ibid). These different motivations reduced knowledge and resource sharing, for example:

H&S manager: *‘Teams aren’t communicating. Teams aren’t sharing resources. We have a generator could power the whole town but it is not been shared...It’s a complete waste.’*

The lack of knowledge and resource sharing was a sign of a lack of collaboration between the partners who were managing the various teams on the project. Ozorhon, et al. (2008) argued that cultural distance can lead to communication problems that in turn, may hinder knowledge exchange and inter-organisational learning. Kivrak, et al. (2014) found that language difficulties were critical barriers to successful knowledge sharing in multicultural project teams; and Oswald et al. (2014) revealed that such communication challenges acted as a barrier for worker training on a multinational project. A common perception on the project was that departments needed to improve the communication within the IJV:

Works manager: *‘Where more than one department is operating in the same area there should be regular meetings with representatives from both departments. We have no idea what each other are doing.’*

Within the partnership communication allows for clear understanding of the goals, and the roles and responsibilities of all the actors (Ozorhon, et al. 2008). It can be expected that more successful partnerships will exhibit higher levels of

communication quality and undertake more information sharing (ibid). The lack of collaborative communication and awareness of works from teams in the same areas inevitably led to conflicts on site, which broke down relationships:

H&S advisor: *'If you have a spare gumshield you can come out [on site]... It is like a bag of snakes out there; they are all hissing at each other'*

Fey and Beamish (1999) defined IJV conflict as the interaction between IJV partners, where the actions of one partner prevent or compel some outcome against the resistance of another partner. These conflicts were damaging for project collaboration and performance, as conflict among partners tended to cause frustration and dissatisfaction, so negatively affecting the motivation of the workforce. The conflict was not helped by the IJV 'politics' on the project. The researcher observed the following conversation:

Construction manager: *'The politics here are incredible. We have a position open, and I know who the best person for the job is, and HR have recommended them. But if the main players on the IJV don't agree; they employ someone else, who works for one of their companies. They want to employ their own people, not necessarily the best people. You can understand it, especially with the economic situation over there.'*

H&S advisor: *'...there are a lot of politics with it being an IJV. It is not a level playing field. It depends who you are and who you work for. But then your 'one team' culture goes out the window'*

Advantages of an IJV project include improved access to local markets; broadened expertise; and an ability to maintain an international workload (Norwood and Mansfield, 1999). Yet agreement as to whom to employ is not always reached amongst the IJV partners, as they can each have their own agendas, driven by loyalty to their own individual organisations. This was exacerbated when one of the partners primarily operated in a country that had an economic downturn, as they had resources that were surplus to demands, and therefore had much stronger motivation to move employees onto the project, even if they were not the most suitable candidates for the available positions.

COLLABORATION BETWEEN THE JV PARTNERSHIP AND OTHER STAKEHOLDERS

On construction projects, the client is often the developer, the contractor is the producer, and together, alongside other stakeholders, they must work together for the common goal of project completion. Aligning all stakeholders towards this common goal is a challenge that the IJV partners need to negotiate to maximise project success. When working in one project with multiple organisations, project managers must adapt their people to multiple policies, procedures and organisational cultures (Binder 2016). There is likely to be a level of uncertainty amongst employees, as

international construction projects involve multinational participants from different political, legal, economic, and cultural backgrounds (Chan and Tse 2003). Adapting all stakeholders to align with the same policies, procedures and ways of working was a continuous challenge for the JV partner's project management team. For example, a H&S advisor explained how the lack of compliance to the policy and procedure, not only raised safety concerns, but caused conflict:

'Some subcontractors don't expect to work to our standards, some don't see what they are doing as work, some have a different perception of what a risk is, but they [subcontractor] turn up with no intention of following the rules. It is an on-going battle of conflict and confrontation.'

It is important to note that subcontractors' employees are sometimes not familiar with the rules and regulations of the principal contractor (Choudhry and Fang 2008), especially those on international projects from different national backgrounds (Oswald, et al. 2018). In Danish construction industry case studies, Richter and Koch (2004) found that while there are some common cultural manifestations and values present amongst subgroups, there were also a number of cultural subgroups whose views and values are strongly differentiated, and that common language and values are affected by ambiguity. Avoiding such ambiguity through communicative collaboration, rather than conflict and confrontation was a challenge.

There was also a lack of clear management structure on the project that did not help to resolve these issues. For example, a H&S advisor stated a common perception:

'The rank structure in the B3 section is not clear... we are unsure whose boss is whose. So we don't know who to talk to.'

Without visible leaders driving collaboration, project success was more challenging on the IJV. The complexity of the IJV structure promoted hierarchal confusion, and the flow of effective communication was hampered. Multinational projects can be more challenging due to different language and cultural barriers, and contractors may more frequently use non-verbal communication (Oswald, et al. 2015), or even create their own language (Tutt, et al. 2013). The communication challenges were repeatedly highlighted across the project:

Operative: *'The information received is too late or too little. Communication must get out to the workforce in good time'*

The fragmented structure of the construction industry has impeded an integrated approach through limited communication channels and created a lack of trust between separate teams (Fewings 2013). Within an IJV the communication challenges between teams can be amplified, as it is often a temporary arrangement where teams have not worked together before, and there are likely to be cultural and language issues. This collaborative challenge was a threat to project performance in terms of production, quality, and also safety:

Work's Manager: *'Some operatives have no idea of safety practice when entering another [team's] work area. They seem to be conditioned to their own working practices. Broader communication of the upcoming works of different departments and safety practices might give more of an insight.'*

As well as various subcontractors and their different teams and departments, IJV partners also need to successfully collaborate with other stakeholders such as the client and the designers. It is important to ensure that a good design is co-ordinated and implemented in terms of the construction and use of the building, and the management of this process is the application of control to the design process in terms of time, quality, cost, health and safety and other issues (Fewings 2013). The design management on a large IJV posed different challenges as designers working for the IJV and on other projects had other priorities:

Engineer: *'There have been problems with designers that are overseas. They are losing money on this job, so are deploying their resources elsewhere and have few designers working on our project. They are then late, and it is putting us behind schedule.'*

This delay has obvious impacts on critical project elements such as time and cost, but the subsequent production pressure can also result in poorer safety performance (see, for example, Han. et al. 2014; Oswald et al., 2013). A tight project schedule deadline meant there was little room for manoeuvre awaiting designers from international partners. Presenting project value to the client includes completion of the job on time, and this pressure was acknowledged throughout the IJV partners:

Works manager: *'The client wants the job done yesterday'*

Successful collaboration with the client, designers, various subcontractors, as well as all the other relevant stakeholders, is important for project success. Due to their make-up, IJV partners have additional and different collaboration challenges to typical construction projects, as they have to attempt to align all stakeholders to a common goal in a complex cultural environment

CONCLUSIONS

IJV projects have typically performed poorly. In terms of research knowledge, there is a lack of understanding surrounding IJV construction projects, and this area deserves more attention. This UK-based case study on a large IJV construction project used an ethnographic approach that can provide avenues to new areas of knowledge. As IJVs are highly project-specific, it is argued that a methodological approach (such as ethnography) that focuses on the particular, rather than the general, is most appropriate. There were six recurrent collaborative challenges on the project involving: (i) loyalty, (ii) conflict and confrontation, (iii) alignment to common goals, (iv) hierarchy confusion, (v) communication, (vi) resource and knowledge sharing.

Collaboration is a key element to success on any project, and on any JV construction project there can be different and additional challenges to those found on ‘typical’ projects. A key barrier to collaboration was that: (i) employee loyalty lay with their own individual companies over the JV partner. IJV partners made decisions based on the best interests of their own companies and not the IJV, which caused (ii) conflict and confrontation amongst partners. While these could be applicable to either JVs or IJVs, the additional challenge the international project had was that economic inconsistencies interfered with the decision-making process for employee hiring. Not only did companies want to be loyal to their own employees, they had a strong motive to select their own employees that were currently working in countries experiencing economic downturns as a method of efficiently utilising their existing resources. However, the other partners did not necessarily view these employees as the most ideal candidates for the job. Having a wider choice of candidates is generally regarded as an advantage of an IJV project, but only if this benefit is appropriately used to the advantages of the IJV project, and not their retrospective companies. As the loyalties and motivations of the JV partners were primarily focused on their own individual best interests; (iii) aligning the partners, and all other relevant stakeholders, to the common goals of the project was particularly challenging. It also meant there was a motivation for companies within the IJV to be competitive with each other rather than collaborative, and contributed to: (iv) an unclear management structure within the hierarchy, (v) a lack of effective communication, (vi) and an absence of resource and knowledge-sharing. The international make-up of the partnering agreement can exacerbate these challenges due to communication barriers and cultural inconsistencies.

The international nature of the joint venture created additional complexities for the project, which included: communication barriers and cultural differences; international misunderstanding and unfamiliarity with the rules and regulations; off-shore-based partners with alternative priorities; and employment decisions being influenced by international economic inequalities rather than skillsets. IJV partners should carefully think about how they set up their partnering agreements, in order to create a collaborative partnership as one team; rather than a disjointed partnership with individual organisations making decisions purely for their own company benefits.

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LEARNING EFFECTS IN CONTRACTUAL DESIGN IN CONSTRUCTION PROJECTS: AN EMPIRICAL INVESTIGATION

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DIFFERENTIATING TWO TYPES OF LEARNING IN CONTRACT DESIGN: EVIDENCE FROM THE CONSTRUCTION INDUSTRY

ABSTRACT

Existing studies have contradictory findings about how contract design features change with partnering experience. To give a comprehensive explanation, this study investigates the learning in contract design from two types of partnering experience by adopting a three-functional view. We suggest that the contract tends to be more complex as a result of the learning from prior experience. Moreover, the differentiation among the pathways reflects a balance of ex-ante and ex-post costs in construction projects.

KEYWORDS

Partnering experience, organizational learning, contractual complexity, contractual functions, contract design capability, interorganizational routines.

INTRODUCTION

It has long been acknowledged that firms can develop various capabilities through experience for superior performance (Kale and Singh, 2007; Levitt and March 1988; Sampson, 2005; Zollo et al., 2002). Whilst the strategic management and organizational literature mainly focus on how firms accumulate and leverage know-how and enhance alliance capability to achieve success, governance arrangement, typically the contract, is also indispensable for collaborative benefits in interfirm relationships. The contract serves as a formal governance mechanism and plays an important role in controlling deviant behavior, mitigating potential transaction hazards, and ensuring the realization of organizational performance (Luo, 2002; Mellewigt et al., 2007; Poppo and Zenger, 2002). Nevertheless, compared to the extensive literature on organizational learning regarding technical knowledge and skills, less research has examined learning related to contract design (Lumineau et al., 2011). Considering that firms tend to absorb prior partnering experience to facilitate contract design (Argyres and Mayer, 2007), this research aims to investigate such processes from an organizational learning perspective.

Some research has been carried out trying to explore the impact of prior partnering experience on contractual complexity, but the existing literature is far from achieving a conclusive consensus. Some studies take the view that prior partnering experience will lower the costs of contracting through learning, leading parties to draft more complex subsequent contracts (Mellewigt et al., 2012; Mayer and Argyres, 2004; Ryall and Sampson, 2009; Xing et al., 2015). Other studies focus on the reduction of behavior uncertainty and the development of trust through repeated collaboration, drawing a conclusion that subsequent contracts tend to be less complex (Arino and Reuer, 2005; Reuer and Arino, 2007). Though contradictory, both views are plausible to some extent. The reason for the debate may lie in that contractual complexity is not a unidimensional construct and that prior partnering experience takes different forms. By fully developing this idea, this research aims at solving the contradiction.

Much research has categorized prior partnering experience into partner-specific experience (i.e., a firm's specific experience accumulated through repeated collaborations with the same partner) and general partnering experience (i.e., a firm's experience accumulated through collaborations with any partner) (Hoang and Rothaermel, 2005; Gulati, 2009; Reuer et al., 2002; Zollo et al., 2002). Additionally, a three-functional perspective of the contract is gradually becoming recognized by researchers, the three functions being control, coordination and adaptation (Mellewigt et al., 2012). These three functions serve to mitigate different types of interorganizational relationship risks, thus each of them is affected by different factors. Regarding the contract as a whole and using a global measurement might neglect the diversity of processes in which contracts change with partnering experience. Either a mere observation of one of the two partnering experiences, or a lack of a multi-functional view of contract in prior research, may have led to the conflicting results. What a firm can learn from repeated collaborations with a single partner and merge into contract design is assumed to be different from the learning through accumulated knowledge from prior interactions with all partners. This study attempts to realize the research purpose by investigating the following questions:

1) What effects do partner-specific experience and general partnering experience have on complexity of contractual control, coordination and adaptation?

2) What are the mechanisms through which partnering experience affect contractual complexity?

To interpret the mechanisms behind these effects, two mediators, interorganizational routines and contract design capability are introduced into this research. It provides a more comprehensive insight into whether and why prior experience, as an attribute characterizing transaction participant, makes a difference to contract design. As contracts in the complex transactions like construction projects involve more components and more likely to be modified through learning, the analysis focuses on the construction industry.

THEORETICAL BACKGROUND AND CONCEPTUAL FRAMEWORK

CONTRACTUAL COMPLEXITY AND THE THREE FUNCTIONS OF CONTRACT

According to transaction cost economics (TCE), economizing of transaction costs is a main concern in the selection of governance structures (Williamson, 1985). The balance of ex-ante and ex-post transaction costs is required when designing a contract (Benaroch et al., 2016). Except for the common practice of choosing the contracting form from several alternatives such as market, hierarchy and other collaborative agreements (Gulati and Singh, 1998; Williamson, 1985), a more specific way to achieve such balance is reflected in the continuous change in contractual complexity (Mellewigt et al., 2012), namely the design feature of the contract agreements which represents the degree of explicitness and elaborateness of level of details. In recent years, the multiple functions of the contract have been addressed by scholars (Lumineau and Malhotra, 2011; Mayer and Argyres, 2004; Reuer and Arino, 2007). Mellewigt et al. (2012) present a three-functional perspective of the contract on the basis of a comprehensive literature review. This framework has its roots in the main threats that inter-firm relationships face: relational risk and performance risk (Das and Teng, 1996). Different transaction attributes arouse different risks, which appeal to corresponding contractual functions to deal with. With regard to relational risk that is

primarily caused by asset specificity, contracts can serve as a mandatory controlling means of easing appropriation concerns (Ryall and Sampson, 2009). Performance risk originating from task interdependence and task complexity brings about coordination concerns, thus contracts also need to work as a coordination device (Vanneste and Puranam, 2010) that helps partners to achieve mutual goals. Performance risk related to transaction instability requires contracts to relieve adaptation concerns over unanticipated contingencies (Schepker et al., 2014).

PARTNERING EXPERIENCE AND CONTRACTUAL COMPLEXITY

The effects of partner-specific experience on contractual complexity

TCE considers humans to be opportunistic in nature, so any transactions involving specific assets need a contract to safeguard investments and property against misappropriation (Williamson, 1985). Does contractual control change significantly with partner-specific experience? Some studies argue that trust emerging from successive collaborative relationships may substitute for formal safeguards in contracts (Reuer and Arino, 2007). However in practice, partners will not remove the extant control provisions from contracts despite a higher level of trust. Zollo et al. (2002) illustrate this point with Hewlett Packard who had had many alliances with a particular partner but never believed the partner would relinquish opportunism. Even with a prior relationship, it is risky to take for granted that the counterparty will not practice opportunism. Contractual control provisions can act as a warning even if they might not be implemented. Hence, the complexity of contractual control is unlikely to be reduced due to a prior relationship; otherwise more ex-post problems may arise.

On the other hand, partner-specific experience will not bring about more contractual control provisions either. Provisions of this type often serve as boilerplates, not partner-oriented (Wang et al., 2017). It's difficult to increase the capacity of enriching these specifications by an insufficient learning from a limited number of transactions with the same partner. Moreover, excessively detailed safeguarding provisions may be deemed as a signal of distrust, impeding interfirm relationships (Gulati, 1995). Therefore, it is suggested that partner-specific experience has little influence over contractual control clauses and the following proposition is developed:

Proposition 1a. Partner-specific experience is unrelated to the complexity of contractual control.

Now that task interdependence may cause performance risk in complex transactions, establishing powerful communication and coordination mechanisms by the contract will reduce this hazard. For example, the contract can specify the scope of works, task descriptions, and how to conduct regular communications, all of which can help reduce ambiguity and information asymmetry. Prior interactions between the parties will deepen their understanding of the counterparty's personnel, technical capacity, management style and communication methods (Reuer and Arino, 2007). As a result, they can integrate their knowledge about their partner into the current contract in order to achieve a better cooperation performance (Poppo and Zenger, 2002; Ryall and Sampson, 2009). Although some of this kind of knowledge is universal to interactions with any partner, a substantial part of it is specific to the focal partner. The cost of adding more coordination terms to the contract is likely to decrease due to familiarity fostered through repeated interactions. Therefore, the following proposition is developed:

Proposition 1b. Partner-specific experience is positively associated with the complexity of contractual coordination.

Compared with contractual control and coordination, contractual adaptation has been less investigated in the literature so far. Adaptation provisions are needed for planning in advance in case of unanticipated contingencies and external disturbances (Arino and Reuer 2004; Luo 2002). However, the parties cannot conceive of all possible future contingencies so they can only restrictedly rely on the capacity of contracts to foresee the potential risks (Mellewigt et al., 2012). It is especially difficult to draw up new clauses to deal with unanticipated contingencies just relying on previous experience with a partner. From this type of experience, firms cannot acquire adequate information and knowledge on more transaction attributes since learning is constrained within the specific range of previous experience (Levinthal and March, 1993). Similar to contractual control, complexity of contractual adaptation will not significantly increase with prior interactions between two firms. Mayer and Bercovitz (2008) also suggest that prior relationships can create interorganizational inertia, which makes firms render the same level of contingency planning in subsequent contracts as that in previous contracts. Such inertia is likely to be a result of balancing ex-ante contracting cost and expected benefits, as drafting extra adaptation provisions are costly and time-consuming. Therefore, the following proposition is developed:

Proposition 1c. Partner-specific experience is unrelated to the complexity of contractual adaptation.

The mediating role of interorganizational routines

During repeated exchanges, partners will develop tacit understanding and fixed processes. Consequently, some stable and recurring patterns of interaction involved in performing collaborative tasks are formed, namely interorganizational routines (Feldman and Rafaeli, 2002; Zollo et al., 2002). These routines extract lessons from the past, making it possible to avoid reinventing the wheel and making repeated mistakes (Gittell and Weiss, 2004; Levitt and March, 1988). Compared to other types of firm experience, partner-specific experience is the very trajectory which leads to the development of dyadic interorganizational routines (García-Canal, 2014; Hoang and Rothaermel, 2005; Zollo et al., 2002). Through repeated interactions, partners acquire specific knowledge about the counterparty's organizational structure and management systems as well as the capabilities of the personnel (Luo, 2002), thereby constituting common performative and ostensive aspects and creating routines (Dionysiou and Tsoukas, 2013). The formation of interorganizational routines can facilitate communication and coordination in return (Zheng and Yang, 2015), enabling partners to build shared meanings (Feldman and Rafaeli, 2002) and create a mutual understanding of how to fit each other's task into the overall work flow (Gittell and Weiss, 2004). With the help of routines, firms can incorporate the ways they interact with each other into contracts to minimize the emergence of potential problems (Park and Kang, 2013). In other words, the costs of designing coordination clauses will decrease considerably with prior experience, making contractual coordination terms more enriched. Therefore, the following propositions are developed:

Proposition 2. Partner-specific experience is positively associated with interorganizational routines.

Proposition 3. Interorganizational routines mediate the relationship between partner-specific experience and the complexity of contractual coordination.

The effects of general partnering experience on contractual complexity

General partnering experience represents a firm's total partnering experience, but it tends to be overlooked in the literature, and is often considered to be less beneficial compared to partner-specific experience (Gulati, 2009; Mayer and Argyres, 2004). Partner-specific experience makes a great contribution to improving a firm's capability to create value in future collaborations, due to the cumulative benefits from a long-term cooperative relationship between the partners (Gulati, 2009). However, in contrast to value creation, contract design is not necessarily related to the dyadic relationship. Contract design is embedded in a continuous learning process in which the firm's own knowledge from past experience matters a lot. Knowledge management in organizations mainly includes creation, retention, and transfer (Argote et al., 2003). As for contract design, the major learning occurs in knowledge retention, i.e., the problems and solutions identified and summarized from previous contracting experience could be incorporated into the contracts that serve as persistent repositories.

While the complexity of contractual control is not assumed to be affected by partner-specific experience, a firm's general partnering experience may offer an explanation for such a cumulative effect. The more transactions a firm has completed, the more opportunistic behavior it may have encountered. Effective means to prevent undesirable behavior will be deposited into the bank of contract. Therefore, the contracts are more likely to include safeguarding clauses when a firm has collaborated with many different partners (Ryall and Sampson, 2009).

Referring to contractual coordination, general partnering experience also has an incremental influence. After engaging in plenty of exchanges with various partners, a firm gets to know the structural features and operating styles of different organizations during the processes of contacting with their business partners. Previous experience with any partner informs the firms of potential communication barriers to a contractual relationship, thus letting it know how to conduct effective communication across organizational boundaries through a contract containing more coordination clauses.

Similarly, contract design of contingency adaptation can benefit from this type of partnering experience. Contracts often play the role of knowledge repositories (Mayer and Argyres, 2004). General partnering experience provides opportunities to run into different unexpected conditions. It enables firms to take the contingencies that were met before into account in future transactions. Therefore, parties will be more knowledgeable in drafting detailed contract terms about how to respond to contingency adaptation.

All in all, a firm can learn from its partnering experience with all the partners in similar transactions and make subsequent contracts more capable to cope with transaction hazards without incurring high ex-ante contract design costs. Based on the above reasoning, the following propositions are developed:

Proposition 4a. General partnering experience is positively associated with the complexity of contractual control.

Proposition 4b. General partnering experience is positively associated with the complexity of contractual coordination.

Proposition 4c. General partnering experience is positively associated with the complexity of contractual adaptation.

The mediating role of contract design capability

Under the effect of learning-by-doing, firms are able to acquire their capabilities over time. Nonetheless, they are faced with trade-offs when allocating limited physical and time resources to alternative capabilities (Ethiraj et al., 2005), only the most cost-efficient ones will be chosen. Accumulated partnering experience could promote a firm's capability in many aspects and create more value in a current exchange (Dyer and Singh, 1998; Kale and Singh, 2007). In particular, as firms' knowledge accumulation is influenced by exchange experience (Zollo et al., 2002), the capacity to amend existing contracts is enhanced (Reuer et al. 2002). Firms tend to embody the relevant knowledge they learn in subsequent contracts rather than other informal ways of governance, because contracts have always been the core governance means and main repository of learning (Mayer and Argyres, 2004). As a firm experiences more extensive interactions with any partner, it is aware of a diverse variety of conditions that need to be specified in the contract. When a firm designs a new contract, the previously obtained information and knowledge can be used as reference because the experience gained from other relationships can also help in the focal contract (Hoang and Rothaermel, 2005). Consequently, less cost is incurred to promote the capability involved in contract design.

Contract design capability may influence firms' contract design choices, but prior studies haven't investigated this sufficiently (Argyres and Mayer, 2007). This capability helps firms better arrange the appropriate volumes and categories of clauses in a contract (Argyres and Mayer, 2007). Different from interorganizational routines, trust and other social ties in a certain dyadic relationship, contract design capability can be enhanced by any partnering experience and be used to modify the contracts in any contracting relationship. As firms gain experience, they develop contract design capabilities and lower contract design costs, thus designing more complex contracts in the future. Therefore, the following propositions are developed:

Proposition 5. General partnering experience is positively associated with contract design capability.

Proposition 6a. Contract design capability mediates the relationship between general partnering experience and the complexity of contractual control.

Proposition 6b. Contract design capability mediates the relationship between general partnering experience and the complexity of contractual coordination.

Proposition 6c. Contract design capability mediates the relationship between general partnering experience and the complexity of contractual adaptation.

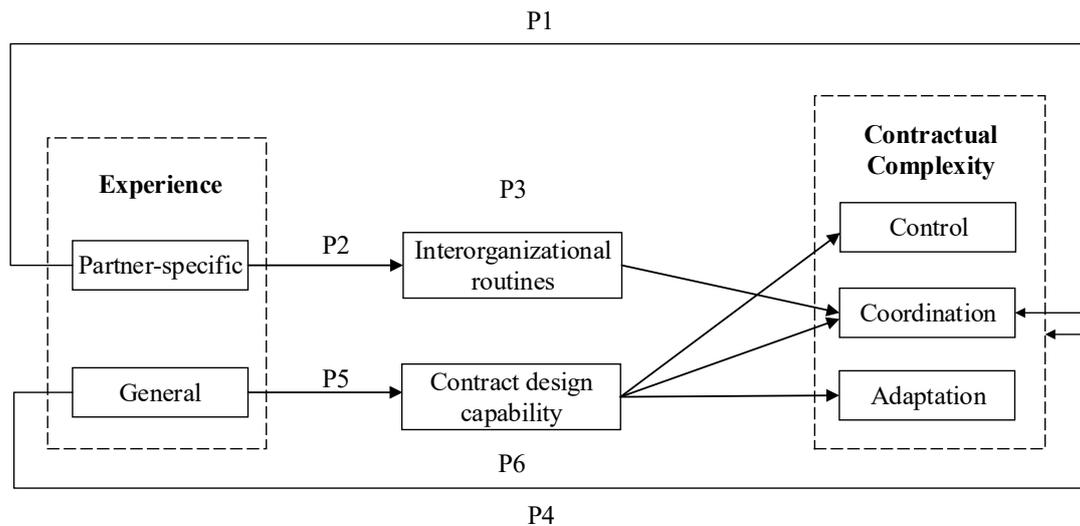


Figure 1. Research framework

METHODS

This research plans to use a questionnaire survey to collect data from Chinese companies in the construction industry.

Hierarchical multiple regression using SPSS software will be applied to test the main effects. After that, the causal steps approach and bootstrapping will be adopted to test for the mediating effects.

MEASURES

Dependent variable: contractual complexity

Many studies measure *contractual complexity* as a simple count of the numbers of provisions incorporated into the contract from a checklist of clauses (Parkhe, 1993; Reuer and Arino, 2007). Capturing issue inclusiveness but missing term specificity of the contract, these measures are not suitable for construction contracts, as construction projects are usually complex and the contract covers a broad range of transactional issues. The variance of contractual complexity of construction contracts lies in the term specificity instead of issue inclusiveness. We developed a reflective measure for the complexity of the three functions following strictly the scale development procedures (The details of the process of scale development are not discussed in this paper). During the data collection stage, most respondents will be chosen from project/ department/ contract managers with rich work experience, in order to ensure their comprehensive understanding of the projects and their capability of making accurate judgments. Subjective assessment can better reflect contractual complexity than obtaining objective data from actual documents, as respondents know contracts better than researchers.

Independent variable: partnering experience

In line with Zollo et al. (2002), *partner-specific experience* was measured by the number of projects that the respondent's firm has completed with the focal partner before contracting for the focal project. *General partnering experience* was measured

by the number of projects of similar type that the respondent's firm has completed with any partner before contracting for the focal project.

Mediating variables: interorganizational routines and contract design capability

Although *interorganizational routines* has been discussed a lot in the literature, scarcely any direct operationalization could be found. According to the conventional definition given by Zollo et al. (2002) and Feldman and Rafaeli (2002), as well as interviews with project managers and contract managers, we developed a seven-point Likert scale which combines with the features of the construction industry.

Based on the major aspects of contract design by Argyres and Mayer (2007), as well as the interviews with sophisticated contract managers, we developed a seven-point Likert scale including three items to value the *contract design capability* of the respondent's firm (i.e. the party issuing the contract).

Control variables

First, *contract price* and *time for completion* were controlled for since these two variables reflect project size which is likely to influence contractual complexity (Benaroch et al., 2016).

Second, *expectations of continuity* were controlled for (Poppo et al., 2008) because the shadow of the future is related to prior relationship and it may affect contract design. It is measured by the possibility of repeated transactions between the focal partners in the future.

Third, *ex-ante trust* needs to be controlled for because prior relationships may build trust (Gulati 1995) and influence the parties' decision of which provisions to be included in the contract (Malhotra and Lumineau, 2011, Mellewigt et al., 2007). In accordance with Jiang (2013), three seven-point Likert items were adopted to measure the level of trust between the partners at the first formal contact for the focal project.

Table 1: Measurement for constructs

<p>Partner-specific experience Before contracting for this project, how many projects has your firm completed with the focal partner?</p>
<p>General partnering experience Before contracting for this project, how many projects of similar type has your firm completed with any partner?</p>
<p>Contractual control</p> <ol style="list-style-type: none"> 1. The contract defines the rights of both parties specifically. 2. The contract specifically stipulates how the party awarding the contract monitors the contractor. 3. The contract specifically stipulates the rights entitled to one party when the other party breaches the contract. 4. The contract specifically stipulates provisions on early termination after breaching the contract.
<p>Contractual coordination</p> <ol style="list-style-type: none"> 1. The contract specifically stipulates how the parties send written documents (such as letters, periodical reports and e-mails). 2. The contract provides detailed technical specifications and drawings. 3. The contract specifically stipulates the quality acceptance procedures.

<ol style="list-style-type: none"> 4. The contract specifically stipulates the personnel qualifications or dispatching issues. 5. The contract defines the division of labor of both parties specifically.
<p>Contractual adaptation</p> <ol style="list-style-type: none"> 1. The contract specifically stipulates the adjustments due to the changes in cost. 2. The contract specifically stipulates the adjustments due to the changes in exchange rates. 3. The contract specifically stipulates the handling procedures when geological conditions, against which an experienced contractor could not reasonably be expected to react, arise. 4. The contract specifically stipulates the handling procedures when climatic conditions, against which an experienced contractor could not reasonably be expected to react, arise.
<p>Interorganizational routines</p> <ol style="list-style-type: none"> 1. Before the focal collaboration, fixed work procedures have been formed between the parties for similar projects. 2. Before the focal collaboration, effective ways of communication have been formed between the parties for similar projects. 3. The handbook and program document used in prior collaborations between the parties would continue to be used in the focal project.
<p>Contract design capability</p> <ol style="list-style-type: none"> 1. Your firm has a strong professional capability in terms of technology for this project. 2. Your firm has a strong law and business negotiation capability for this project. 3. Your firm knows the issues which need attention in the future contract executing stage very well.
<p>Expectations of continuity</p> <p>When contracting for this project, we expect to have further cooperation with this partner in the future.</p>
<p>Ex-ante trust</p> <ol style="list-style-type: none"> 1. The parties thought each other to be trustworthy at the first formal contact for this project. 2. The parties thought each other to be honest at the first formal contact for this project. 3. The parties believed that each party will make decisions for the other party's sake at the first formal contact for this project.

IMPLICATIONS

This research aims contributes to the literature on contract design in construction projects and organizational learning by distinguishing two kinds of learning in contract design, and highlighting the underlying mechanisms. This study will not only give supports to the existence of the incremental effects of two types of partnering experience on contractual complexity, but also recognize the differentiation of these effects on three contractual functions. By adopting a three-functional view of contracts and two different types of partnering experience, we expect that partner-specific experience can be more effective in promoting contractual coordination since this aspect of contract is specific to a particular transaction between partners (Mellewigt et al., 2012), while general partnering experience plays an important role in drafting provisions of the three contractual functions. If it is the case, it implies that firms involved in construction projects tend to rely on formal governance and make their contracts more complex in order to better cope with potential transaction hazards. It can shed some light on the process of organizational learning and improves the

understanding of the influence of relational attributes on governance mechanism design.

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INCORPORATING STAKEHOLDER INTERESTS: WHAT IS THE ROLE THAT MATERIAL ARTEFACTS PLAY IN PUBLIC ENGAGEMENT SETTINGS?

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INCORPORATING STAKEHOLDER INTERESTS: WHAT IS THE ROLE THAT MATERIAL ARTEFACTS PLAY IN PUBLIC ENGAGEMENT SETTINGS?

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ABSTRACT

Public engagement is becoming increasingly commonplace globally, bringing with it unique sets of rituals and procedures that project managers must follow through. The disparate and divergent nature of stakeholder cohorts makes the management of these processes particularly challenging. Much attention has focussed on how the public can be identified as stakeholders to the project, and how they should be managed within this contested environment. Less attention is paid to the actual procedures that are involved, especially the role and use of material artefacts in public engagement processes. In this paper, we examine the material artefacts used in public engagement settings, in particular, how they are used to cross political knowledge boundaries. We take a socio-technical approach to consider these artefacts as nodes in a wider heterogeneous network. Using data collected through an ethnographic study, we show examples where material artefacts i) represent a form of power that is already in-play; ii) control and direct the flow of discussion; and iii) used to rally or promote points of view. By exploring the role these artefacts play, we seek to uncover and explain the highly politicised and value-laden network in which managers often have to operate.

KEYWORDS

Public engagement, stakeholder management, STS, material artefacts, power play

INTRODUCTION

One of the more contentious issues within project management, which has recently gained attention, concerns the way external stakeholders such as the public, who have no direct financial stake in the project and yet may be adversely impacted by the project's outcomes are managed. In response to public pressure, the practice of public engagement and consultation is becoming prevalent in many parts of the world. This provides an avenue for the public to vocalise their concerns and be involved in decision-making processes that have formerly been regarded as strictly state-related. The premise of public engagement is for the project sponsors to meet with stakeholders of the project in a systematic way to facilitate a two-way dialogue between participants (Rowe & Frewer, 2005). By engaging in these dialogues, project managers are provided opportunities to capture feedback on public projects from the public, which includes potential end users of the projects, and adjust the project to

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address their concerns. By so doing, public engagement aims to incorporate legitimate decisions into the project that are ‘broadly owned’ (Legacy, 2012).

Despite its ideological aspirations, the practice of engagement is fraught with difficulties. As the range of stakeholders being considered broadens, so do the range of interests that the project needs to represent. The avenue for public engagement then becomes a contested space where stakeholders vie for their interests to be included (cf. Irwin, Jensen, & Jones, 2013). As such, the question then becomes to what an extent such a process can be effectively managed, and how those involved react to and interact with the many managerial strategies put in place. In this paper we explore the physicality of public engagement processes, taking a socio-technical approach that considers the material artefacts as integral nodal points in a heterogeneous network. We draw on the concept of boundary objects and black boxes, which both has basis in science and technology studies (STS).

We begin with a brief theoretical overview of boundary objects and black boxes, explaining how the development of a design concept can be conceptualised as a network formed as a result of alliances between human and non-human actors. In order to capture these alliances, we utilise a ‘naturalistic’ (Babbie, 2010) data collection approach based around ethnographic techniques. We focus the study on the formal public engagement events for public engagement of urban development projects in Hong Kong and make use of data collected from an ethnographic study to explore how material artefacts are used in these highly politicised and contested environments. The ethnographic observations showcase how material artefacts have the power to constrain, control, and direct the way stakeholders interact. The aim of the exercise is to explore the formation of stakeholder relationships during public engagement processes, especially considering the dynamic power relationships that are formed and disbanded in the process.

MATERIAL ARTEFACTS IN ORGANISATIONAL SETTINGS: BOUNDARY OBJECTS AND BLACK BOXES

The role that material artefacts play in spanning knowledge boundaries is often explored under the remit of the ‘boundary object’ construct. With its origins in sociology, a ‘boundary object’ is an object that intersect multiple social worlds, thus allowing agents to create meaning along the margins of their overlapping worlds (Star & Griesemer, 1989). The concept has been used in managerial studies to explain the use of artefacts including engineering drawings, project tools, and timelines to span knowledge boundaries (e.g. Carlile, 2002; Sapsed & Salter, 2004; Yakura, 2002). While we take inspiration from these studies, our focus moves beyond the artefacts as singular objects towards viewing these artefacts as part of a much wider sociotechnical system. To understand our approach it is first necessary to explain how the concept of boundary objects originated from science and technology studies (STS).

Within a STS worldview, the social order can be described as a power network made up of a combination of tangible and intangible elements. The network is held together by the strength of the alliances that makes up this network. These ‘alliances’ are formed during the process of spanning social worlds. For example, when a design

idea is turned into architectural drawings, which are then eventually transformed into a built form, the process requires spanning multiple social worlds. First there is the world of the design professionals who engage in verbal talk around design ideas. Then, the world of technical drawings which has a different (and much wider) audience. Finally, the world of construction professionals who must interpret the drawings and turn them into reality. The architectural drawings in this scenario may be described as boundary objects, but they are also part of a much wider network that includes architects and construction professionals. This network of human and non-human actors engages in actions that require them to form alliances with each other. In fact, when an intangible element (the design idea) is transformed into more tangible forms (design drawings), they stabilise part of the network by locking in the alliances that were formed as a result of previous discussions. The boundary object in this scenario does more than span knowledge boundaries; they become a reservoir for power by allowing an actor to delegate their power to that material. The ‘power’ held by tangible elements are evident in our everyday lives. As Latour points out, once a speed bump is installed, the local police officer can turn their attention elsewhere (Latour, 1991).

The way the social order is established is directly relatable to the extent to which material artefacts are utilised. As the network consisting of series of social practices becomes more established, more aspects of the network are transformed from intangible to tangible forms. Examples of these tangible forms include uniforms, medals, names, and signs (Callon & Latour, 1981). When a set of practices is strongly associated with a range of durable materials, they become stabilised within the power network, such that the associations no longer need to be considered. For example, instead of explaining the size and density of a proposed building in relation to each site, urban planners may simply refer to the site’s designated plot ratio.

When these associations become taken for granted they, alongside the materials they are associated with, are put into ‘black boxes’ (Callon, 1986; Callon & Latour, 1981; Latour, 1987). The ‘black-boxing’ concept may be appropriated to managerial settings, and to some extent, dovetail with some of the characteristics identified by Carlile (2004) as part of his ‘integrative framework’ for managing knowledge across political boundaries. But rather than focusing on characteristics of the object, a ‘black box’ is always considered in relation to the rest of the network, as all elements are intricately linked in such a network. The exploration of black boxes places the emphasis on the relationships and alliances within a network, rather than on its disparate components. Going back to its STS roots requires us to acknowledge and explore how the multiple elements of a network, both tangible and intangible, work together; and how they in turn form the power networks that make up the ‘social order’.

RESEARCH METHOD

This paper draws from a larger research project that investigates the public engagement phenomenon in Hong Kong. For this research project, qualitative data were collected over 34 months using ethnographic techniques including participatory observations, ethnographic interviewing, and document analysis by the primary author. By immersing into the field, an ethnographic account aims to trace the

symbolic forms, patterns, discourses and practices that give a phenomenon its essence and defining characteristics (Willis & Trondman, 2002). The project used an ‘iterative-inductive research approach’ (O’Reilly, 2005) which evolved in design throughout the study.

In the following section, we first present an overview for how public engagement is conducted in Hong Kong, before presenting three observations that explores how participants express their values through interacting with material artefacts that are embedded into the public engagement event format. These observations are drawn from numerous events and display the characteristics of a ‘multi-sited’ ethnographic approach. A multi-sited approach treats the objects of study as emergent and argues that actions taken by individuals may be assembled into a structural network of relations deemed pertinent to the type of scenes witnessed, rather than by the specificity of the issues discussed (Marcus, 1998). These observations are presented as ‘thick descriptions’ (Geertz, 1973) to communicate the cultural nuances of the actors engaged in the events. Ethnography rests on the “peculiar practice of representing the social reality of others through the analysis of one's own experience in the world of these others” (Maanen, 1988, p. xiii); it is a personal and reflexive exercise that nonetheless forms the base for wider comparison across settings. The experience, and specifically the researcher’s experience, is central to ethnographic studies, both empirically and theoretically. To stay true to this ethnographic tradition, the personal voice of the primary author is used liberally in the ethnographic accounts that follow.

PUBLIC ENGAGEMENT IN HONG KONG

The type of engagement that we are about to describe can be classified as ‘non-statutory’ public engagement, as it is not legislatively enforced. However, although there is no formal written consensus for how public engagement should be conducted in Hong Kong, reviewing public engagement processes for the past 8-10 years shows that the protocol for public engagement is set to 2 or 3 general stages. The premise is to present a draft design plan to the public and seek the public’s input before progressing to the final stage of design. A 2-stage public engagement strategy would begin engaging with the public at a more refined stage of design, whereas a 3-stage strategy would begin engaging at a more preliminary stage of design. In other words, a 2-stage strategy begins the public engagement at a similar stage to Stage 2 of a 3-stage strategy. The formal events of each stage involve face-to-face interaction with a public audience, usually in a town hall meeting style session. At the end of each stage, a consultation report is generated by the project owner, which is published online. The project team will aim to incorporate the feedback collected into their final design, which is then developed into their formal application to the Town Planning Board for funding and approval.

Typically, each stage of the public engagement process lasts for two to three months and is interspersed with a period of one year or more for analysis of comments received and preparation of an updated plan. Each stage usually consists of a combination of several types of activities: a “roving exhibition” where the plans are put on display; a series of gatherings in a more intimate setting to garner views from the community (such as focus groups or community workshops); and a large-scale

public forum. The public forum takes the form of an ‘open mic’ session which begins with each participant being given feedback forms to fill in. Completed feedback forms are entered into a ballot box and drawn out at random, and those that are selected are given a chance to voice their comments. An expert panel consisting of academics and professionals, who have an understanding of the project, are on hand to respond to the public’s comments or answer their questions, if they are of a technical nature. The workshops and forums are usually held in a civic building, such as a lecture theatre, school hall, or community hall, which the organiser deems to be ‘neutral’ in the sense that it is not affiliated with any particular interest group.

OBJECTS FROM PUBLIC ENGAGEMENT EVENTS

THE BALLOT SYSTEM

The physical box from which ballots are drawn epitomises the ballot system, and the ballot box often becomes the focus of attention during an event. This leads to a wider acknowledgement of the ancillary artefacts surrounding the procedure for conducting the ballot, such as the feedback forms and the registration procedure. It has already been established that the rules for drawing ballots are often contested. In some instances, the anger and frustration held towards the voting system may be directed to other objects within close proximity to it:

Discussion became heated as the event progressed. Speakers voiced their concern that the completed development will not match the images shown in the video, and that the numbers published in the socio-economic study were incorrect. When discussion about these technical details could not be progressed, hostility began to be directed towards the format of the forum, the mental capacity of the event host, and the legitimacy of the ballot. When a few speakers representing the same interest group were picked in a row, a couple of men from local villages shouted that the ballot was unfair because the box was somehow rigged, even though it was clear plastic and completely transparent. [Public forum, Sept 2013]

There is a juxtaposition between the lofty idealism associated with public engagement and the mundane realism of a ballot box. The attention that is paid to the box, its physical dimensions, its literal transparent nature, and the way the hosts ceremoniously draw ballots from it, are significant to the successful running of an event. Similarly, clear signage to mark the amount of time a speaker has remaining to speak, plays more than a pragmatic role in event planning. The interface between the participant and the event is regulated by the ballot system, and the ballot system is in turn regulated by the action of drawing ballots from a box. The ballot box holds the pragmatic and literal function for transferring knowledge, and yet its role as a boundary object was challenged by the participants present. The ballot system is a mutually agreed set of rules to ensure the procedure is conducted fairly. But it also acts as the means of controlling the order and direction of traffic through relegating potential speakers to a randomised time slot. To the disinterested observer, an attack on the validity of a transparent ballot box would seem to bypass rational argument. Yet, it still points to the acceptance of a power structure that encompasses a ballot

system. None of the participants at any of the events observed based their argument on whether there should be a ballot system: that is already taken for granted; it has been ‘black-boxed’.

THE MICROPHONE SYSTEM

If the public forum is promoted as a way to ‘give voice’ to the public, then the microphone is the physical manifestation of this ‘voice’. It is through the use of microphone equipment whereby the common 3-minute time limit for speakers may be enforced. Being in control of the microphone equipment also means that the organisers have the discretion of allowing an audience member to finish speaking if they exceed the time limit, or not. Consider the following public forum, attended by around 200 participants. The participants who attended this event were very distinctively split into two demographics: young to middle aged expat residents who spoke little to no Cantonese, and elderly local residents who spoke little to no English:

The event organisers provided real-time translation of the proceedings through interpretative headsets for those who did not speak Cantonese. Additionally, after each of the expats made their speech, the event host gave a brief overview of their main points for the benefit of the members of the audience who do not understand English. This procedure soon became contentious when a young Cantonese-looking man wearing a white polo shirt interrupted the host to say that he was mistranslating the last speaker’s comment, and that the host missed out the point about “the hospital” (putting in an alternative route through the hospital complex). The host responded by saying that their main point is not to translate word-for-word, and that the event was being recorded by technicians who understand English and all comments will go into the official records. The young man requested, and was given, a microphone; and he used it to make his case. He knows it’s not his turn, he said, but he feels that his group is being misrepresented. As he spoke, his speech became increasingly emotional and irate, until several members of the audience, myself included, felt obliged to correct him: “No, he did talk about the hospital”, I muttered in Cantonese (other discordant voices emanating from the audience at large were also making the same point), “but he called it by the hospital’s name, ‘Tung Wah’”. After a while (2 minutes, maybe?), his microphone was switched off; and without an amplified voice, he had no choice but to sit down, looking disgruntled. [Public forum, April 2015]

Just as the ballot box is key for the enactment of a ballot system, the microphone is essential for directing voices and allowing speakers to be heard one at a time. The fact that this particular event involved translating between two languages added another obstacle to the task of ‘giving voice’ to participants. It also demonstrates the difficulties participants face in representing their interests across this language barrier. In this scene, the young man’s quest to represent his group was hindered by the lack of control he had over the language it was conveyed in. The young man sought to speak out of turn and attempted to take over the role of the event host to translate between languages. However, he failed to align his own interest with those of other

participants, as the other participants did not accept his Cantonese translations. When the microphone was switched off, it bluntly terminated the young man's ability to voice his interests and participate in the value co-creation process. It is such a blunt act, in fact, that it is usually not employed unless a participant resolutely refuses to yield the floor. Before the extreme act of shutting off the microphone, speakers are usually given fair warning by the event host politely informing them their time is up. After such a disruption, a host will also often remind participants that they may submit any further comments they have as a written submission. The constant reference to a written account seems appropriate, since after all, the public engagement report produced at the end of each stage is the sole reference point summarising the proceedings for future readers.

THE TECHNICAL DOCUMENTS

Scientific texts may be viewed as not only a production of scientific knowledge, but also as a means to an end for the scientist to establish their worldviews and persuade others. Similarly, the technical documents that are disseminated at public engagement events take on multiple roles. They represent the technical world as constructed by the project team, and they help to transfer knowledge about the project to a wider audience. Once within the public domain, participants use them in different capacities to advance an argument about the project. Different meanings are assigned to the objects by agents who participate in a public engagement event setting. Hence, when these documents are challenged, it is the meaning participants have assigned to the documents that becomes the point of contestation. Consider the following observation from a community workshop:

The design schemes were presented as standard zoning plans, accompanied by architectural site cross sections and some artists' renditions. During the group presentation at the end of the workshop, one group's representative voiced his dissatisfaction with the material provided, and said defiantly to the event organisers that: "we cannot understand the blobs and the squiggles of this so-called zoning plan; it doesn't show the height or the real impact, so why don't you come back with a 3D perspective and then we can have an honest discussion!" [Community workshop, June 2013]

This comment exposes the difficulties of communicating across knowledge boundaries. The speaker rejects the validity of a zoning plan and instead proposes the use of 3D perspective drawings; the point of contestation is the physical representation of a series of technical details that include building height, density, and visual impact. These types of information may be represented in a factually correct manner in either form, although it is arguably easier to understand as a 3D perspective drawing. A comparable but conflicting set of interpretations to technical drawings were experienced by the research subjects in Woodcock *et al.*'s (2012) study. The study gauged the reaction by local residents to different types of architectural representations and found that buildings represented as solid blocks with little architectural details were likely to have its height and bulk misinterpreted by laypersons. The same information presented as architectural 3D rendering was easier for laypersons to understand, yet the local residents were likely to conclude that they

were being misled by developers; that the built reality would not reflect the version shown to them in the focus group; and that the drawings were used to seduce and manipulate them into agreeing to a scheme they may later regret.

The results of Woodcock et. al's study seems to contradict the scene observed at this event, but what it really reveals is the difficulties of boundary objects to cross political boundaries (cf. Carlile, 2002, 2004). This view acknowledges that transfer of knowledge in situations where interests are misaligned needs to also take into consideration the political consequence that may arise as a result of the knowledge transfer. By acknowledging the role of vested interests embedded in the production of technical documents, this view also helps to make sense of why some modes of representation may be accepted and others rejected. When a piece of technical knowledge is presented as a 'proposed design drawing', its meaning may still be open to co-production through negotiations and contestations with participants who engage with the material. But once the piece of technical knowledge is accepted as a product, as in the case of a published report or statistic, its role within a power network shifts into a more stabilised state. Like the ballot system or the microphone system, it may then be used by agents participating in a power network as a way of delegating their power to more durable materials.

DISCUSSION AND CONCLUDING REMARKS

The observations presented in this paper demonstrate examples where material artefacts are used in different ways by various stakeholder who attend public engagement events. Since the aim of public engagement events is to capture the feedback from the public, they are exemplified by the attendance of large cohort of stakeholders, who break from their usual living routine to come together to discuss a particular project, within a specific and well-defined timeframe. They come and go throughout the engagement process and an attendee who may be present at one event may decide not to attend the next. Because of the disparate nature of the attendees, the format of the event plays a significant role in providing the event with a sense of cohesion and authority.

The event has been imbued with cultural expectations and normative moral values, which influenced the way attendees can interact with each other. As the observations demonstrate, the material artefacts play an active role in the management framework of these proceedings. Although intended as mere 'tools' to facilitate the proceedings, they in fact contribute to control or restrict what attendees can do. They do so by directing the flow of communication between participants, by controlling the level of discourse that can take place, and by containing the knowledge that can be transferred from one party to another. It is more than likely that material artefacts have a similar effect on other organisational settings. But because public engagement events are often contentious and acrimonious, the way these artefacts have become 'power' in a reified form becomes more readily observable. One of the advantages of introducing an STS framework to examine stakeholder relationship is in its focus on the process rather than the outcome of stakeholder relationships, thus providing insights into the evolving and emergent nature of stakeholder relationships (e.g. Missonier & Loufrani-Fedida, 2014). By critically evaluating the material artefacts as part of a

socio-technical network, this study hopes to broaden the utility of an STS approach to study power relations in different organisational settings.

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AVOIDING FAILURE: THE USE OF QUALITATIVE COMPARATIVE ANALYSIS TO IDENTIFY PATHWAYS TO SUCCESSFUL SANITATION INTERVENTIONS

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AVOIDING FAILURE: THE USE OF QUALITATIVE COMPARATIVE ANALYSIS TO IDENTIFY PATHWAYS TO SUCCESSFUL SANITATION INTERVENTIONS

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ABSTRACT

In resource-limited communities, up to 70 percent of sanitation systems fail within two years of construction, leading to diminished public and environmental health and heightened economic costs. Previous research has focused on isolated factors that influence success or failure, neglecting to evaluate the effects of multiple factors in combination. In order to reduce failure in sanitation, we need to understand how social, economic, technical, institutional, and organizational factors combine together to lead to success or failure. Combinations of factors that lead to success can guide implementing organizations towards avoiding failure-prone scenarios and promote success by focusing limited resources on strengthening these pathways. We applied qualitative comparative analysis to evaluate the pathways of combined factors that lead to successful and failed sanitation systems. Two pathways led to successful sanitation systems and three pathways led to failed sanitation systems. All successful systems required *Sufficient O&M Funds*, *Organization Sanitation Experience*, a *Clear O&M Plan*, a *Skilled Operator*, and *Ongoing External Support* in addition to either *Addressed Sanitation Priorities* and *Organization Embeddedness* or *Municipality Involved in Planning* and *Lack of Organization Embeddedness*. All failed systems had *Lack of Municipality in Planning*, *No Ongoing Support*, *Lack of Skilled Operator*, and *Unaddressed Sanitation Priorities* in addition to other conditions including a *Previous Failed System*, *Lack of Organization Sanitation Experience*, *Insufficient O&M Funds*, *Lack of Clear O&M Plan*, or *No Community Participation in Planning*. Pathways demonstrate that multiple conditions influence success, thus to reduce failure we need to implement sanitation systems with a holistic perspective. Further, our findings elucidate what social, economic, technical, and institutional conditions must be present in *combination* with different organizational factors to yield successful outcomes. This research works towards building a comprehensive theory of success and failure in resource-limited communities by viewing sanitation systems, organizations, and their surrounding environments through a systems-theoretic lens.

KEYWORDS

Sanitation, Success, Failure, Qualitative Comparative Analysis

INTRODUCTION

In resource-limited communities, up to 70 percent of sanitation systems fail within two years of construction (Davis 2015), leading to diminished public and environmental health (Mara et al. 2010) and heightened economic costs (WSP 2017). Sanitation failure has been attributed to inadequacies within the enabling environment, which is the set of all social, institutional, technical, and economic capacity factors that allow for systems to function and meet basic needs long-term (Tilley et al. 2014). In alignment with this definition, the many potential causes of sanitation system success or failure include social factors, such as community priorities (Seymour 2014) and community participation (Battacharyya 2015); institutional factors, such as government support (Kooy and Harris 2012) and regulations (Eldho 2014); technical factors, such as construction quality (Chatterley et al. 2014) and operator knowledge (Brikké and Bredero 2003); and economic factors, such as adequate funds for operation and maintenance (O&M) (Eales et al. 2013; Starkl et al. 2013). The high sanitation failure rate is mostly attributed to a lack of holistically integrating these technical and non-technical factors.

Additionally, it is expected that the causes of both sanitation system success and failure are influenced by implementing organizations' characteristics and implementation processes. In resource-limited communities, sanitation systems are implemented by a variety of organization types including state and municipal governments, local non-governmental organizations (NGOs), and international aid organizations. These organizations have different implementation processes, which could influence project outcomes. For example, NGOs often encourage more community participation than government agencies (Devas and Grant 2003). In addition, research suggests that an organization's experience in the project sector is important for project outcomes (Chism and Rintala 2010). Finally, the embeddedness, or familiarity of an organization with the local regulations, culture, and social norms, may be important for system outcomes (Jordan et al. 2016). Highly embedded organizations, like local NGOs, likely face fewer challenges in implementation due to their knowledge of important processes and institutional and cultural factors (Javernick-Will and Scott 2010). While the potential influence of organizational factors is known, these factors have still not been investigated in the context of sanitation systems, particularly in combination with other enabling environment factors.

Finally, and perhaps most importantly, sanitation failure persists because most studies evaluate the influence of an individual factor on sanitation outcomes. There is a need to recast sanitation systems as complex systems that interact with a vast web of similarly complex human, economic, infrastructure, and institutional systems (Mihelcic et al. 2009; Voulvoulis 2012). This view, coined as "systems thinking" or "systems theory", posits that the behavior of one system must be examined based on its relationships to other systems (Amadei 2014; Labi 2014). Despite the renewed call in literature and practice for systems thinking approaches, very little research has applied systems theory to understand causes of sanitation outcomes, amid continued sanitation system failure (Davis 2015). Recognizing sanitation systems as complex systems that interact with other complex systems can illuminate how planning and management strategies unite with the enabling environment to consistently lead to success. To respond to this gap in literature, we draw

from systems theory to inform the identification and selection of important causal factors that interact together to influence the success or failure of sanitation systems.

To reduce failures in sanitation, we need to understand how social, economic, technical, institutional, and organizational factors combine together to lead to success or failure. Combinations of factors that lead to success can guide implementing organizations towards avoiding failure-prone scenarios and promote success by focusing limited resources on strengthening these pathways. The phenomena are complex, with causes of failure not necessarily the inverse of the causes for success, and thus we investigated pathways to both outcomes.

To do so, we applied qualitative comparative analysis (QCA) to evaluate the pathways of combined social, technical, and organizational factors that lead to successful and failed sanitation systems. In this paper, we define a successful system as one that is (1) continuously used, (2) adequately maintained, and (3) meets local regulations; failure occurs when at least one of the success criteria is not met.

RESEARCH METHODOLOGY AND APPROACH

This paper uses a systems approach to investigate sanitation system outcomes across social, institutional, technical, economic, and organizational factors. These factors rarely operate in isolation and instead affect and are affected by one another. Thus, we employed QCA to elucidate how these factors combine and interact and to increase our holistic understanding of the causes of success or failure in sanitation. QCA uses set theory and Boolean algebra to analyze pathways of causal conditions that lead to an outcome of interest (Ragin 2008). In QCA, *causal conditions* are factors from theory, or identified from case knowledge, that are hypothesized to influence an outcome of interest (i.e., success or failure). *Pathways* are the combinations of causal conditions that together lead to an outcome of interest. QCA is particularly useful for describing complex causal relationships by analyzing the ways in which causal conditions combine together to yield an outcome, rather than quantifying the effects of independent variables (Ragin 2008; Ragin et al. 2003). QCA is well-suited to analyze causal relationships for intermediate sample sizes that fall between the small sample size of traditional case studies and the large sample size of statistical analyses (Kaminsky and Jordan 2017). This method retains the power of rich, in-depth case knowledge of case studies, while providing more generalizable results (Ragin 1987). While the use of theoretical knowledge is essential for analysis and interpretation throughout QCA, in-depth case studies are also essential for QCA as the strength of the method increases when empirical and theoretical evidence are wielded simultaneously. Figure 1 presents an overview of the methods used to analyze pathways to success or failure. The causal conditions and outcomes are defined using fuzzy sets and calibrated based on case and theoretical knowledge, so that the same “measuring stick” can be applied across diverse cases (Ragin 2008). Fuzzy values are assigned to all cases, and fsQCA software is used to identify the logical combinations of conditions, like equations or “recipes” that lead to the outcomes (Ragin 2008).

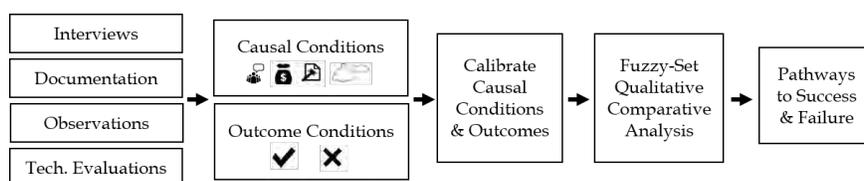


Figure 1. Overview of data collection and analysis methods to identify pathways to success and failure.

RESEARCH CONTEXT

Presently, India is home to the world's fastest growing population but still faces some of the most significant challenges for successful sanitation systems. In India, more than 50% of sanitation systems have failed (Davis 2015) and 60% of the population lacks access to safely managed sanitation (WHO and UNICEF 2017). The central government has responded with ambitious national initiatives to increase sanitation access and has called for increased participation of local and international NGOs to achieve these goals (Government of India 2016).

As such, 20 cases (i.e., communities) in southern India were selected based on comparable populations and demographics. Each community had one sanitation system that served 800 to 1000 users; these systems were all community-based, meaning that the systems were centralized and community members were expected to take some role in the management of the systems. All sanitation systems were implemented between 2005 and 2008, and all implementing organizations stated that the intended lifetime of the systems was between 20 and 30 years. Each community was a peri-urban slum resettlement where most residents were from India's lowest caste and found employment primarily through day labor. In India, slum resettlements often lack clarity as to which government agency (e.g., slum development board vs. water and sanitation department) is responsible for providing infrastructure and services in the community. Consequently, NGOs often fill this gap by implementing community-based projects to ensure that basic infrastructure needs, like sanitation, are still met. In ten cases, the systems were operated and maintained by a male operator from the community. In five cases, the systems were managed by a women's self-help group (WSHG). The remaining six cases lacked a formally appointed operator, which is discussed further in the Results and Discussion section. Cases were selected to ensure variability between outcomes and causal conditions in order to analyze causal relationships (Ragin 2008). The communities varied in terms of sanitation technologies, system outcomes, and implementing organizations (Table 1). Ten communities had successful sanitation systems, and ten communities had failed systems. Sanitation technologies included DEWATS (a type of decentralized wastewater treatment system with a settling tank or biogas digester, baffled reactor, and gravel filter), improved septic tanks with gravel filters, and Ecological Sanitation (EcoSan) urine diverting dry toilets. Finally, cases were selected to ensure variation across implementation processes, thus, a mix of local NGOs, international NGOs, and government agencies were chosen.

Table 1. Summary of selected cases.

	Case Number	District, State	Implementing Organization Type	Technology Type
Successful Cases	1	Trichy, Tamil Nadu	Local NGO	DEWATS + Biogas Digester
	2	Bangalore, Karnataka	Local NGO	DEWATS + Biogas Digester
	3	Musiri, Tamil Nadu	Local NGO	DEWATS + Biogas Digester
	4	Musiri, Tamil Nadu	Local NGO	EcoSan Community Toilets
	5	Villupuram, Tamil Nadu	State Gov't	Improved Septic Tank + Gravel Filter
	6	Villupuram, Tamil Nadu	State Gov't	DEWATS
	7	Kancheepuram, Tamil Nadu	Out-of-State NGO	DEWATS
	8	Nagapattinam, Tamil Nadu	State Gov't	DEWATS
	9	Kanyakumari, Tamil Nadu	In-State NGO	DEWATS
	10	Trichy, Tamil Nadu	Local NGO	Biogas Digester
Failed Cases	11	Bangalore, Karnataka	Local NGO	DEWATS + Biogas Digester
	12	Bangalore, Karnataka	Int'l NGO	DEWATS + Biogas Digester
	13	Musiri, Tamil Nadu	Local NGO	Improved Septic Tank + Gravel Filter
	14	Bangalore, Karnataka	Int'l NGO	Improved Septic Tank + Gravel Filter
	15	Kolar Gold Fields, Karnataka	Local NGO	DEWATS + Biogas Digester
	16	Mysore, Karnataka	Local NGO	DEWATS
	17	Kancheepuram, Tamil Nadu	State Gov't	DEWATS
	18	Cuddalore, Tamil Nadu	State Gov't	DEWATS
	19	Bangalore, Karnataka	Int'l NGO	DEWATS
	20	Nagapattinam, Tamil Nadu	Int'l NGO	DEWATS

CAUSAL AND DOMAIN CONDITION IDENTIFICATION

We identified an initial list of potentially important causal conditions from literature. For example, Eales et al. (2013) found that sanitation systems with *Skilled Operators* were more likely to meet regulations. We expanded that list during data collection in the field. For example, interviews uncovered the importance of a *Previous Failed System in the Community*, where a prior negative experience with sanitation led some community members to be less willing to pay for the next system. A final list of causal conditions was assembled after collecting data from all 20 cases (Table 1).

We also identified domain conditions, which are conditions that remain relatively constant across cases, and therefore cannot be included in cross-case comparison (Ragin 2008). The following conditions did not vary significantly across the 20 cases: *Socio-Economic Status*, *Weather*, *System Size*, *System Age*, *Community Leadership Structure*, *Community Participation in Construction*, *Community Contributions*, and *Regulations*.

Table 2. Causal conditions hypothesized to influence sanitation success and failure. Note: The presence of conditions is hypothesized to influence success and the absence of conditions is hypothesized to influence failure. The one exception is *Previous Failed System in Community*, where the presence of this condition is hypothesized to influence failure, and the absence is hypothesized to influence success.

	Category	Hypothesized Causal Condition	Definition	Source
Enabling Environment Conditions	Social	Addressed Priorities	The extent to which the sanitation system addresses the community's priorities for sanitation, based on priority importance	(Hacker and Kaminsky 2017; Seymour 2014)
		Community Participation in Planning	The meaningful involvement of community members in planning, including decisions such as site and technology selection	(Battacharyya 2015; Roma and Jeffrey 2010)
		Previous Failed System in Community	A community's prior exposure to failed sanitation	Case Knowledge
	Institutional	Municipality Involved in Planning	The meaningful involvement of the local municipality in planning meetings and decision-making	(Harris et al. 2011; Sansom 2011)
	Technical	Skilled Operator	Trained operator that demonstrates adequate technical knowledge to perform maintenance and independently diagnose and fix problems	(IDECK 2015; Sakthivel et al. 2014)
		Clear O&M Plan	Required maintenance tasks are known and all stakeholders agree on whose responsibility it is to perform and finance each of those maintenance tasks	(Brikké and Bredero 2003; Chatterley et al. 2014)
	Economic	Sufficient Funds for O&M	The availability of funds equal to or in excess of O&M costs; generated through system income or external sources	(Eales et al. 2013; Starkl et al. 2013)
Organizational Conditions	Organizational	Organization's Embeddedness	Familiarity of an organization with the local regulations, culture, and social norms	(Barenstein and Iyengar 2010; Jordan et al. 2016)
		Organization's Sanitation Experience	Organization's prior sanitation experience, based on organization focus and number of previous projects completed	(Sujaritpong and Nitivattananon 2009)
		Ongoing Support	Technical and managerial support provided by government or implementing organizations to communities for ongoing O&M	(Bakalian and Wakeman 2009; Sansom 2011)

DATA COLLECTION

For each case, data was collected through interviews, documentation, technical evaluations, and observations to characterize the hypothesized causal conditions and system outcomes.

Interviews. Interviews were conducted with community members, operators, implementing organizations, and local governments to explore project history, decision-making, and stakeholder roles. Example interview questions include: *Can you describe for me how the sanitation system in your community was planned?* and *What support does your organization provide for the community regarding the sanitation system?* We added additional project-specific questions after reviewing available documentation from each community, such as *The project reports show that an exposure visit was organized, can you describe the visit?* In all communities, at least two interviews were conducted with government representatives and at least three interviews were conducted with implementing organization representatives. Seventeen communities had a formal community leader; a minimum of two interviews were conducted with the leader in each case. Five communities had WSHGs that managed the systems; a minimum of five interviews with at least three WSHG participants were conducted in each case. Ten communities had one male operator; a minimum of two interviews were conducted with the operator in each case. Finally, community members with no formal roles in the community were interviewed. For community member perspectives, theoretical saturation—where no new themes or concepts arise in subsequent interviews—was reached after 8 to 12 participants. In total, at least 14 interviews were conducted in each case, and the average interview length was 44 minutes.

Documentation. To evaluate project history, decision-making, system designs, system costs, and system performance, we collected documentation from implementing organizations and local government. Implementing organizations' standard operating procedures reflected general planning and implementation strategies. Feasibility studies tracked decision-making, project goals, and planning processes. Meeting notes summarized the various stakeholder roles in the project and decision-making and planning processes. Detailed project reports provided final system designs, cost information, and material quantities. Monitoring and evaluation reports yielded historical performance data, system challenges, maintenance performed, and ongoing organization support. We used documentation to triangulate data from other sources and as a guide for follow-up interviews with communities, organizations, and government.

Technical Evaluations. Technical system evaluations included detailed observations of construction quality (e.g., design errors, cracks, damage), use (e.g., water levels in tanks), and system function (e.g., smells, wastewater color, presence of solid waste). In addition, influent and effluent wastewater samples were taken from fourteen of the twenty communities and analyzed for chemical oxygen demand (COD), biochemical oxygen demand (BOD), and pH; these are the three parameters regulated for domestic wastewater in India (Central Pollution Control Board 2017). In six communities where systems were no longer being maintained, wastewater samples could not be taken due to inaccessibility

(e.g., Case 11 had extensive damage, Case 16 had flooding) or extended lack of use resulting in no wastewater in the system (Cases 12, 14, 15, 19).

Observations. We also performed observations in each community to supplement other data sources to evaluate the design, use, maintenance, performance, and challenges of each system. As an example, to augment interview data on use, we observed the number of individuals using toilets for fixed periods of time in the morning and evening. We also observed the cleanliness of toilets, which could reflect proper use or misuse, and evaluated the water levels in the treatment tanks to determine if the wastewater generation was consistent with reported use patterns. Finally, we observed the amount of open defecation in the community by visiting community-reported open defecation sites and observing human feces. On every site visit, we took detailed notes.

DATA ANALYSIS

Interview transcriptions, observation notes, and documentation were uploaded into QSR NVivo, a qualitative coding software (QSR International 2015). Coding is a process where qualitative data is categorized based on important themes of interest (Maxwell 2013). Qualitative data were coded using both deductive and inductive methods (Saldana 2009). Deductive coding uses theory to hypothesize important topics and themes (Saldana 2009). For example, the theme of *Training* was identified prior to the start of coding, because literature shows that training is important for transferring technical knowledge to communities (Castro et al. 2009). Alternatively, inductive coding allows themes to emerge from the data (Saldana 2009). For example, the priority of *Water Supply* was identified inductively, where this priority emerged when participants described water as a problem or value important to the community. To ensure internal validity, a second coder (undergraduate research assistant) was used to code the data for approximately 50% of the qualitative material. The coding dictionary was developed iteratively between the two coders, and discussions helped to attain consensus in code definitions. Inter-rater reliability, or the agreement between coders, was measured using Cohen's Kappa coefficient, which is a statistical comparison between the amount of qualitative data coded the same and what could happen by chance (Bazeley and Jackson 2013). Kappa coefficients greater than 0.7 reflect exceptional agreement between coders; Kappa coefficients above 0.4 are generally acceptable; Kappa coefficients below 0.4 reflect poor agreement. The final Kappa coefficient was 0.59, reflecting acceptable agreement between the two coders. We then summarized the qualitative data within each code, and resolved conflicting statements between participants by triangulating answers with documentation and observations (Basurto and Speer 2012).

Fuzzy-set Qualitative Comparative Analysis

Condition Calibration. In QCA, set theory is used to evaluate the degree of membership each case has in or out of the set for each causal condition and outcome (Basurto and Speer 2012). Fuzzy-set QCA (fsQCA) is a variant of QCA that uses fuzzy logic, where cases can have partial membership in a set and is useful when cases do not dichotomously fall fully in or fully out of a set (Jordan et al. 2011; Kaminsky and Jordan 2017; Ragin 2008). To evaluate membership, these sets are defined through an iterative process called calibration,

so that cases can be compared using the same measuring stick. Calibrations are defined and revised to ensure fuzzy set definitions reflect meaningful separations between cases and are rooted in theory. For all conditions included in this analysis, except *Sufficient O&M Funds*, we used the indirect calibration approach, where set membership was determined qualitatively based on case knowledge and theory (Basurto and Speer 2012). For example, the calibration for *Organization Embeddedness* was adapted from Jordan et al. (2016) using a 4-value fuzzy set, presented in Table 3. All indirect calibrations used 4-value fuzzy sets.

Table 3. Calibration for *Organization Embeddedness* (Jordan et al. 2016). Note that in all four cases with an international organization, the organization had not previously worked in the communities.

Fuzzy-Score	Definition
0	Out-of-set. International aid organization.
0.33	Partially out-of-set. Out-of-state Indian NGO or state government.
0.67	Partially in-set. Local Indian NGO new to the community.
1	In-set. Local Indian NGO or municipality that previously worked in community.

For the *Sufficient Funds for O&M* condition, we used the direct calibration approach (Ragin 2008), where quantitative anchor points were identified based on theoretical and case knowledge; available funds as a percentage of O&M costs were normalized within these anchor point definitions (Figure 2). In-set membership was defined as funds equal to or in excess of 100 percent of O&M costs, indicating that a system consistently could pay for all required maintenance. Literature supports that the ability to pay for maintenance is an important determinant of O&M (Chatterley et al. 2013). Out-of-set membership was defined as when no funds were generated or no funds were available for O&M. The cross-over point was identified as when the funds available equaled 50 percent of required O&M costs, reflecting the most ambiguous point.

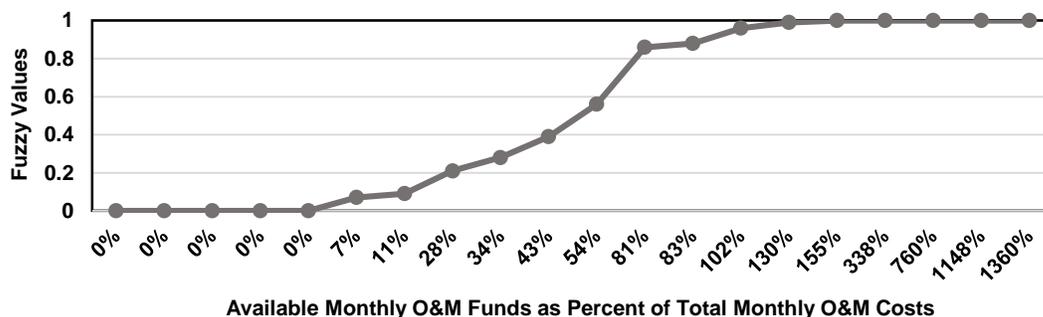


Figure 2. Direct calibration for *Sufficient O&M Funds*.

Outcome Calibration. There were three intermediate outcomes that needed to be present for success: use, maintenance, and performance. Use and maintenance were calibrated directly. In-set membership for use was defined as more than 75 percent of the community members (in the system's target population) use the system correctly, daily, and exclusively (i.e., no open defecation) (Andres et al. 2014; Harris et al. 2017). In-set membership for maintenance was defined as at least 90 percent of the total required

maintenance tasks were performed correctly and on time (Brikké 2000; Eales et al. 2013). Performance was calibrated indirectly using a three-value fuzzy set; in-set membership was defined as a system complying with pH, BOD, and COD regulations. India's regulated pH, BOD, and COD requirements depend on the end use of water, such as discharge to a municipal sewer, irrigation, surface water, or coastal waters (Central Pollution Control Board 2017). Out-of-set membership was defined by a system failing to comply with all three regulations. An intermediate value of 0.3 was assigned for systems that failed to comply with one, but not all regulations. Finally, success outcome scores were determined by taking the minimum of the fuzzy-scores for the use, maintenance, and performance intermediate outcomes, since all three criteria must be present simultaneously for success. It should be noted that all sanitation systems were implemented at a similar time (between 2005 and 2008), and all systems were intended to function for at least 20 to 30 years. Consequently, all systems had a minimum of seven years remaining in their intended lifetime at the time of data collection. System outcomes were determined based on the status of use, maintenance, and performance at the time of data collection and were validated based on interview and documentation evidence establishing that the outcomes were representative and steady and not reflecting a recent (and potentially short-lived) change. It is presumable that successful systems could fail prior to the end of the intended lifetime or that failed systems could become successful; however, the future potential outcomes of the systems were not considered in this analysis.

Truth Table Analysis. Fuzzy scores for all conditions and outcomes were assigned for every case and summarized in a truth table (Table 4), which reflects the empirical configurations of causal conditions associated with outcomes (Ragin 2008). Through minimization of the truth table using fuzzy logic, logical combinations of conditions that are sufficient to yield the outcomes of interest are identified (Ragin 2008). The rows in the truth table can be expressed using Boolean operators, where AND expresses the combinatorial aspect of causality and OR expresses equifinality, or the idea that multiple combinations of conditions can lead to the same outcome. Minimization allows for the logical simplification of these combinations. For instance, two rows in the truth table that result in the same outcome might differ by only one condition, and removing the differing condition produces a more simplified expression. The minimization process performs these stepwise comparisons for all possible combinations and yields the simplified combinations that are minimally sufficient to produce the outcome. We used the software fs/QCA (Ragin 2013) to analyze (and minimize) the truth table and to identify pathways to success and to failure.

In research focusing on social phenomena, such as how social and institutional conditions influence sanitation systems, the problem of limited diversity must be addressed. Social phenomena are naturally limited in their diversity, thus, it is very common to find it impossible to identify an empirical case that represents each possible combination of conditions; this set of all possible combinations is called the logic space (Ragin 2008). While theory can suggest what outcomes might occur for combinations that lack empirical cases, conclusions about those combinations cannot be drawn with as much certainty. As a result, researchers aim to reduce the logic space by increasing the number

of cases and reducing the number of causal conditions analyzed (Ragin 2008). To reduce the logic space, we limited our analysis of the 20 cases to ten causal conditions, which is a well-accepted amount for QCA (Jordan et al. 2011).

Granted, it is optimistic to presume that increasing the number of cases and reducing conditions eliminates all causal combinations without empirical cases, called counterfactuals in QCA; thus, they are evaluated using counterfactual analysis (Ragin 2008). Counterfactual analysis is a hypothetical thought experiment where researchers use theoretical knowledge to make assertions about whether the presence or absence of causal conditions would lead to the outcome (Kaminsky and Jordan 2017). The goal of counterfactual analysis is to determine which of the possible combinations of causal conditions could theoretically lead to the outcome and which combinations would likely not occur. For instance, based on theory, one would expect that a failed system could occur without either *Sufficient O&M Funds* or a *Skilled Operator* and that there are likely unobserved failed systems without both of those conditions. Thus, the researcher could use theoretical evidence to make the assertion that the absence of both *Sufficient O&M Funds* and a *Skilled Operator* would be associated with failure.

To address the counterfactual combinations in our study, we assumed for the outcome of success that *Addressed Sanitation Priorities*, *Skilled Operator*, *Clear O&M Plan*, *Sufficient O&M Funds*, *Organization Sanitation Experience*, and *Ongoing Support* would be present. This decision was further validated by these causal conditions having high necessity scores when present and low necessity scores when absent for the outcome of success. For the outcome of failure, we assumed the opposite: that *Addressed Sanitation Priorities*, *Skilled Operator*, *Clear O&M Plan*, *Sufficient O&M Funds*, *Organization Sanitation Experience*, and *Ongoing Support* would be absent. For both the success and failure outcomes, we marked *Community Participation in Planning*, *Past Experience with Failed System*, *Municipality Involved in Planning*, and *Organization Embeddedness* as “either present or absent” to explore the influence of these less-theorized conditions.

Table 4. Truth table that summarizes the fuzzy scores assigned to all conditions and outcomes for the 20 cases analyzed. All values were then used in fsQCA to determine pathways to success and to failure.

Case Number	Causal Conditions										Outcomes			
	Addressed Sanitation Priorities	Community Participation in Planning	Past Experience with Failed System	Municipality Involved in Planning	Skilled Operator	Clear O&M Plan	Sufficient O&M Funds	Organization Embeddedness	Organization Sanitation Experience	Ongoing Support	Use	Maintenance	Performance	Success (min(Use, Maintenance, Performance))
1	0.82	1	0	0.67	1	1	0.96	0.67	1	1	1	1	1	1
2	0.6	0.67	0	0.33	1	0.67	1	0.67	1	1	1	1	1	1
3	0.85	0.33	0	1	1	1	1	1	0.67	1	0.92	1	1	0.92
4	0.94	0.33	0	0.33	1	1	1	0.67	1	0.67	0.91	1	1	0.91
5	0.83	0.33	0	1	0.67	1	1	0.33	1	0.67	0.95	1	1	0.95
6	0.32	0.33	1	1	0.67	1	1	0.33	1	0.67	0.91	0.92	1	0.91
7	0.4	0.67	1	0.67	0.67	0.67	0.88	0.33	0.67	0.67	0.81	0.91	1	0.81
8	0.51	0.33	1	1	1	1	1	0.33	1	1	0.90	1	1	0.90
9	0.32	0	0	0.67	1	1	1	0.33	1	0.67	1	0.91	1	0.91
10	0.92	1	0	1	1	1	1	1	1	1	1	1	1	1
11	0.35	0.33	0	0.33	0.33	0	0.99	1	0	0.33	0.32	0.07	0	0
12	0.11	1	1	0	0.33	1	1	0	1	0	0	0	0	0
13	0.19	0	1	0.33	0	0	0.27	0.67	0	0	0.22	0	0.3	0
14	0.19	0.33	1	0	0	0	0.46	0	1	0	0	0	0	0
15	0.3	0.67	0	0	0.33	0.33	0.21	1	0	0.33	0.48	0.07	0	0
16	0.32	0.67	0	0	0.33	0.67	0.07	1	0	0.33	1	0.20	0	0
17	0.03	0	1	0	0	0	0.48	0.33	0.67	0	0.06	0	0.3	0
18	0.11	0	1	0	0	0	0	0.33	0.67	0	0.31	0.03	1	0.03
19	0.19	0.33	1	0	0	0	0	0	1	0	0.88	0.20	0	0
20	0.16	0	1	0	0	0	0.56	0	0	0	0.82	0.60	0	0

Pathway Identification and Interpretation. To interpret the quality of these pathways, there are four main metrics. Causality for success and failure was determined based upon measures of pathway *consistency* and *coverage*. Consistency (Equation 1) demonstrates how consistently a pathway leads to that particular outcome. Generally, consistency scores above 0.8 are required for a pathway to be “consistent” (Ragin 2006). Coverage (Equation 2) is the percent of cases with an outcome that are explained by a given pathway (Rihoux and Ragin 2009). Since QCA is not a probabilistic method, pathways with low coverage are acceptable. Higher coverage indicates a greater number of cases are explained by a given pathway, which can help to illuminate generalizability. Two additional metrics are commonly used to further interpret pathway results by examining the *necessity* and *sufficiency* of individual conditions in leading to each outcome of interest. A necessity score for a condition is calculated using the same equation as consistency (Equation 1). Scores above 0.9 are generally required for a condition to be considered necessary (Ragin 2008), which means that nearly all cases have that condition present and have the outcome of interest. A condition is sufficient when it nearly always results in a positive outcome. Sufficiency is calculated using Equation 2, and scores above 0.8 are generally required for a condition to be considered sufficient (Ragin 2008).

$$\text{Consistency and Necessity} = \frac{\sum \min(X_i Y_i)}{\sum X_i} \quad \text{Equation 1}$$

$$\text{Coverage and Sufficiency} = \frac{\sum \min(X_i Y_i)}{\sum Y_i} \quad \text{Equation 2}$$

X_i is the membership score for a given combination of conditions;
 Y_i is the outcome score for that combination.

RESULTS AND DISCUSSION

Pathways to Success

The analysis of the ten successful sanitation cases yielded two pathways to success (Figure 3). Each uniquely represented five of the ten successful cases. Together, these two combinations (or the “solution”) had a consistency of 1.0 and a coverage of 0.74. The extremely high consistency of the solution shows that all cases exhibiting either of these two combinations of conditions were successful. Pathways are combinatorial, not additive or longitudinal, and thus conditions are presented in order of necessity. Within both of these pathways, there were four necessary conditions: *Sufficient O&M Funds*, *Organization Sanitation Experience*, *Clear O&M Plan*, and *Skilled Operator*. All four of these conditions had necessity scores above 0.90, which is the criteria for a condition to be necessary (Ragin 2008). While these four conditions were necessary, they alone were not sufficient for success, and additional conditions were thus present in both pathways. The fifth common condition was *Ongoing Support*. The five common conditions reflect factors from the enabling environment. A branch occurred in the pathways, where they subsequently differed on the organizational conditions. The first pathway additionally contained *Addressed Sanitation Priorities* and *Organization Embeddedness*, and the second pathway additionally had *Municipality Involved in Planning* and *Lack of Organization Embeddedness*. These pathways to success included a combination of social, institutional, technical, economic, and organizational conditions, thus emphasizing the need to attend to both the enabling environment and organizational factors in sanitation projects.

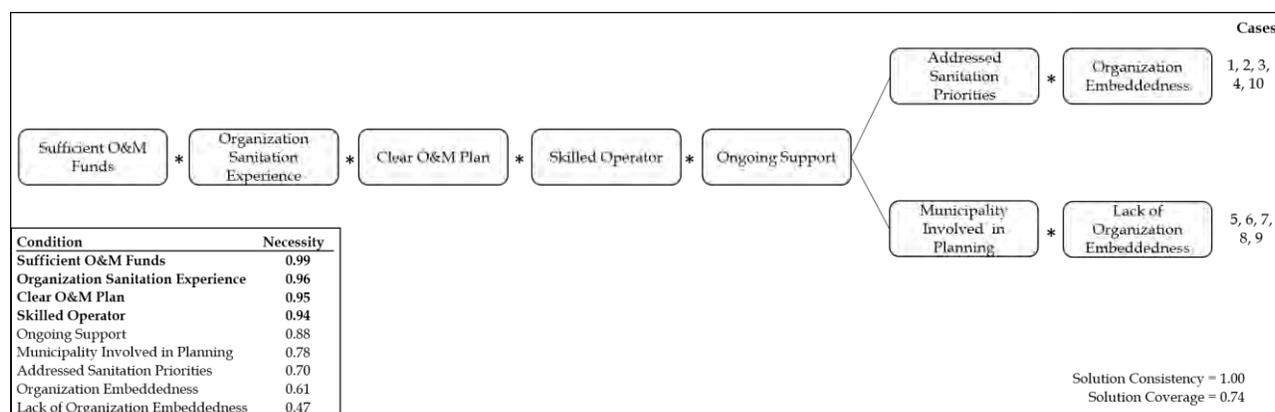


Figure 3. Pathways to success. Note: * means “and” and lines represent distinctions between separate pathways.

Overall, the two pathways to success demonstrate the importance of adequate skills, resources, and support for sanitation system O&M combined with leveraging local knowledge in planning. This aligns with findings from Chatterley et al. (2013 and 2014), who also determined that ongoing support, maintenance plans, and adequate finances were essential for well-maintained school toilets in Belize and Bangladesh. Further, these findings underscore that social, economic, technical, and institutional conditions most often function together to produce successful outcomes and cannot be well-understood in isolation.

The first pathway represents cases that all received a greater amount of ongoing support from the implementing organization, in part due to these organization’s existing and lasting relationships with the communities. Further, the organizations’ reputations and presence in the communities were important to diffusing government opposition. For instance, in Community 1, a government sanitary engineer acknowledged “at first, we didn’t see the need for anything different [than the old, failed sanitation system], but [the implementing organization] was persistent. They kept returning day after day to convince us to let them do the project. We agreed, but only because they had run so many successful programs in [Community 1] before.” The organizations’ intimate knowledge of the community and existing relationships laid the foundation for increased community acceptance and satisfaction with the sanitation system. The organizations’ prior sanitation experience also fostered effective project planning and management mechanisms, including operator training, lasting O&M plans, funding sources, and external support.

The second pathway describes cases that received ongoing support from municipalities, notably because the implementing organizations for these cases were state government agencies and out-of-state NGOs. Case knowledge indicates that these implementing organizations’ prior sanitation experience caused them to recognize the importance of engaging local government to bridge their contextual knowledge gap as well as to provide ongoing support in their stead. One engineer from an out-of-state Indian NGO stated, “we know that government is important, we must do more than just ask for permission for the project to be successful, we must ask them for help in the planning.” Similar to the first pathway, these cases were all characterized by the strength of their O&M plans, financial resources, and external support.

Enabling Environment Conditions

In alignment with Tilley et al. (2014), the pathways to success stress the importance of the enabling environment in fostering successful sanitation outcomes. All successful cases exhibited a combination of social, economic, technical, and institutional conditions. For both pathways,

removing any one of the causal conditions significantly reduced consistency below acceptable levels. As such, the conditions presented in each pathway must be present *together* to be sufficient for success; this underscores the importance of analyzing sanitation outcomes using a systems thinking approach.

Sufficient O&M Funds. In all successful cases, sanitation systems either generated income equal to or in excess of the O&M costs or communities had access to regular, established sources of external funding to cover the O&M costs. In all 10 cases, income was generated from user fees, and in four cases income was also generated by selling resources recovered from the sanitation system (e.g., vegetables grown from water reuse (Case 1), compost sales (Cases 3 and 4), and biogas for cooking fuel (Case 10)). In these cases, systems generated over twice the amount of the O&M costs, and were able to save the money in a bank account that the implementing organization set up; lend the money as interest-generating micro-loans to women in the community; or use the funds to improve other community infrastructure such as building a community hall and a water storage tank in Case 10. In seven of the ten successful cases, sanitation systems both generated income through user fees and received financial support from the implementing organization or government. Case knowledge indicates that this financial redundancy was important, particularly when large, unexpected O&M costs arose, such as damage from flooding or vandalism. For example, while Case 1 generated funds from user fees and resource recovery in excess of O&M costs, the excess fund generation was seasonal, coinciding with the harvest and sale of vegetables. In two instances, prior to the influx of these additional funds, vandals damaged doors, water taps, and stole the water supply pump. The municipality split the costs for these repairs with the community, which meant the community did not have to take out loans or deplete saved funds to ensure repairs happened. Additionally, the presence of a *Clear O&M Plan* was important to ensure that adequate funds would be available and managed well.

Clear O&M Plan. Clear, agreed-upon responsibilities for O&M between an organization, community, and municipality were essential for sanitation success. In successful cases, this clarity was achieved through written documentation, such as Memorandums of Understanding (MOUs) that were signed by all stakeholder groups. Alternatively, O&M responsibility was established during the formal handover process where the implementing organization signed over responsibility and ownership of the sanitation system to the community or municipality. In all cases, these MOUs or handover processes were coupled with meetings where O&M tasks and responsibilities were discussed.

Skilled Operator. All sanitation system operators received technical training and demonstrated the ability to diagnose system issues and perform O&M. In Cases 2, 5, 6, and 7, a member of the community was trained and paid to operate the sanitation system as their primary form of employment. These operators all worked alongside either a previous system operator or an operator from the implementing organization for a minimum of three months, thus learning the system's O&M tasks hands-on. In Case 4, the operator received similar training from the implementing organization and also was selected because he held a degree in sanitation engineering. In two of the successful cases, sanitation systems were managed by WSHGs. In these cases, the WSHGs had received significant technical training, including multi-day exposure visits to nearby successful sanitation systems, where they learned how to perform maintenance and repair tasks and manage system finances. In Cases 3, 8, and 9, the operator was a municipal employee tasked with operating several water and sanitation systems in the municipality. In these cases, the operators received training from the implementing organizations as well as annual

training from the municipal government. Perhaps more importantly, these three operators were supervised by two sanitary inspectors (a permanent municipal government position), who both championed sanitation in their municipality more than their counterparts in other municipalities. The additional managerial support and O&M oversight proved to both increase the operator's skillset and strengthened O&M for the sanitation systems.

Ongoing Support. As indicated, ongoing support was another essential tenet of successful sanitation. Initially, both the source of support (i.e., municipality vs. implementing organization) and the type and quality of support were analyzed. Consistent with the literature, we found that the type and quality of support was more important than the source of support (Chatterley et al. 2014; Eales et al. 2013). Successful cases all received significant technical and managerial support from either a municipality, the implementing organization, or both. Technical support was important for large and difficult maintenance tasks, namely desludging the system which usually required extra equipment or a contract with a vacuum truck company. Managerial support was helpful to responsibly manage finances and to resolve conflicts such as challenges to the land ownership for the system. Interestingly, all five cases described by the second pathway received *Ongoing Support* from the municipality, and case knowledge indicates that municipal support was clearly defined and secured when the municipality was engaged in creating a long-term O&M plan alongside the community and implementing organization.

In either pathway to success, *Participation in Planning* was not found to be important. Case knowledge indicates that while some successful cases had high membership for *Participation in Planning*, several failed cases also had high membership. Thus, community participation did not consistently lead to success in combination with other conditions. While community participation is thought to positively influence community acceptance of a system, and thus use (Murphy et al. 2009), community participation was not a sufficient condition for success. Instead, these pathways to success illuminate that strong external support combined with adequate resources for O&M (financial, technical, and managerial) are essential for success.

Organizational Conditions

Organization Sanitation Experience. For all successful cases, the implementing organizations had completed five or more sanitation projects, demonstrating a high level of experience in the sector, which was a necessary condition for success. Other case studies conducted for sanitation and transportation infrastructure have also found that an organization's past experience in the project sector positively influences the project's outcome because the organization may be more aware of potential challenges and best practices prior to planning (Chism and Rintala 2010; Sujaritpong and Nitivattananon 2009).

Addressed Sanitation Priorities & Organization Embeddedness. In the first pathway, the implementing organizations were embedded, thus having more familiarity with the communities and their localized norms and culture. Interestingly, these cases also had more addressed sanitation priorities, which may have stemmed from the organizations' heightened knowledge of the communities prior to the start of the sanitation project. For example, in Case 10, the implementing organization was a local Indian NGO based in the same city as the community and had worked on drinking water, health, solid waste management, education, and women's empowerment projects in the community for over 20 years. The NGO's long and close relationship with the community allowed them to be knowledgeable of community needs and priorities. In our initial analysis, we calibrated *Priority Assessment*, but found that this condition had extremely low necessity and had

an extremely weak correlation ($R^2=0.017$) with *Addressed Sanitation Priorities*. In other words, whether an organization conducted a priority or needs assessment in project planning had little influence over how well priorities were addressed, but instead, embeddedness may be more important.

Municipality Involved in Planning & Lack of Organization Embeddedness. In the second pathway, the implementing organizations were not embedded in the communities, such as being international NGOs, state government, or out-of-state Indian NGOs. For these cases, municipal involvement in planning was essential for the outcome of success, and may have served as a bridge for the contextual community knowledge that the unembedded organizations lacked.

Although government agencies and NGOs tend to have different implementation processes (Devas and Grant 2003), *Organization Type* was not present in either pathway to success. In each pathway, both governments and NGOs implemented successful systems, which highlights that a strong enabling environment and sanitation experience can be achieved by both types of organizations.

Pathways to Failure

Ten of the 20 communities studied had failed sanitation systems. The analysis of failed sanitation cases yielded three pathways to failure (Figure 4). The solution had a consistency of 0.98 and a coverage of 0.73. In all failed cases, systems were not being consistently used by the majority of community members, were not adequately maintained, and failed to meet at least one regulation. Low scores across all three of these intermediate outcomes for failed systems was expected, since lack of maintenance inhibits performance and discourages use in sanitation (Seymour 2014). In the pathways to failure, only one condition, *Lack of Municipality in Planning*, was necessary, having a necessity score equal to the threshold of 0.90. Although below the threshold for necessity, the *No Ongoing Support*, *Lack of Skilled Operator*, and *Unaddressed Sanitation Priorities* conditions were common to all pathways to failure. In the first pathway, these four conditions were combined with *Previous Failed System in Community*. In the second pathway, they were combined with *Lack of Organization Sanitation Experience* and *Insufficient O&M Funds*. In the third pathway, they were combined with *Lack of Organization Sanitation Experience*, *Lack of Clear O&M Plan*, and *No Community Participation in Planning*. The removal of any one of the conditions included in any of the failure pathways significantly reduced consistency and coverage.

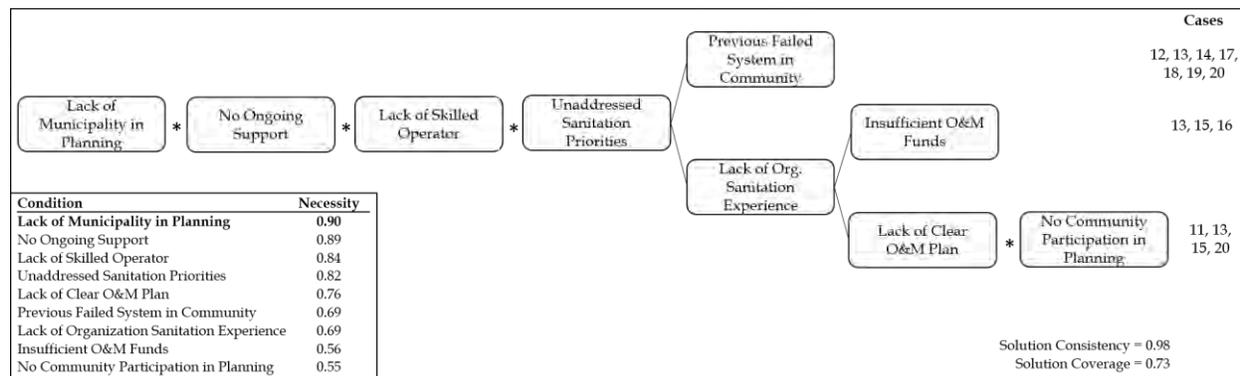


Figure 4. Pathways to failure. Note: * means “and” and lines represent distinctions between separate pathways.

Some cases were explained by more than one pathway; however, cases that were explained by only one pathway contained distinct case details that lead the pathways to branch. In the first pathway, Cases 12, 14, 17, 18, and 19 were uniquely explained by this pathway. All of these cases

had a *Previous Failed System in the Community*, in addition to the other four common pathway conditions. The history of sanitation failure in these communities may have further solidified social norms for open defecation. For example, in Community 17, one individual said: “Even if they come back and fix this system, we don’t want it. This is the second system we’ve had that has increased sickness and smells in the community. They tell us it will be different and will be a good thing for us, but we refuse to believe them. We don’t want the toilets.” In Case 18, the system complies with all regulations, but is not being used or maintained by the community and many community members cite their dissatisfaction with the sanitation system as a reason they no longer use their toilets. All cases described by the first pathway are marked by a similar dissatisfaction and distrust of the sanitation system, leading a majority of community members to opt for open defecation or break the connections from their toilets to the treatment system.

In the second pathway, Case 16 was distinct. While Case 16 had a *Clear O&M Plan, Community Participation in Planning*, and no *Previous Failed System in the Community*, the *Insufficient O&M Funds* proved to be an important causal condition. In this case, the municipal government was not involved in planning and had little relationship with the community and NGO. Despite recommendations otherwise, the municipality connected 120 new households to Case 16’s treatment system, flooding the system and damaging the treatment tanks. The lack of adequate O&M funds compounded these challenges, as the community was not able to pay for expansion or rectification of the system.

Finally, Case 11 was the only case uniquely explained by the third pathway, having neither a *Previous Failed System in the Community* nor *Insufficient O&M Funds*. The lack of community participation in planning combined with the lack of a clear O&M plan and the lack of ongoing support in Case 11 meant that the community was unprepared to shoulder responsibility for the sanitation system and was unable to overcome challenges like vandalism.

Enabling Environment Conditions

Weak enabling environments, such as those with low municipality involvement, low external support, and low local technical capacity for O&M, were critical to explain sanitation failure.

Lack of Municipality in Planning. In all failed cases, the local municipality was uninvolved in the planning process, which may have led to the lack of ongoing government support and in some cases, outright government opposition to the sanitation system. In Cases 17 and 18, a state government agency implemented the sanitation systems without coordinating with the local municipality, who they expected to provide ongoing O&M support. As a result, the municipalities did not originally allocate financial and human resources to support the sanitation infrastructure. In Case 11, the system operator and community leader expressed concern that “if we don’t come here every day and keep by system, [the municipality] will seize the land and turn it into something to make money.” In this case, the municipality verbally gave permission for the project to proceed over a decade ago, but never signed any project documentation and was not invited to any further planning meetings. In Case 12, the municipality was not engaged in project planning and thus was unaware of the time and effort dedicated by the community towards O&M. After five years of operation, the municipality revoked the land lease from the WSHG managing the system and did not replace the group with a municipal operator. The WSHG has since struggled to contact the municipality to regain ownership of the system, and the municipality’s disinterest and lack of political will may stem from inadequate engagement of this important stakeholder from the

beginning. In Case 16, the municipality was not aware of the sanitation project until three years after construction. At this time, the municipality was constructing a new housing development and because they had not previously interacted with the NGO, they connected 120 new houses to the sanitation system, causing a massive shock overload to the system (which today resembles a wastewater lagoon rather than a contained treatment system). In all of these cases, engaging the municipality in the early planning stages could potentially have mitigated these challenges.

No Ongoing Support. The absence of ongoing support in all pathways to failure highlights the importance of providing ongoing technical and managerial support to resource-limited communities. Failure to engage the municipality in planning also meant that none of these cases received any meaningful government support for their sanitation system. Further, many of the implementing organizations left the communities, either because the organizations expected the government to fill this supporting role or because they lacked the resources themselves to continue to support the communities. In resource-limited communities, like the cases in this study, sanitation systems are prone to heightened challenges resulting from vandalism, community conflict, weather, etc. (Chatterley et al. 2014; Seshadri 2009). Having an external source of support is extremely important to backstop the communities and ensure that problems do not go unaddressed.

Lack of Skilled Operator. Two cases had operators who never received training and thus only collected fees and performed basic tasks like toilet cleaning and providing water for toilet flushing, if at all. Two cases had operators who received basic instruction on daily maintenance tasks but still lacked technical knowledge and the ability to independently recognize and rectify system issues. Six cases had no operator in charge of O&M for the system. For the cases without operators, two systems never had operators due to challenges with system ownership and handover (described further below). In the remaining cases, operators existed during the first year of system operation, but inadequate O&M funds meant that their salaries went unpaid, and the operators subsequently quit. As a result, all failed cases did not receive adequate maintenance.

Unaddressed Sanitation Priorities. In all failed cases, sanitation systems did not address a majority of each community's priorities for sanitation. Sanitation technologies must be designed and selected so that communities' priorities are addressed (Brikké 2000; Murphy et al. 2009). In resource-limited communities, where users are often required to be more actively involved in their own sanitation provision, the need for technologies to meet priorities is especially important (Breslin 2003; Seymour 2014). Community acceptance can be an extremely important determinant of success for sanitation systems (Harris-Lovett et al. 2015; Roma and Jeffrey 2010; Starkl et al. 2013), and acceptance is less likely to occur if communities' priorities are not addressed (Freudenberger 2011; WHO 2004). In the failed cases, community members may not be using the systems because these systems do not meet important priorities.

Previous Failed System in Community. In seven of the ten failed cases, the communities had been exposed to at least one failed sanitation system prior the systems studied for this research. Often, the sanitation system studied were implemented to replace the failed sanitation systems, but the negative experiences may have inhibited the community's willingness to use and maintain these new systems. For example, in Case 17, one woman stated "no one wants to talk about sanitation here. We had a system few years back that got so many blockages in the sewers that when this new system came, most people closed their toilets and went out [for open defecation] because they are afraid of the blockages and smells that would happen." Particularly in communities where previous

sanitation failure has occurred, organizations should emphasize behavior change education and ensure that adequate human and financial resources are consistently available for proper O&M.

Insufficient O&M Funds. In five of the failed cases, the system generated no income. In only one case (Case 12), income was generated in excess of O&M costs. The other four income-generating systems struggled to cover O&M costs, either because community members were unwilling to pay user fees or because funds collected were mismanaged. In one case, a community member stated, “why should I pay to use the toilet when the toilet is never cleaned?” The lack of adequate O&M funds often worked as a negative feedback loop to maintenance performed, each increasing its negative influence upon the other. In all failed cases, financial support was unable to overcome the poor income generation and was usually not planned for or regularly allocated to the systems.

Lack of Clear O&M Plan. In failed cases, formal processes such as MOUs or handover did not occur and stakeholders either disagreed on responsibilities or were unable to identify which O&M tasks fell under each group’s purview. Despite a Government Order (GO) that places the responsibility for the provision and management of sanitation infrastructure on the local municipality (Ministry of Urban Development 2008), unclear land tenure and lack of coordination between NGOs and municipalities continues to add confusion to system ownership and responsibility. For example, in Case 18, the municipality refuses to assist the community with system maintenance because they never formally received handover from the NGO, and thus state that they cannot interfere with a project until it no longer belongs to the NGO.

No Community Participation in Planning. In four cases, the community was entirely uninvolved in the planning process. A common feeling echoed across these communities was articulated by one community member: “The first time we learned about the sanitation system was when the contractor came and started building. We went and watched and asked them one day what they were building. That’s when we learned it was for our toilets.” The lack of community participation in planning may have also led to fewer addressed sanitation priorities and lack of clarity in O&M responsibilities.

Organizational Conditions

When we calculated the initial necessity scores of all conditions, both the presence and absence of *Organization Embeddedness* and *Organization Type* had very low necessity scores (<0.30) and did not appear in any of the consistent pathways to failure; thus, we removed these conditions from the analysis of failure. As with success, both government agencies and NGOs implemented cases that appeared in all three pathways to failure.

Lack of Organization Sanitation Experience was present in two of the pathways to failure, but was not a necessary condition for failure, as organizations with significant prior experience still implemented failed systems (3 of the 7 cases described by the first pathway). Interestingly, the cases that did have organization sanitation experience also lacked organization embeddedness. Case knowledge indicates that organizations that were implementing their first sanitation projects tended to omit important best practices, including creating a *Clear O&M Plan* that detailed if and when the organization was going to stop providing support. In Case 11, the organization’s lack of sanitation experience meant that the employee assigned to mobilize the community and train the operator did not have adequate knowledge to build the technical capacity of the community. The organization also, as one employee said: “...felt very overwhelmed with how complicated sanitation is. We didn’t expect the project to last so many years. If we had known we would have to go back to the community again and again for this problem and that problem, we would not

have done a sanitation project.” *Organization Sanitation Experience* may lead to improved planning and good construction quality, but also is not sufficient to avoid failure.

Implications from Understanding Success and Failure

While the solutions to success and the solutions to failure were, expectedly, not mere inverses of each other, all five pathways share some similarities. In all five pathways the presence/absence of *Ongoing Support* and a *Skilled Operator* were important conditions and likely had some of the greatest influence on each system’s (in)ability to overcome challenges such as vandalism, government opposition, or major repairs. The differences in the success and failure solutions also illuminate combinations that are sufficient to overcome the absence of important conditions. This is particularly valuable for sanitation projects in resource-limited communities where unique challenges may require organizations to seek alternative planning and management strategies to use limited resources effectively. For instance, in all failed cases, the municipality was not involved in planning, which was sometimes due to the municipality refusing to participate (Cases 15, 16, 17), the municipality changing its mind during the process (Cases 14, 19), or the municipality lacking the personnel and resources to engage (Cases 11, 12, 13, 18, 20). *Municipality Involved in Planning* was included in only one of the two pathways to success, and thus absent in some successful cases. Under these limitations, organizations must then employ strategies to fill this gap, and the first success pathway suggests that conditions such as *Addressed Sanitation Priorities* plus *Organization Embeddedness* are sufficient to overcome the lack of municipal engagement. Similarly, *Unaddressed Sanitation Priorities* was common to all failed cases and four successful cases. All four of these successful cases are described by the second success pathway, which is distinguished by the *Municipality Involved in Planning*. Included the municipality in decision-making for technology selection and system management could be sufficient to overcome the lack of addressed priorities for these cases.

Together, the solutions for success and failure demonstrate actionable ways in which implementing organizations and government agencies can strengthen sanitation planning, implementation, and management to increase access to successful systems. Organizations should focus their efforts on reducing the vulnerability of O&M by bolstering operator skills and reliability, ensuring dependable and adequate income streams, formulating clear and comprehensive plans for O&M responsibility, and securing ongoing financial, technical, and managerial support for the duration of the systems’ lifetime. Additionally, organizations should aim to increase community acceptance and satisfaction for sanitation systems by improving the quality of service delivered, addressed contextualized needs and priorities, and building trust in the organization’s ability to execute successful projects. Finally, implementing organizations should concentrate on engaging local governments in the planning, implementation, and management of sanitation systems in order to provide additional support to communities and reduce uncertainties in land tenure, ownership, and maintenance responsibilities.

Limitations

The findings from this research are specific to small, community-based sanitation systems in India. While the coverage scores for the solutions for success and failure are high, indicating high replicability within the set of 20 cases studied, the results cannot be generalized beyond the study context. However, since the results align with theory that advocates the importance of strengthening the social, technical, institutional, and economic pillars of the enabling environment, these results may provide a basis for sanitation implementing organizations in other contexts to

target improved interventions and learning. While the domain conditions may be influential for the outcomes of success or failure, these conditions were not included in the analysis due to lack of variation. Domain conditions such as *Socio-Economic Status*, *Weather*, *System Size*, *System Age*, *Community Leadership Structure*, *Community Participation in Construction*, *Community Contributions*, and *Regulations* may also be influential for the outcomes of success or failure, but further research that includes cases that vary across these conditions is required.

CONCLUSION

Two pathways led to successful sanitation systems and three pathways led to failed sanitation systems. All successful systems required *Sufficient O&M Funds*, *Organization Sanitation Experience*, a *Clear O&M Plan*, a *Skilled Operator*, and *Ongoing External Support* in addition to either *Addressed Sanitation Priorities* and *Organization Embeddedness* or *Municipality Involved in Planning* and *Lack of Organization Embeddedness*. Overall, the pathways to success demonstrate the importance of providing adequate financial, technical, and managerial resources for maintenance and of involving government, organization, and community stakeholders in all project phases. Failed systems lacked many of these important conditions for success. All failed systems had *Lack of Municipality in Planning*, *No Ongoing Support*, *Lack of Skilled Operator*, and *Unaddressed Sanitation Priorities* in addition to other conditions including a *Previous Failed System*, *Lack of Organization Sanitation Experience*, *Insufficient O&M Funds*, *Lack of Clear O&M Plan*, or *No Community Participation in Planning*. The pathways to failure emphasize the importance of engaging government and community stakeholders, as well as establishing clear mechanisms for ongoing technical, managerial, and financial support for resource-limited communities.

The use of fsQCA to investigate sanitation systems furthers our understanding of the complex relationships between the enabling environment and organizations and the success or failure of sanitation in resource-limited communities. Pathways demonstrate that multiple conditions influence success, thus to reduce failure we need to implement sanitation systems with a holistic perspective. Practically, the findings identify the processes needed for successful sanitation systems, such as engaging local municipalities, training operators, addressing priorities, creating a clear O&M plan, and providing ongoing support, which is particularly important for implementing organizations to know and understand. Further, our findings elucidate what social, economic, technical, and institutional conditions must be present in *combination* with different organizational factors to yield successful outcomes. This research works towards building a comprehensive theory of success and failure in resource-limited communities by viewing sanitation systems, organizations, and their surrounding environments through a systems-theoretic lens. Further, a comprehensive understanding of the combined causes for sanitation success and failure contributes to improving interventions and increasing successful sanitation coverage globally.

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Is “Being Green” Rewarded in the Market?: An Empirical Investigation of Decarbonization and Stock Returns*

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Abstract

Climate change could have potentially devastating effects on societies and economies globally, and climate finance to combat the challenges related to it demands a quantum of capital. Yet, this form of investment has been hampered by the unclear relationship between corporate environmental performance and financial performance. In this regard, this study empirically investigates the risk-return relationship of low-carbon investment and characteristics of carbon-efficient firms. Based on 74,486 observations of 736 US firms from January 2005 to December 2015, we construct a carbon efficient-minus-inefficient (EMI) portfolio by carbon efficiency, defined as revenue-adjusted greenhouse gas (GHG) emissions at firm-level. Our EMI portfolio generates positive abnormal returns since 2010 and an investment strategy of “long carbon-efficient firms and short carbon-inefficient firms” would earn abnormal returns of 3.5–5.4% per year. The only exception is found in small firms. We find that these carbon-efficient firms tend to be “good firms” in terms of financial characteristics and corporate governance. Our findings are not driven by a small set of industries, variations in oil price, or changing preferences of bond investors caused by the low-interest-rate regime, starting with the 2008 financial crisis.

Keywords: Environmental, Social, Governance (ESG), Low-Carbon Investment, Asset Pricing, Carbon Efficient-Minus-Inefficient (EMI) Portfolio, Climate Finance

JEL Codes: G12, G30, P18

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1 Introduction

Rising temperatures due to climate change will radically damage the functioning of human societies and specifically global economic activity (Burke et al. (2015); Dell et al. (2014); Hsiang et al. (2013)). According to the International Energy Agency (2014), combating climate change is projected to require \$53 trillion in cumulative investment by 2035.¹ The critical question is, then, how to source this massive capital. The funding gap far exceeds any single government’s budgetary capacity, so it is crucial to address it with broader funding sources and scaled capital. Nonetheless, many investors and business leaders continue to resist managing climate risks because they are uncertain whether traditional financial objectives can accommodate the inclusion of environmental factors. Therefore, before calling for investors, business leaders, and policymakers to take serious action about climate change, it is first necessary to understand what it means to invest in firms that are “being green.”

A growing number of investors are looking at “impact investing” (interchangeably described as environmental, social and governance [ESG] investing, socially responsible investing [SRI], and value-based investing), a form of investing that seeks to overlay non-traditional investment criteria alongside the traditional pursuit of financial returns. Yet impact investing has not resolved the question of whether it is possible to maximize risk-adjusted returns while integrating environmental factors in investment decisions. Therefore, most mainstream investors, especially those with fiduciary obligations to maximize profit, continue to lack confidence in this form of investing, with the result that the \$53 trillion funding gap remains unresolved.

Although voluminous research has studied the compatibility of a firm’s environmental performance (EP) and financial performance (FP), the debate has been inconclusive both theoretically and empirically. In principle, a theoretical argument about the relationship between EP and FP can go either direction. Some researchers claim that a firm’s environmental improvement may not be compatible with profit maximization (e.g., Friedman (1970); Aupperle et al. (1985); Luken (1997); McWilliams and Siegel (1997); Clift and Wright (2000); Jensen (2012)). On the contrary, others see environmental improvements as a cost-saving instrument and potential source of a firm’s competitiveness in a rapidly changing world and climate (e.g., Schmidheiny (1992); Porter and Linde

¹Note that all dollar signs in this paper indicate US dollars unless otherwise indicated.

(1995)). Empirical evidence is also mixed. While previous studies such as Hart and Ahuja (1996), Russo and Fouts (1997), Dowell et al. (2000), King et al. (2002), and Konar and Cohen (2001) suggest that EP is positively related to FP, other studies still find a negative or insignificant relationship (e.g., Filbeck and Gorman (2004); Telle (2006); Ziegler and Seijas Nogareda (2009)). A lack of consensus on reliable EP measures, along with different methodologies and data, is also responsible for this discrepancy in empirical studies.

Using the data based on firm-level greenhouse gas (GHG) emissions, this research provides novel empirical evidence about firms' carbon efficiency, stock market performance and other characteristics in order to clarify the risk-return relationship of low-carbon investment. Specifically, we use portfolio analysis to investigate whether carbon-efficient firms outperform carbon-inefficient firms, and we conduct regression analysis to identify the characteristics of carbon-efficient firms. Our key research questions thus are as follows:

1. Do investors achieve higher returns on their low-carbon investment portfolios?
2. If so, are they abnormal returns (“alpha”) or compensation for bearing additional risk?
3. What are the sources of the observed abnormal returns?

Our main data set consists of 74,486 observations of 736 US firms during the period from January 2005 to December 2015. We basically merge four databases: Trucost for firm-level GHG-related data, MSCI ESG (formerly KLD) Stats for measures on ESG performance, Compustat for financial variables, and CRSP for stock returns.² Our key variable is firm-level “carbon efficiency” (or “carbon intensity”) from Trucost, which we define as the actual amount of GHG emissions of a firm divided by that firm’s revenue.³ Carbon efficiency can be interpreted as the amount of GHG a firm needs to emit in order to make \$1 million in revenue. Unlike prior studies that use a firm’s EP rating based on self-reported surveys or reputational indices to quantify social and environmental performance (Cohen et al. (1995)), we use a quantitative and standardized EP measure so that we can compare across firms and industries.

²A majority of previous literature uses ESG data provided by Kinder, Lydenberg and Domini and Company Research & Analytics, Inc. (KLD). But, from 2010, MSCI ESG Research is the successor to KLD, Innovent and IRRC, which were acquired through MSCI’s acquisition of RiskMetrics in 2009. The MSCI ESG Stats was created by KLD in 1991.

³Hereafter, we use the terms carbon (emissions) intensity, carbon efficiency, and carbon inefficiency interchangeably as a measure of EP. High carbon efficiency corresponds to low carbon inefficiency, low carbon intensity, and low carbon emissions per revenue.

As to our first question of whether carbon-efficient firms outperform carbon-inefficient firms, we form portfolios by carbon-efficiency tertiles and construct a carbon efficient-minus-inefficient (EMI) portfolio. It is a zero-cost portfolio, which can be interpreted as an investment strategy that takes a long position in carbon-efficient stocks and a short position in carbon-inefficient stocks. We construct three versions of EMI portfolio: a single-sorted portfolio based on carbon efficiency (EMI1), a double-sorted portfolio based on carbon efficiency and book-to-market ratio (EMI2), and a double-sorted portfolio based on carbon efficiency and firm size (EMI3). We find all three EMI portfolios earn positive cumulative returns from 2010, implying carbon-efficient firms do in fact outperform carbon-inefficient firms. The only exception is found in very small firms.

As to the second question, we find that the observed extra returns on our EMI portfolios are not fully explained by the well-known risk factors (or styles), such as market, size, book-to-market ratio (B/M), operating profitability, investment, and momentum. That is, a strategy of “long carbon-efficient firms and short carbon-inefficient firms” would earn alpha. For example, the magnitude of alpha amounts to the annualized returns of 3.5–5.4% for EMI1 and EMI2 portfolios.

As to the third question, we find that carbon-efficient firms are those with higher firm value measured in higher Tobin’s q , higher net income relative to invested capital (i.e., return on investment [ROI]), lower return on asset (ROA), higher cash flow, and higher coverage ratio). We also find that firms with better governance tend to be carbon-efficient. And the statistical association of carbon efficiency with ROA, cash flow, and coverage ratio increases after 2009.

For robustness, we examine whether investors explicitly consider firms’ efforts to improve carbon efficiency and whether other macroeconomic factors, such as fluctuations in oil price or unconventional monetary policy, may affect the performance of our EMI portfolios. We evaluate the performance of portfolios formed on *changes* in carbon efficiency. The results suggest that investors may not closely and directly monitor firms’ decarbonization efforts, so these factors are not explicitly considered in their investment decisions. In addition, we confirm that changes in oil price do not drive EMI portfolio performance. Also, we check whether unconventional monetary policy has any impact on the performance of EMI portfolio. Due to extremely low interest rates after the 2008 global financial crisis (GFC), bond investors have moved their funds to equity markets and are looking for stable and high-dividend-paying industries, such as utilities, telecommunications, and consumer durables. Therefore, we construct the same EMI portfolio without these industries

and find that it tracks the benchmark EMI portfolio closely, suggesting that a change in investor preference caused by unconventional monetary policy cannot explain our findings.

Our study makes unique contributions in several respects. First, we form portfolios using revenue-adjusted GHG emissions at the firm-level, which is a more objective and easily comparable EP measure. Second, we consider intrinsically different levels of GHG emissions across industries when forming portfolios, in contrast to some prior studies that do not consider industry effect. Third, our measure of EP covers a firm's entire value chain and thus considers indirect GHG emissions from supply chains, which has become increasingly important. Fourth, our analysis goes beyond determining the sign of the empirical link between EP and FP, and investigates a more general question of how well carbon-efficient firms perform compared to carbon-inefficient firms in the stock market while accounting for risks they face.

We expect that our empirical findings will help scholars, investors and policymakers understand how decarbonization and related firm characteristics are perceived in financial markets. While we acknowledge that the observation of the abnormal return is relatively short since the outperformance of carbon-efficient firms starts around 2010, our research indicates their outperformance may be a long-term sustainable trend. Because the variables that we use to characterize carbon-efficient firms are relatively slow-moving variables (compared to stock market returns), we anticipate that the trend of carbon-efficient firms' outperformance may persist over longer time periods.

The rest of the paper is structured as follows. Section 2 reviews related empirical studies. Section 3 explains our data and key variables, while providing summary statistics on carbon efficiency. We also explain the advantage of using the Trucost database, compared to other EP-related measures used in the previous literature. In Section 4, we construct EMI portfolios in various ways and examine whether they can be priced by well-known risk factors and whether they can earn positive alphas. We also examine the firm-level characteristics of carbon-efficient firms and perform various robustness tests. Section 5 discusses the implications for climate finance along with several unanswered questions that warrant future research. Section 6 concludes with a summary.

2 Literature Review

While early empirical studies focus on determining the sign of the relationship between a firm's EP and FP, recent studies expand to investigating mechanisms through which EP can positively impact FP. We have identified at least three strands of empirical research: (1) event studies, (2) regression analysis, and (3) portfolio analysis. In addition, we refer to the literature on corporate social responsibility (CSR) and firm characteristics because firms' environmental actions are often integrated into CSR discussions. Incorporating this CSR literature will help us understand what kinds of firms are carbon-efficient and carbon-inefficient, which is the main topic of Section 4.2.

2.1 Event Studies

Researchers use event-study methodology to gauge the impact of an exogenous event on a firm's FP. A typical event study finds a discrete event related to a firm's EP and compares the variables of interest (e.g., stock prices) over a short time period before and after the event. Events include macroeconomic ones such as environmental data releases or regulation enactment, and firm-specific news such as data releases or voluntarily or involuntarily joining an environmental program. Researchers are interested in whether and why the selected event might have a positive (or negative) impact on firms' FP. Related literature shows that investors are concerned because a firm would be subject to (1) an environmental penalty; (2) a potential gain or loss in revenue; and (3) a governance issue, and thus react to the event.

First, investors react to news when they believe a firm's environmental activities are directly related to liability, compliance, and regulatory risks, thereby affecting the cost and value of the firm. For instance, Hamilton (1995) tracks the stock value of 436 publicly traded firms from the New York and American Stock exchanges before and after the day that the Environmental Protection Agency (EPA) first released the Toxics Release Inventory (TRI) in 1989, and finds that high-polluting firms experience abnormal negative stock returns. The author argues that the investors take TRI data as news because it may relate to the costs of environmental laws, leading to a higher cost of operation and loss of reputation and goodwill. Similarly, Jones and Rubin (2001) find that, even among 73 negative environmental news reports by the Wall Street Journal, the market only reacts to firms that would be subject to penalty. Lott and Karpoff (1999) find that the magnitude of market-value

losses of firms that violate environmental laws is closely correlated to the legal penalties imposed.

Second, some event studies argue that an “event” need not necessarily relate to environmental penalties but to sales and revenue. More recently, Bushnell et al. (2013) analyze the stock value of 552 stocks in the EURO STOXX index over a three-day window when the EU CO₂ allowance price dropped 50% in late April 2006. Despite the carbon price drop, which may have led to a reduction in environmental costs, they observe a sharp stock price drop in carbon- and electricity-intensive firms. They point out that investors consider the declining carbon price in terms of its product price impacts (e.g., lower carbon price would also lower electricity prices). The finding that the market pays close attention to subsequent changes in firms’ revenues due to the release of the news is also consistent with the event studies joining an environmental program. Cañón-de Francia and Garcés-Ayerbe (2009) find that, among the 80 Spanish firms that voluntarily adopted ISO 14001, only less-polluting and less internationalized firms experienced a drop in their stock prices. This implies that investors do not expect a profit gain from adopting ISO 14001 to compensate for the extra cost of this action.

Third, other event studies suggest that investors are also concerned with corporate governance issues in reacting to the event. Fisher-Vanden and Thorburn (2011) find that companies announcing membership in the EPA’s Climate Leaders, a voluntary environmental program targeting reductions in GHG emissions, experience significantly negative abnormal stock returns. The authors find that firms facing climate-related shareholder resolutions or firms with weak corporate governance standards are more likely to join Climate Leaders, suggesting the endogeneity of such actions. Krüger (2015) demonstrates that investors react negatively not only to negative news about firms’ CSR performance, but also – in weaker and less systematic ways – to positive news as well, because investors assume it can result from agency problems inside the firm.

The event-study approach may mitigate the endogeneity problem (i.e., doing well by doing good vs. doing good by doing well) by looking at short time windows around an event. However, the findings of event studies can be limited. Because the event-study approach is based on one-time events, it is hard to analyze long-term trends or consistent measures of a firm’s EP that are not tied to a particular date (Konar and Cohen (2001)). In addition, it is also difficult to find an exogenous event. If the event is not fully exogenous, a study using that event may involve endogeneity issues.

2.2 Regression Analysis

Regression studies examine the relationship between key explanatory variables (e.g., EP measures) and dependent variables (e.g., firm value or profitability), while controlling for other variables. This form of analysis examines long-term effects, but the empirical findings of existing studies are not consistent with one another: the full body of research has found positive, negative and not-significant empirical relationships between EP and FP. Even the large-scale meta studies (e.g., Margolis et al. (2009); Fulton et al. (2012); Mercer (2009)) that examine the results of over 100 academic studies report mixed results on the empirical link between EP and FP. We find two significant challenges in regression studies in this field. First, studies have not reached a consensus on the right measure for EP and have suffered from the lack of such data. Second, there remains the endogeneity issue of determining whether the observed correlation is causal or not.

It is challenging to find a large sample that effectively represents the market and, at the same time, has consistent EP measures across the sample period. Most early regression studies use the pollution database generated by the Council on Economic Priorities (CEP). Bragdon and Marlin (1972) examine 17 CEP firms during 1965–1970 and find a strong positive correlation between firms' pollution control and financial performance, such as profitability and earnings per share. On the contrary, Mahapatra (1984) finds a negative association between these variables when he expands the sample to 67 firms in six industries – chemical, iron and steel, paper, petroleum refining, metal, and textile – from 1967 to 1978. As such, because the CEP database has a small sample size, studies based on the CEP data fail to deliver a level of confidence that is acceptable to a large audience. To address this problem, Konar and Cohen (2001) examine a large sample from S&P, and two environmental performance measures from the Investor Responsibility Research Center, which includes the aggregate pounds of toxic chemicals per dollar of revenue of the firm and the environmental lawsuits pending against the firm. However, due to the limited availability of EP data, their sample mostly consists of manufacturing firms and is not suitable for cross-industry analysis.

Another aspect of the empirical limitation is the lack of standardization of EP measures. In fact, Konar and Cohen (2001) criticize previous empirical analysis for “relying upon subjective or anecdotal analysis to characterize environmental performance.” As a result, the non-standardized

EP disclosure practices may result in a misunderstanding of the relationship between EP and FP, as the empirical results can differ depending on what EP measurement the study uses (e.g., Chatterji et al. (2009); Sharfman (1996); Sz wajkowski et al. (1999)). We discuss the issues regarding EP measures in Section 3.2.

The second limitation of regression analysis, as mentioned earlier, is that findings of simple regression studies do not strictly differentiate between correlation and causality (Krüger (2015)). For example, studies that simply regress the annual CSR ratings on the annual values of a firm cannot address the question of whether the firm does well because it does good or vice versa. Prior studies, such as Porter and Linde (1995) and its follow-up studies (see Ambec et al. (2011)), attempt to demonstrate that corporate environmental actions have a causal impact on economic success and thus firm value. As such, the empirical literature has evolved away from determining the positive or negative link between EP and FP, and toward an examination of the pay-off mechanism of corporate environmental actions. Some studies explain their findings in terms of a trade-off between environmental costs and current/future cash flows (e.g., Gregory et al. (2014)). Some recent studies suggest that the financial benefits of environmental actions stem from mitigating liability, compliance and regulatory risks (e.g., Godfrey et al. (2008); Jo and Na (2012); Oikonomou et al. (2012)). Others point to operating efficiency and management capability gains. The financial advantages of a firm's EP are also tied to non-environmental factors that happen to deliver EP alongside other external and internal outputs (e.g., Barnett (2007); Christmann (2000); Cohen et al. (1995); Karagozoglu and Lindell (2000); Schaltegger and Synnestvedt (2002); Schaltegger and Figge (2000); Servaes and Tamayo (2013)).

In addition to studies that investigate how EP is related to FP, CSR literature has also long discussed the issue of endogeneity. Since CSR has broader criteria that also contain social and governance criteria in addition to the environmental factor, empirical discrepancies in determining the relationship between CSR and its financial returns are also pervasive. Some researchers note that CSR can affect a firm's FP through intermediate variables, such as stakeholder management or customer satisfaction, and the omission of these confounding variables may mislead the empirical results (McWilliams et al. (2006); Orlitzky (2009)). Servaes and Tamayo (2013) use models with firm fixed effects to examine the firm-level cross-sectional differences, and they find the link between CSR and firm value is significantly positive only for firms with high customer awareness. Barnett

(2007) makes a similar argument that the financial merit of CSR resembles one’s own investments in intangible assets such as R&D and marketing.

Some studies on CSR use an instrumental variable (IV) to address potential endogeneity concerns or correlated omitted variables issues. Cheng et al. (2017) find that firms with better CSR performance have significantly lower capital constraints, and these firms have better stakeholder engagement and transparency around CSR performance. Ferrell et al. (2016) also use the IV approach and demonstrate that well-governed firms suffering less from agency concerns (proxied by less cash abundance, positive pay-for-performance, small control wedge, and strong minority protection) engage more in CSR. They also show that a positive relation exists between CSR and firm value, and that CSR attenuates the negative relation between managerial entrenchment and firm value.

2.3 Portfolio Analysis

Different from an event study or a regression analysis, the portfolio approach has the advantage of explicitly considering the risk-return relationship. A typical portfolio analysis approach is to form portfolios sorted on an EP measure, to compare the average returns of those portfolios, and to test whether differences in average returns can be explained by risk factors or styles. For instance, Cohen et al. (1995) construct two portfolios based on environmental performance, naming them “environmental leaders” and “environmental laggards,” and show that the former outperform the latter in the stock market between 1987–1990.⁴

However, different EP measures result in different outcomes as well. Derwall et al. (2005) construct two portfolios in terms of the eco-efficiency scores published by Innovest Strategic Value Advisors, and demonstrate that the high eco-efficient portfolio provides substantially higher average returns than the low eco-efficient one from 1995 through 2003.⁵ Puopolo et al. (2015), on the other hand, find no linear relationship between EP and FP when they use Green Score (GS) by Newsweek

⁴They create a single EP measure based on nine different measures from government data and 10-K filings such as number of environmental litigation proceedings, superfund sites, number of noncompliance penalties, TRI, number of chemical spills, and number and volume of oil spills.

⁵Innovest evaluates a firm’s eco-efficiency relative to its industry peers via an analytical matrix. Firms are evaluated along approximately 60 dimensions, which jointly constitute the final rating. For each of these factors, each firm receives a score between 1 and 10. The criteria can be grouped into five broad categories, which address five fundamental types of environmental factor.

as their EP proxy.⁶

To address this issue of inconsistent EP measurements, ET Index (2015b) measures a firm's EP based on the absolute amount of carbon emission. It defines firm-level carbon intensity as firm-level GHG emission, in tons of carbon dioxide equivalent (tCO₂e), divided by revenue.⁷ ET Index (2015a) analyzes 2,267 stocks available from the ET GHG emissions database from January 2009 through March 2015. It double-sorts the stocks by carbon intensity and size, and it constructs a “efficient-minus-intensive” portfolio. It finds that the portfolio exhibits positive returns and is not related to the standard risk factors: market, size, value, and momentum. Although ET Index provides evidence that portfolios of low carbon intensity stocks outperform portfolios of high carbon intensity stocks, their Fama-MacBeth test result shows that all the factors in the model have statistically insignificant and very weak explanatory powers. We cannot confirm whether this limitation results from their methodology or their sample because the ET Index does not report how the sample is constituted in this report. In addition, as ET Index does not control for industry effects, it is possible that several outlier industries may drive the result.

Oestreich and Tsiakas (2015) construct a dirty-minus-clean (DMC) portfolio using 65 German stocks from November 2003 through December 2012. The dirty portfolio is a portfolio of firms that received a high number of free carbon emission allowances granted under the EU Emissions Trading System during its Phase I and II. The clean portfolio includes all firms that did not receive any allowances. Oestreich and Tsiakas define the carbon premium as the excess return of the DMC portfolio. They show that the dirty portfolio outperforms the clean portfolio during Phase I and II, but not before or after. However, the observed carbon premium is more about the cash flow effect, not about the risk-return relationship. Firms receiving free allowances can reduce their production costs or increase revenue by selling them.⁸

⁶GS is based on three components: an environmental impact score, an environmental management score, and an environmental disclosure score, weighted at 45%, 45%, and 10%, respectively. To form the sample, the authors surveyed 500 biggest publicly traded US firms belonging to the 2009-2014 Newsweek Green Rankings, and 31.5% of them disclose the requested data on their environmental impact.

⁷ET Index is a private research company that specializes in low-carbon investment.

⁸Related to our research, a more interesting observation is that clean portfolios have outperformed dirty portfolios since 2009 when the EU announced that free allowances would be no longer be available beginning in 2013. The DMC portfolio has generated positive returns in Germany from 2009 onward. However, they focus on the period of 2003–2009 to see if free allowances affect the prices of dirty stocks.

3 Data

3.1 Data Description and Sample Representativeness

Our main data set is merged from four databases: Trucost for carbon emission measures; Compustat for financial variables; MSCI ESG Stats for ESG indices; and CRSP for stock prices and returns. The first three databases are yearly data and the stock return data is monthly. In this study, we focus on the US stock market because the US case provides the largest sample, and there exists a relatively well-established consensus on risk factors or styles such as market, size, value, operating profitability, investment, and momentum effects.⁹

The final sample consists of 736 publicly traded US firms and the total number of observations is 74,486 from January 2005 to December 2015. Panel (a) in Table 1 shows the number of total observations and distinct firms in our sample. There are 11 industries: consumer discretionary, consumer staples, energy, finance, health care, industrials, information technology, materials, real estate, telecommunications, utilities. We drop finance industry when we perform portfolio analysis. We also exclude observations that do not report firm size and B/M. We also winsorize observations at level 1% and 99%, and 2% and 98% and check robustness when calculating portfolio returns and analyzing firm characteristics.

Prior to the main analysis, we confirm that there is no severe selection bias in our sample based on Trucost's dataset. In order to check whether our sample well represents the stock universe, we categorize firms in our sample based on Fama-French breakpoints for size and B/M and compare our sample's distribution to Fama-French breakpoints using all NYSE stocks. According to the breakpoints, the top 50% firms in terms of market capitalization in the stock universe are big firms and the bottom 50% firms are small firms. Also, the top 33% firms in terms of B/M are value firms, the middle 33% are neutral and the bottom 33% are growth firms. Panel (b) in Table 1 shows that our sample is tilted toward large and growth firms; in our sample, there are 63,196 big firms (84.8% of the total sample) relative to 11,290 small firms (15.2% of the total sample), and 37,341 growth firms relative to 26,186 neutral firms and 10,959 value firms (50.1%, 35.2% and 14.7% of the total

⁹From 2005 to 2015, the number of observations for the United State in Trucost database is 9,510 while those for Japan, the United Kingdom, China, South Korea, France, Germany, and China are 4,516, 3,586, 2,335, 2,119, 1,203, and 1,009, respectively. In et al. (2018a) take the same approach of this paper and analyze the advanced and emerging economies in Europe and East Asian countries.

sample, respectively).

There may be concerns that our sample is tilted toward big and growth firms, but this is consistent with findings of other studies that use different US stock samples. For instance, Guerard (1997), Kurtz (1997), Bauer et al. (2005), and Derwall et al. (2005) find that environmentally and socially screened portfolios in the US tend to be biased toward big and growth stocks. In addition, while this bias toward large and growth firms may affect the average returns, it will not affect alpha because we include SMB and HML factors as regressors in the following analysis and portfolios consisting of those large and growth firms will exhibit large coefficients (in absolute values) on SMB and HML factors.

Furthermore, we compare the returns of industry portfolios from Trucost and Fama-French in five directly comparable industries: energy, finance, health, telecommunications, and utilities.¹⁰ Panel (c) in Table 1 shows the correlation coefficients of industry portfolio returns in these five comparable industries. It shows that all correlation coefficients are close to one except for telecommunications sector. Even the lowest correlation coefficient, which is for telecommunications sector, is 0.80. This result suggests that returns of industry portfolios based on our sample track very well those of all NYSE stocks.

3.2 Issues with EP Measures

While investors have begun to integrate ESG data in their valuation models, the availability of reliable corporate EP measure is still limited today. This is primarily due to several factors: low disclosure rates, the lack of reporting standards, and weak transparency and accuracy of the data.

First, a number of firms partially disclose their GHG emission data or do not disclose at all. Trucost (2015) shows that only 44% of firms in the five major global indices, including MSCI World, MSCI Europe, S&P 500, MSCI ACWI and MSCI Emerging Market, disclose GHG data. Although an increasing number of countries have begun to mandate the disclosure of ESG information, either through laws and regulations or through stock exchange listing requirements, sustainability reporting on ESG issues still remains voluntary in most countries including the US.¹¹

¹⁰Trucost and Fama-French industry portfolios use different industry classification; the former uses Global Industrial Classification Standard (GICS) and the latter uses Standard Industrial Classification (SIC). We find that these five industries are directly comparable.

¹¹In the US, for example, Securities and Exchange Commission (SEC) issued a concept release in 2016 soliciting public input on modernizing the disclosure requirements in Regulation S-K.

Second, current practices of corporate carbon assessment generally do not consider carbon exposure throughout a firm’s entire value chain, which may underestimate the firm’s actual carbon risk. According to the GHG Protocol accounting and reporting standard, GHG emission is categorized into three scopes in term of emission source: direct emissions from operations (Scope 1), indirect emissions from purchased electricity by the owned or controlled equipment or operations of the firm (Scope 2), and other supply chain emissions (Scope 3).¹² Trucost (2015) indeed finds that the greatest carbon exposure is concealed in the supply chain. Only in the transportation and utilities sectors, Scope 3 is insignificant because the high portion of fossil fuel consumption is included in direct operation — Scope 1. We also show evidence from our sample that the presence of Scope 3 is not negligible, and discuss this in Section 3.3.

Third, as Ioannou and Serafeim (2017) highlight, the comparability and credibility of disclosed EP measures are important as well. Companies start to disclose their ESG performance in a quantifiable form using a single rating or reputational indices (Cohen et al. (1995)). But a single-dimensional ESG or CSR performance measure may mislead its evaluation. Waddock and Graves (1997) argue that CSR performance is a multidimensional construct that includes a wide variety of inputs, and thus an aggregated ranking or score cannot address wide variation across companies and industries. More importantly, previous studies claim that firms could be in a position to game their ESG ratings so they can gain access to increasingly available SRI investors and potentially lower cost of capital (Chatterji et al. (2009), Cheng et al. (2017)). Even if firms disclose their GHG emission data, they often make reporting errors and there is no rigorous validation process for firm-disclosed data.

Third-party rating agencies have emerged to provide more credible and easily comparable corporate EP measures, such as MSCI’s ESG ratings, ASSET4 from Thomson Reuters, and Sustainalytics. They set consistent standards to apply across firms, industry and countries and their reporting criteria cover companies’ multidimensional ESG measures. However, the currently available ESG ratings are still limited by information omissions and convergence issues. For example, it is a common practice to subtract the scores of concerns or weaknesses from that of strengths to arrive at a

¹²Scope 3 thus covers all other indirect GHG emissions from the firm’s operation that are not covered in Scope 2. For example, Scope 3 includes the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the firm, electricity-related activities (e.g. transmission and distribution losses), outsourced activities, waste disposal, etc.

single net environmental score (e.g., Graves and Waddock (1994); Griffin J.J.; Mahon J.F. (1997); Waddock and Graves (1997); Johnson and Greening (1999); Ruf et al. (2001)). But the aggregation process may drop important information as each score can represent distinct constructs (Mattingly and Berman (2006)). In fact, Chatterji et al. (2009) examine the validity of KLD (now merged as MSCI) ESG rating's sub-categories with a company's EP, and find that its environmental concern ratings constitute fairly good summaries of past EP while its environmental strength ratings do not accurately predict future EP. Furthermore, Lee and Faff (2009) argue that the ratings are often inconsistent across different rating agencies. Semenova and Hassel (2015) investigate the convergent validity of environmental rating of three major global agencies, KLD, Thomson Reuters, and Global Engagement Services (GES). They find that those ratings have common dimensions, but on aggregate they do not converge.

The above discussion on the drawbacks of today's EP measures underscores the relative advantage of using Trucost carbon emission data in this study. Trucost assesses the carbon footprint of approximately 13,000 publicly listed companies worldwide by compiling corporate and supplier emission data on the seven GHGs covered by the Kyoto Protocol and measuring them as carbon dioxide equivalents (CO₂e).¹³ We consider Trucost data as a unique carbon data source based on the following points: First, it provides firm-level carbon exposure based on actual GHG emissions in metric units. This approach can minimize the information asymmetry due to inconsistent evaluation criteria and reporting standards by different rating agencies. Second, Trucost's GHG emission data includes GHG emissions throughout a firm's entire value chain by following the GHG Protocol Standard. Third, Trucost validates firms' disclosed data by using the input-output modeling methodology, minimizing inaccurately reported outliers.¹⁴ Therefore, our measure of EP is more comparable across industries and relatively free from measurement error.

¹³Globally, collaborative actions have been taken to address inconsistent, incomplete and incomparable EP measurement issue. Thus, the Kyoto Protocol introduced CO₂ equivalents (CO₂e) as a standard unit for measuring corporations' carbon footprint. It compiles emission data on seven GHGs including carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydro fluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF₆), and nitrogen trifluoride (NF₃).

¹⁴Trucost's input-output model estimates the amount of resources required to produce a unit of output, and the related level of pollutants (Trucost (2013)). Trucost compiles the environmental impacts of 464 industries. The sector classification used is the North American Industrial Classification System (NAICS). Trucost constructs the prices of 700 environmental indicators per unit of output, and this classification is consistent with the United Nations Millennium Ecosystem Assessment. This input-output model identifies segmental revenue data for each firm primarily using FactSet along with company statements. Trucost then creates company profiles by mapping each firm to a set of industries, inputs and outputs. It then integrates a company profile to the library of environmental impact, and it calculates GHG emission per unit of output.

3.3 Definition of Variables

We use four carbon emission measures: (1) firm-level absolute amounts of GHG emissions (tCO₂e), (2) carbon efficiency (tCO₂e/\$mil), (3) external costs, and (4) impact ratio provided by Trucost. Carbon efficiency is defined as the amount of GHG emissions (tCO₂e, tonnes of CO₂e) divided by one million USD of revenue. It is thus estimated in metric units of (tCO₂e/\$m), allowing us to compare firm-level carbon efficiency in all firm sizes and across industries. External cost is the total cost that a firm incurs directly and indirectly on the environment through its own activities and supply chains. Impact ratio is the external cost divided by a firm's revenue.

From here, we denote the absolute GHG emission of Scope 1 (tCO₂e), Scope 2 (tCO₂e) and Scope 3 (tCO₂e) as Scope 1, Scope 2 and Scope 3, respectively. We also denote carbon efficiency based on Scope 1, Scope 2 and Scope 3 GHG emissions divided by revenue as *Scope1*, *Scope2* and *Scope3*, respectively. Carbon efficiency based on the partial sum of scopes, such as *Scope1* and *Scope2* or *Scope2* and *Scope3* will be denoted as *Scope12* and *Scope23*, respectively. And carbon efficiency based on the sum of all three scopes will be denoted as *Scope* hereafter. Thus, the unit of *Scope* is (tCO₂e/\$mil).

We find that Scope 3 GHG emissions should be included in *Scope*, our primary measure of carbon efficiency, and this distinguishes our findings from other studies that rely on the volume of a single type of emissions from operation. Panel (a) in Table 2 reports the average value of *Scope1*, *Scope2*, *Scope3*, *Scope*, external cost, and impact ratio by industry. Column (3) shows that the average values of *Scope3*, which reflect value chain emissions, are not small relative to those of *Scope1* and *Scope2*. Also, Figure 1 clearly shows that the relative shares of Scope 3 are very large in some industries. While relative shares of Scope 3 are less than 40% in industries that are generally known for being carbon intense, they are higher than 50% of total carbon exposure in other industries, such as consumer discretionary, consumer staples, health care and IT. It is also important to examine carbon emission measures with varying scopes because it can provide different information. Panel (b) in Table 2 reports the correlation coefficients among our GHG emission measures. As one can see from the patterns in Panel (a) in Table 2, columns (1)-(3), the correlation coefficients between *Scope1*, *Scope2* and *Scope3* are low. The correlation of external cost with *Scope1* is higher compared to those with *Scope2* and *Scope3*. And the correlation coefficients

of impact ratio with *Scope1* and *Scope* are close to one.¹⁵ While correlation between *Scope* and *Scope1* is very high at 0.97, we find that it varies across industries from 0.40 (telecommunications) to 0.97 (utilities).

Figure 2 shows the time trends of carbon efficiency over time. It clearly shows *Scope* and *Scope12* have been declining over time, suggesting that firm-level carbon efficiency has improved. It also suggests that we need to consider time fixed effects when we examine the relationship between carbon efficiency and firm characteristics in Section 4.2.

4 Main Analysis

This section consists of three parts: (1) analysis on carbon efficiency and stock returns, (2) analysis on carbon efficiency and firm characteristics, and (3) robustness tests. First, we construct portfolios based on carbon efficiency (single-sorted), carbon efficiency and B/M (double-sorted), and carbon efficiency and firm size (double-sorted). We examine whether there are differences in average returns between carbon-efficient and carbon-inefficient portfolios and, if there are any, whether these differences can be explained by well-known risk factors. Second, we examine the empirical relationship of carbon efficiency with a set of firm-level characteristics. We conduct logit analysis to investigate what types of firms are more likely to be carbon-efficient. Finally, we check whether investors explicitly consider firms' decarbonization efforts and conduct robustness checks to ensure that our findings are not driven by a small set of industries, variations in oil price, or changing preferences of bond investors caused by the low interest rate regime starting with the 2008 financial crisis.

4.1 Carbon Efficiency and Stock Returns

Before conducting our portfolio analysis, we must first assess whether there are a sufficient number of stocks in each portfolio for diversification and then check the effect of the most and least carbon-intensive industries. We refer to the existing literature on the number of stocks and risk reduction. Campbell et al. (2001) claim that a larger number of stocks are needed to achieve a certain level of diversification because the volatility of individual stocks has been increasing over time. They

¹⁵Initially, we expect to calculate the cost incurred by negative externalities using impact ratio. However, we find that the correlation between impact ratio and *Scope* is over 0.9, and it does not provide additional information.

find that a portfolio of 20 stocks reduces annualized excess standard deviation to about 5% during 1963-1985. However, this level of excess standard deviation requires almost 50 stocks during 1985-1997. Domian and Louton (2007) claim that risk reduction continues even after portfolio size is increased above 100 stocks. Since we have 424-679 firms each month, we are cautious in increasing the number of portfolios and thus reducing the number of stocks in each portfolio. Increasing the number of portfolios may result in poorly diversified portfolios, in which idiosyncratic returns could drive our results. We thus decide to include at least 50-100 firms for all of our univariate-sort portfolios, if possible.

We also check whether certain industries or fluctuations in energy prices dominate a firm’s environmental performance and returns. We choose three industries with the highest *Scope* (utilities, materials, energy) and three industries with the lowest *Scope* (health, IT, telecommunications). Figure 3 shows the cumulative returns of these selected industry portfolios. It shows that all carbon-efficient industries do not necessarily outperform carbon-inefficient industries and vice versa. It also shows that, not all industries are negatively affected by a sharp drop in oil price, such as the one that took place in mid 2014. It seems that only the energy industry was negatively hit by the shock. In the following sections, we check the effect of a small set of industries on the performance of portfolios we construct.

4.1.1 Constructing the Efficient-Minus-Inefficient (EMI) Portfolios

We form three kinds of portfolios based on carbon efficiency: EMI1 (formed on carbon efficiency), EMI2 (formed on carbon efficiency and B/M), and EMI3 (formed on carbon efficiency and size). As a measure of carbon efficiency, we define *Scope* as:

$$Scope = \frac{Scope1 \text{ (tCO}_2\text{e)} + Scope2 \text{ (tCO}_2\text{e)} + Scope3 \text{ (tCO}_2\text{e)}}{revenue \text{ ($mil)}}$$

Since the variable of *Scope* can be interpreted as “how much tCO₂e a firm needs to emit in order to generate one million dollars of revenue,” a lower value of *Scope* corresponds to higher carbon efficiency or lower carbon intensity.

Our first benchmark EMI portfolio (EMI1) is single-sorted on carbon efficiency:

$$\text{EMI1} = \text{top 33\% efficient} - \text{bottom 33\% efficient} \quad (1)$$

We divide firms in each industry into three groups in terms of the previous year's carbon efficiency, updating portfolio formation annually. To minimize the look-ahead bias, we form portfolios using the previous year's carbon efficiency data.¹⁶ The top 33% of the portfolio consists of firms that are the top 33% carbon-efficient firms in each industry and each year. These portfolios are value-weighted based on market capitalization. Given very different levels of carbon efficiency across industries, as shown in column (4) in Table 2, picking up carbon-efficient and carbon-inefficient firms in each industry prevents particular industries that are extremely carbon-inefficient (or carbon-intensive) from driving empirical results.

Panel (a) in Table 3 displays the average monthly returns of three portfolios sorted on carbon efficiency and EMI1 portfolio.¹⁷ It shows that, in terms of average returns, the carbon-efficient portfolio outperforms the carbon-inefficient one during the period of January 2006–December 2015. The difference in average returns of the first and third tertile, 0.20 percentage point (1.33%–1.13%), is not statistically significant. However, during the period of January 2010–December 2015, the average monthly return of carbon-efficient firms is 1.73%, which is far higher than 1.23% of carbon-inefficient ones. The difference in average monthly returns of top and bottom 33% portfolios, which is the average return of EMI1 portfolio, is 0.50 percentage points and is statistically significant.

As Fama and French (2015) emphasize, value-weighted portfolios from univariate sorts on variables other than size are typically dominated by big stocks. To address this issue, we examine the return patterns when portfolios are sorted on two characteristics, carbon efficiency and B/M or carbon efficiency and size. We form nine portfolios sorted on B/M and carbon efficiency to see if B/M, carbon efficiency, and stock returns are related to each other. We divide firms into three groups based on B/M. Top 33%, middle 34%, and bottom 33% firms are value, neutral, and

¹⁶Different from other datasets, such as MSCI, Trucost database does not release its data at one date; it releases on a rolling basis throughout the year. Due to this reason, we assume that investors form portfolios using the previous year's data. Thus our sample period for portfolio analysis becomes 2006–2015 from 2005–2015 since a portfolio formed in 2006 is based on carbon efficiency data in 2005.

¹⁷When we calculate average portfolio returns, we also use stock returns that are winsorized at 1% and 99%, and 2% and 98% levels. We find that winsorizing does not change our result much. In fact, winsorizing makes the average returns of carbon-efficient stocks a little higher.

growth firms, respectively. We divide firms based on carbon efficiency in the same manner. We construct our second EMI portfolio (EMI2) in a similar way to the Fama-French procedure used for the construction of SMB and HML factors.¹⁸:

$$\text{EMI2} = 0.5(\text{growth efficient} + \text{value efficient}) - 0.5(\text{growth inefficient} + \text{value inefficient}) \quad (2)$$

The portfolio of “growth efficient” firms consists of growth firms whose carbon efficiency is in the top 33% in each industry. Likewise, the portfolio of “value inefficient” firms consists of value firms whose carbon efficiency is in bottom 33%. Panel (b) in Table 3 shows the average monthly returns of the nine portfolios. During the period of 2006–2015, carbon-efficient firms outperform carbon-inefficient firm in case of growth firms. However, the average return difference of neutral firms is close to zero, and the one for value firms is even negative. During the latter period of 2010-2015, efficient firms outperform inefficient firms in the case of growth and neutral firms. The differences in monthly average returns amount to 0.95 and 0.43 percent points, respectively. And they are statistically different from zero.¹⁹

We also form nine portfolios on carbon efficiency and size to construct EMI3 portfolio. Similar to EMI2 portfolio, we divide firms into three groups based on market capitalization. We also divide firms based on carbon efficiency in the same manner. We initially construct EMI portfolio by carbon efficiency and size as follows:

$$\text{EMI3} = 0.5(\text{big efficient} + \text{small efficient}) - 0.5(\text{big inefficient} + \text{small inefficient}) \quad (3)$$

Panel (c) in Table 3 shows the average returns of nine portfolios. While carbon-efficient firms outperform carbon-inefficient firms during the period of 2006–2015 for medium and big firms, small efficient firms underperform small inefficient firms. However, the return differences are not statistically significant. For the latter period of 2010-2015, big efficient firms outperform big inefficient firms while small efficient firms underperform small inefficient firms. The differences in monthly

¹⁸For example, see the description of Fama-French size and value factors (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/Data_Library/f-f_factors.html)

¹⁹This pattern holds also for the case of 2*3, 3*2, 3*5, 5*3, and 4*4. However, the pattern of monotonically increasing or decreasing returns tends to be less robust as we increase the number of portfolios (for example, 7*7, 10*10). As discussed in Section 4.1, given the not-that-large sample size, reducing the number of firms in each portfolio may undermine the benefit of using well-diversified portfolios.

average returns amount to 0.62 and -0.36 percent point, respectively.²⁰ Due to the outperformance of small inefficient firms, we find that EMI3 portfolio defined as (3) does not produce a large positive return. Instead, we define EMI3 as follows:

$$\text{EMI3} = (\text{big efficient}) - (\text{big inefficient}). \quad (4)$$

Alternatively, we include medium-sized firms:

$$\text{EMI3} = 0.5(\text{big efficient} + \text{medium efficient}) - 0.5(\text{big inefficient} + \text{medium inefficient}). \quad (5)$$

For now, we report the result of EMI3 portfolio based on (4) and use the definition of (5) for robustness check later.

Figure 4 displays the cumulative returns of EMI1, EMI2, and EMI3 portfolios. As we have seen that efficient firms outperform inefficient firms after 2009, the cumulative returns of all EMI portfolios start to rise around 2009 or 2010. Note that all three cumulative returns based on different sorting exhibit similar patterns. Since our definition of carbon efficiency, GHG emission divided by revenue, can be sector- or industry-biased, we compare the cumulative returns of EMI1, EMI2, and EMI3 including all industries in our sample and excluding most carbon-inefficient and most carbon-efficient industries, which are utilities and telecommunications respectively. All figures in Figure 5 show that the two industries that are extreme in terms of carbon efficiency do not significantly affect the performance of our EMI portfolios.

In the following sections, as the patterns that the outperformance of carbon-efficient firms has started around 2010 are clearly shown in Figure 4, we report our results based on two sample periods: January 2006 – December 2015 and January 2010 – December 2015.

4.1.2 Pricing EMI Portfolios

Having discovered that our EMI portfolios exhibit noticeable positive returns, especially after 2009, we then test whether these are pure alpha or result of taking risks. We perform GRS test to see

²⁰We also calculate the average returns after controlling for microcaps. Following Hou et al. (2015), we drop microcaps (stocks with market equity below the 20th percentile at New York Stock Exchange), which takes 1.7% of our sample, and calculate the average returns of portfolios in Table 3. We find that the patterns are similar.

if these factors can price EMI portfolio. We consider four models: (1) CAPM, (2) Fama-French three-factor (FF 3 factor) model, (3) Fama-French three-factor model with momentum factor, and (4) Fama-French five-factor (FF 5 factor) model, as shown in equations (6) - (9):

$$r_{it} - r_{ft} = \alpha_i + b_i(r_{Mt} - r_{ft}) + e_{it}, \quad (6)$$

$$r_{it} - r_{ft} = \alpha_i + b_i(r_{Mt} - r_{ft}) + s_iSMB_t + h_iHML_t + e_{it}, \quad (7)$$

$$r_{it} - r_{ft} = \alpha_i + b_i(r_{Mt} - r_{ft}) + s_iSMB_t + h_iHML_t + m_iWML_t + e_{it}, \quad (8)$$

$$r_{it} - r_{ft} = \alpha_i + b_i(r_{Mt} - r_{ft}) + s_iSMB_t + h_iHML_t + r_iRMW_t + c_iCMA_t + e_{it} \quad (9)$$

where r_{it} is the return of portfolio formed on carbon efficiency, r_{ft} is the risk-free rate, and $(r_{Mt} - r_{ft})$ is the monthly value-weighted market return minus the risk-free rate. The terms SMB_t (small minus big), HML_t (high minus low), WML_t (winner minus loser), RMW_t (robust minus weak), and CMA_t (conservative minus aggressive) are the monthly returns on zero-investment factor-mimicking portfolios designed to capture size, B/M, momentum, operating profitability, and investment, respectively. If one interprets the above factors as “styles” and factor models as a method of performance attribution, a positive alpha (α) implies the abnormal return in excess of what could have been achieved by passive investments in those factors.

Before pricing portfolios, we examine the statistical properties of EMI and factor-mimicking portfolios during the sample period. Table 4 reports the average monthly returns, standard deviations, and Sharpe ratios of our three versions of EMI portfolio along with well-known factor-mimicking portfolios. During January 2006–December 2015, the average returns of all portfolios except HML are positive, suggesting that growth stocks outperform value stocks during this period. The average monthly return of EMI1 portfolio is 0.19%, which is not high relative to other portfolios. Also note that the market portfolio earns the highest average return of 0.61%. The Sharpe ratios of EMI1–EMI3 are 0.12, which is not that high compared to others. However, if we examine the period after 2009, EMI portfolios become quite attractive with relatively high returns and relative low standard deviations. Consequently, Sharpe ratios of EMI1–EMI3 are highest at 0.35–0.41, showing the attractiveness of EMI portfolios. Panel (b) in Table 4 shows the correlation coefficients of EMI portfolios with other portfolios. Looking at the statistically significant correlation coefficients for the period of 2006–2015, it shows that EMI portfolios move with the market and

behave like firms with weak operating profitability. However, from 2010, EMI portfolios behave like growth firms and short-term winners. And EMI1 and EMI3 move like firms with more aggressive investment. Figure 6 shows the cumulative returns of these factor-mimicking portfolios. Note that the cumulative return of market risk factor ($r_{Mt}-r_{ft}$) has increased from 2009 and its pattern is similar to those of EMI portfolios in Figure 4. However, EMI portfolios exhibit negative returns before GFC while market excess return is positive before GFC.

We run four models of (6)–(9) on three portfolios sorted on carbon efficiency and EMI portfolio and test if EMI1 portfolio can be priced. For single-sorted portfolios, the null hypothesis of GRS test is $H_0: \alpha_1=\alpha_2=\alpha_3=0$ where α_i is the intercept of portfolio i . $i = 1$ refers to the top 33% efficient portfolio and $i = 3$ refers to the bottom 33% portfolio. If the intercepts (α) in the above time-series regressions turn out to be positive and statistically significant, it suggests that the return on these portfolio cannot be priced with the standard risk factors and one can earn extra returns without taking further risks.

Table 5 shows the result of the GRS test on the three single-sorted portfolios by carbon-efficiency (*Scope*) and EMI1 portfolio. Panel (a) (columns (1)–(4)) are for the period of January 2006–December 2015, and Panel (b) (columns (5)–(8)) are for the period of January 2010–December 2015. Columns (1)–(3) show that all three portfolios sorted on carbon efficiency earn positive alphas even after accounting for various risk factors. For example, after considering Fama-French three-factors, the average monthly abnormal returns are 0.62% for the efficient portfolio and 0.48% for the inefficient portfolio. Even after accounting for Fama-French five-factors, those abnormal returns are 0.59% and 0.37%, respectively. In all four models, the p -values of our GRS test statistics are virtually zero, thereby rejecting the null hypothesis of $\alpha_1=\alpha_2=\alpha_3=0$. Also note that we obtain high R^2 s in all specifications. This suggests that, while risk factors explain the returns of portfolios sorted by carbon efficiency quite well, there are also positive alphas that cannot be explained by the standard risk factors. Column (4) shows that the estimated alpha of EMI1 is not statistically significant, implying that a strategy of “short inefficient firms and long efficient firms” does not produce statistically significant positive alpha. It is mainly because all three portfolios sorted on carbon efficiency produce positive alphas that are of similar magnitudes. For example, if we look at the Fama-French three-factor model with momentum factor, the efficient portfolio produces 0.62% of alpha while the inefficient portfolio produces 0.47%. Since alphas of the efficient and inefficient

portfolios are similar in magnitude and both are statistically significant, it turns out that 0.15% of their difference (i.e. the alpha of EMI1 portfolio) is not statistically different from zero.

When we run the same test on the latter sample period, January 2010–December 2015, we find a very different and interesting result. A major difference between the two sample periods is that, for January 2010– December 2015, alphas of the inefficient portfolio become smaller and their statistical significance becomes weaker, while alphas of the efficient portfolio are not much affected. As a result, alphas of EMI1 portfolio become positive and statistically significant, suggesting that a strategy of “long efficient firms and short inefficient firms” is rewarding even after accounting for the well-known factors. Efficient firms behave more like growth firms and winner firms from 2010. In the case of the top 33% of efficient firms, the factor loadings on HML and WML are negative and positive, respectively. Given the negative average return of HML in our sample, as shown in Panel (a) in Table 4, a negative factor loading on HML implies a positive extra return. This pattern is also found in EMI1 portfolio. Column (4) shows that factor loadings on HML and WML are negative and positive, respectively, contributing to higher returns of EMI portfolio.

This comparison reveals where alphas come from. While returns of all three portfolios sorted on carbon efficiency cannot be fully explained by risk factors and thus produces positive alphas, the magnitude and statistical significance of the top 33% efficient portfolios’ alphas are not much affected even after 2010, while the bottom 33% efficient portfolios fail to earn positive alphas since 2010. Thus, the positive alphas of EMI portfolio come from positive alphas of efficient firms after 2010. These alphas are equivalent to annualized extra returns of 3.5–5.4%, which are quite large.

Now we examine whether standard risk factors can price double-sorted portfolios by *Scope* and B/M (EMI2). Table 6 shows that, for the period of 2006-2015, EMI2 is priced by risk factors and it does not earn positive alphas with any of four models. However, for the period of 2010-2015, EMI2 produces positive alphas, which are statistically significant. For example, for the case of the Fama-French three-factor model and five-factor model, EMI2 earns 0.38% of alpha in this period. When momentum factor is considered, our EMI2 still earns 0.29%. Factor loadings suggests that WML subsumes some explanatory power of HML. However, even in this case, we find that the efficient portfolio earns statistically significant positive alpha of 0.58%. Alphas in column (6) are equivalent to annualized extra returns of 3.5–5.4%. Note that the magnitudes of alphas of EMI2 portfolio is similar to those of EMI1 portfolio.

Table 7 shows the result for EMI3. It shows EMI3 also earns a large positive alpha for the latter period of 2010-2015. In particular, EMI3 portfolio earns 0.45% and 0.49% of alpha for Fama-French three- and five-factor models, respectively. When we include the momentum factor in addition to Fama-French three factors, the alpha of EMI3 is 0.38%. These alphas then translate into the annualized extra returns of 4.6–7.0%, which are quite large. When we use EMI3 defined as (5), which include mediums-sized firms, the range of estimated alphas are 2.8%–4.2% (not reported in Table 7). When we use the definition of (3), we find that the estimated alphas are close to zeros and they are not statistically significant. Thus, the only exception regarding the outperformance of carbon-efficient firms is found in small firms.

4.2 Carbon Efficiency and Firm Characteristics

We examine the relationship of carbon efficiency with a set of firm-level characteristics to examine the sources of alpha we observe in Section 4.1. Based on previous literature that investigates the financial implications of ESG activities, we deliberately choose variables that reflect firm-level characteristics. For variables related to firm characteristics, we use market capitalization, B/M, Tobin's q , ROA, ROI, EPS (earnings per share), PER (price-earnings ratio), cash flow, coverage ratio, dividend payout ratio, leverage ratio, share of tangible assets, and capital intensity. We include free cash flow and cash holdings as a measure of agency problem following Ferrell et al. (2016). We also use the ratings of environmental strength and concern, and governance strength and concern from the MSCI ESG Stats. The construction of these variables is described in Appendix A.1.

Table 8 reports the average values of firm characteristics for the top 33% efficient, bottom 33% efficient groups, and their differences with statistical significances. It shows that firms in the top 33% efficient portfolio, compared to firms in the bottom 33% efficient portfolio, are firms of smaller size, lower B/M, higher firm value measured in Tobin's q , and higher ROI. However, a simple comparison of the average values may not control for industry fixed effects and time trends in carbon efficiency. Table 2 clearly documents that levels of carbon efficiency are very different for each industry and Figure 2 shows that our measures of carbon efficiency, $Scope$ and $Scope12$, are declining over time, suggesting that firms emit less and less carbon to generate the same amount of revenue over time.

To address this problem, we estimate logit models with industry and time fixed effects. We use the following logit regression equation:

$$Pr(y_{it} = 1|x_{it}, \alpha_j, \alpha_t, \alpha_{jt}) = \alpha + x_{it}\beta + \alpha_j + \alpha_t + \alpha_{jt} + u_{it}. \quad (10)$$

The dependent variable y_{it} is a dummy variable that takes a value of one if firm i at year t is in the top 33% efficient portfolio in each industry, and zero if it is in the bottom 33% efficient portfolio in each industry. x_{it} includes a set of firm-level characteristics for firm i at year t . We use two versions of x_{it} : raw numbers and z-scores.²¹ We use z-scores to control for inherently different industry characteristics. α_j denotes the fixed effect of industry j and α_t denotes year fixed effect. We also consider industry-year fixed effect α_{jt} . While a variable is defined as ratios, we take logs if it is not well nested within zero and one. For example, we take logs in coverage ratio. Note that we do not attempt to uncover the causal relationship between carbon efficiency and a set of firm characteristics in order to specify the exact source of positive abnormal returns. Rather, this logit estimation simply examines what kinds of firms are carbon-efficient or carbon-inefficient on average after controlling for industry and time fixed effects.

Table 9 shows the estimation results for two sample periods (2006–2015 and 2010–2015) and two sets of explanatory variables (raw numbers and z-scores). The characteristics of the carbon-efficient firms contrast with those of carbon-inefficient firms, regardless of whether we use raw numbers or z-scores. Firms with higher carbon efficiency tend to have higher Tobin’s q , ROI, cash flow and coverage ratio.^{22,23} And they have less amount of tangible assets with lower ROA.²⁴ In addition, carbon-efficient firms tend to be large and better-governed.²⁵ The positive sign of environmental

²¹For a variable x_{it} of firm i in industry j at time t , x_{it} is standardized using the following z-score formula:

$$\frac{x_{it} - x_{jt}}{\sigma_{jt}},$$

where x_{jt} and σ_{jt} are the mean and standard deviation of x in industry j at time t .

²²We find that carbon-efficient firms exhibit higher operating profitability. However, because correlation between ROI and operating profitability is quite high, we do not include operating profitability in regression equations. We do not include B/M for the same reason since B/M is highly correlated with Tobin’s q .

²³We also run the same regressions with adding return on equity (ROE) and find that the estimated coefficients of ROE are not statistically significant and other estimates are not much affected.

²⁴One may ask if higher ROA is desirable. However, higher ROA is not always better (e.g, Gallo (2016)). A firm may increase its ROA through “denominator management,” by which it sets up separate entities and sell its assets to them. Or higher ROA may simply suggest that the company is not renewing its asset and not investing in new machinery, sacrificing its long-term prospect. In our context, a firm that is reluctant to invest in more carbon-efficient equipment may exhibit higher ROA.

²⁵Note that the average size of carbon-efficient firms is smaller when we compare the average values in Table 8.

concern ratings implies that carbon-efficient firms tend to have a smaller number of environmental concerns. Regarding measures of corporate governance, Servaes and Tamayo (2013) point out that managerial agency problems can be acute when a firm generates substantial free cash flows. Ferrell et al. (2016) suggest that high values of free cash flow and cash holdings can be an indication of agency problems. We obtain the negative signs of coefficients both for free cash flow and cash holdings, suggesting that carbon-efficient firms may suffer less from agency problems. When we compare the results of the two sample periods, 2006–2015 and 2010–2015, the signs and statistical significances are still maintained in most cases. Interestingly, variables that include stock prices or number of shares (EPS, PER), or dividend payout (payout ratio) are not closely related to carbon efficiency especially in the latter period. The estimated coefficients of ROA, cash flow, and (log of) coverage ratio become larger in absolute values during the latter period. Summing up the results in Table 9, carbon-efficient firms are good firms in terms of financial characteristics and corporate governance.²⁶

As to the signs and statistical significance of variables from the MSCI, we have an interesting result. While we expect the opposite signs of estimated coefficients for ratings of environmental strength and environmental concern, both turn out to be positive.²⁷ Chatterji et al. (2009) suggest that environmental concern ratings are likely to be consistent with firms' past environmental performance, but environmental strength ratings are not. Semenova and Hassel (2015) show that MSCI environmental concerns converge with the GES environmental industry risk and company emissions from the ASSET4 database. In et al. (2018b) examine the endogeneity of environmental strength ratings. According to them, a firm with more environmental concerns may invest more to improve its environmental performance or take more environmentally-friendly corporate actions to avoid regulatory penalties or to raise its reputation, leading to a higher rating of environmental strength. If we regard the ratings of environmental concern as a better measure of a firm's environmental performance, following Chatterji et al. (2009) and Semenova and Hassel (2015), our results suggest that firms with less environmental concerns tend to be carbon-efficient.

We also check the possibility that some “outlier” industries may drive our results, by re-

²⁶In a related study, Chava (2014), who also uses the same MSCI database for environmental concern ratings, shows that lenders charge a significantly higher interest rate on the bank loans issued to firms with environmental concerns, and this environmental profile of a firm is not a proxy for an omitted component of default risk.

²⁷See the definitions of these variables in Appendix A.1.

estimating equation (10) with or without three most and least carbon-intensive industries. From Table 2, we identify the three most carbon-inefficient industries in terms of *Scope* as utilities, energy and materials, and the three most carbon-efficient industries as telecommunications, health and IT. Columns (1)–(3) are for the period of 2006-2015 and columns (4)–(6) is for the period of 2010–2015. Table 10 shows that many of the signs and statistical significances are maintained regardless of whether we exclude the three most carbon-efficient industries or three most carbon-inefficient industries. It suggests that the relationships of carbon efficiency with firm characteristics we find are not driven by a small set of industries. However, there are some exceptions. In the latter period, the statistical association of carbon efficiency with Tobin’s q , free cash flow, and cash holdings becomes weaker without three most carbon-efficient industries. It suggests that these relationships are more pronounced in carbon-efficient industries such as telecommunications and health.

4.3 Robustness Tests

In this section, we perform some robustness checks. Having already found that carbon-efficient firms outperform carbon-inefficient firms, we examine whether investors explicitly consider firm-level carbon-efficiency when making investment decisions. We also assess if fluctuations in oil price and unconventional monetary policy can explain our empirical findings.

4.3.1 Investors’ Perception of Decarbonization Efforts

It is natural to ask whether market participants evaluate carbon efficiency of firms and invest accordingly. To test if investors make their investment decision based on carbon efficiency, we sort by *changes* in carbon efficiency in each industry at each year and form portfolios in the same manner as we do for EMI1 portfolio. Our conjecture is that, if investors monitor firms’ carbon efficiency and value decarbonization effort in their portfolio selection, we should observe some patterns in average returns of the portfolios formed not only on levels of carbon efficiency, but also those formed on changes in carbon efficiency.

Similar to the univariate-sort portfolios based on carbon efficiency, we form portfolios based on *changes* in carbon efficiency. We measure a firm’s effort in improving carbon efficiency as follows:

Definition of $gScope^j$:

$$gScope^j = \frac{Scope_{i,t-1} - Scope_{i,t-1-j}}{Scope_{i,t-1-j}}$$

where $Scope_{i,t-1-j}$ is the firm i 's $Scope$ at year $(t-1-j)$. We use $Scope_{i,t-1-j}$, not $Scope_{i,t-j}$, to minimize the look-ahead bias. The variable of $gScope^j$ measures how much a firm has improved its carbon efficiency for the past j year. We use $j=1$ and 2 . That is, we consider portfolios formed on change in carbon intensity for the past one year ($j=1$) and two years ($j=2$), denoted as $gScope^1$ and $gScope^2$, respectively.

We divide firms into three groups and construct three portfolio based on $gScope^j$. We calculate the average monthly returns on three portfolios sorted by $gScope^j$ (not reported in table). For $j=1$ case, the average returns of three portfolios formed on $gScope^1$ are 1.19% (top 33% carbon-efficient), 1.12%, and 1.07% (bottom 33% carbon-efficient) for the period of 2006-2015. For the latter period of 2010-2015, they are 1.47%, 1.37%, and 1.29%. The top 33% portfolio earns the highest return, and we observe a monotonically decreasing pattern in average returns. However, the difference between the top 33% and bottom 33% portfolio returns turns out to be not statistically significant. For $j=2$ case, the average returns for the period of 2007-2015 are 1.09% (top 33% carbon-efficient), 1.08%, and 1.13% (bottom 33% carbon-efficient). And they are 1.29%, 1.51%, and 1.43% for the latter period of 2010-2015. In the case when $j=2$, we do not find any monotonic patterns in average returns on portfolios, and the difference in average returns is not statistically significant.

Figure 7 shows the cumulative returns of our benchmark EMI portfolio single-sorted by $Scope$ (EMI1), EMI portfolio formed by $gScope^1$ (EMI [change, 1-year]) and EMI portfolio formed by $gScope^2$ (EMI [change, 2-year]). It clearly shows that the performance of EMI portfolios formed on *changes* in carbon efficiency is not rewarding as much as the EMI1 formed on the level of carbon efficiency. While EMI portfolio formed on $gScope^1$ earns a positive cumulative return, the increasing pattern is less steep compared to that of EMI1. And the cumulative return of EMI portfolio formed on $gScope^2$ is rather close to zero or negative. We perform the GRS tests on these two portfolios and find that they do not earn positive abnormal returns. We also estimate the same logit model in Section 4.2 and find that few covariates are statistically significant.

Evidence from the average monthly returns and Figure 7 illustrates that improvement or deterioration in carbon efficiency is not closely related to stock market performance, suggesting that

investors may not closely and directly monitor firms' decarbonization efforts in their investment decisions.²⁸

4.3.2 Effect of Oil Price

Since oil price is closely related to energy use and efficiency, changes in oil price may affect our measure of carbon efficiency differently across firms and industries. For example, a sharp increase in oil price may affect carbon-inefficient firms more negatively compared to carbon-efficient firms even in the same industry.²⁹ This possibility suggests that fluctuations in oil price may affect the formation of carbon-efficient and carbon-inefficient portfolios and thus the performance of EMI portfolio.

We find that our empirical results on the behavior of EMI portfolios are not mainly driven by changes in oil price. Panel (a) in Figure 8 shows the time-series of oil price and the cumulative return of our EMI1 portfolio. It is hard to find a positive or negative relationship. Sometimes the performance of EMI1 and oil price move in the same direction, sometimes in opposite directions. Panel (b) shows the time-series of a rolling correlation coefficient between oil price and the cumulative return of EMI1 portfolio.³⁰ As the rolling correlation coefficient swings between positive and negative values as shown in Panel (b), we confirm our impression from Panel (a). The average of rolling correlation coefficient is quite small at 0.08, suggesting that there is no relationship between the two during our sample period.

²⁸Considering the possibility of diminishing returns in a firm's effort to improve its carbon efficiency, this result should be interpreted with caution. Suppose that a firm makes huge investment to improve its carbon efficiency at year t and obtains a relatively higher value of $gScope^1$ between t and $t+1$. However, if the return of a firm's investment for higher carbon efficiency diminishes, it is very hard for this firm to stay in the top 33% portfolio for long time. It implies that, different from the case of *Scope*, turnover of firms will happen more frequently in portfolios formed on $gScope^1$ and heterogeneous firms in many aspects would be included in the same portfolio. We find that firms move across three portfolios more frequently when portfolios are formed on $gScope^1$. In case of EMI1 formed on *Scope*, a firm that is included in the most carbon-efficient portfolio at least once stays in that portfolio for 77.7% of the sample period on average. For medium 34% and bottom 33% portfolio groups, a firm stays 62.7% and 75.8% respectively. In contrast, in case of EMI portfolio formed on $gScope^1$, a firm in efficient, medium and inefficient portfolios stays 39.9%, 38.3% and 35.3% respectively. It suggests that carbon-efficient firms tend to stay carbon-efficient during the sample period and vice versa. However, the rankings in terms of $gScope^1$ change frequently within each industry over time, making it difficult to find spreads in average returns of portfolios formed on $gScope^1$.

²⁹Balvers et al. (2017) construct a factor-mimicking portfolio that tracks temperature shocks and find that industries or firms that are more vulnerable to temperature shocks have higher loadings (in absolute value) on the temperature shock factor.

³⁰We also calculate the rolling correlation coefficient between oil price and the return of EMI portfolio. We find that there is no stable relationship between the two.

4.3.3 Effect of Unconventional Monetary Policy

We also confirm that our empirical results are not driven by a change in bond investors' investment style caused by unconventional monetary policy. Due to the prolonged period of extremely low interest rates caused by unconventional monetary policy during and after the 2008 GFC, bond investors moved their funds into equity markets. Following the risk appetite of typical bond investors, they prefer the industries that pay high and stable dividends. We thus check whether this increased investment shifting toward these industries affects our empirical results.

By comparing the average dividend payout ratios of each industry, we identify four high-dividend-paying industries in our sample: utilities, telecommunications, IT, and consumer goods.³¹ Also, by estimating the betas of value-weighted industry portfolios based on our sample, we identify four low-beta industries: utilities, telecommunications, consumer staples, health care. In addition, mass media coverage on this issue typically recommends utilities, telecommunications, and consumer durables to investors who prefer stable dividend payout.³²

We find that, with or without these four industries (utilities, telecommunications, IT, and consumer staples), the performance of our EMI portfolio does not change much. Figure 9 shows the cumulative returns of our benchmark EMI1 portfolio, EMI1 portfolios constructed without four industries, and EMI1 portfolio without IT industry, which is to check the effect of tech stocks. We also apply GRS test to EMI portfolio excluding the four industries and confirm that it earns positive abnormal returns, which is statistically significant.

5 Discussions

This section discusses the implications of our findings for both academic research and investment practices, as well as proposing several questions for future research.

³¹We find that real estate industry also pays relatively higher dividends. However, we do not include this industry because its sample size is too small, less than 400 observations during the period of 2005-2015. Low-dividend-paying industries in our sample are energy and materials.

³²For example, see <https://www.cnbc.com/2014/07/20/what-stock-sectors-offer-the-best-dividends.html>.

5.1 Implications for Climate Finance

For too long, investors have seen carbon as a non-financial risk; one to be considered and utilized in investment decision-making only with extreme caution. It has been very difficult to convince investors of the financial legitimacy of climate and environmental risks. Indeed, there is still a widespread perception among investors today that explicitly managing environmental risks could and likely would reduce investment returns, because traditional finance theory instructs us that anything that arbitrarily limits the investable universe of companies and opportunities would reduce risk-adjusted returns.

The global community of fiduciary bound investors, such as pension funds, endowments, foundations, sovereign funds and insurance companies that are representing today over \$100 trillion in assets under management, often are required to generate high risk-adjusted returns in order to live up to their promise and meet their fiduciary obligations. Many have adopted a strict interpretation of fiduciary duty, which has led investors to consider only those risk factors that have been explicitly shown to drive corporate and project returns, unequivocally. Any risks that were not explicitly linked to profit were deemed as “extra-financial” and considering them in an investment could be a breach of fiduciary duty if it was shown an investor gave up commercial return for some other non-commercial return.

In the context of the environment, however, the risks to assets and companies are intuitively real and of financial nature but they are long-term. This dynamic of long-term fiduciaries ignoring environmental risks is particularly nefarious, as it places in direct contradiction the solutions of one of our society’s biggest challenges (i.e., funding the retirement and health care of a rapidly aging population) with the solution of another of society’s biggest challenges — unlocking the financial capital required to prevent the most catastrophic consequences of climate change. This contradiction exists today, and its persistence is something we should all be concerned about.

And yet, if we could show that carbon-efficient firms do outperform carbon-inefficient firms, then we could actually flip this negative dynamic into a combination of mutual reinforcing solutions in which the path to secure the retirements of our aging population explicitly encourages the transformation of our economy into one that is carbon efficient. That is precisely what we attempt to test in this paper and why we believe the implications of our findings are so profound.

Our research has important implications for investors, business leaders and policymakers because it clarifies the risk-return relationship of low-carbon investment. With a growing body of research in this field, this study helps understand market incentives on low-carbon investment. As our findings demonstrate that an investment strategy of “long carbon-efficient firms and short carbon-inefficient firms” would earn abnormal returns of 3.5-5.4% per year, this study indeed indicates that investing in carbon-efficient firms can be profitable even without government incentives.

By showing that our carbon-efficient portfolios dramatically outperform our carbon-inefficient portfolios, we will free investment organizations to consider environmental risks, and, we acknowledge with some satisfaction, potentially obligate them to do so. Just as we now see clearly that financial markets are not efficient and financial actors are not rational, we too hope that business leaders and investors will see that environmental factors clearly have a place among the traditional risk factors that drive investments and returns.

In addition, our clarification on the low-carbon investment’s risk-return relationship will also benefit policymakers by helping them understand how much the risk-return relationship observed in the current financial market is (in)consistent with social optimum in terms of externality. This clarification will also help policymakers design policies that can reduce negative externality associated with carbon emissions and induce private investors to reallocate their capital on the basis of environmental impact.

5.2 Future Research Agenda

In this section, we discuss several future research agenda that are necessary to additionally validate our empirical results. First, will this alpha (or at least higher return) of “being green” persist? If our estimated abnormal returns are the result of mispricing, they should disappear out-of-sample as the sophisticated investors and traders learn about this mispricing and invest accordingly. In this regard, Mclean and Pontiff (2016) study the out-of-sample and post-publication return predictability of 97 variables and find that portfolio returns are 26% lower out-of-sample and 58% lower post-publication. Their finding strongly suggests that investors are informed by academic publications.³³ Meanwhile, if the cross-sectional relationship between our EP measure (*Scope*) and portfolio returns

³³In addition, they show that post-publication declines are greater for predictors with higher in-sample returns, and returns are higher for portfolios concentrated in stocks with high idiosyncratic risk and low liquidity.

reflects risks or styles that are not fully captured by well-known factors, then there is no reason for this pattern to decay. In a related study, Edmans (2011) finds that the stock market does not fully value intangibles such as employee satisfaction and thus certain SRI screens may improve investment returns. While we do not uncover the direct and causal relationship on the outperformance of carbon-efficient stocks, we show that those firms share the characteristics of higher firm value, higher ROI, higher cash flow, and better governance. Since these variables are expected not to change rapidly compared to stock returns, it is still possible to see this alpha to persist unless those characteristics are not fully exploited by investors' decision-making. For the time being, it would be best to sit back and wait for more data to be accumulated in order to answer this question.

Second, why do carbon-efficient firms start to outperform from 2009 or 2010, as shown in Figure 4 and Figure 5?³⁴ While the cumulative returns of industry portfolios (Figure 3) and market excess return (Figure 6) has increased from 2009 like our EMI portfolio, a key difference between industry portfolios and EMI portfolio is that the latter is a zero-cost portfolio, showing the relative performance of carbon-efficient stocks relative to carbon-inefficient stocks. Moreover, the patterns of these cumulative returns are different from ones before 2009. The cumulative returns of industry portfolios and market excess return has increased until 2008, but carbon-efficient firms underperform until 2009. Giese et al. (2017) report the similar patterns. They perform a monthly rebalancing of five portfolios based on ESG ratings and show that higher ESG-rated companies outperform those with lower ratings both in the US and global market. More interestingly, the period of outperformance in Giese et al. (2017) starts around 2009 or 2010 as well. Andersson et al. (2016) report that S&P 500 Carbon Efficient Select Index portfolio used by AP4 (the Fourth Swedish National Pension Fund) has outperformed the S&P 500 by about 24 bps annually since it first invested in the decarbonized index in November 2012. In addition, MSCI Global Low Carbon Leaders Index family, based on existing MSCI equity indexes, delivers a remarkable 90 bp annualized outperformance over the MSCI Europe Index for November 2010–February 2016.³⁵ At this juncture, it is crucial to ask what makes carbon-efficient firms or firms with higher ESG-rated firm start to outperform around 2009. One way to answer is to check if any changes favorable to

³⁴While we report our empirical results for the period of 2010-2015, our main results still hold for the period of 2009-2015, but with lower statistical significances for some numbers.

³⁵Basically, they are constructed so as to minimize tracking errors with respect to the market indexes such as the S&P 500 and MSCI equity indexes after dropping out firms with the worst carbon efficiency.

these firms take place around this time. In this regard, we examine if a change in bond investors' strategy precipitated by unconventional monetary policy that started in the late 2008 affect the performance of carbon-efficient portfolio. We find that fund shifting from bond market to equity market does not affect our empirical results much. However, we admit that our robustness check is not sufficient to answer this question and future research toward this direction is warranted.

Third, does our EP measure (*Scope*) fully capture how much a firm care about the environment? Although we believe that our EP measure is a better measure in explaining a firm's EP compared to self-reported surveys or one-digit summaries that attempt to reflect multi-faceted aspects of a firm's environmental actions and governance, our variable may at least partially capture business plans rather than the extent to which it cares about the environment. To address this problem, we need to examine how a firm's intention toward the environment can be translated into our measure of EP, *Scope*. Alternatively, we need direct evidence of linking a firm's intention and its carbon efficiency.

6 Conclusion

Today, the threat of climate change could potentially have devastating impacts to economies around the world. The International Energy Agency (2014) estimates that \$53 trillion is needed by 2035 to combat these impacts. However, investment has been hampered by the unclear relationship between corporate EP and FP. Therefore, this study empirically investigates the risk-return relationship of low-carbon investment, and characteristics of carbon-efficient firms. The underlying objective of this study is to provide reliable evidence on the market evaluation of low-carbon investment.

Based on 74,486 observations of 736 US firms from January 2005 to December 2015, we construct three versions of carbon efficient-minus-inefficient (EMI) portfolios based on carbon efficiency — EMI1 (sorted on carbon efficiency), EMI2 (sorted on carbon efficiency and B/M), and EMI3 (sorted on carbon efficiency and size). We find that our EMI portfolios generate positive abnormal returns since 2010, which cannot be explained by well-known factor-mimicking portfolios, such as market, size, B/M, momentum, profitability, and investment. An investment strategy of “long carbon-efficient firms and short carbon-inefficient firms” would earn abnormal returns of 3.5–5.4% per year for EMI1 and EMI2 portfolios. EMI3 portfolio earns 4–6–7.0% of alpha when we consider big firms

and 2.8–4.2% when we include medium-sized firms. The only exception is that small carbon-efficient firms do not outperform small carbon-inefficient firms. We also investigate the source of EMI portfolio's abnormal returns by examining the relationship between carbon efficiency and firm-level characteristics. Carbon-efficient firms are likely to be “good firms” in terms of financial performance (measured by Tobin's q , ROI, cash flow, coverage ratio) and corporate governance. However, we do not find strong evidence that investors explicitly consider carbon efficiency in their investment decision. Our findings are not driven by a small set of industries and other macroeconomic factors. Although we acknowledge that the observation period of the abnormal returns is relatively short because the outperformance of carbon-efficient firms start around 2010, we nevertheless assert that our findings are promising enough to encourage investors, business leaders and policymakers to rethink their approach to low-carbon investment.

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A Appendix

A.1 Variable Description

(a) Firm-level Carbon Data (Source: Trucost)	
Scope 1 (tCO ₂ e)	Greenhouse gas emissions generated from burning fossil fuels and production processes which are owned or controlled by the company (reference: GHG Protocol), unit: tCO ₂ e.
Scope 2 (tCO ₂ e)	Greenhouse gas emissions from consumption of purchased electricity, heat or steam by the company (reference: GHG Protocol), unit: tCO ₂ e.
Scope 3 (tCO ₂ e)	Other indirect Greenhouse gas emissions, such as from the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. T&D losses) not covered in Scope 2, outsourced activities, waste disposal, etc. (reference: GHG Protocol), unit: tCO ₂ e.
<i>Scope1</i>	Scope 1 emissions divided by a firms revenue, unit: tCO ₂ e/\$mil.
<i>Scope2</i>	Scope 2 emissions divided by a firms revenue, unit: tCO ₂ e/\$mil.
<i>Scope3</i>	Scope 3 emissions divided by a firms revenue, unit: tCO ₂ e/\$mil.
<i>Scope12</i>	Sum of Scope 1 and Scope 2 divided by a firms revenue, unit: tCO ₂ e/\$mil.
<i>Scope</i>	Sum of Scope 1, Scope 2 and Scope 3 divided by a firms revenue, unit: tCO ₂ e/\$mil.
External direct cost	Cost that a company incur directly on the environment through its own activities, unit: USD million.
External indirect cost	Cost that arises when a firm purchases goods and services or through supply chains, unit: USD million.
External cost	Sum of external direct and indirect cost, unit: USD million.
Direct impact ratio	External direct cost/revenue.
Indirect impact ratio	External indirect cost/revenue.
Impact ratio	Sum of direct and indirect impact.
(b) Variables Related to Firms Financial Performance and Corporate Governance (Source: CRSP/Compustat Merged [CCM])	
Firm size (Size)	Total assets (AT). unit: one million dollar.
Book-to-market ratio (B/M)	Book value (AT-LT) to market value (MKVALT). Alternatively, book value can be defined as the number of shares (CSHO) multiplied by book value per share (BKVLPS).
Tobin's <i>q</i>	Ratio of the market value of a company's assets (as measured by the market value of its outstanding stock and debt) divided by the replacement cost of the company's assets (book value). $(AT+(CSHO*PRCC_F)-CEQ)/AT$.
Return on Assets (ROA)	Return on assets, net income (NI) divided by AT.
Return on Equity (ROE)	Return on equity; NI divided by market value of equity (MKVALT or CSHO*PRCC_F).
Return on Investment (ROI)	Return on investment; NI divided by invested capital (ICAPT).
Earnings per share (EPS)	NI divided by the number of common shares outstanding.
PER	Price-earnings ratio; closing price (PRCC_F) divided by NI.
Cash flow	Sum of income before extraordinary items (IBC) and depreciation and amortization (DP), scaled by AT.

Free cash flow	Earnings before interest and taxes (EBIT) multiplied by (1-tax rate), plus depreciation & amortization (DPC), minus change in working capital (WCAPCH), scaled by AT. Tax rate is calculated as the ratio of income taxes (TXT) to pretax income (PI). Zero observation for WCAPCH.
Cash holdings	Amount of cash and short-term investment (CHE), scaled by AT.
Coverage ratio	EBIT divided by total interest and expense (XINT).
Payout ratio	Dividend-payout ratio; sum of preferred dividend (DVP), common/ordinary dividend (DVC), purchases of preferred and common stocks (PRSTKC), divided by income before extraordinary items (IB).
Leverage ratio	Sum of long-term debt (DLTT) and current debt (DLC), scaled by stockholders equity (SEQ).
Tangible assets	Net amount of property, plant, and equipment (PPENT) scaled by AT.
Capital intensity	Capital expenditure (CAPX) divided by AT.
Operating profitability	(revenue (REVT) – cost of goods sold (COGS) interest and related expenses (XINT) – sales, general and administrative expenses (XSGA)), divided by AT.
Cost of capital	XINT divided by DLC.
R&D intensity	R&D expenditures divided by AT.
(c) Variables Related to Firms Environmental Performance and Governance (Source: MSCI)	
Environmental strength	Number of yes on 7 categories on a firms strengths in environmental issues (env_str_num).
Environmental concern	Number of yes on 7 categories on a firms concerns in environmental issues (env_con_num).
Governance strength	Number of yes on 5 categories on a firms strengths in corporate governance issues (cgov_str_num).
Governance concern	Number of yes on 6 categories on a firms concerns in corporate governance issues (cgov_con_num).

A.2 Portfolios Formed by Fama-French Breakpoints

Table 1: Sample Properties

(a) Number of total observations and distinct firms

	Sample period	Number of observations	
		Total	Distinct
Trucost	2005-2015	9,510	1,124
merged with Compustat	2005-2015	8,607	975
merged with KLD	2005-2015	8,124	903
merged with CRSP	Jan 2005-Dec 2015	87,609	851
excluding financial industry	Jan 2005-Dec 2015	75,638	739
applying exclusion criteria	Jan 2005-Dec 2015	74,486	736

(b) Number of firms by Fama-French breakpoints (size and B/M 2×3 breakpoints)

Year	Small			Big			total
	Growth	Neutral	Value	Growth	Neutral	Value	
2005	413	388	130	2,740	1,730	678	6,079
2006	426	301	119	2,800	1,861	669	6,176
2007	294	258	315	2,985	1,658	795	6,305
2008	379	386	798	1,825	1,874	1,265	6,527
2009	325	278	124	3,754	2,098	200	6,779
2010	302	340	143	3,286	2,330	565	6,966
2011	323	434	461	2,746	2,064	1,048	7,076
2012	313	465	266	3,451	2,177	646	7,318
2013	464	569	196	4,181	2,138	464	8,012
2014	386	601	548	3,428	2,327	839	8,129
2015	135	222	188	2,385	1,687	502	5,119
Total	3,760	4,242	3,288	33,581	21,944	7,671	74,486

(c) Correlation coefficients of selected industry portfolios with Fama-French industry portfolios

Industry	Jan 2005 - Dec 2015	Jan 2010 - Dec 2015
Energy	0.99	0.99
Finance	0.95	0.97
Health	0.98	0.98
Telecommunications	0.80	0.75
Utilities	0.96	0.94

Table 2: Summary Statistics of Carbon Emissions and Efficiency, by Industry

Panel (a) shows the average values of carbon intensity defined in terms of *Scope1*, *Scope2* and *Scope3*, external cost, and impact ratio (external cost/revenue) by eleven GICS industry sectors. Panel (b) reports the correlation coefficients. * and ** denote *p*-value < 0.10 and *p*-value < 0.01, respectively.

(a) Summary statistics							
	(1)	(2)	(3)	(4)	(5)	(6)	
GICS industry sectors	<i>Scope1</i>	<i>Scope2</i>	<i>Scope3</i>	<i>Scope</i> ((1)+(2)+(3))	External cost	Impact ratio	<i>N</i>
Consumer Discretionary	19.9	36.4	142.4	198.7	78.4	0.70	15,306
Consumer Staples	40.5	41.4	447.7	529.6	430.0	1.86	4,884
Energy	447.4	59.8	216.3	723.5	602.0	2.55	6,451
Financials	3.3	7.0	42.7	53.0	19.2	0.19	7,186
Health Care	17.2	18.9	103.8	139.9	59.8	0.49	7,911
Industrials	160.9	22.9	216.0	399.7	141.4	1.42	13,964
Information Tech	15.2	23.2	101.7	140.1	40.5	0.49	12,070
Materials	497.7	174.5	425.1	1,097.2	327.6	4.01	6,699
Real Estate	116.7	51.1	154.6	322.4	76.6	1.12	385
Telecommunications	8.0	30.5	54.5	93.0	96.3	0.33	1,357
Utilities	3,780.9	96.4	319.2	4,196.6	1,096.7	14.73	5,663
Total	375.9	45.5	194.5	615.8	229.9	2.18	81,876

(b) Correlation coefficients.						
	<i>Scope1</i>	<i>Scope2</i>	<i>Scope3</i>	<i>Scope</i>	External cost	Impact Ratio
<i>Scope1</i>	1					
<i>Scope2</i>	0.09**	1				
<i>Scope3</i>	0.26**	0.07**	1			
<i>Scope</i>	0.97**	0.26**	0.40**	1		
External cost	0.45**	0.05**	0.30**	0.47**	1	
Impact ratio	0.97**	0.27**	0.39**	0.99**	0.47**	1

Table 3: Average Returns of Portfolios, by Different Portfolio Formations

This table displays the average monthly returns of value-weighted portfolios formed on *Scope* only, *Scope* and book-to-market ratio, and *Scope* and firm size. *, **, and *** denote p -value <0.10 , p -value <0.05 , and p -value <0.01 , respectively.

(a) Average returns, single-sorted on carbon efficiency

	1 (Efficient)	2	3 (Inefficient)	total	differences
2005m1-2015m12	1.33	1.15	1.13	1.20	0.20
2010m1-2015m12	1.73	1.28	1.23	1.41	0.50***

(b) Average returns, double-sorted on carbon efficiency and book-to-market ratio (3×3)

Sample period: 2006m1-2015m12					
	Efficient	2	Inefficient	total	difference
Growth	1.65	1.26	1.01	1.31	0.64***
2	1.04	1.01	1.03	1.03	0.01
Value	1.30	1.15	1.53	1.32	-0.23
Total	1.33	1.14	1.19	1.22	0.14
Sample period: 2010m1-2015m12					
	Efficient	2	Inefficient	total	difference
Growth	2.13	1.34	1.18	1.55	0.95***
2	1.52	1.17	1.09	1.26	0.43*
Value	1.54	1.23	1.51	1.43	0.03
Total	1.73	1.25	1.26	1.41	0.47

(c) Average returns, double-sorted on carbon efficiency and size (3×3)

Sample period: 2006m1-2015m12					
	Efficient	2	Inefficient	total	difference
Big	1.26	1.07	1.02	1.12	0.24
2	1.48	1.44	1.37	1.43	0.11
Small	1.73	1.76	1.99	1.83	-0.26
Total	1.49	1.42	1.46	1.46	0.03
Sample period: 2010m1-2015m12					
	Efficient	2	Inefficient	total	difference
Big	1.73	1.20	1.11	1.35	0.62***
2	1.72	1.68	1.57	1.66	0.15
Small	1.59	1.67	1.95	1.74	-0.36**
Total	1.68	1.52	1.54	1.58	0.14

Table 4: Summary Statistics of EMIs and Factor-Mimicking Portfolios

This table shows the average monthly returns, standard deviations, and Sharpe ratios of EMI (efficient- minus-inefficient) portfolios, market excess return, portfolios of SMB (small-minus-big), HML (high-minus-low), RMW (robust-minus-weak), CMA (conservative-minus-aggressive), and WML (winner-minus-loser), along with correlation coefficients among them. * and ** denote p -value <0.10 and p -value <0.01 , respectively.

(a) Average monthly returns, standard deviations, and Sharpe ratios

	EMI1	EMI2	EMI3	mktrf	SMB	HML	RMW	CMA	WML
Sample period: 2006:1-2015:12									
Average returns	0.19	0.21	0.24	0.61	0.09	-0.14	0.26	0.08	0.09
Standard deviations	1.62	1.77	2.01	4.46	2.38	2.61	1.56	1.33	4.98
Sharpe ratios	0.12	0.12	0.12	0.14	0.04	-0.05	0.17	0.06	0.02
Sample period: 2010:1-2015:12									
Average returns	0.47	0.49	0.62	1.09	0.02	-0.19	0.03	0.09	0.57
Standard deviation	1.27	1.40	1.51	3.91	2.23	1.92	1.50	1.25	3.00
Sharpe ratios	0.37	0.35	0.41	0.28	0.01	-0.10	0.02	0.07	0.19

(b) Correlation coefficients

	EMI	EMI2	EMI3	mktrf	SMB	HML	RMW	CMA	WML
Sample period: 2006m1-2015m12									
EMI1	1.00								
EMI2	0.80**	1.00							
EMI3	0.98**	0.77**	1.00						
mktrf	0.21*	0.16*	0.19*	1.00					
SMB	0.13	0.05	0.14	0.40**	1.00				
HML	0.00	0.05	0.04	0.33**	0.29**	1.00			
RMW	-0.26**	-0.22*	-0.27**	-0.51**	-0.40**	-0.27**	1.00		
CMA	-0.07	0.05	-0.04	-0.01	0.07	0.50**	0.03	1.00	
WML	-0.23*	-0.06	-0.22*	-0.35**	-0.17*	-0.44**	0.25**	-0.07	1.00
Sample period: 2010m1-2015m12									
EMI1	1.00								
EMI2	0.78**	1.00							
EMI3	0.97**	0.75**	1.00						
mktrf	0.14	0.10	0.08	1.00					
SMB	-0.08	-0.10	-0.09	0.39**	1.00				
HML	-0.48**	-0.22*	-0.47**	0.21*	0.19	1.00			
RMW	-0.11	-0.05	-0.12	-0.40**	-0.46**	-0.22*	1.00		
CMA	-0.39**	-0.12	-0.37**	0.16	0.10	0.65**	0.01	1.00	
WML	0.30**	0.34**	0.31**	-0.08	0.09	-0.26*	0.13	-0.03	1.00

Table 5: GRS Tests on EMI1, Sorted on Carbon Efficiency

This table shows the GRS tests based on equation (4), (5), (6), and (7) for two sample period: 2006m1–2015m12 and 2010m1–2015m12. There are three portfolios formed on Scope. EMI1 is “efficient-minus-inefficient” portfolio. The null hypothesis of GRS test is $\alpha_1 = \alpha_2 = \alpha_3 = 0$. p -values based on GRS test statistics are provided.

	(a) 2006m1-2015m12				(b) 2010m1-2015m12			
	(1) Efficient	(2) 2	(3) Inefficient	(4) EMI1	(5) Efficient	(6) 2	(7) Inefficient	(8) EMI1
	CAPM				CAPM			
mktrf	0.95*** (0.018)	0.92*** (0.021)	0.88*** (0.025)	0.08** (0.033)	0.97*** (0.028)	0.92*** (0.029)	0.93*** (0.025)	0.04 (0.036)
alpha	0.65*** (0.083)	0.50*** (0.092)	0.50*** (0.111)	0.15 (0.146)	0.66*** (0.112)	0.27** (0.116)	0.22** (0.099)	0.45*** (0.146)
R^2	0.96	0.94	0.91	0.04	0.95	0.94	0.95	0.02
	average alpha = 0.55, p -value = 0.00				average alpha = 0.39, p -value = 0.00			
	Fama-French 3 factor model				Fama-French 3 factor model			
mktrf	0.98*** (0.020)	0.95*** (0.022)	0.90*** (0.028)	0.08** (0.037)	1.01*** (0.026)	0.98*** (0.026)	0.93*** (0.027)	0.09** (0.034)
SMB	-0.01 (0.036)	-0.11*** (0.041)	-0.05 (0.051)	0.05 (0.068)	-0.07 (0.045)	-0.24*** (0.046)	-0.02 (0.047)	-0.05 (0.060)
HML	-0.12*** (0.032)	-0.07* (0.036)	-0.07 (0.045)	-0.05 (0.060)	-0.25*** (0.049)	-0.09* (0.050)	0.08 (0.051)	-0.33*** (0.065)
alpha	0.62*** (0.079)	0.48*** (0.089)	0.48*** (0.110)	0.14 (0.148)	0.57*** (0.096)	0.19* (0.098)	0.24** (0.100)	0.34** (0.128)
R^2	0.96	0.95	0.92	0.05	0.96	0.96	0.96	0.3
	average alpha = 0.53, p -value = 0.00				average alpha = 0.33, p -value = 0.00			
	Fama-French 3-factor model + momentum				Fama-French 3-factor model + momentum			
mktrf	0.98*** (0.020)	0.93*** (0.022)	0.92*** (0.027)	0.06 (0.037)	1.02*** (0.023)	0.98*** (0.026)	0.93*** (0.027)	0.09*** (0.034)
SMB	-0.01 (0.037)	-0.11*** (0.039)	-0.06 (0.049)	0.05 (0.067)	-0.10** (0.041)	-0.23*** (0.046)	-0.03 (0.047)	-0.07 (0.059)
HML	-0.12*** (0.035)	-0.12*** (0.037)	-0.01 (0.047)	-0.11* (0.064)	-0.20*** (0.046)	-0.11** (0.052)	0.09* (0.053)	-0.29*** (0.066)
MOM	0 (0.018)	-0.07*** (0.019)	0.08*** (0.024)	-0.08** (0.033)	0.12*** (0.029)	-0.05 (0.033)	0.03 (0.033)	0.09** (0.042)
alpha	0.62*** (0.079)	0.49*** (0.084)	0.47*** (0.106)	0.15 (0.145)	0.51*** (0.088)	0.22** (0.099)	0.22** (0.102)	0.29** (0.127)
R^2	0.96	0.95	0.92	0.1	0.97	0.96	0.96	0.34
	average alpha = 0.53, p -value = 0.00				average alpha = 0.32, p -value = 0.00			
	Fama-French 5 factor model				Fama-French 5 factor model			
mktrf	0.99*** (0.022)	0.98*** (0.024)	0.95*** (0.029)	0.04 (0.040)	1.01*** (0.027)	1.01*** (0.025)	0.93*** (0.026)	0.07** (0.035)
SMB	0 (0.037)	-0.08** (0.041)	-0.01 (0.050)	0.01 (0.069)	-0.07 (0.048)	-0.17*** (0.044)	0.01 (0.046)	-0.08 (0.063)
HML	-0.13*** (0.038)	-0.07* (0.042)	-0.08 (0.051)	-0.06 (0.071)	-0.32*** (0.065)	-0.04 (0.060)	-0.02 (0.063)	-0.30*** (0.086)
RMW	0.07 (0.061)	0.19*** (0.066)	0.29*** (0.081)	-0.22** (0.113)	-0.02 (0.074)	0.30*** (0.068)	0.13* (0.071)	-0.15 (0.098)
CMA	0.06 (0.070)	0.05 (0.076)	0.07 (0.092)	-0.02 (0.129)	0.17* (0.099)	-0.06 (0.091)	0.27*** (0.095)	-0.1 (0.131)
alpha	0.59*** (0.082)	0.41*** (0.090)	0.37*** (0.109)	0.22 (0.152)	0.55*** (0.097)	0.16* (0.089)	0.18* (0.093)	0.37*** (0.128)
R^2	0.96	0.95	0.93	0.09	0.96	0.97	0.96	0.34
	average alpha = 0.46, p -value = 0.00				average alpha = 0.30, p -value = 0.00			

Table 6: GRS Tests on EMI2, Sorted on Carbon Efficiency and B/M

This table shows the results of GRS test, based on two sample periods, January 2006-December 2015 and January 2010-December 2015. We use four well-known factor models (CAPM, Fama-French 3-factor model, 4-factor models with momentum, Fama-French 5-factor model) to see if they can price carbon-efficient, carbon-inefficient, and EMI2 portfolios. *, **, and *** denote p -value <0.10 , p -value <0.05 , and p -value <0.01 , respectively.

	2006m1-2015m12			2010m1-2015m12		
	(1) Efficient	(2) Inefficient	(3) EMI2	(4) Efficient	(5) Inefficient	(6) EMI2
	CAPM			CAPM		
mktrf	1.04*** (0.022)	0.97*** (0.031)	0.07* (0.037)	1.03*** (0.031)	0.99*** (0.027)	0.04 (0.043)
alpha	0.75*** (0.100)	0.58*** (0.138)	0.07 (0.164)	0.71*** (0.123)	0.26** (0.109)	0.45** (0.171)
R^2	0.95	0.89	0.03	0.94	0.95	0.01
	Fama-French 3 factor			Fama-French 3 factor		
mktrf	1.04*** (0.025)	0.97*** (0.035)	0.07* (0.042)	1.06*** (0.032)	0.98*** (0.030)	0.07 (0.046)
SMB	0.06 (0.046)	0.07 (0.064)	-0.02 (0.077)	-0.05 (0.056)	0.03 (0.052)	-0.08 (0.079)
HML	-0.07 (0.041)	-0.07 (0.057)	0.00 (0.068)	-0.15** (0.061)	0.02 (0.057)	-0.18** (0.087)
alpha	0.74*** (0.100)	0.57*** (0.138)	0.07 (0.167)	0.65*** (0.120)	0.27** (0.112)	0.38** (0.170)
R^2	0.95	0.9	0.03	0.95	0.95	0.09
	Fama-French 3 factor + momentum			Fama-French 3 factor + momentum		
mktrf	1.03*** (0.026)	0.96*** (0.036)	0.07 (0.043)	1.07*** (0.030)	0.98*** (0.030)	0.08* (0.043)
SMB	0.06 (0.046)	0.08 (0.064)	-0.02 (0.077)	-0.08 (0.053)	0.04 (0.053)	-0.12 (0.077)
HML	-0.09* (0.044)	-0.09 (0.061)	-0.01 (0.074)	-0.10* (0.060)	0.01 (0.059)	-0.11 (0.085)
WML	-0.03 (0.023)	-0.03 (0.032)	0.00 (0.038)	0.12*** (0.038)	-0.03 (0.038)	0.16*** (0.054)
alpha	0.74*** (0.100)	0.57*** (0.139)	0.07 (0.167)	0.58*** (0.114)	0.29** (0.114)	0.29* (0.164)
R^2	0.95	0.9	0.03	0.96	0.95	0.19
	Fama-French 5 factor			Fama-French 5 factor		
mktrf	1.06*** (0.027)	1.02*** (0.036)	0.04 (0.045)	1.05*** (0.032)	0.99*** (0.030)	0.06 (0.048)
SMB	0.07 (0.047)	0.12* (0.063)	-0.05 (0.078)	-0.06 (0.058)	0.05 (0.054)	-0.11 (0.086)
HML	-0.08 (0.048)	-0.04 (0.064)	-0.05 (0.080)	-0.29*** (0.079)	-0.07 (0.074)	-0.22* (0.117)
RMW	0.12 (0.077)	0.36*** (0.102)	-0.24* (0.127)	-0.05 (0.090)	0.08 (0.084)	-0.12 (0.132)
CMA	0.07 (0.088)	-0.05 (0.117)	0.13 (0.145)	0.31** (0.120)	0.24** (0.112)	0.07 (0.177)
alpha	0.69*** (0.104)	0.45*** (0.138)	0.14 (0.172)	0.61*** (0.118)	0.23** (0.110)	0.38** (0.173)
R^2	0.95	0.91	0.06	0.95	0.96	0.10

Table 7: GRS Tests on EMI3, Sorted on Carbon Efficiency and Size

This table shows the results of GRS test, based on two sample periods, January 2006-December 2015 and January 2010-December 2015. We use four well-known factor models (CAPM, Fama-French 3-factor model, 4-factor models with momentum, Fama-French 5-factor model) to see if they can price carbon-efficient, carbon-inefficient, and EMI3 portfolios. *, **, and *** denote p -value <0.10 , p -value <0.05 , and p -value <0.01 , respectively.

	2006m1-2015m12			2010m1-2015m12		
	(1) Efficient	(2) Inefficient	(3) EMI3	(4) Efficient	(5) Inefficient	(6) EMI3
	CAPM			CAPM		
mktrf	0.92*** (0.024)	0.83*** (0.030)	0.09** (0.042)	0.93*** (0.036)	0.89*** (0.031)	0.03 (0.046)
alpha	0.61*** (0.106)	0.43*** (0.135)	0.09 (0.187)	0.72*** (0.145)	0.14 (0.126)	0.58*** (0.186)
R^2	0.93	0.87	0.04	0.9	0.92	0.01
	Fama-French 3 factor			Fama-French 3 factor		
mktrf	0.96*** (0.025)	0.88*** (0.032)	0.08* (0.047)	1.00*** (0.032)	0.91*** (0.033)	0.09* (0.044)
SMB	-0.10** (0.047)	-0.17*** (0.060)	0.07 (0.087)	-0.20*** (0.056)	-0.14** (0.057)	-0.06 (0.078)
HML	-0.10** (0.041)	-0.07 (0.053)	-0.04 (0.077)	-0.28*** (0.061)	0.11* (0.063)	-0.39*** (0.085)
alpha	0.58*** (0.101)	0.40*** (0.130)	0.08 (0.189)	0.59*** (0.120)	0.14 (0.122)	0.45*** (0.166)
R^2	0.94	0.88	0.04	0.94	0.93	0.26
	Fama-French 3 factor + momentum			Fama-French 3 factor + momentum		
mktrf	0.96*** (0.026)	0.91*** (0.032)	0.06 (0.048)	1.01*** (0.028)	0.92*** (0.033)	0.10** (0.044)
SMB	-0.11** (0.047)	-0.18*** (0.057)	0.08 (0.086)	-0.24*** (0.050)	-0.15** (0.058)	-0.09 (0.077)
HML	-0.09** (0.045)	0. (0.054)	-0.1 (0.082)	-0.21*** (0.055)	0.13** (0.065)	-0.34*** (0.086)
WML	0.02 (0.023)	0.11*** (0.028)	-0.09** (0.042)	0.17*** (0.035)	0.05 (0.041)	0.11** (0.054)
alpha	0.58*** (0.101)	0.39*** (0.123)	0.10 (0.187)	0.50*** (0.106)	0.11 (0.124)	0.38** (0.164)
R^2	0.94	0.89	0.08	0.95	0.93	0.31
	Fama-French 5 factor			Fama-French 5 factor		
mktrf	0.98*** (0.028)	0.94*** (0.033)	0.04 (0.051)	0.99*** (0.033)	0.93*** (0.030)	0.07 (0.046)
SMB	-0.09* (0.048)	-0.12** (0.057)	0.02 (0.088)	-0.19*** (0.059)	-0.08 (0.055)	-0.12 (0.082)
HML	-0.14*** (0.049)	-0.09 (0.059)	-0.05 (0.091)	-0.39*** (0.080)	-0.01 (0.074)	-0.38*** (0.111)
RMW	0.07 (0.077)	0.38*** (0.093)	-0.32** (0.144)	-0.02 (0.091)	0.21** (0.084)	-0.23* (0.126)
CMA	0.13 (0.089)	0.13 (0.106)	0.00 (0.165)	0.26** (0.122)	0.34*** (0.113)	-0.08 (0.169)
alpha	0.54*** (0.105)	0.25* (0.126)	0.19 (0.195)	0.55*** (0.119)	0.06 (0.111)	0.49*** (0.165)
R^2	0.94	0.9	0.08	0.94	0.95	0.30

Table 8: Comparison of Firm Characteristics

This table shows the average values of firm characteristics variables for top 33% carbon-efficient portfolio and bottom 33% carbon-efficient portfolio, along with their differences during the period of 2006-2015 and 2010-2015. Variables are winsorized at 2% and 98%. *, **, *** denote p -value <0.10 , p -value <0.05 , and p -value <0.01 , respectively.

	2006-2015			2010-2015		
	efficient	inefficient	differences	efficient	inefficient	differences
size (unit: millions)	12,611	15,452	-2,841***	13,560	16,587	-3,027***
Book-to-market ratio	0.403	0.465	-0.062***	0.398	0.452	-0.054***
Tobin's q	2.135	1.942	0.194***	2.127	1.939	0.188***
ROA	0.061	0.059	0.002	0.061	0.058	0.002
ROI	0.102	0.092	0.009***	0.1	0.091	0.009**
EPS	2.266	2.407	-0.141*	2.56	2.576	-0.016
PER	0.178	0.171	0.007	0.184	0.174	0.011
Cash flow	0.103	0.099	0.004*	0.103	0.099	0.004
Free cash flow	0.061	0.064	-0.003	0.064	0.064	0
Cash holdings	0.129	0.132	-0.004	0.13	0.134	-0.004
Coverage ratio	32.923	28.704	4.219*	34.237	25.474	8.763***
Payout ratio	0.742	0.726	0.016	0.761	0.731	0.03
Leverage ratio	0.883	0.911	-0.028	0.941	0.968	-0.027
Tangible assets	0.28	0.346	-0.066***	0.272	0.345	-0.073***
Capital intensity	0.057	0.054	0.003*	0.053	0.054	0
Environmental strength	0.472	0.872	-0.400***	0.761	1.194	-0.432***
Environmental concern	0.241	0.734	-0.492***	0.196	0.543	-0.347***
Governance strength	0.149	0.223	-0.075***	0.169	0.2	-0.031
Governance concern	0.611	0.605	0.006	0.428	0.367	0.061**

Table 9: Carbon Efficiency and Firm Characteristics, Logit Regressions

This table reports the results of logit regression. The dependent variable is a dummy variable that takes a value of one when a firm is carbon-efficient and zero when a firm is carbon-inefficient. Column (2) and (4) report the results when all explanatory variables are standardized using z-scores in each industry. All regressions include industry fixed effects, year fixed effects, and industry-year fixed effects. Variables are winsorized at 2% and 98%. *, **, *** denote p -value <0.10 , p -value <0.05 , and p -value <0.01 , respectively.

	2006-2015		2010-2015	
	(1) raw numbers	(2) z-score	(3) raw numbers	(4) z-score
ln(asset)	0.44*** (0.06)	0.63*** (0.08)	0.35*** (0.08)	0.48*** (0.11)
Tobin's q	0.24*** (0.07)	0.29*** (0.07)	0.28*** (0.10)	0.32*** (0.11)
ROA	-23.26*** (3.39)	-1.25*** (0.21)	-28.33*** (4.98)	-1.71*** (0.31)
ROI	6.56*** (1.32)	0.55*** (0.15)	4.74** (1.90)	0.42** (0.21)
EPS	-0.08*** (0.03)	-0.21*** (0.07)	0.00 (0.04)	-0.06 (0.10)
PER	0.06 (0.16)	0.09 (0.06)	-0.15 (0.22)	-0.01 (0.09)
Cash flow	15.46*** (2.68)	1.04*** (0.17)	19.58*** (3.97)	1.42*** (0.24)
Free cash flow	-4.80*** (1.27)	-0.42*** (0.08)	-4.71*** (1.80)	-0.46*** (0.11)
Cash holdings	-2.03*** (0.47)	-0.26*** (0.05)	-2.12*** (0.65)	-0.26*** (0.07)
ln(coverage)	0.13*** (0.04)	0.17** (0.07)	0.24*** (0.06)	0.38*** (0.09)
Payout ratio	0.02 (0.05)	-0.04 (0.05)	0.08 (0.07)	0.01 (0.07)
Leverage	0.05 (0.03)	0.09 (0.05)	0.08* (0.04)	0.12 (0.07)
Tangible assets	-5.13*** (0.40)	-0.87*** (0.07)	-4.72*** (0.57)	-0.71*** (0.11)
Capital intensity	5.38** (2.13)	0.1 (0.08)	1.93 (3.18)	-0.23* (0.12)
Environmental strength	-0.47*** (0.05)	-0.51*** (0.06)	-0.46*** (0.07)	-0.56*** (0.09)
Environmental concern	-1.03*** (0.07)	-0.90*** (0.07)	-0.94*** (0.12)	-0.70*** (0.09)
Governance strength	0.04 (0.12)	0.04 (0.05)	0.33* (0.18)	0.15** (0.08)
Governance concern	0.18** (0.08)	0.17*** (0.05)	0.38*** (0.13)	0.26*** (0.07)
N	2,951	2,724	1,431	1,276

Table 10: Logit Regressions, Without Some Industries

This table reports the results of logit regressions. Columns of ‘w/o efficient’ reports the estimated coefficients without 3 most carbon-inefficient industries (utilities, energy, materials) and columns of ‘w/o inefficient’ reports the coefficients without 3 most carbon-efficient industries (telecommunications, health, IT). All regressions include industry fixed effects, year fixed effects, and industry-year fixed effects. Variables are winsorized at 2% and 98%. *, **, *** denote p -value<0.10, p -value<0.05, and p -value<0.01, respectively.

	2006-2015			2010-2015		
	(1) all	(2) w/o efficient	(3) w/o inefficient	(4) all	(5) w/o efficient	(6) w/o inefficient
ln(asset)	0.44*** (0.06)	0.58*** (0.07)	0.50*** (0.06)	0.35*** (0.08)	0.39*** (0.09)	0.52*** (0.09)
Tobin's q	0.24*** (0.07)	0.16* (0.09)	0.27*** (0.08)	0.28*** (0.10)	0.16 (0.13)	0.32*** (0.11)
ROA	-23.26*** (3.39)	-21.52*** (4.03)	-24.30*** (3.87)	-28.33*** (4.98)	-30.81*** (5.95)	-29.89*** (5.96)
ROI	6.56*** (1.32)	6.34*** (1.58)	6.13*** (1.44)	4.74** (1.90)	4.42** (2.20)	3.77* (2.05)
EPS	-0.08*** (0.03)	-0.17*** (0.03)	-0.03 (0.03)	0 (0.04)	-0.07 (0.05)	0.02 (0.05)
PER	0.06 (0.16)	0.27 (0.19)	0.03 (0.18)	-0.15 (0.22)	-0.25 (0.25)	-0.09 (0.26)
Cash flow	15.46*** (2.68)	15.69*** (3.18)	16.32*** (3.16)	19.58*** (3.97)	23.65*** (4.81)	22.29*** (4.99)
Free cash flow	-4.80*** (1.27)	-1.83 (1.41)	-4.57*** (1.44)	-4.71*** (1.80)	-2.01 (2.05)	-4.74** (1.98)
Cash holdings	-2.03*** (0.47)	-1.58** (0.67)	-1.38*** (0.50)	-2.12*** (0.65)	-1.46 (0.93)	-1.77** (0.70)
ln(coverage)	0.13*** (0.04)	0.14** (0.06)	0.16*** (0.05)	0.24*** (0.06)	0.25*** (0.07)	0.28*** (0.07)
Payout ratio	0.02 (0.05)	-0.01 (0.07)	0.03 (0.06)	0.08 (0.07)	0.04 (0.10)	0.09 (0.08)
Leverage	0.05 (0.03)	-0.02 (0.04)	0.04 (0.04)	0.08* (0.04)	0.01 (0.05)	0.06 (0.05)
Tangible assets	-5.13*** (0.40)	-4.68*** (0.43)	-3.85*** (0.45)	-4.72*** (0.57)	-4.00*** (0.60)	-3.49*** (0.65)
Capital intensity	5.38** (2.13)	9.07*** (2.38)	-0.41 (2.58)	1.93 (3.18)	4.05 (3.55)	-6.3 (4.25)
Environmental strength	-0.47*** (0.05)	-0.36*** (0.06)	-0.57*** (0.06)	-0.46*** (0.07)	-0.40*** (0.08)	-0.56*** (0.08)
Environmental concern	-1.03*** (0.07)	-1.07*** (0.08)	-0.84*** (0.10)	-0.94*** (0.12)	-1.00*** (0.12)	-0.85*** (0.17)
Governance strength	0.04 (0.12)	0.09 (0.13)	-0.11 (0.14)	0.33* (0.18)	0.57*** (0.20)	0.15 (0.21)
Governance concern	0.18** (0.08)	0.23** (0.09)	0.32*** (0.09)	0.38*** (0.13)	0.64*** (0.17)	0.52*** (0.15)
N	2,951	2,180	2,141	1,431	1,051	1,052

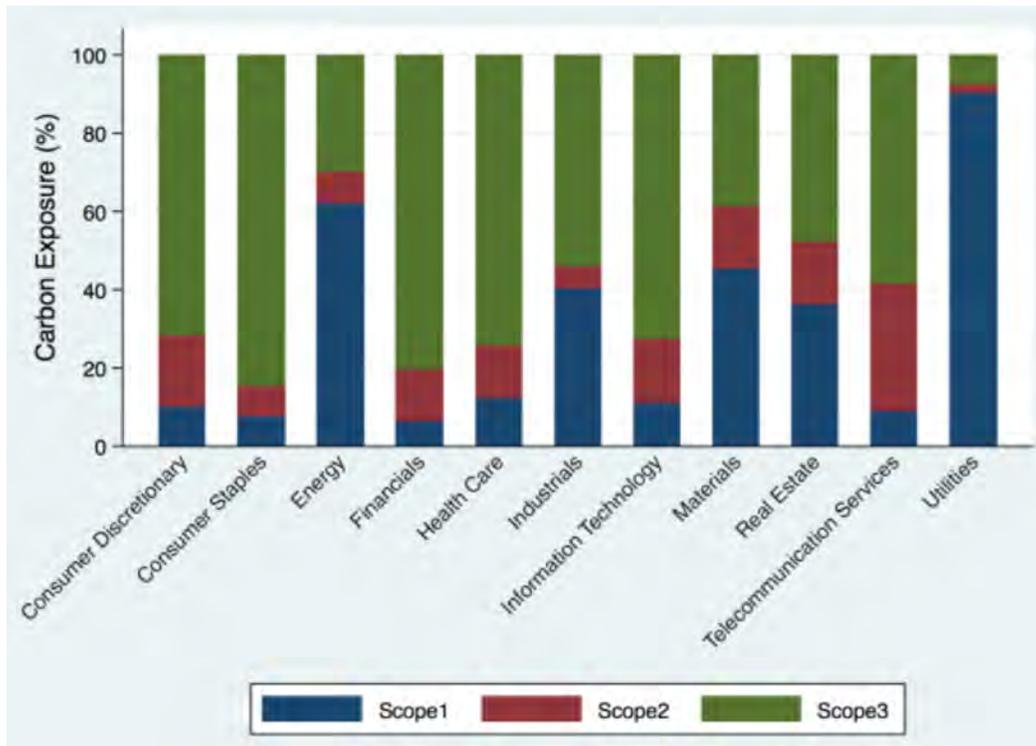


Figure 1: **Carbon emissions by *Scope* measures and industry**

This figure shows the relative shares of carbon efficiency (tCO₂e/\$mil) in terms of *Scope1*, *Scope2*, and *Scope3* by each industry in the sample. The relative shares are obtained from the average values of each *Scope* measure for each industry from 2005 to 2015.

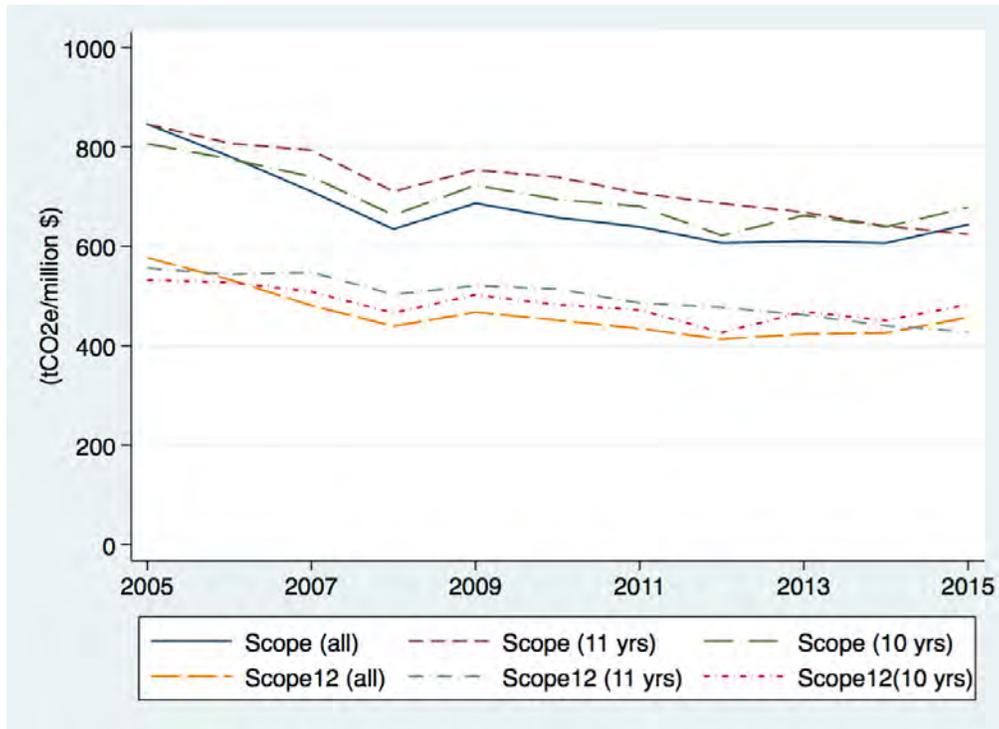


Figure 2: **Trends in Carbon Intensity**

This figure shows the average values of our *Scope* measures over time. ‘Scope’ is the sum of Scope 1, 2, and 3, divided by a firm’s revenue. ‘Scope (11 yrs)’ is the average values of Scope based on firms that exist in the sample from 2005 to 2015. ‘Scope (10 yrs)’ is based on firms that stays in the sample for at least 10 years. ‘Scope12’ is the sum of Scope 1 and 2, divided by a firm’s revenue.

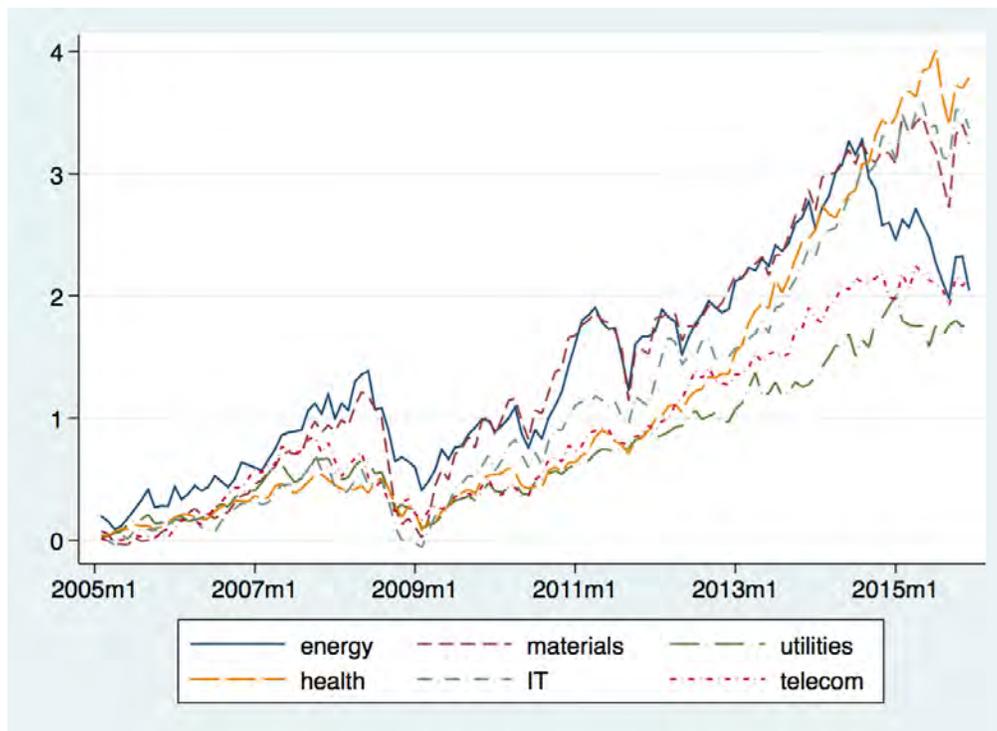


Figure 3: **Cumulative returns of selected industry portfolios**

This figure shows the cumulative returns of selected industry portfolios. Among 11 GICS industries, we choose 3 industries with lowest carbon efficiency (utilities, materials, energy) and 3 industries with highest carbon efficiency (health, IT, telecommunications). We use *Scope* (tCO₂e/\$mil) for carbon efficiency.

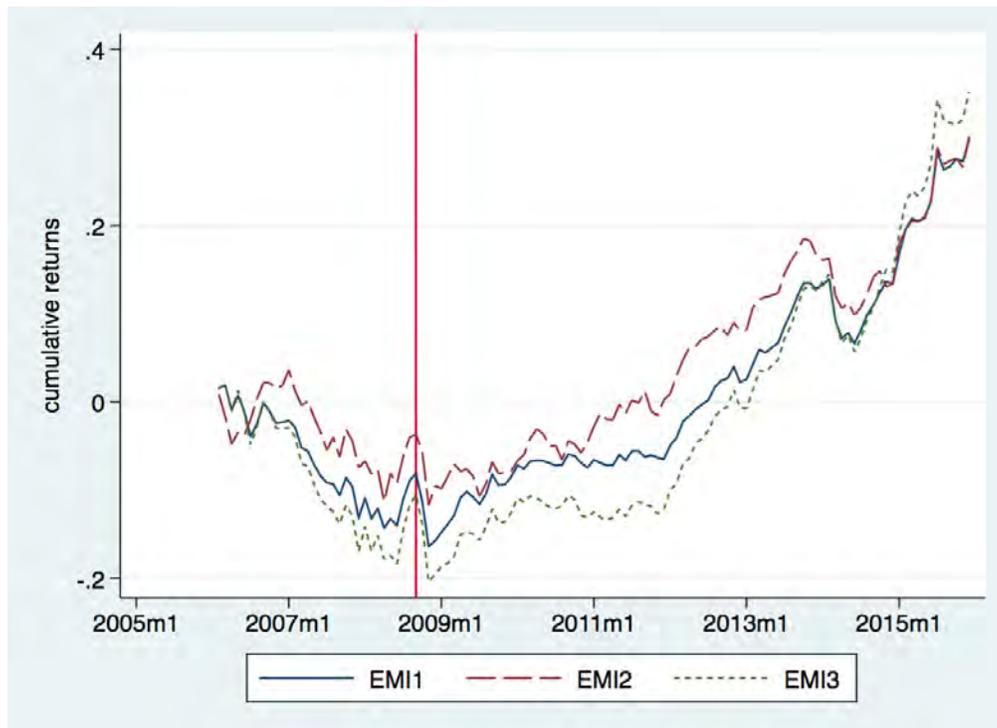
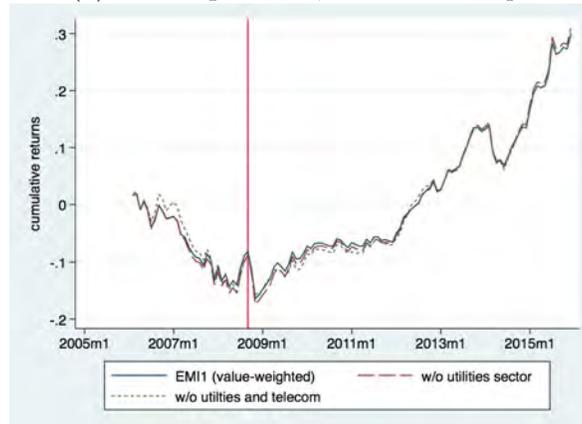


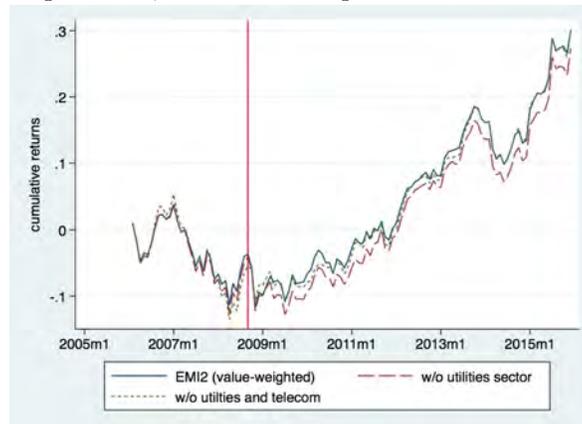
Figure 4: **Cumulative returns of EMI1, EMI2, and EMI3 portfolios**

This figure shows the cumulative returns of EMI portfolios, defined in various ways. EMI1 is the single-sorted portfolio based on *Scope*. EMI2 and EMI3 are the double-sorted portfolios based on *Scope* and book-to-market ratio and *Scope* and size, respectively.

(a): EMI1 portfolio, sorted on *Scope*



(b): EMI2 portfolio, sorted on *Scope* and book-to-market ratio



(c): EMI3 portfolio, sorted on *Scope* and market capitalization

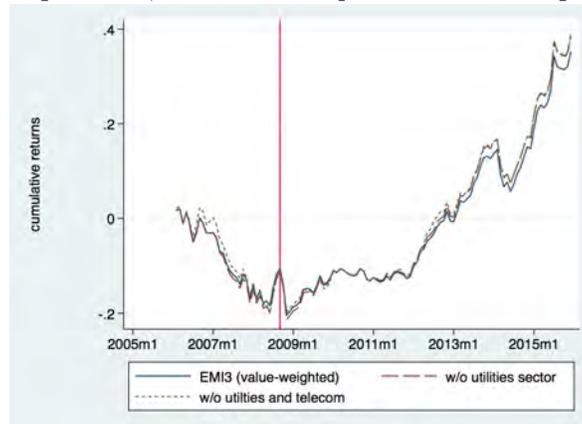


Figure 5: **Cumulative returns of EMI portfolios**

This figure shows the cumulative returns of EMI portfolios, defined in various ways. A line of ‘w/o utilities sector’ is for the cumulative return of value-weighted EMI portfolio formed without utilities sector. A line of ‘w/o utilities and telecom’ is for the cumulative return of value-weighted EMI portfolio formed without utilities and telecommunications sector.

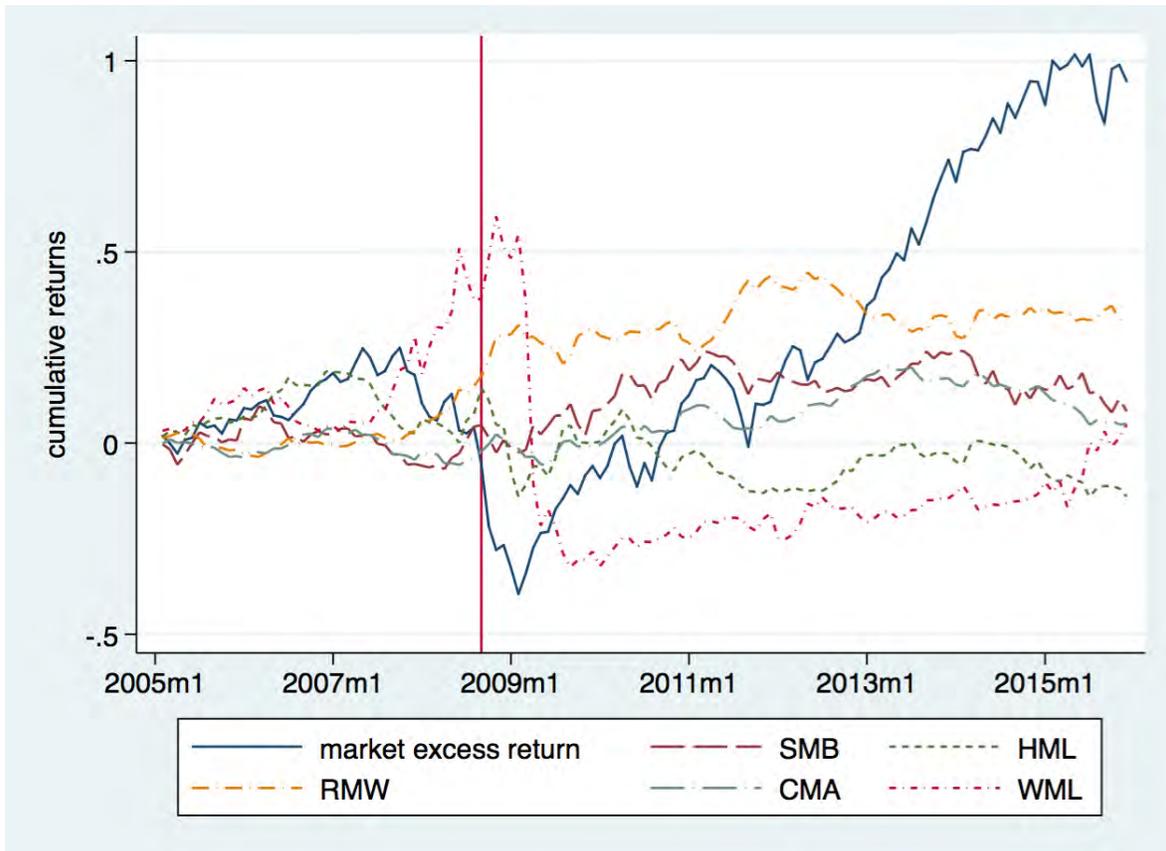


Figure 6: **Cumulative returns of factor portfolios**

This figure shows the cumulative returns of factor portfolios. We include the market excess returns, SMB (small-minus-big) for size effect, HML (high-minus-low) for value effect, RMW (robust-minus-weak) to capture the effect of operating profitability, CMA (conservative-minus-aggressive) for investment, and WML (winner-minus-loser) for momentum effect.

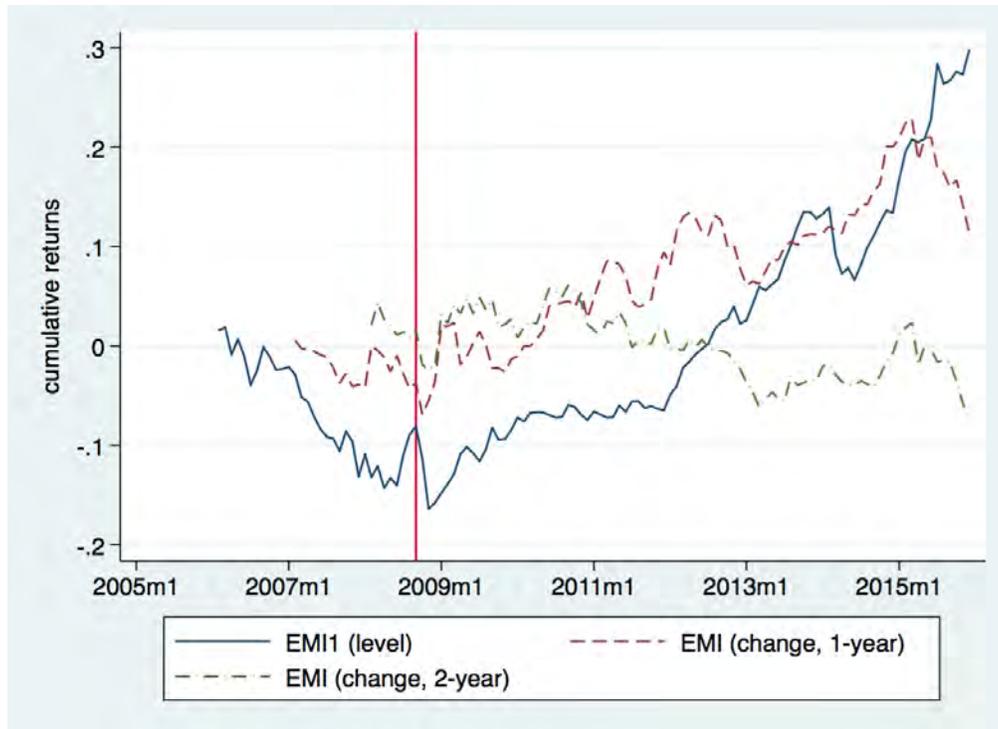
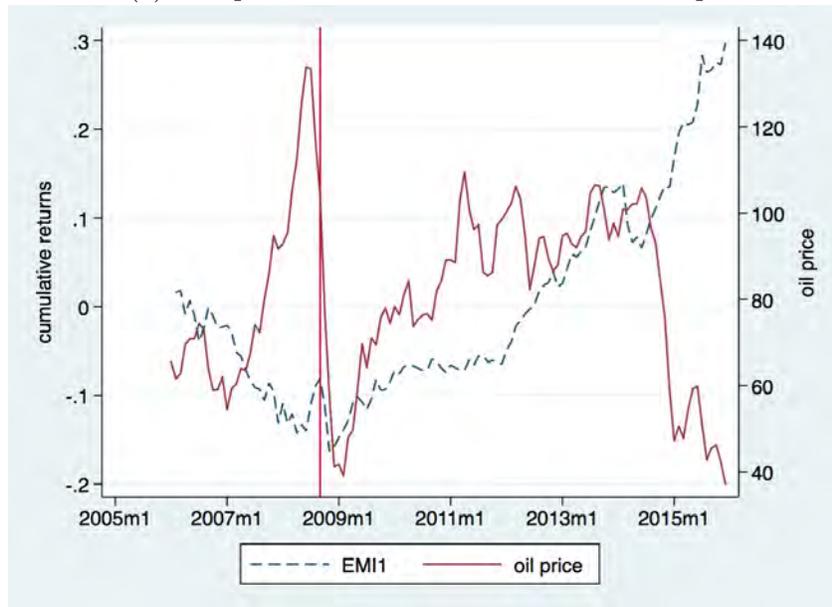


Figure 7: **Cumulative returns of EMI portfolios sorted on changes in carbon intensity**

This figure shows the cumulative returns of value-weighted EMI portfolios, defined in various ways. A solid line labeled as ‘EMI1 (level)’ shows the cumulative return of EMI portfolio sorted on *Scope* (tCO₂e/\$mil). A line of ‘EMI (change, 1-year)’ shows the cumulative return of EMI portfolio sorted on the changes in *Scope* for the past 1 year. A line of ‘EMI (change, 2-year)’ is for the cumulative return of EMI portfolio formed on the changes in *Scope* for the past 2 year. A red vertical line denotes September 2008, when Lehman Brothers filed for bankruptcy.

Panel (a): Oil price and cumulative return of EMI portfolio



Panel (b): Rolling correlation coefficient between oil price and cumulative return of EMI portfolio, 18-month window

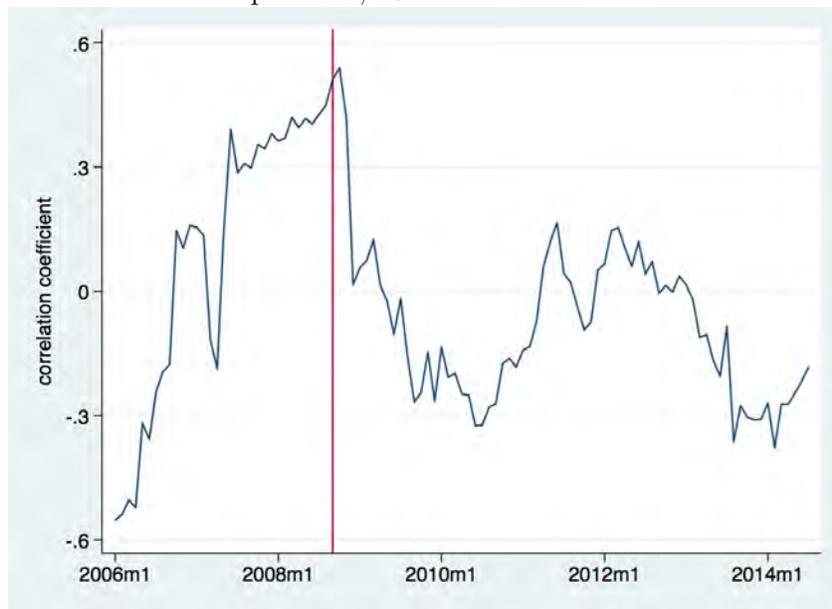


Figure 8: **Oil price and EMI portfolios**

Panel (a) shows the global price index of WTI Crude oil (US dollars per barrel) with the cumulative return of EMI1 portfolios. Panel (b) shows the rolling coefficient between oil price and cumulative returns of EMI1. The rolling window is 18 months.

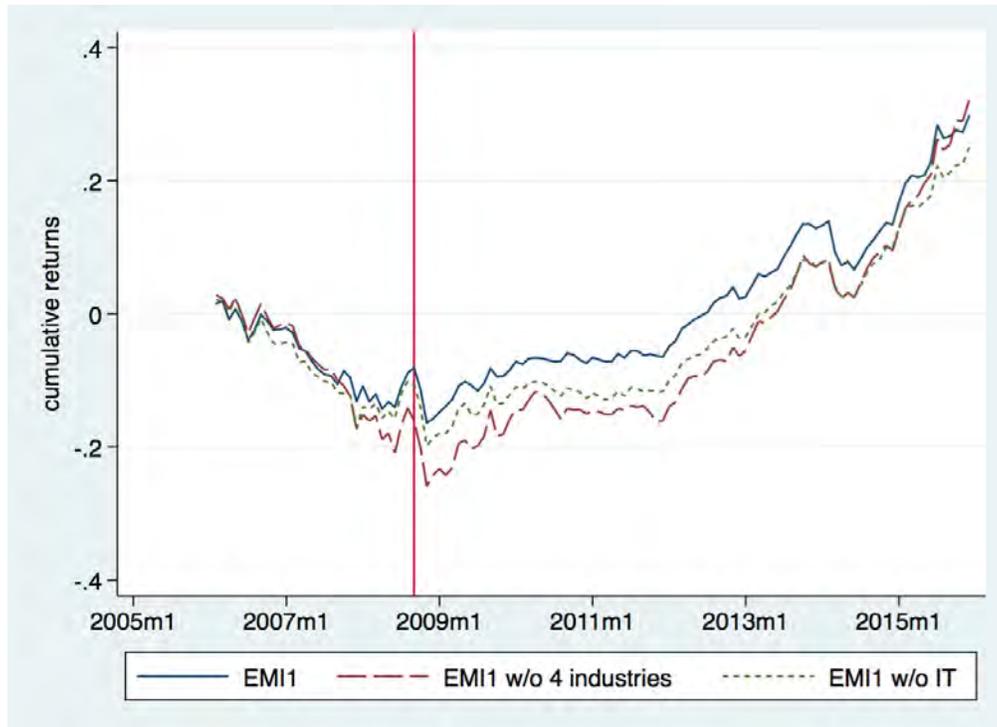


Figure 9: **Cumulative returns of EMI portfolios without some industries**

This figure shows the cumulative returns of three portfolios. One is EMI1 portfolio (single sort on carbon intensity). ‘EMI1 w/o 4 industries’ is the cumulative return of EMI portfolio formed without four stable and high-dividend-paying industries (utilities, telecommunications, IT, and consumer staples). ‘EMI1 w/o IT’ is the cumulative return of EMI portfolio formed without IT industry.

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OPERATIONALIZING PROTOTYPING AS A DESIGN METHOD FOR MORE SUSTAINABLE INFRASTRUCTURE PROJECTS

Miguel Andres Guerra¹ and Tripp Shealy²

ABSTRACT

Prototyping as a design method is used in fields such as mechanical engineering and industrial design to help break from the status quo. Prototyping works by providing a feedback mechanism that removes designers' fear of failure. The objective of the research presented in this paper is to understand how prototyping can be more readily adopted for large-scale and complex infrastructure systems. Design of infrastructure is predominately a top-down process from local government planning to civil engineering then construction. However, a bottom-up approach led by citizens using physical prototypes has recently emerged. In total, 55 cases where prototyping was used in the design of new sanitation systems, transportation systems, government housing, and urban revitalization projects were compared. Six-dimensions emerged from this comparison across cases: level of formality, resources, community involvement, number of participatory stakeholder groups, duration of the prototype phase, and purpose of prototyping. Relationships between the six dimensions are discussed. For example, the level of formality influences across other dimensions such as resources, community involvement, and stakeholder participation. Similarly, the duration of the prototype is more related to the purpose of prototyping rather than type of infrastructure to be design. Future research can now begin to use this model to explore alternative ways to build this feedback mechanism into the design of infrastructure systems—studying the relationships of these dimensions with prototyping goals and the types of infrastructure systems—and explore how virtual and immerse environments compare to real world prototypes.

KEYWORDS

Design of infrastructure systems, design methods, prototyping

INTRODUCTION

Civil infrastructure systems account for the vast majority of energy use and associated climate-changing emissions in the United States (US EPA 2014). Unfortunately, emissions from these infrastructure systems continue to increase annually (US EPA 2016). At the same time, service capacity continues to decline. For example, traffic congestion is at an all-time high (Schrank et al. 2015). The U.S. electricity grid loses more power today than in the 1980s (Hobbs and Kameshwar 2013; Hoffman and Bryan 2012) costing businesses, on average, \$150 million annually (Department of Energy, 2014). Traffic fatalities rose in 2015, ending a 5-decade decline (Henry, 2016). These are inherently sustainability challenges, with impacts to the environment, local communities, and economies. Solving such challenges is complex because more sustainable infrastructure systems that are less carbon-intensive and more user-centered likely require a shift from traditional ways of thinking.

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A barrier to new ways of thinking is the perceived risk that comes from moving beyond the status quos (Brown 2014). For example, a resistance to change old behaviors and adopt new inter-organizational collaboration led to under performance of a Dutch maintenance contractor (Van Buiten and Hartmann 2013). In California, the reluctance to adopt grey-water systems due to perceived risk led citizens to illegally adopt the practice in their homes. Newly constructed government facilities in the U.S. lack resilient design features, in part, because of status quo bias (US EPA 2014).

Prototyping as a design method is used in fields such as mechanical engineering (Chiu et al. 2015; Felix 2017), industrial design (Rix et al. 2016), and business (Karlsson et al. 2018), 201 to help break from the status quo. Prototyping works by providing a feedback mechanism that removes designers' fear of failure (Kelley and Kelley 2006). The intent is to gain user feedback and improve the design through iterations (Guerra and Shealy 2018). Prototyping is recognized as a critical step in design thinking processes (Bell 2008). Yet, this critical step is often missing during design of infrastructure (Guerra and Shealy 2018), in part, because of the size and complexity of the systems being designed and constructed.

Computer aided design (CAD) and three-dimensional building information modeling (BIM) do provide a type of digital prototype, in which architects and designers can test physical function and characteristics (e.g. performance of materials under various environmental conditions). Physical prototyping is also used in architecture in miniature models and massing of shapes (Lydon and Garcia 2015; Magnusson 2015). However, infrastructure systems provide both a physical function (e.g. bridge connects to sides of a river) and a service (e.g. increased mobility for citizens across the river). While digital prototypes and miniature models accurately represent the physical function aspect, they often fall short representing the service because human behaviour and user feedback is difficult to accurately predict or recreate. For instance, transportation engineers in Dresden, Germany, predicted that without a new bridge in the city center, traffic would become unbearable within a decade. In reality, this prediction never came to fruition because citizens adopted alternative modes of transportation when cars became less convenient and the engineering models did not account for this change human behaviour (Berthod 2013).

In other words, modelling how these systems will perform physically (under stresses and loads) is only part of the function of infrastructure. The benefit of prototypes in other fields is observing how users interact with the product and incorporating this information into future iterations.

The objective of this research is to understand how design prototyping can be adopted for large-scale and complex infrastructure systems. Design of infrastructure is predominately a top-down process from local government planning to civil engineering then construction. However, a bottom-up approach led by citizens using physical prototypes has recently emerged. For example, in Macon, Georgia, a community-based initiative used inexpensive materials to install temporary bike lanes, dieting of streets, structures for pedestrians, and public spaces in vacant lots. These temporary installments (lasting only one week) reduced perceived risk among city planners and design engineers contributing to a less than conventional roadway design. The citizen led prototyping increased designers' consideration and observation of user needs and provided insight about how the prototype met product (e.g. a road) and service (e.g. traffic reduction) design constraints.

Methods to develop physical prototypes in architecture, urban design, and infrastructure include placemaking and tactical urbanism and increasingly are used by local governments and citizens (Guerra et al. 2017; Kent 2016). In total, 55 cases where prototyping was used are detailed in this paper. The 55 prototyping cases include four types of infrastructures: urban revitalization projects, transportation systems, sanitation systems, and government housing. By comparing similarities and differences of these 55 cases, the purpose is to define and

operationalize the use of prototyping for infrastructure. A formal process for prototyping infrastructure systems includes answering questions such as how to do it, where is it most effective, who must be involved, and tools for measuring its effectiveness to improve both the product and service aspects of infrastructure. Researchers and practitioners can then begin to institutionalize this critical feedback mechanism within the design of infrastructure systems, in effort to encourage more novel and innovative design solutions that better meet user' needs.

The paper starts with a description of prototyping in design theory and then provides examples of how design thinking extends prototyping to multiple fields. Based on these concepts, prototyping for infrastructure systems is defined and dimensions for prototyping of infrastructure systems are described. The 55 prototyping cases are then characterized using across six dimensions. Finally, the paper ends with outlining future research.

BACKGROUND

Design theory started to formalize design methods and approaches in the 1950s. Shortly after, in 1962, Levi Strauss brought prototyping into design (Guggenheim 2010). Prototyping was defined as building an early sample of a final product to test its functions and characteristics in order to improve final product replication (Floyd 1984). Since then, the definition of prototyping has continued to evolve with the development of technology, as various fields have adapted the concepts and applications of prototyping to their particular needs and technological capabilities, such as simulation, virtual reality, or scaled models. A central theme in all of its definitions and uses is that prototyping allows designers to build hypothesized solutions and test them.

The design thinking process, popularized by IDEO and Stanford's Design School (OpenIDEO 2016), introduces prototyping as a step to incentivize creativity and "out of the box" thinking (Plattner et al. 2009), Prototyping works as a design strategy by reducing designers' fear of failure because the success of a prototype is not measured by how well users receive the prototype but whether this information informs a future better design (Kelley and Kelley 2006). Prototyping in design thinking reframes the purpose of an initial design in order to get information rather than creating the optimal solution. This is often referred to as "failure immunity," where prototyping is simply a mechanism to enrich the design process (Kelley and Kelley 2006).

In addition to reducing the fear of failure, prototyping enables the designer to obtain much richer knowledge of future users. The feedback obtained from users when they are testing a product or service is richer because users can see what a future product looks like, which improves the quality of data to feed the design (Burnett 2016). Physical prototypes or installments work better than digital representations (da Silva and Kaminski 2016). The more frequent the feedback the more information designers are provided (Denning 2013).

Prototypes are intentionally temporary. In the design thinking process, design does not end with the execution of the prototype (Razzouk and Shute 2012), rather the process goes back to any of the previous phases (i.e. empathizing, defining, ideating), repeating each step as many times as necessary (Dym et al. 2005). In other words, prototyping is a thinking-by-doing methodology (Hartmann et al. 2006), in which the short life span of the prototype creates a sense of urgency in the design process. Similar to the charrette (NCI 2017), reducing the time frame encourages intensive thought (Lennertz 2003).

DEFINITION OF PROTOTYPING FOR INFRASTRUCTURE SYSTEMS

Prototyping within infrastructure systems has a similar meaning as from design theory (Budde et al. 1992; Exner et al. 2014; Kelley and Kelley 2006; da Silva and Kaminski 2016): building an early version of an infrastructure to be experienced by future users and stakeholders, in a

way that allows a clear and transparent flow of information from the users to the designers, not only in terms of physical characteristics but in terms of the service being provided.

Just as in other domains, the main purpose of prototyping for infrastructure is to provide a flow of information between designers and users. The first direction is from the designers to the future users to inform them about the proposed solutions. The second is from the future users to the designers to provide feedback after experiencing the proposed design. Because of the dual-nature of infrastructure systems (i.e. provides both a product and service), prototyping should include feedback about this product-service system relationship. This dual nature feedback requires a whole-systems lens (Blizzard and Klotz 2012), in which the prototype not only includes particular design features working independently, but their interaction with one another, which influences the system's behaviour and alters the whole outcome (Meadows and Wright 2008). This means that when prototyping an infrastructure system design, all the design traits and system inputs must be included, so future users and stakeholders can actually experience the proposed solutions.

For infrastructure systems, past projects should inform current ones. In the design and construction of buildings this is often done through post-occupancy evaluation (Leaman 2003). Architects and engineers learn how their designs met user needs once the project is complete and incorporate this feedback into future projects. While post-occupancy does provide a feedback process, the distinction is the duration and ability to incorporate this feedback to improve the same project under design. For example, in the design of the recent constructed National Renewable Energy Lab (NREL), in Golden, Colorado. The design team created physical prototypes of office spaces and invited NREL employees to use the space while the design team observed their behaviour (Hootman 2012). This type of physical prototype is fundamentally to improve the current building. Digital prototypes can provide similar information about the physical function of materials and environmental constraints, but the imitation is limiting in how users interact with the design and the feedback from the users to the design team.

An extreme example that helps to illustrate the idea of when a project can and cannot be prototyped is an infrastructure project like an airport or a dam. A hydroelectric dam cannot be prototyped on its own because it is too costly and would require too much effort and resources; however, if a state is building an airport system or a hydroelectric dam system that contains a significant number of the airport or dam project units, prototyping may be usefully in initial units to enrich the final design of the whole infrastructure system. In that case, the design is using a permanent prototype, and therefore the prototyped solutions must be a very close version of a fully functional working version.

OBJECTIVE

The objective of this paper is to contribute to the design of sustainable infrastructure systems by operationalizing the use of prototyping as a design method and providing examples of prototyping being used in at least four different types of infrastructure systems: urban revitalization projects, transportation systems, sanitation systems, and government housing. The benefit of operationalizing prototyping for practitioners and researchers is clearly defining the dimensions of what prototyping means and represents. These dimensions help answer, for example, the level of formality (i.e. government or community driven) and permanence (i.e. one-day, one-week, one-month installments). For practitioners who want to adopt prototyping, these dimensions offer a guideline for the design and implementation process. For researchers, these dimensions can help classify projects and future research can correlate the outcomes of the design process to these prototyping dimensions.

METHODS

To operationalize prototyping for infrastructure and develop dimensions to distinguish variabilities among prototyped infrastructure, the authors began by searching Google Scholar using the keywords “*infrastructure pilot project*,” “*infrastructure testing project*,” “*tactical urbanism*,” “*temporary structures*,” “*temporary infrastructure*,” “*urban prototypes*,” “*prototyped buildings*,” “*community installed projects*,” “*low-cost infrastructure*,” “*guerilla urbanism*,” “*pop-up urbanism*,” “*DIY urbanism*,” and “*DIY city repair*.” This search led to identifying organizations that are prototyping infrastructure designs, although not formally. The database of projects for Team Better Block (“Team Better Block” 2018), Walnut Hills Redevelopment Foundation (“Walnut Hills Redevelopment Foundation” 2018), and Urban I (“URB-I” 2018) were also used. These three organizations are well established in developing infrastructure using a prototype-like process. The majority of cases are located in the US, but several include cases abroad. For example, Team Better Block and Urban I include international cases in South America, Europe, and the Middle East. Team Better Block and Urban I are formal organizations who frequently partner with local governments to facilitate a prototype-like event for urban change. Of the 55 cases, 44 are from these organizations. The remaining 11 were from the internet search and prior knowledge. These “gorilla or renegade” prototypes are citizen driven. Typically, without the local governments approval. In these instances, case information was verified through digital newspapers and phone calls with local government agencies and staff.

The definition of prototyping provided in the background section served as a screening tool to determine which of the projects were and were not an example of infrastructure design prototyping. To be able to compare projects in terms of cost, timeframe, technologies, only cases from the last five years were considered.

In total, 55 cases are included. The majority of cases are of urban revitalization and transportation systems (51 out of 55). All 55 cases meet the three characteristics of prototyping, in that the feedback informs the current project not a future project, the feedback occurs between users and designers, and the prototype represents both product and service traits. While these 55 projects meet these three characteristics, none formally acknowledge this as a conscious design approach.

Similarities and differences between the projects were identified by reviewing case information found through the websites, newspaper reports, and the three organizations mentioned. Based on the case information, some appeared to be initiated by local or regional governments while others were done illegally by community members or individuals. Some cases had government permission, some lasted for a weekend, and others lasted for a month. Some used hay bales and chalk paint (cheap and temporary materials) to create defined spaces while others had commissioned artifacts and pop-up shops and businesses. These differences and similarities among projects were categorized into dimensions and a scale was developed to characterize future projects. Each of the 55 cases were then plotted along these dimensions.

RESULTS

Six dimensions emerged when comparing similarities and differences among these prototyped projects. The dimensions include: *levels of formality*, *resources*, *community involvement*, *number of stakeholder groups*, *duration*, and *purpose*. By comparing and plotting each prototyped project across these dimensions a scale was developed to quantify low and high values for each dimension. Table 1 shows these dimensions and the number of projects within each level across the spectrum. The appendix provides a comprehensive table of all of the projects, including the project title, references, and values for each dimension. The comprehensive table begins to demonstrate trends that emerged within the projects and the relationship between dimensions. For example, the majority of the prototype projects with a high level of formality (i.e. government led) include a medium to high level of resources but

appear to lack community involvement compared to projects that are lower in formal structure. The subsections below further detail each dimension, provide examples, and detail the measurement scale.

Table 1: Six dimensions of prototyping among infrastructure projects

Dimension Category	Dimension Measurements				
Level of formality	Governmental institution: city, state, etc.	Community leaders and advocating groups	Community members and community groups		
Resources	Long-lasting materials, requires construction and skilled labor, and includes procedures and staff for data collection (surveys, interviews, observations)	Long-lasting materials, some installation of objects or artifacts with or without skilled labor, data collection with staff or volunteers	Designed professionally but relies on volunteer participation for implementation and data collection	Little to no skilled labor, includes materials readily available, data collection may be less defined or direct.	Minimum labor, includes materials readily available, data collection is very informal.
Community involvement	High	Medium-high	medium-low	Low	
Number of participatory stakeholder groups	4-3 groups of stakeholders	3-2 groups of stakeholders	2-1 groups of stakeholders	1 group of stakeholders	
Duration of the prototype phase	Temporary (short term) (days to few weeks)	Temporary (medium term) (few weeks to few months)	Temporary (long term) (few months to few years)	Permanent (part of a larger project)	
Purpose of prototyping	Challenge official norms or procedures (early in design)	“Bring the community on board” (halfway through design phase)	Both (User feedback for designers to develop the final design)		

LEVEL OF FORMALITY

The level of formality of the prototype refers to the degree of official permission, such as city permits to modify a street. On the formal side of the spectrum are “top-down” approaches that come from city or government initiatives. When an official agency is developing a prototype, they usually get legal authorizations. For example, when New York City developed a prototype for the Times Square revitalization project, permits were obtained and the planning commission reviewed the proposal (Urb-i 2015). This was a highly regulated process.

In the middle of the spectrum are projects that are promoted by community leaders or advocating groups. When these groups organize, they acquire permits to put in place the prototype, however, there may be some regulation violations that occur either because the community is not familiar with the official process or because it is part of the intended purpose of the project. For example, The Better Block team intentionally disregarded multiple regulations during a prototype in Texas (Roberts 2012). The purpose was to demonstrate to city officials that some regulations were outdated and needed modifications.

Further down the spectrum are “bottom-up” approaches that often lack authorization or permission and originate from members of the community. These solutions can be renegade. For example, a safe biking advocating group in Omaha prototyped street bollards to create a protected bike lane by gluing 120 toilet plungers to a street (Burbach 2017). The unregulated solution was removed by the department for Public Works within hours, but the prototype demonstrated how a bike lane could be incorporated into the current lane without negatively affecting drives and provide an additional and safe option for daily transportation. Figure 1 illustrates this spectrum of formality with top-down approaches, initiated by government institutions, on the left and bottom-up approaches initiated by renegade community members on the right.



Figure 1: Spectrum of formality among prototyped infrastructure

RESOURCES

Resources invested in an infrastructure prototype include things such as *quality of materials*, *construction procedures*, *time to plan and execute the prototype*, and the *process for collecting users' feedback*. Because this dimension includes several different variables, the spectrum from high to low *resources* includes five possible levels. A “high” *resources* score is when a prototype includes durable and long-lasting materials (e.g. wood, concrete, steel) with some level of permanence. Instead of just placing new objectives or removing existing objects the prototype requires scheduled construction or demolition. The prototype also includes a written procedure for collecting user feedback, maybe through observation, interviews, or surveys. A “medium-high” *resources* score is given when a prototype is built with long-lasting materials, some tasks require installation or demolition, and volunteers may participate in data collection (e.g. surveys, interviews, observations). An example is New York City Time Square prototype that required design drawings to obtain city permits. The prototype was not drastic but rather in incremental changes that included more permanent structures as the feedback kept evolving the design.

A “medium” *resources* score is given when the design and planning is done professionally, but the project heavily relies on volunteer participation for the implementation and testing and data collection. For example, in Macon, Georgia, the five-mile pop-up bike lane was prototyped with all the official permits, but the prototype construction relied on the community volunteers. A “medium-low” *resources* score is when installation of the prototype takes little skilled labor and includes materials readily available. The data collection process may be less defined or direct. For example, in Bradley Avenue, Los Angeles, the project was built by community volunteers with little experience in construction and using available paint from a nearby project. Finally, a “low” *resources* score is given when there is little to no need for materials and skilled labor. For example, in Omaha, Nebraska a renegade group of community members installed plungers using an adhesive to the road to create a barrier between the bicycle lane and car lane. This type of project requires only two resources (plungers and an adhesive) and no trained skilled staff to install.

Of the 55 projects, more than half that are high in level of formality are also high in resources. A prototype developed by an official institution or government typically have more resources than a prototype developed by an advocating community group (“An Introduction to City Finances” 2017). Community groups must frequently rely on fundraising, donations, and collective grants. The Better Block projects in Akron, Ohio are an example (Roberts 2012).

While supported by the city (medium formality) they are community led and sponsored predominately by the Knight Foundation (“Knight Foundation” 2018).

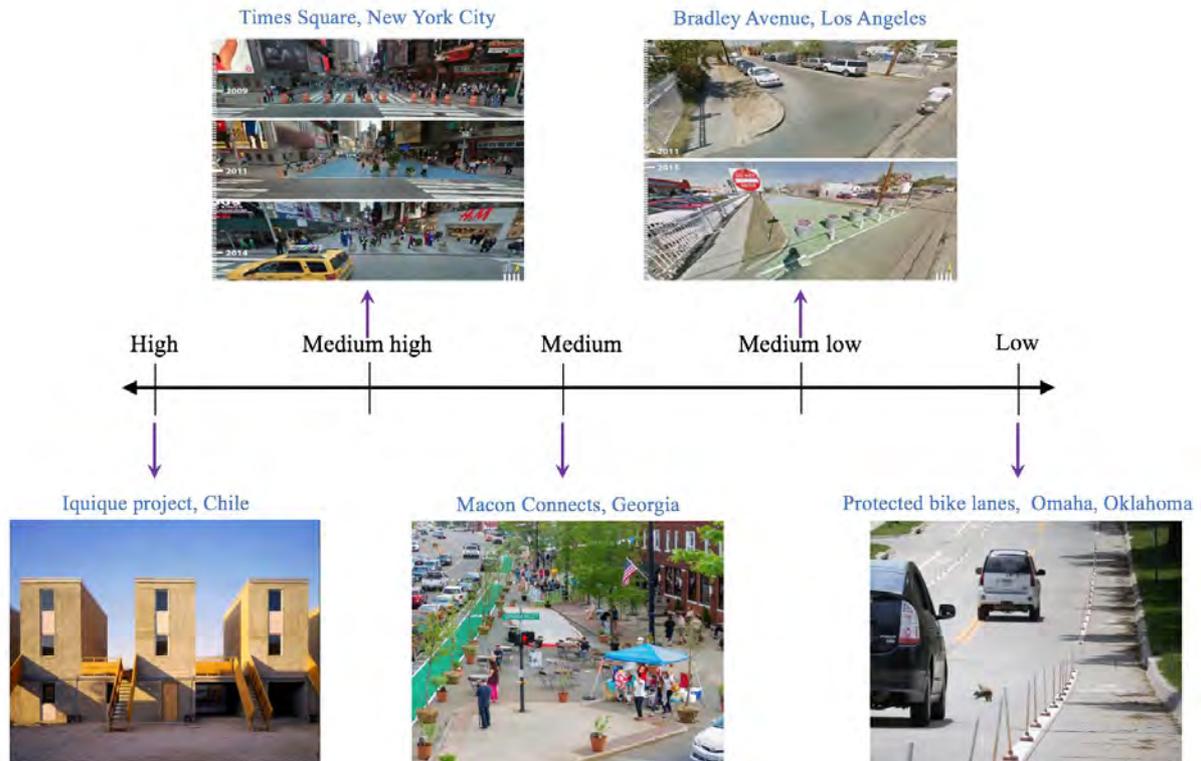


Figure 2: Resources dimension

COMMUNITY INVOLVEMENT

Community involvement in prototyping is critical to providing new information to the design team. Similar to the connection between level of formality and resources, community involvement appears to be connected to the level of resources available because when a project is developed by a government or municipality, there is less use of volunteers in the prototype and thus less community involvement. High resources and high community involvement based on the 55 projects, appears to require a strong, established communication process between the government or municipality and community groups. Observed in several of the projects, for example in the North Hill Akron (Diodati 2015) and Macon Connects (Rogers 2017), when a community group is highly invested, the design team runs the risk of the feedback from the prototype only representing a particular section of the community and therefore limiting the information learned in the process.

In regards to the spectrum from high to low *community involvement*, a “high” score is given when community involvement extends beyond just participation and includes leadership roles in organizing, directing and designing the prototype. For example, Macon Connects project was community lead and it involved community associations, residents, business owners, biking advocacy groups, private institutions on board, and a non-profit that works in revitalizing downtown Macon. A “medium-high” score is given when the project receives input from multiple community groups and the prototype involves these groups to help install or promote the project. A “medium-low” score is given when at least one major community group is invested and participatory in the testing of the prototype. For example, the Niazi Chohfi project in Brazil involved only business owners’ groups, while residents, home owners, and other users were not included. A “low” score is given when the organizing group takes little to

no effort to seek community input, rather relies on the prototype itself to receive initial input. For example, the North State Street installment in Chicago required little input from the community. The city installed the project and waited for indirect feedback by observing how the space was being used.

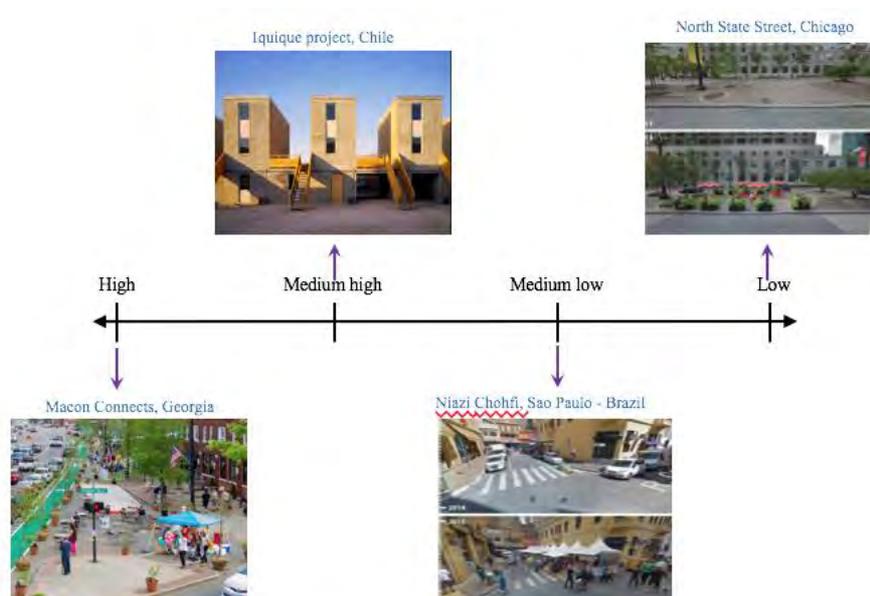


Figure 3: Community involvement dimension

NUMBER OF PARTICIPATORY STAKEHOLDER GROUPS

Number of stakeholder groups characterizes the interaction, involvement, and participation of stakeholders during the prototyping. To help classify participation among stakeholder groups, the types of stakeholders was divided in four groups by direct or indirect and internal or external. Table 2 summarizes these classification (Vanegas 2003).

Table 2: Infrastructure stakeholder types

Type	Example	Role
Internal direct	Owners, users, developers, clients	Development of prototype project and use
Internal indirect	Investors, users, consumers	Indirectly affected/influenced by the finished project
External direct	Planners, architects, engineers, contractors	Design and help implement the prototype project
External indirect	Regulatory agencies, suppliers, financiers	Support project development and use

In this dimension, a “high” score means that three to four types of stakeholders participate in the prototyping process. A “medium-high” classification is given when two or three types of stakeholders participate in the prototyping process. For example, stakeholder participation in the Macon Connects project was high because many groups, such as (id) owners, (ii) investors, and (ed) planners, participated. The majority of the 55 cases fall within high or medium high number of participatory stakeholder groups. A “medium-low” score means that only one or two types of stakeholders are involved in the prototype. The cases that were medium-low typically involved a local government or an advocating group leading the prototyping project

and included low stakeholder involvement. For example, the Niazi Chohfi street prototype in Brazil, where the business owners and property owners were the only stakeholder groups involved.

A “low” score means that only one type of stakeholder participated in the prototype and there was little evidence of effort to increase participation among other types of groups. This only occurred in two of the 55 cases: the bike lane prototyped with plungers in Omaha, NE and chalk drawn intersection in Springmount Ave. in Toronto, CA.

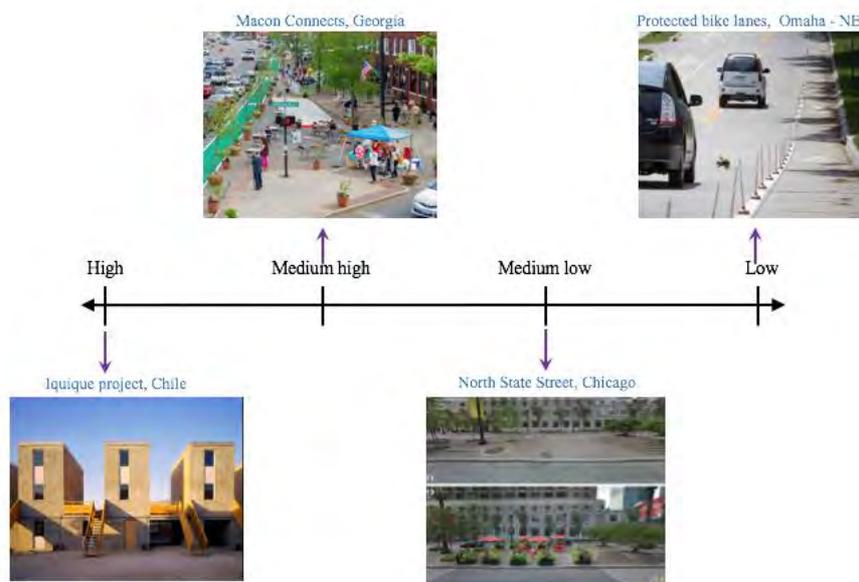


Figure 4: A spectrum of stakeholder groups who participate in the prototyping process

DURATION OF THE PROTOTYPING PHASE

The duration of the prototyping phase was divided into short-, medium- and long-term. Some prototypes are built to be tested for just a few days, like the Macon Connects project in Georgia, where a downtown revitalization project was built for a weekend (Rogers 2017). Other prototypes are built to be tested for months, like the new biking lane project in north Minneapolis. Three types of bike lanes were built: (1) a path for sharing the road with cars, an (2) exclusive path for bikes, and (3) a hybrid system. The community tested them for 7 months before the city chose the final design to implement on other roads in the city (Minneapolis 2017). Prototypes may also last for years, such as the public spaces project in New York City’s Times Square. The prototype was in constant evolution. The prototype started in 2009 and the final installment occurred in 2014 (Urb-i 2017).

The majority of prototyping cases were either short- or long-term. A few included more permanent durations. Where multiple similar units, such as sanitary piping or government housing facility, were being constructed and the design and construction team prototyped several units. For instance, the Iquique housing project was made up of one thousand houses, but the builders used one block of 30 houses to prototype their design before constructing the others (CCHC 2012).

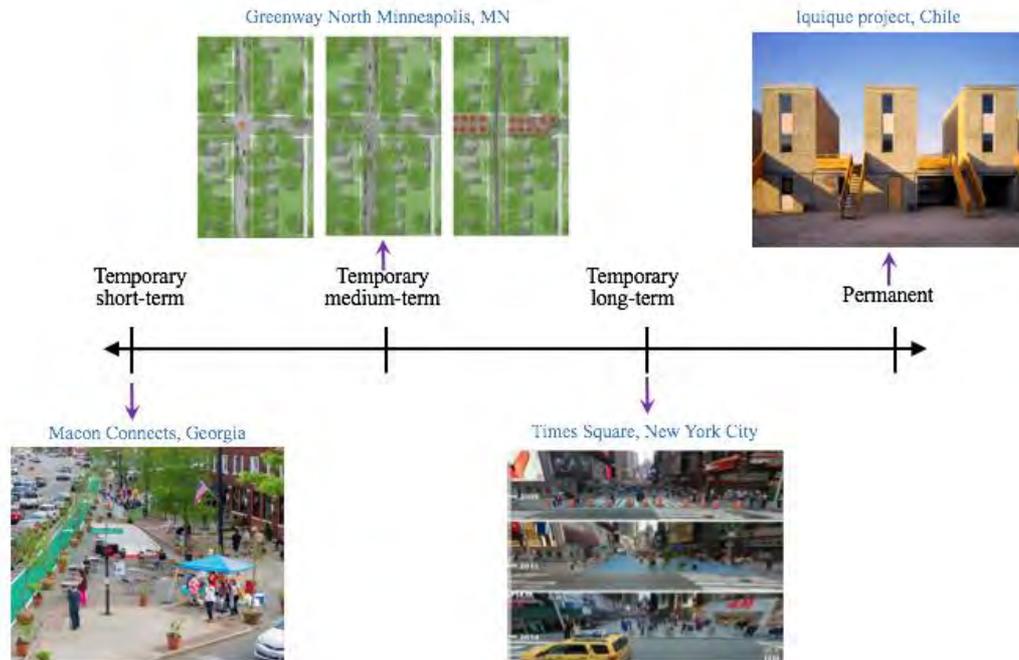


Figure 5: Duration of prototype installment

PURPOSE OF PROTOTYPING

Depending on the phase of the design, prototyping can have slightly different purposes. Early in the design phase, community led prototyping was observed to intentionally challenge norms, regulations, or procedures by the local government. For example, the North Hill Akron prototype aim for the city to see the potential of the neighborhood by adding infrastructure changes, and to be consider in the list of neighborhoods for special investment.

In other cases, the level of formality is high and the local government is intending the prototype to challenge norms of the community. In these cases, the local government aims to “get the community on board”. For example, the prototype built for the Macon Connect project tested eight different street designs that incorporated multimodal forms of transportation, in downtown Macon, Georgia. Traditionally, in Macon, roads predominantly only included space for vehicles. In this type of prototype, the designers aim to change perceptions about transportation choices and offer a test bed for users without fully committing to the change before getting feedback from the community. By calling the installments temporary, the city reduces potential negative criticism from implementing new designs that appear against community norms.

The intent of the prototype may be both to challenge official norms and bring the community on board. For example, New York City Time Square challenged the social norm that roads are only for vehicles. In 2009, the city temporarily installed orange cones to block vehicles from entering Time Square. Later, the city painted the street to highlight the space as not for vehicles but pedestrians. In 2014, the city installed permanent bollards and added street benches and landscaping. Overtime, the norms changed and the community, including store owners, vehicle drivers, and residents were more receptive of the street closure. Likely, by slowly transitioning the idea into a permanent installation helped the community and city leaders observe the positive effects (Urb-i 2017).



Figure 6: Purpose of prototyping or design phase

CASE STUDIES

The purpose of these additional case studies is to demonstrate how these dimensions of prototyping for infrastructure can help classify projects. The purpose of this classification is to control for these variables in future research about, for example, how prototyping during the design of infrastructure reduces perceived risk among engineers, how prototyping helps design infrastructure that better meets users' needs, and what new information is developed (or learned) about the product and service relationship of infrastructure through prototyping?

Detailed below are two cases, out of the 55, to illustrate what the key findings of this process include. The dimensions for each case are depicted in Figure 7. Both cases are in the United States. The first case is located in Macon, Georgia and the second is in Akron, Ohio. Both projects are representative of urban revitalization and transit system cases.

Macon Connects is a transit system that consisted in prototyping eight different types of bike lanes in the 5 miles world largest bike lane popup. Akron Better Block is an urban revitalization case where the community proposed to prototype for a weekend a new design of the neighborhood infrastructure, including bike lanes, bus stops, dieting streets, popup business, activity plazas, and public spaces.

These projects were conceived by the community, and their community leaders and advocating groups took the initiative to develop the projects within the last two years. Both projects were funded by private resources for the design phase and also for the implementation of the prototype. During the design phase, many specialized experts participated in the different tasks and for the implementation and testing of the prototype, both projects had a high number of community volunteers. Both projects were also short term in their duration, Macon Connects (Macon, GA) was implemented for five days while Akron Better Block (Akron, OH) was implemented for three days.

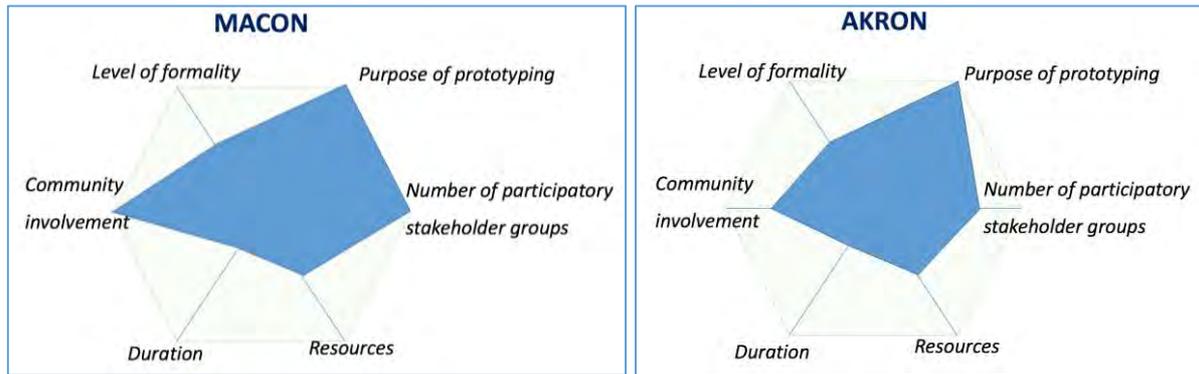


Figure 7: Cases of Macon and Akron infrastructure six-dimension prototypes

The Macon Connects project is described as having a “medium” level of formality because it was developed by the community and advocating groups with the acknowledgement and blessing from the local government. The second project, Akron Better Block, was similar to Macon Connects, in that it was community led (medium level of formality). Both projects were born by community leader efforts and then proposed to the city to prototype. The city provided the permits but was not involved in the prototype implementation. Figure 8 compares both the Macon Connects and Akron Better Block projects with the remaining 55 cases. The majority (75%) of the cases are similar, including some level of community and/or advocating group initiating the design. The remaining 25% are either government sponsored and led or “renegade” projects enacted by citizens without permission or knowledge from the local government.

PROTOTYPE INFRASTRUCTURE		Level of formality			
Project name	Type of infrastructure system	Governmental institution	Community and advocating groups	Community member group	Represents % of type of infrastructure
		←-----→			
Macon Connects	Urban infrastructure downtown revitalization		X		75.51%
Acron Better Block project	Urban infrastructure transit systems		X		75.51%

Figure 8: Both projects were community and advocate led

The Macon project required a medium-to-high level of resources compared the remaining 55 cases. This project counted with private funding to plan, design, and build. This project had the biggest bike lane pop up ever built, and this required a lot of resources to build, temporarily, eight different types of bike lanes. This level of resources is similar to nearly 30% of all the remaining cases. The Akron Better Block used slightly less resources. The project used hay bales for benches and plaza figures, plastic tables for ping pong tables at the activity field, temporary paint instead of permanent paint for the buffers of the bike lanes, metal signs and old tires for delimiting the beer garden and to extend the sidewalks. This level of resource requirements is similar to 60% of the remaining cases.

PROTOTYPE INFRASTRUCTURE		Resources					
Project name	Type of infrastructure system	High	Medium-high	Medium	Medium-low	Low	Represents % of type of infrastructure
		←-----→					
Macon Connects	Urban infrastructure downtown revitalization		X				28.57%
Akron Beter Block project	Urban revitalization infrastructure transit systems			X			59.18%

Figure 9: The two cases are representative of nearly 90% of the total projects

The Macon Connects project subcontracted professionals to help engage the community. The project used volunteers but they followed procedures developed by the community organizer. The community was involved throughout the project and included many different stakeholder groups. For example, business owners, users, advocacy groups, and private institutions were involved in the prototype. This is only representative of about 20% of all cases. The Akron project also includes a higher than average level of community involvement (45%) compared to the other 55 cases, and an average number of stakeholder participation (similar to 60%) of the cases.

PROTOTYPE INFRASTRUCTURE		Community involvement				
Project name	Type of infrastructure system	High	Medium-high	Medium-low	Low	Represents % of type of infrastructure
		←-----→				
Macon Connects	Urban infrastructure downtown revitalization	X				20.41%
Akron Beter Block project	Urban revitalization infrastructure transit systems		X			44.90%

PROTOTYPE INFRASTRUCTURE		Number of participatory stakeholder groups				
Project name	Type of infrastructure system	High	Medium-high	Medium-low	Low	Represents % of type of infrastructure
		←-----→				
Macon Connects	Urban infrastructure downtown revitalization	X				20.41%
Akron Beter Block project	Urban revitalization infrastructure transit systems		X			61.22%

Figure 10: The two cases are representative of nearly 65% in Community involvement and 80% of the total projects

The Macon Connect project was short lived. It lasted only five days, which is similar to half (50%) of the remaining cases. The project was design to be prototyped for two days, but installed, the Mayor requested to keep the prototype for the whole week due to the use from the community and overwhelmingly positive feedback. Similar to Macon Connects the Akron project was short lived. It lasted only three days over an extended weekend.

PROTOTYPE INFRASTRUCTURE		Duration of the prototype phase				
Project name	Type of infrastructure system	Temporary short term	Temporary medium term	Temporary long term	Permanent	Represents % of type of infrastructure
		←-----→				
Macon Connects	Urban infrastructure downtown revitalization	X				53.06%
Akron Beter Block project	Urban revitalization infrastructure transit systems	X				53.06%

PROTOTYPE INFRASTRUCTURE		Purpose of Prototyping			
Project name	Type of infrastructure system	Challenge social norms	Bring community momentum	Both	Represents % of type of infrastructure
		←-----→			
Macon Connects	Urban infrastructure downtown revitalization	X			72.16%
Akron Beter Block project	Urban revitalization infrastructure transit systems	X			72.16%

Figure 11: The two cases are representative of nearly 65% in Community

DISCUSSION AND CONCLUSION

The purpose of this research was to define and operationalize prototyping for infrastructure systems. Cases included sanitation systems, transportation, government housing, and urban

revitalization projects. Due to the exploratory nature of this research, each type of infrastructure system was not independently reviewed but rather all were used under the broad definition of prototyping. These cases were identified through newspaper articles and urban design and architecture firms that have informally explored prototyping-like design processes. From these cases, six dimensions of prototyping emerged. These dimensions are level of formality, resources, community involvement, number of participatory stakeholder groups, duration of the prototype phase, and purpose of prototyping. After analyzing all 55 cases, the dimension level of formality seems to have an influence across the other dimensions such as resources, community and stakeholder participation; and the duration of the prototype is more related to the purpose of prototyping rather than type of infrastructure to be design. Future research should study the relationship these dimensions have with the goals and outcomes of the prototype, as well as with the type of infrastructure system under design.

Knowing and classifying these cases along these six dimensions is the first step to future research in describing, measuring, and predicting how this type of feedback through prototyping leads to improved design outcomes. Future research can now classify prototypes on these dimensions and determine which matter most according to their outcomes, and to answer questions such as are all six dimensions equally important and if their relevance varies among different types of infrastructure. Future research can also use these dimensions to provide new evidence of how prototyping impacts, for example, design cognition among engineers and stakeholder groups, or how prototyping can predict future performance of these systems and along which dimensions.

A limitation of this study is that it stops short in comparing the various infrastructure types to one another and does not fully explore the prototype's effect on the long-term outcome of the infrastructure project. Another limitation is that the information used to develop the cases does not come from first-hand experience nor direct inquiry but rather from news sources and local government reports. Future research should explore the long-term effects of these prototype interventions on the long-term outcomes of the projects and should use more direct interviews with participating stakeholders to provide richer information about the characteristics and relationship of the dimensions of infrastructure prototyping. Additional next steps should include case studies within each of the four types of infrastructure systems included in this paper and how the feedback loop through prototyping works among designing engineers, future users, and city officials, and developers.

Ultimately, the goal is to add a tool or approach for those designing and delivering infrastructure enabling them better meet user needs, quickly break from the status quo, and fully conceptualize the complexity of the system in which they are designing. Prototyping appears to be an approach grounded in design literature that can help but not yet fully recognized by those responsible for designing and delivering infrastructure.

Current codes, laws, and regulations likely reinforce previously made decisions even when only small transaction costs are involved to change them (Samuelson & Zeckhauser, 1988). Directly related to construction industry, status quo bias may be leading to a reluctance to adopt new building technologies with improved energy performance (Klotz, Mack, Klapthor, Tunstall, & Harrison, 2010). Decision-makers considering whether to break from the status quo may perceive such choices as riskier and uncertain (Brown & Krishna, 2004; Dinner et al., 2010; Fox & Langer, 2005), further amplifying the preference to keep with industry norms. In design theory, prototyping can reduce perceived risks of failure. Applying this approach to infrastructure may have similar affects as in other domains.

While physical prototypes may not be feasible for every infrastructure design case due to economic or resource constraints, the dimensions developed here can also be used to operationalize and measure virtual prototypes. Virtual prototyping includes degrees of virtual reality from three-dimensional renderings to immersive experiences. The dimensions

developed here can be used to understand whether and how virtual prototypes substitute the experience of real world installments and how this influences design cognition among stakeholder groups. Improved understanding and a more formalized process of the impact of prototyping as a design methodology for infrastructure can help lead to more user-centered and evidence-based solutions. This type and scale of prototyping enables more feedback than previous design approaches for infrastructure and at a fraction of the cost of the actual infrastructure system. The dimensions and scale developed through this research should be further tested and developed with additional infrastructure cases but offer a starting point for others interested in adopting and developing new approaches for the design of infrastructure systems.

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Appendix

All 55 cases are listed in Table 3 and Table 4. Each dimension of prototyping is listed in the columns and individual projects were scored. Table 3 shows dimensions level of formality, resources, and community involvement. Table 4 shows dimensions number of participatory stakeholder groups, duration of the prototype phase, and purpose of prototyping. Cases range from sanitation, government housing, transportation, and urban revitalization projects. The majority (30) are urban revitalization, two are sanitation, two are housing, and 21 are transportation systems. All projects were completed within the last five years.

Table 3: Dimensions (level of formality, resources, and community involvement) of prototyping among 55 cases

#	Project name	Type of infrastructure system	PROTOTYPE SPECTRUM VARIABLES OF THE PROTOTYPE														
			Level of formality			Resources					Community involvement						
			Governmental institution	Community and	Community member	High	Medium-high	Medium	Medium-low	Low	High	Medium-high	Medium-low	Low			
1	Sanitation system in Bangladesh	Sanitation system	X			X										X	
2	Dry sanitation systems for Manabí in Ecuador	Sanitation system		X							X					X	
3	Iquique Social Housing in Chile	Government housing system		X		X							X				
4	Guangaje emergency housing in Ecuador	Government housing system		X						X			X				
5	Coenties Slip in New York	Urban revitalization	X						X							X	
6	Akron Better Block in Akron, Ohio	Urban revitalization		X					X						X		
7	Five Points Better Block in Denver, Colorado	Urban revitalization		X					X						X		
8	San Antonio Better Block in Texas	Urban revitalization		X				X						X			
9	Wilmington Better Block in Delaware	Urban revitalization		X					X					X			
10	Bethel Better Block in Vermont	Urban revitalization		X					X					X			
11	Glass Street project in Chattanooga	Urban revitalization		X					X						X		
12	Norfolk Better Block	Urban revitalization		X					X						X		
13	San Diego Better Block	Urban revitalization		X					X						X		
14	Hotel Erin in Ixearkana	Urban revitalization		X					X						X		
15	The Haverhill project in Massachusetts	Urban revitalization		X					X						X		
16	Richmond Better Block in Virginia	Urban revitalization		X					X						X		
17	McGinley Square Street in New Jersey	Urban revitalization		X					X						X		
18	Mount Rainier Better Block in Maryland	Urban revitalization		X					X						X		
19	Brownsville Better Block in Texas	Urban revitalization		X					X						X		
20	Ludvine Better Block in Oklahoma	Urban revitalization		X					X					X			
21	Oak Cliff Better Block in Texas	Urban revitalization		X					X					X			
22	Jefferson Park in Denver	Urban revitalization		X					X					X			
23	Middlesborough Better Block in Kentucky	Urban revitalization		X					X					X			
24	Walnut Hill project	Urban revitalization		X					X					X			
25	Five Points Alley	Urban revitalization		X					X						X		
26	St. James Pocket Park	Urban revitalization		X					X						X		
27	Music Box in Millan	Urban revitalization		X					X						X		
28	Cincinnati Street Food Festival	Urban revitalization		X					X					X			
29	Concord Community Garden	Urban revitalization		X					X						X		
30	North State Street in Chicago	Urban revitalization	X						X								X
31	Praca Tiradentes in Curitiba, Brazil	Urban revitalization		X					X						X		
32	Av. Rio Branco in Recife, Brazil	Urban revitalization		X					X						X		
33	Boulevard Anspach in Brussels, Belgium	Urban revitalization		X					X						X		
34	Parque Milenio in Puebla, Mexico	Urban revitalization		X					X						X		X
35	Pedestrian prototype in Times Square, NYC	Transit system	X						X						X		
36	Greenway in Northern Minneapolis	Transit system	X						X						X		
37	Omaha protected bike lane	Transit system			X							X					X
38	Macon Connects in Macon, Georgia	Transit system	X						X						X		
39	Queens, 37th Rd in New York	Transit system	X						X						X		
40	Queens, Broadway 37th Rd in New York	Transit system		X					X						X		
41	Brooklyn, 1st 2nd St in New York	Transit system	X						X						X		
42	Brooklyn, Water St in New York	Transit system	X						X						X		X
43	Granby Street in Norfolk, VA	Transit system		X					X						X		
44	University Street in Seattle	Transit system		X					X						X		
45	9th Avenue in Seattle	Transit system	X						X						X		X
46	Bradley Avenue in Los Angeles	Transit system	X						X						X		
47	West 3rd Place in Los Angeles	Transit system	X						X						X		
48	Stockton St in San Francisco	Transit system		X					X						X		X
49	Castro St, Market St in San Francisco	Transit system	X						X						X		
50	Annie Alley in San Francisco	Transit system		X					X						X		
51	Willcocks St in Toronto, Canada	Transit system		X					X						X		
52	Rue Victoria in Montreal, Canada	Transit system		X					X						X		
53	Regal Road-Springmount Ave in Toronto, Canada	Transit system			X				X				X				X
54	Juan de la Luz Enriquez in Jalapa, Mexico	Transit system		X					X						X		X
55	Mier y Pesado in Mexico City	Transit system		X					X						X		

Table 4: Dimensions (number of participatory stakeholder groups, duration of the prototype phase, and purpose of prototyping) of prototyping among 55 cases

#	PROTOTYPE INFRASTRUCTURE		PROTOTYPE SPECTRUM VARIABLES OF THE PROTOTYPE								Purpose of Prototyping (Design Phase)		
	Project Name	Type of Infrastructure System	Number of Participatory Stakeholder Groups				Duration of the Prototype				Challenge of Official Norms	Bring Community on Board	Both
			High	Medium/High	Medium/Low	Low	Temporary/Short-term	Temporary/Medium-term	Temporary/Long-term	Permanent			
1	Sanitation System in Bangladesh	Sanitation System			X								X
2	Dry Sanitation Systems for Manabí in Ecuador	Sanitation System		X						X			X
3	Iquique Social Housing in Chile	Government Housing System	X								X		X
4	Guangajie Emergency Housing in Ecuador	Government Housing System		X						X	X		
5	Coenties Slip in New York	Urban Revitalization	X							X	X		
6	Akron Better Block in Akron, Ohio	Urban Revitalization		X				X					X
7	Five Points Better Block in Denver, Colorado	Urban Revitalization		X				X			X		
8	San Antonio Better Block in Texas	Urban Revitalization		X				X					X
9	Wilmington Better Block in Delaware	Urban Revitalization		X				X				X	
10	Bethel Better Block in Vermont	Urban Revitalization			X			X				X	
11	Glass Street Project in Chattanooga	Urban Revitalization		X				X					X
12	Norfolk Better Block	Urban Revitalization		X				X					X
13	San Diego Better Block	Urban Revitalization		X				X			X		
14	Hotel Grimaldi in Exarkana	Urban Revitalization			X			X					X
15	The Haverhill Project in Massachusetts	Urban Revitalization		X				X					X
16	Richmond Better Block in Virginia	Urban Revitalization	X					X			X		
17	McKinley Square Street in New Jersey	Urban Revitalization		X				X			X		
18	Mount Rainier Better Block in Maryland	Urban Revitalization		X				X			X		
19	Brownsville Better Block in Texas	Urban Revitalization		X				X				X	
20	Ludvine Better Block in Oklahoma	Urban Revitalization		X				X			X		
21	Oak Cliff Better Block in Texas	Urban Revitalization			X			X			X		
22	Jefferson Park in Denver	Urban Revitalization		X				X			X		
23	Middlesborough Better Block in Kentucky	Urban Revitalization		X				X				X	
24	Walnut Hill Project	Urban Revitalization		X				X				X	
25	Five Points Alley	Urban Revitalization		X				X					X
26	St. James Pocket Park	Urban Revitalization		X				X				X	
27	Music at McMillan	Urban Revitalization		X				X				X	
28	Cincinnati Street Food Festival	Urban Revitalization			X			X					X
29	Concord Community Garden	Urban Revitalization			X			X					X
30	North State Street in Chicago	Urban Revitalization	X						X				X
31	Praca Tiradentes in Curitiba, Brazil	Urban Revitalization	X						X				X
32	Av. Rio Branco in Recife, Brazil	Urban Revitalization	X						X		X		
33	Boulevard Anspach in Brussels, Belgium	Urban Revitalization	X						X		X		
34	Parque Milenio Central in Puebla, Mexico	Urban Revitalization		X					X				X
35	Pedestrian Prototype in Times Square, NYC	Transit System		X						X			X
36	Greenway Northern in Minneapolis	Transit System	X						X				X
37	Omaha Protected Bike Lane	Transit System				X		X					X
38	Macon Connects in Macon, Georgia	Transit System	X						X		X		
39	Queens, 37th Rd in New York	Transit System	X						X		X		
40	Queens, Broadway 37th Rd in New York	Transit System	X						X			X	
41	Brooklyn, N 3rd St in New York	Transit System		X					X		X		
42	Brooklyn, Water St in New York	Transit System		X					X		X		
43	Granby Street in Norfolk, VA	Transit System	X						X			X	
44	University Street in Seattle	Transit System		X					X			X	
45	9th Avenue in Seattle	Transit System		X					X				X
46	Bradley Avenue in Los Angeles	Transit System		X					X				X
47	West 3rd Place in Los Angeles	Transit System			X				X		X		
48	Stockton St in San Francisco	Transit System			X				X			X	
49	Castro St. Market St. in San Francisco	Transit System		X					X		X		
50	Annie Alley in San Francisco	Transit System				X			X			X	
51	Willcocks St in Toronto, Canada	Transit System		X					X		X		
52	Rue Victoria in Montreal, Canada	Transit System		X					X			X	
53	Regal Road - Springmount Ave. in Toronto, Canada	Transit System				X			X				X
54	Juan Belaluz in Toluca, Mexico	Transit System		X					X				X
55	Mier y Pesado in Mexico City	Transit System		X					X				X

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PUBLIC PRIVATE PARTNERSHIP FIELD EVOLUTION VIEWED THROUGH A STRATEGIC NICHE MANAGEMENT PERSPECTIVE

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PUBLIC PRIVATE PARTNERSHIP FIELD EVOLUTION VIEWED THROUGH A STRATEGIC NICHE MANAGEMENT PERSPECTIVE

ABSTRACT

It is observed from literature that there exists a difference in the evolution paths of Public Private Partnership (PPP) enabling fields across geographical territories despite similar beginnings. This difference in the evolution pathways of PPP fields in different contexts have been studied by researchers who have attributed this phenomenon to path dependency. However, these existing studies lack a micro-perspective, where, the processes, socio-psychological drivers of field creation, and spatiality of the contexts have not been given adequate attention while analysing the transition pathways of the PPP fields. We argue that these drawbacks can be compensated by using a Strategic Niche Management (SNM) perspective as theoretical lens. The use of SNM can assist the analysis of historical cases of transition with a micro-process approach and socio-cognitive orientation, and thereby, delivering a structured framework that can help in mapping out the evolution process of PPP enabling fields within a particular context. The objective of the paper is to analyse the transition process of evolution of PPP fields in a particular geographical territory, utilizing SNM. In doing so we aim to answer the question of ‘How does the PPP field evolution take place within a geographical territory? The analysis was carried using a framework designed by combining the SNM theory with the concept of Translation from Actor-Network theory. The ‘Translation’ concept was used, since it would incorporate real world chaos into the scenario, unlike SNM by itself, which has been criticised for viewing transitions as a structured and patterned phenomenon.

KEYWORDS

Public Private Partnerships, Transition, Strategic Niche Management, Translation moment, Spatiality

INTRODUCTION

The ‘public–private mix’ in delivering public services has a rich history and it existed since the routage of organized government (Wettenhall 2010). A definition of Public Private Partnerships (PPPs) given by (Powell & Glendinning, 2002, 3) has its real essence of partnerships and reads ‘*It requires the involvement of at least two agents or agencies with at least some common interests or interdependencies, and would also... require a relationship between them that involves a degree of trust, equality or reciprocity (in contrast to a simple sub/superordinate command or a straightforward market-style contract)*’.

It was only in the 1990s that public private partnerships became popular and widely recognized since the launch of the Private Finance Initiative (PFI) in 1992 in the UK which was the forerunner of the current Public Private Partnerships movement (Bing Li et al., 2005; Bovaird, 2010, 43). In 1997, the PFIs were renamed and transformed as

‘Public Private Partnerships (PPPs)’ and then were promoted sharply into use (Broadbent and Laughlin 1999).

Being one of the earliest proponents, policy makers have looked upon the UK for formal and informal guidance to set up their own PPP programs (Dewulf et al. 2011). For instance, Partnerships UK (PUK), the coordination agency in charge of PPPs in the UK have played an active role in developing PPP policy in India. The PPP policy drafts in India had directly borrowed sections from the UK PPP policy and elsewhere (Dewulf et al. 2011). Examples of other countries that have borrowed from the UK model are Australia, Canada, the Netherlands, and South Africa (Dewulf et al. 2011; Jooste et al. 2011). Although these aforementioned countries/states started off by following similar PPP policies, mostly based out of the UK’s initial experience, and had roughly similar amounts of political support and comparable institutional settings across similar timelines, the implementation of PPP programs across these countries/contexts were observed to be unidentical, thereby necessitating a context specific approach to explain and predict PPP field development (Jooste et al. 2011).

The term ‘PPP field’ refers to the network of PPP enabling organizational fields, which from now on would be extensively used across the paper. (Jooste et al. 2011) explicates that there is no one-size-fits-all institutional evolution that is universally applicable for the pursuit of PPPs and indicates that PPP enabling fields develop very differently in regions with similar features. In fact, it is observed that most of the social change processes are path dependent and incremental (David 2001), and changes can occur through internal developments or forces within the field of the sector (Jooste et al. 2011).

We observed that the existing studies lacked a micro-perspective and missed out on paying adequate attention to the processes and the socio-psychological drivers of field creation and evolution. We argue that viewing the evolutionary process of PPP fields through a ‘Strategic Niche Management (SNM) lens would compensate for the drawback in the existing literature and thereof address the proposed research question of ‘how the PPP field evolution/transition process materialise within a place context?’

PPP FIELD EVOLUTION LITERATURE

(Matos-Castaño et al. 2014) attempted to study ‘how path dependent institutional change take place and why institutional environments evolve differently, while stressing on the non-existence of a ‘one-size fits all institutional framework’ for enacting PPPs. However, the study lacked continuity along the longitudinal timeline since they chose projects at discrete points in time within the context.

Owing to the demand from various researchers (Hoffman and Ventresca 2002; Wooten and Hoffman 2008) for improved understanding of fields as mechanisms or processes, as well as the scant research done with regards to understanding the relations between organizations within the field, another study in similar lines was done by (Mahalingam and Delhi 2012) which analysed the evolutionary path of PPP fields, and brought out findings that were different from the previous studies. The study used Strategic Action Fields (SAFs) as a theoretical framework (regulative, normative, and cognitive institutions that exists in the context of study comprise the SAFs) and focused on a contested relational perspective of organizational fields, to understand the dynamics that lead to the evolution of PPP enabling fields.

Attributing to path dependency, it was anticipated that, contextual factors and the persistence of existing institutions (refer Zucker 1977) interacts with new PPP regimes to create a field that is unique to a particular country/state (Dewulf et al. 2011; Jooste et al. 2011; Matos-Castano et al. 2012). In contrast to these earlier findings, the SAF study affirms that, the outcomes of the contestation within the organizational field are not direct effects of initial conditions by itself, and the fields are not shaped by institutional logics alone (Kitchener 2002; Zilber 2006), but involves strategic moves by actors (Oliver 1991), and continuous shaping mediated by their social skills (Fligstein 2001) via diverse sequences of contention (Fligstein and McAdam 2011). Therefore, the importance of agency in the dynamics of fields and field settlement is affirmed.

NEED FOR AN ALTERNATIVE THEORETICAL LENS

Both (Mahalingam and Delhi 2012) and (Matos-Castaño et al. 2014) add onto the literature on PPP field evolution, laying emphasis on the importance of process and interactions in the development of PPP field outcomes in their attempt to explain path dependency in the development of PPP fields. However, it was observed that none of the existing studies had really explained with a micro-perspective ‘how the PPP field transition process unfolds within a specific geographical territory?’

We reason that, since the existing studies had a macro or meso-level perspective, it portrays the transition process in a much simpler and superficial fashion and misses out on the micro-level aspects which would have been playing a major role behind these macro or meso-level events. These micro level aspects could be attributed to facets such as socio-cognitive influence of the actors involved, the role of path dependant historical processes within their temporal context (Pierson 2013), influence of the spatial dimensions (Hansen and Coenen 2015), and the role of external influences on the case setting. These drawbacks call towards the need for an approach, with a micro-perspective, that can fill the existing gaps and aid in understanding the processes behind PPP field transitions within a context.

The transitions literature appears to be helpful in this scenario. (Coenen et al. 2012) (with the perspective of (Geels et al. 2008)) defines transitions as ‘*shifts or ‘system innovations’ between distinctive socio-technical configurations encompassing not only new technologies but also corresponding changes in markets, user practices, policy and cultural discourses as well as governing institutions*’. Transition analysis has the ability to assess long-term evolutionary trajectories of social change which enables it to deal with the structure-agency duality (Coenen et al. 2012). In the ‘Transitions literature’, theory developments have occurred at the intersection of evolutionary economics, and constructivist approaches in the Studies of Technology and Science (STS) resulting in conceptual frameworks such as technological Innovation Systems (TIS), the Multi-Level Perspective (MLP), and Strategic Niche Management (SNM) (Hansen and Coenen 2015; Markard et al. 2012).

We claim that the use of both TIS and MLP may not address satisfactorily the question of ‘how the transition process take place’ due to the absence of a micro-perspective, although they could very well explain ‘why the transitions happen differently across different contexts’ due to their meso-macro level orientation. The third conceptual framework SNM, works at a micro-level (Loorbach and van Raak 2006) and hence we choose SNM as the research lens for our study, based on the

conclusion that, it will serve better in addressing our question of ‘how PPP fields evolve within a specific context’. We believe that SNM’s micro-level orientation, evolutionary origin, process-oriented approach, and the consideration of socio-cognitive attributes would be beneficial in unpacking the underlying processes and configurations that lead to the evolution of PPP fields within that context. Although we choose SNM for our analysis, we do not claim that it is the ultimate panacea for such a study and the drawbacks of the approach would be identified as the study progresses.

THEORETICAL PINNINGS

STRATEGIC NICHE MANAGEMENT (SNM)

SNM builds on the Multi-Level Perspective (MLP) of socio-technical change, but at a micro-level (Loorbach and van Raak 2006). MLP (first formulated by Rip and Kemp 1998) recognizes three analytical levels, namely a) the niches (at the micro-level, where radical innovations emerge); b) socio-technical regime (at the meso-level, that accounts for the stability of large scale incumbent systems that contains shared cognitive routines, belief systems, regulative and normative rules, the wide-ranging community of social groups, and alignment of activities (refer Bijker 1995)); and c) the socio-technical landscape (at the macro-level, comprising an exogenous environment to niche and regimes; involves macro-economics, deep cultural patterns, macro-political developments; undergoes slow changes across decades) (Schot and Geels 2008). According to the MLP notion, transitions happen due to the interaction between these three levels, viz when the combined effect of ‘the internal momentum created by the niche innovations, and the changes at the landscape level’ exerts pressure on the regime to destabilise it and create windows of opportunity for niche innovations to emerge (refer Schot and Geels 2008). While MLP has a meso-macro orientation with a big picture approach, SNM limits itself to the management of protected spaces called niches for given technologies by taking a specific radically innovative technology as the starting point and focusing on aligning this technology with its user environment (Loorbach and van Raak 2006) through the internal niche processes of expectations, networking, and learning (Mourik and Raven 2006), and thereby permits the development and rate of application of the new technology (Kemp et al. 1998, 186).

SNM can be used both as a research model and a policy tool. Although its application as a policy tool still lacks practical guidelines and is understudied, it has been very effective in analysing and explaining historical transitions and emerging innovation (Mourik and Raven 2006). It is to be noted that although the term sustainable is used as characteristic of SNM, there is no direct connection to research on sustainable development nor are the definitions of sustainability made obvious (Loorbach and van Raak 2006).

SNM AS A RESEARCH MODEL

As a research model, the SNM approach can be used for analysing historical case studies (e.g. van Eijck and Romijn 2008; Hoogma 2000; van der Laak et al. 2007; Lopolito et al. 2011; van Mierlo 2002; Raven 2005; Raven et al. 2011; Valdez Juárez 2015; Verbong et al. 2010; Xue et al. 2016) in order to analyse the experimental introduction of innovations in various fields, and to devise recommendations for policy makers, firms or other technology promoting actors (e.g. Hoogma et al. 2002; Kemp et

al. 1998; Raven 2005; Weber et al. 1999). It is observed that these two applications of SNM are interrelated in many cases, whereby SNM can be used to analyse historical cases and the cases can then be used to articulate policy and governance suggestions. Therefore, as a research model, SNM can understand technological change, emerging innovation and explain historical transitions; plus, as a policy tool it is expected to influence technological change in the desired direction although it still lacks practical guidelines and is understudied as a policy tool (Mourik and Raven 2006; Raven 2005).

MECHANISMS BEHIND THE APPROACH OF STRATEGIC NICHE MANAGEMENT

Niches are spaces where the radical innovations are experimented and further advanced, while being protected from the mainstream market competitions in the regime (Geels 2002; Schot and Geels 2008) thus acting as ‘incubation rooms’ for radical novelties (Schot 1998). Such niches of technologies which do not have existing market niches (application domains where the new technology has advantage over the existing established technology (Raven 2005) are called ‘technological niches’ (Hoogma et al. 1996). They are the breeding place for radical innovation (Raven 2005). ‘When incubation goes well, a technological niche will evolve into an actual market niche, in which the innovation can sustain itself commercially in a specific market segment’ (Hoogma et al. 2002, 30).

The most important processes in the creation of a technological niche comprises the three niche internal processes namely (Mourik and Raven 2006; Schot and Geels 2008): (a) the voicing, shaping, and convergence of expectations, and their power in turning promises about the innovation into requirements that lead to the creation of the innovation, (b) establishment of social networks involving the niche actors to build a community for the new technology to facilitate communication between relevant stakeholders and deliver adequate resources which could be money, people or expertise, and (c) first and second order learning processes across multiple dimensions (that could be spread across ‘technical aspects, market and user preferences, cultural attributes, infrastructure networks, industries, regulations and policies, societal and environmental effects’ (Schot and Geels 2008). (Hoogma 2000, 58) refers to the first order learning processes as the learning about the effectiveness of the particular technology in attaining a specific goal, while second order learning refers to the identification of the inherent assumptions and norms in order to frame new rules. The interaction of these three mechanisms that take place in iterative loops through efficient knowledge creation, diffusion and learning is fundamental to the creation of an innovation niche (Lopolito et al. 2013; Raven 2005).

CRITICISM OF SNM

COMBINATION OF SNM WITH TRANSLATIONS

(Lovell 2007) has criticized SNM for laying too much emphasis on a planned, well ordered and consensual management approach. (Raven et al. 2011) backs up this criticism and attempted to address this identified gap in SNM linking it with the ‘concept of translations’. Translation is a concept originating from Actor network theory (Callon 1986) and it denotes the transfer of objectives from one actor to other actors, thereby recruiting others into the network surrounding the primary actor. The

literature on translations is expected to bring agency, contestation, real world chaos and complexity of SNM into light. The four translation moments that are defined in the actor-network theory are: Problematisation, Interestment, Enrolment and Mobilisation. Corresponding to each of these moments requires inclusion of data regarding ‘the respective initiating actor’, ‘the mechanisms/resources that the actor exploits to perform agency’, and ‘the targeted audience of that agency’.

(Raven et al. 2011) defines the translation moments as follows: (a) Problematisation ‘refers to framing of problems by the actor intended to realise its actor-world in such a way that they become ‘indispensable’ or an ‘obligatory passage point’; (b) Interestment ‘refers to the actions that the ‘translator-spokesperson’ undertakes to interest other actors in their actor-world’; (c) Enrolment ‘is the outcome of successful Interestment, i.e. when actors accept their new roles and support it with positive actions’ and finally, (d) Mobilisation of allies ‘refers to Successful enrolment of actors will in many cases be the result of reduction of the networks they represent into a single element of the initial actor-world or vision.’ (Raven et al. 2011) examines how actors, and networks operating within niches, coordinate their actions and mutually adapt using the combination of SNM and Translation moments.

Therefore, we propose to use a combination of SNM and ‘the concept of Translations’ as our research lens in order to analyse the ‘PPP fields’, which is our chosen unit of study in place of technological innovation and aims to identify how these fields evolved across time within a spatial context.

SPATIALITY

The term spatiality has been used multiple times across the paper and it needs an appropriate explanation before proceeding further. Sustainability transitions literature of which SNM is a part has been criticized by geographers for ignoring a vital dimension – ‘space’ (Coenen et al. 2012; Hansen and Coenen 2015) and plainly focusing on the narrow domain of geography of transitions (Geels 2013). (Coenen et al. 2012) points out that transition analysis have missed out factors such as ‘where does the transition occur’, and ‘the socio-spatial relations and dynamics’ within which transitions evolve, which comprises the ‘spatial context’ resulting in a drop in the comparability between the places of the study that aims to understand how and why transitions occur in one place and not in another, thus preventing the generalisability of the identified results of the study that could have led to a coherent body of theoretical knowledge.

‘Trying to think clearly about space is not easy’ (Dainton 2001). We found that there are multiple views regarding the conceptualisation of space. According to (Raven et al. 2012) ‘Space is not simply about physical territoriality. Space is also constructed space, created through physical, economic and social networks. Interactions and representations are multi-layered, in which boundaries are contingent and continually negotiated and revised. Space has meaning only in relation to the perceptions of actors, and to their interests and strategies’. By focusing on the organizational routines and their development over time as the object of analysis (refer Nelson and Winter 1982), (Hansen and Coenen 2015) conceptualises space as ‘the geographical distribution of routines, which is closely associated with industrial and technological specialisation’.

(Hansen and Coenen 2015) indicates that ‘in order to conduct an effective transition analysis, it is important to analyse the respective place specific settings (place

specificity) in which the transitions are embedded and at the same time focusing on the geographical connections and interactions (spatial relations) within and between that place and other places’.

The literature on geography of transitions reveals a multifaceted version regarding the conceptualisation of space. Getting into the details of explaining the different versions of the geography of sustainability is beyond the scope of this paper. Therefore, in our study we would be emphasising on ‘economic geography’, which we believe, would enable us in unpacking the transition path of the PPP fields within a context. We chose economic geography, since, it is the sub-discipline within geography that has been extensively used to plot and scrutinise uneven geographical landscape of innovation and technological change (Coenen et al. 2012). In addition to economic issues of innovative activities, economic geography encompasses ‘social, institutional, and to some extent cultural dimensions’ (Hansen and Coenen 2015). The dimensions of economic geography include industry base, natural resource endowments, and consumers and local market formation (refer Xue et al. 2016).

METHODOLOGY AND DATA

The proposed research question for the study is ‘how PPP field evolution processes within a place context can be understood by operationalising SNM as a research model?’ A case study approach (Yin 1994) is selected. The reason for choosing such an approach is that it would be useful in answering the ‘how’ and ‘why’ questions when there is no control over the behavioural events and the focus is on contemporary events, and also since it helps in making generalizations and allows replication logic.

The choice of case study context could have been either countries or states who had attempted to implement PPPs within their territories. For our study we chose an Indian State named Kerala due to the fact that it was conspicuous with respect to its PPP implementation wherein a lot of experimentations and innovations had taken place.

Since the study is novel with respect to its micro-perspective approach, we consider the nature of the study as exploratory and therefore chose to have a single case study aiming to explore how the SNM framework can be used in the case of PPPs and in the process, unpack the PPP field evolution and emergence using the lens of SNM. The scope of the case study includes a record of all the incidents relevant to PPPs in the state from the year 2000 onwards, irrespective of the infrastructure sector, so that a bigger picture with continuity along a longitudinal timeline could be created. Data on the evolution of the PPP enabling field in this state was collected from secondary documents, archival sources, policy releases, and audit reports. The case data was then transcribed into a detailed, chronological case study. Open coding of the case study was then conducted. This step was followed by viewing the case through an analysis framework designed out of the SNM theory combined with the concept of Translation from Actor-Network theory.

Two categories of data were tabulated namely the Core processes in SNM and the Translation moments from Actor-Network theory. The core SNM processes include identifying the dynamics of vision and expectation, identifying the actor network and its alignment, and identifying the first and second-degree learning processes (Mourik and Raven 2006). The translation moments include Problematisation, Interestment, Enrolment and Mobilisation (Raven et al. 2011). The process involves identifying the

initiating actor of a translation moment, the mechanisms or resources used by the actor to execute agency and the targeted audience of that agency.

CASE DESCRIPTION

Case background

Kerala is a small state located in southern India occupying just 1.18% of the total area of India, but with a high population density. Looking at its sector wise contribution towards the state GDP during FY 2015-16, the tertiary sector (trade, commerce, real estate, and services) overpowers the primary (agriculture, mining) and the secondary (construction industry; manufacturing industry; electricity, gas and water supply) sectors, contributing 62%, 26% and 12% respectively towards the state GDP. The economic status of the state for the past four financial years from FY 13 to FY 16 indicates that it has a volatile agricultural sector and is taking up a steady growth in industry and manufacturing sectors. Formed in 1956, following the ‘States Reorganization Act’ by organizing the state boundaries along linguistic lines, the state’s economy was dominated by agriculture and was industrially backward. The industrial sector consisted of traditional industries, medium scale industries and few large-scale industries in the public and private sectors. The state remained industrially backward despite the huge inflow of expatriate income when extensive migration to the Arab states of the Persian Gulf (Gulf Cooperation Council Countries) started, known as the ‘Gulf Boom’ which happened during 1972 to 1983. In 1974-75, the primary, secondary and tertiary sectors constituted 48.9%, 18.3% and 33.6% of the state’s GDP respectively. But by 2004-2005 this status changed to 16.6%, 18.7% and 64.7% indicating that the primary sector declined steeply and the secondary sector remained still, while the share of tertiary sector jumped high to a value of 64.7% of the State’s economy indicating that the industries sector involving the manufacturing and the construction industries remained stagnant.

Although the government had been creating various industrial promotion agencies right from the 50s itself (among which a large number turned out to be white elephants eventually), it was observed that the industries were unable to attract investors while the tertiary sector kept growing. However, during the 90s, due to the inadequate and inferior quality of infrastructure facilities, the tourism sector, (belonging to the tertiary sector) which was the perennial source of economy boost for the State, started getting affected, leading to an urgent need to fillip both the tourism sector as well as the infrastructure sector. In addition, due to the high population density and scarcity of land resource for setting up industries, the government identified the need for creating good infrastructure, in order to attract industrial investors into the state. Moreover, the government had also learnt that industrial development would help with the reduction of the high unemployment levels that prevailed in the State despite its high literacy rates.

Case data

The scope of the case study is restricted to the lineage of all events from the year 2000 onwards that were directly or indirectly associated with PPPs in the State. In order to boost up and revitalise the economy, the government specifically aimed towards promoting both the industrial and tourism growth from the year 2000 onwards.

The first step towards this was the introduction of the Single Window Clearance (SWC) system, made effective from June 1st, 2000, aimed at expediting the clearance process of new projects. According to this, the final clearance of approval or rejection for all new projects would be made within a specific period from the date of submission of application and was made a statutory requirement. The government expected that such a provision would act as an attractive attribute for potential investors to take adequate investment actions in the State. Meanwhile the government had also undertaken certain strategic actions in order to revitalise the tourism sector which included, handpicking a team of tourism professionals from civil services to create a team of strategists; changing the conventional marketing approach by moving towards promoting the Kerala Tourism brand at a more sophisticated level in terms of its exotic attributes to appeal the higher sense of a person; decision by the Kerala Tourism Board (KTB) to work in absolute synchronisation with the tourism industry and to ensure top priority to the visitors' experience by having trained service providers ranging from homestays to skilled employees of hotels, taxi drivers to government staff. The State government started consulting the private partners in the tourism sector for promoting the State in both the domestic and international market; they decided to pick up the role of a facilitator instead of a promotor by conceiving that the private sector is more efficient and knowledgeable in business compared to them; the private players would conduct roadshows and tourism fairs in and outside the country to promote the State. In addition, the government created a PPP initiative called 'Kerala Travel Mart (KTM)' in the year 2000, which was the /tourism industry's/ newly introduced major event of promotion in the tourism industry which would act as a business platform for all tourism stakeholders to showcase their products to domestic and international buyers. Collective work was done by tour operators, hoteliers, house boat owners and other stakeholders of the State in working out special products and services for the overseas tourists.

The Industrial policies put forth by the State government in 2001 and 2003 targeted at having a comprehensive approach towards the development and enhancement of infrastructure so as to ensure optimum utilization of the resources of the State. Both policies intended to accelerate the industrial growth through the creation of a favourable investment climate in the State by focusing on ensuring sustained industrial growth and generation of higher employment; creating an investment friendly climate; maximising private investment in infrastructure development; elimination of inhibitory labour practices with a new work culture related to productivity; linking educational system with skill development; re-engineering the delivery mechanism of the government to make them responsive, result-oriented and transparent; industrial development consistent with environmental concerns and energy conservation. Specific to the infrastructure development context, the policy aimed at employing the State's opportunities and resources optimally by involving the private sector; establishing transparent methods for private participation in infrastructure development in the interest of the public; developing industrial areas via Build Operate Transfer (BOT), and Build Own Operate Maintain (BOOM) basis; promoting private sector participation in 22 critical sectors which included the power sector, and also enable constant coordination with the Central government to ensure higher central investments in the State.

The plan to incorporate private sector participation in the generation, transmission and distribution of electricity as indicated in the Kerala Infrastructure Development Bill 2001 was opposed by the Kerala State Electricity Board Officers' Association (KSEBOA) citing the failure experiences of other States in the country. They indicated that ultimately profits of the private sector had been made a priority over the necessities of those States, and also criticised the decision of the State of Kerala to include the private sector into the power transmission arena. It is noteworthy that the decision of the newly formed State government (formed by the political party 'United Democratic Front (UDF)'), who took charge in 2001, to involve private parties into the power sector was in contrast to the previous governments' (comprised by the political party Left Democratic Front (LDF)) decision in 1998 against the power sector reforms proposed by the Centre at that time. The Central government had mandated the creation of national and state level regulatory bodies which was an indication of the setting out of power sector corporatisation. The then LDF government had clearly indicated in its Power Policy Statement of the Government of Kerala 1998, that private sector investment would not be allowed in transmission and distribution, and that the State Electricity Board (SEB) would be retained with the public sector. Later when the UDF came into action in 2001, they agreed to undergo the widely criticised power-sector reforms proposed by the Electricity Regulatory Commission Act 1998, as per which they signed an MoU with the Union Power ministry indicating that the Kerala State Electricity Board (KSEB) would be running on commercial lines and that it would be securitising all its dues to the Central Public Sector undertakings (CPSUs). In addition the Centre had directed the KSEB to be desegregated and made accountable, along with the prescription of setting up of a State Electricity Regulatory Commission. Later in 2003, the Union government again came up with a new Act which was meant to replace all the existing acts governing the power sector and aimed to introduce competition, protect consumer interests, and supply power for all. The provisions of this act implied that all the SEBs will disappear eventually which led to rising controversies since, due to the desegregation, setting up of regulatory commissions, and corporatization, the hand of government in managing the Electric Supply Industry (ESI) would diminish profoundly. As per the provisions of the Electricity Act 2003, the SEB was allowed to perform as a 'State Transmission Utility (STU) and licensee', for a limited period of time which was permitted to be extended on mutual terms between the State and Central governments. Accordingly, the Kerala government obtained extension to enact this provision till September 2008, which was still kept pending even after the lapsation of the extended period, since the LDF government who took charge again in May 2006, was not the least bit ready to yield.

The new LDF government released the 'Industrial and Commercial Policy, 2007' in which the new government's discontent over the previous government over the period of 2001-2006 was displayed by blaming the liberalisation policies of the previous government that had led to the need for downsizing and employee pruning from the State and Central PSUs. The policy document indicates that the Foreign Direct Investment (FDI) share of the State was only 1.26% of the total FDI approved in India during the period from January 1999 to December 2005. It also pointed out that the State had been deprived of large central investments in industrial sectors, despite the pleas of the State government for the past five decades.

The immense need for creating large amounts of quality infrastructure in the State leading to the requirement of huge investments and the need for efficient project delivery with high value for money, led the State to adopt the public-private partnership mode of infrastructure delivery as a part of its rapid development strategy. Thus, as planned by the government in 2006, the Infrastructure Kerala Limited (INKEL) was founded in 2007 in order to function as an infrastructure development company. What made INKEL different from the existing infrastructure development companies was that, the company by itself was a public-private initiative between the government of Kerala who holds 26% stake; and the remaining 74% owned by private sector entities, of which the major share belonged to the Non-Resident Indian (NRI) population of the State, thereby making it the first of its kind. The aim behind INKEL's creation was that, the large scale private capital and professional expertise could be manoeuvred for developing large infrastructure projects under government control in the State. It was set up to deal with infrastructure facilities, Special Economic Zones (SEZs), and industrial parks, inclusive of their promotion, setting up, operation and sale. Over the years INKEL had actively carried out building projects majorly in the form of SEZs, Industrial parks, Education hubs, Standard Design Module Buildings, Convention Centres, a Container Freight Station, Skill development Centre, Business park, PURA (Provision of Urban Amenities to Rural Areas) projects at two locations in the State, modernisation of 210 treasuries across the State, agricultural farming projects, major public health projects etc. It was also observed that INKEL had formed joint ventures with PSUs like the KSIDC (to form INKID), KINFRA (to form INKIF), and Kerala State Industrial Enterprises (KSIE) for enacting specific infrastructure projects.

In February 2012, the Defence sector became opened to the private sector, thereby providing multiple opportunities for Indian industries, since the defence forces would procure all range of items produced, manufactured, and developed by Indian industries. In April, 2012, the Kerala Industries and IT minister, belonging to the UDF political party, announced that the State government would be adopting the PPP mode for all proposed mega projects. This decision was made on the lines of the promotion of the manufacturing and service sectors in an eco-friendly manner.

Meanwhile in 2013, in the road sector at the national level, it was observed that the attractiveness of PPPs to the private sector had started to fall. Around 20 PPP projects which were set out for bidding by the National Highway Authority of India (NHAI) did not attract any bidders since 2012-2013. Even exit policy incentives such as allowing the concessionaire to divest full equity did not seem to appeal any bidder and the Engineering Procurement Construction (EPC) route was preferred by the private players, since the risks are not borne by them.

In May 2014, news on a draft PPP policy prepared by the State government for infrastructure development was published. The draft policy also had a bill titled 'The Kerala Infrastructure Development Bill, 2014' in the pipeline as per which an Infrastructure Development Board would be in charge of the PPP projects by acting as a nodal agency. The Bill was meant to be applied to projects exceeding a value of INR 10 crore. According to the draft policy, the government would propose a two-level PPP institutional framework namely, an Empowered Committee on PPP (ECPPP), and an Apex Committee on PPP (ACPPP). But unfortunately, this bill never took off to attain the Status of an Act.

In August 2015, the Public Works Department (PWD) of Kerala took the decision of empanelling consultants for works committed by the government based on the recommendations of the Chief Engineers Committee and appointed 46 firms in seven categories till March 2016. The aim of the PWD was to get access to the most recent technological knowledge and to be able to break away from conventional ideas. But this act of appointing consultants was frowned upon within the PWD itself, since the Department had overlooked the presence of the in-house expertise and their talents, which includes the Design, Research, Investigation and Quality Control Board (DRIQ Board, the separate wing that was responsible for the design of bridges and buildings); and the Design and Architecture wing; both of which had owned a very good reputation within the PWD.

In September 2015, INKEL registered a growth of 170% in the year 2014-15 compared to the previous year. The pattern of revenue earnings during 2014-15 changed substantially to ‘income from operations’ from ‘the other income category’ which predominantly was from consultancy and other sources. INKEL paid a dividend of INR 1.21 crore to the GoK for the FY 2014-15. This was the third dividend INKEL had disbursed, since the issue of shares to the government and public in 2008.

In December 2015, the State government had planned on providing high-end skill development of the workforce of the State with the help of private participation. The government identified that tying up with the private sector would help in providing employment in addition to the training process. The need for skill development was also felt due to the migration of Keralites to other countries for job opportunities, which demanded a need for constant upgradation in their skills to match up with the international standards, and also to aid them to earn better and ultimately improve the quality of their lives. For this purpose, the State government made its plans towards organizing an international skill summit that was to be held in 2016, in which industry leaders across the world would be invited for initiating partnerships.

In January 2015, the rehabilitation work of a 22km highway in the district of Thiruvananthapuram, was meant to be carried out by the INKEL – E.K.K Consortium Company (E.K.K being a private sector infrastructure developer) through the design, build, finance, operate, and transfer (DBFOT) style via the PPP Hybrid annuity mode that specifies 20 per cent upfront payment from the government. The adoption of this PPP mode happened in concurrence with various projects across the country, on account of the mass failure of PPP road projects during the 2012-2013 period after which the road PPPs had become unattractive in general to the private sector.

In July 2016, it was noticed that although the State had excelled on a number of social and economic indicators in comparison to the other States in the country and had been making aggressive investments in infrastructure in the past decade, the infrastructure standards of the State was still way behind the levels of a fully developed State, thus pointing towards the need for fast tracking the efforts to meet its targets. Such a need was most obvious in the tourism sector wherein, despite the State being a tourism hotspot, the infrastructure related to it were identified as disorderly and tussled.

In August 2016, INKEL introduced a single window system to help entrepreneurs in other States set up their businesses in Kerala through which all services, from guidance to implementation, were to be taken up by INKEL. The streamlining was expected to revolutionise the industrial sector in Kerala. This programme was planned to be launched by hosting business meets in the key metropolitan States in the country.

In September 2016, the then Chief Minister projected the Kerala Infrastructure Investment Fund Board (KIIFB), established in 1999, as a solution to the infrastructure cries of the State. He also indicated that handling the rehabilitation of the returning NRKs from West Asian countries due to an impending economic crisis was in process and was being planned to be jointly done by the ‘Centre for Rehabilitation’ and the State, for which although the State had submitted a project to the Centre had not received useful response. A notable fact was that the State government had tried to stay transparent with its activities and remain connected with the public, via means like press conferences, a well-developed e-governance system, the Information and Public Relations Department (IPRD, Kerala) etc.

In May 2017, the Dakshin Railway Employees Union (DREU) protested against the Railway Ministry’s plan to develop the Kozhikode railway station (in the district of Kozhikode) via PPP mode, under a mistaken impression that the motive of the Railway ministry was total privatisation of the railways and that the ministry would be selling off its assets in Kozhikode to private companies. In September 2007, on the event of ‘World Tourism Day’, a brainstorming session was conducted for making sustainable tourism as a tool towards development which had tourism industry stakeholders, experts and the State government as participants.

The data from the case study was viewed through the framework created by combining the two interpretative categories of the Translation moments and the core SNM processes. Since detailing the whole case through the interpretative categories would be too extensive, we would be explaining the translation moments and niche processes by means of randomly picked case examples.

CASE ANALYSIS

TRANSLATION MOMENTS

The approach of (Callon 1986) has been followed in order to analyse the translation moments that have taken place in the case study.

(i) Problematization

Problematization concerns the translation of ‘previous experiences and perceived opportunities in the wider context into a new expectation’. It ‘refers to framing of problems by the actor intended to realise its actor-world in such a way that they become ‘indispensable’ or an ‘obligatory passage point’ (Raven et al. 2011). The term problematization indicates that the problem definition arises from an operation and not just from a view and also indicates that the problematization is not a one-time event but is recurrent since dynamic practices leads to the creation of problematization (Broer et al. 2010).

Problematization starts with the initiating actor, known as the primary actor (prime actor), raising the basic necessary question that indicates the problem which the prime actors would want to get solved. This is followed by the two steps namely the ‘interdefinition of actors and the definition of Obligatory Passage Points (OPP)’ (refer Callon 1986). Based on the proposed question, the actors who can have direct correlation with the proposed question would be enlisted by the prime actor along with their individual motives which comprises the interdefinition of actors. The second step of defining the OPP by the prime actor involves indicating that the enlisted actors’

interests/motives depends on accepting the proposed plan of the prime actor. This implies that irrespective of the motives/interests of the individual actors, they should understand that in order for them to achieve their motives they must a) know the answer to the question; b) realize that their coalition with respect to this question would be individually beneficial to them. These actors cannot individually attain their goals, and therefore need to work together as an alliance in a dynamic manner in order overcome the obstacles and barriers that springs up in their way. Therefore, the problematisation refers to a scheme of alliances between entities formed on the basis of the basic question proposed by the prime actor and letting them know that through the alliance they would be able to achieve their ultimate motives, thus projecting the prime actors as obligatory passage points.

Case Example

The prime actor refers to the State government, who after identifying that the State's economy was going down during the 90s proposed the basic question necessary for problematisation 'How to revitalize the economy of the State?' As part of the next step that involves '*interdefinition of actors*', the actors who could have had direct correlation with the proposed question were enlisted by the prime actor along with their individual motives. This list included potential investors who aimed to make investments in the State; industries who wished to set up units in the State; tourism stakeholders who expected to benefit from the destinations becoming attractive to tourists; builders who were in search of winning bids of projects that were to be built; financing bodies who wanted to offer finance and loans to upcoming projects; and the State PSUs who intended to perform their designated functions and run successfully without losses. The second step of problematisation which was '*the definition of obligatory passage points (OPP)*' by the prime actor, involved indicating that the enlisted actors' interests/motives depends on accepting the proposed plan of the prime actor implying that, irrespective of the motives/interests of the individual actors, they should understand that in order for them to achieve their individual motives they must a) know the answer to the question: 'How to revitalise the economy of the State?' b) realise that their coalition with respect to this question would be individually beneficial to them. Since these actors cannot individually attain their goals, they had to work together as an alliance in a dynamic manner in order to overcome the roadblocks that could prop up in their path. The identified obstacles in the State were majorly un-coordinated government departments which led to clearance delays of projects, lack of land availability, poor quality infrastructure, troublesome labour unions, eco-friendly psyche of the public etc. Therefore, the moment of problematisation enacted by the prime actor entailed the creation of a scheme of alliances between the enlisted actors associated with the basic question and letting them know that by joining hands, they would be able to achieve their ultimate individual motives, thus projecting the prime actors as obligatory passage points. It should be noted that the same basic question can have multiple events of problematisations at various points in the time line which is evident from the various strategies brought in by the prime actor at various points in the time line with the aim of addressing the basic question.

(ii) Interestment

Interestment denotes the actions undertaken by the 'translator-spokesperson' to interest other actors in their actor-world (Raven et al. 2011). It is a process of struggle since the

views of the targeted audience may not match with that of the translator-spokesperson. This translation moment translates the expectations created from Problematisation into networking activities. The translator spokesperson can use specific mechanisms or resources as devices for ensuring successful locking in of allies who were described during problematisation into the network of the prime actor. The expectation from the ‘interestment’ is that, if it became successful, it would broaden the network thereby leading to the next translation moment called ‘enrolment’ wherein the actors form a network in working towards addressing the basic question raised during the stage of problematisation.

Case Example

In order to interest the enlisted actors into the previously described problematisation, the government, who is the translator-spokesperson in this case declared its decision to make Single Window Clearance (SWC) as statutory requirement from June 2000 onwards, with the aim to expedite the clearance process for all new projects, as per which the final approval or rejection would be made within a specific period from the date of submission of application. Thus, the translator-spokesperson used the mechanism of SWC as a device for ensuring successful locking-in of allies who were described in problematisation into the network of the prime actor.

(iii) Enrolment

Enrolment is the outcome of successful interestment, i.e. when actors accept their new roles and support it with positive actions. It is also about displacement since actors are being displaced into a new position in the network with different roles (Raven et al. 2011). Enrolment requires more than one set of actors who should be capable to dominate and enforce their motives on the other actors who are meant to yield in to join the network through successful enrolment. It might require multilateral negotiations, transactions, etc. (refer Callon 1986).

Case example

If the mechanism of SWC attracts the actors to come forward and make use of it to enter into new projects and accept their new roles (indicating successful interestment), then the translation moment of enrolment occurs. Enrolment requires more than one set of actors who should be capable to dominate and enforce their motives on the other actors who are meant to yield in to join the network through successful enrolment. It might require multilateral negotiations, transactions, etc. (refer Callon 1986).

In the case study it was found that the successful interestment happened only to an extent in the case of industries who used SWC to get enrolled wherein few investors made use of the SWC, thus enrolling into the network in order to deliver projects. However, it was observed that in the tourism sector the successful enrolment occurred at a higher rate leading to creation of a broader network due to the enrolment of more actors in to the network. The lower level of enrolment in the industries and infrastructure sector was due to the obstacles of unsolved issues which remained in the state as that of lack of land availability, unruly trade unions, high eco-friendly psyche etc. This indicates the need for further problematisation and need for added interestments in order for enrolment to happen. An example of a later interestment was the creation of the body called INKEL a PPP initiative of the State government, who was sent as a ‘translator-spokesperson’ to attract potential investments from the

neighbouring State of Tamil Nadu to join the network of agency that focussed on its ambitious development of projects across the state of Kerala.

(iv) Mobilisation of allies

Mobilisation of allies refer to successful enrolment of actors will in many cases be the result of reduction of the networks they represent into a single element of the initial actor-world or vision (Raven et al. 2011). This moment ensures the representativeness of the delegates in the formed network with respect to the ultimate aim of the prime actors. The prime actors should answer the questions of ‘who speaks in the name of whom? Who represents whom?’ (Callon 1986).

Case example

Unfortunately, this moment of translation did not quite take place in the case of Kerala which indicates the reason for the ‘prime question’ remaining unresolved. Even in the case of tourism sector where successful enrolment took place, mobilisation of allies was hindered. This hindrance was caused due to barriers like poor quality of infrastructure which remained unresolved even after the introduction of SWC thereby affecting the tourism sector by stopping them from achieving their ultimate motives. If the moment of enrolment in the tourism sector had included actors from the infrastructure sector, then a better degree of mobilisation of allies would have taken place in the tourism sector, with the barrier of ‘poor quality of infrastructure’ affecting the sector being removed.

INTERNAL NICHE PROCESSES

The three internal niche processes include i) Voicing and Shaping of Expectations, ii) Building of Social Networks, and iii) Learning process. (Elzen et al. 1996; Hoogma et al. 2002; Raven 2005; Schot and Geels 2008) explains the attributes based on which the quality of niche processes can be assessed which is explained as follows:

i) The voicing and shaping of expectations can contribute to successful niche development when: a) the expectations are more robust, which implies that it is shared by more actors; b) the expectations are more specific, implying that exceedingly general expectations cannot provide guidance, and c) the expectations have high quality which happens when the subject matter of the expectations is actualized by ongoing projects.

ii) The building of social networks contributes towards successful niche development when: a) the networks are broad indicating that a variety of stakeholders are included to enable the voicing of numerous views, opinions, and understandings which would ensure the broadening of the ‘cognitive frames’, thereby enabling second order learning, while the networks are deep when the organizational representatives are able to carry out the visions within their own firms and networks; b) the networks are aligned when the actors’ ideas, visions and other cognitive aspects are in similar lines and does not contradict.

iii) The learning processes adds onto the niche development processes when the actors are focussing on the accretion of data and facts which comprises the ‘first order learning’, combined with permitting changes to happen to the existing cognitive frames and conventions thus encompassing ‘second order learning’.

The above-mentioned niche processes are iterative in nature and occurs in loops with respect to time. Therefore, in this paper, for the purpose of understanding how to identify the niche processes we intend to explain each of these processes by picking random examples from the case study that can best depict the occurrence of the process.

i) Voicing and shaping of expectations

Level of Robustness

The level of robustness implies that the expectations shaped in the trial projects/pilots should be shared across more actors (Xue et al. 2016).

The pilot PPP of the state which was an innovative and successful model, a first of its kind in the country, the ‘Cochin International Airport Limited (CIAL)’ project in which 10,000 NRIs who were native of the State, across 30 countries invested in to project as interest free loans to finance the project, which started its operations in 1999. Along similar lines, later in 2007, the government launched a PPP initiative which would be tapping the trademark income source of the State ‘the Non- Resident Keralites (NRKs) remittance inflow’. The government thus created a company called Infrastructure Kerala Limited (INKEL) in which the government held 26% stake, 60% owner by NRI Keralites and the remaining 14% owned by financial institutions and members of the public. The expectation behind its creation was that large scale private capital and professional expertise could be manoeuvred for developing large infrastructure projects under the government control in the State.

It is identified that since, expectations from the pilot project had been shared indicated by the successful performance of INKEL that was identified based on the number and type of projects enacted, as well as its profit percentage that was consistently well above 100% which enabled them to pay the government its respective share of dividends; therefore, it is inferred that the level of robustness of the expectation to boost infrastructure in the state was high.

Level of Specificity

The Specificity of expectations becomes sharper when they are able to ‘turn a promise into a requirement... and define the design criteria’ (Mourik and Raven 2006).

It is observed that the level of specificity of expectations were mediocre in the case of transportation infrastructure delivery through PPPs since the expectations were too general and were not guiding enough to meet the goals. Observing the PPP history of the State post 2000, it is observed that, the dream of the State in delivering high quality transportation infrastructure has been below average, given the promises of projects made by the ruling governments as they took stage.

Level of Quality

Level of quality of expectations refers to ‘the level at which the content of expectations is realised by the ongoing projects’ (Schot and Geels 2008).

The expectation of the government to provide high quality transportation infrastructure was a failure, since it was not reflected in the projects across the timeline. This could be due to an absence of PPP supporting formal institutions in the State. Although a draft PPP policy was prepared in 2014, it never became official indicating the absence of supportive formal institutions to guide the expectations to become

realities. Contrastingly, in the tourism sector, even in the absence of supportive institutions, the quality of expectations was observed to be high.

ii) Building of Social Networks

Level of Breadth

'The networks are broad when multiple kinds of stakeholders are included to facilitate the articulation of multiple views and voices ..., when relative outsiders are involved who could broaden the cognitive frames and facilitate second order learning... The networks are deep when the people who represent organizations are able to mobilise commitment and resources within their own organizations and networks' (Schot and Geels 2008).

It is observed that the social network formed for creation of industrial infrastructure was comparatively broader than the very narrow network formed for creating transportation infrastructure. This is identified from multiple examples of joint ventures which were formed between the PPP body INKEL and other public-sector bodies for the purpose of delivering infrastructure, whereas such kind of co-operative merges were typically absent in the case of transportation infrastructure. Involvement of outsiders in the social network were observed only in the tourism sector where the network was globally connected.

Level of Alignment

Alignment refers to the degree to which actors' strategies, expectations, beliefs, practices, visions, and so on go in the same direction, run parallel. (Raven 2005). Alignment needs dedicated endeavours (e.g. from macro-actors like public authorities, specially dedicated consortiums, and other general interest actors) and does not happen naturally, since the different actors/firms would be having varying visions associated with the use of the newly introduced idea/mechanism (Raven 2005). According to (Hoogma 2000, 85) if the network has a history of complex, stable and multiple cross relations then its alignment would be higher. In general the alignment of the network is an indicator of the scope of the niche development wherein the higher the alignment, the greater the scope of niche development (Hoogma 2000, 348).

The best level of alignment and co-operation was observed in the tourism sector where there was an aligned network of actors which included tour operators, hoteliers, houseboat owners and other stakeholders of the State working out special products and services for the overseas tourists. Also, an initiative called 'Responsible Tourism' was created with the objective to involve and provide economic benefits to the local community via tourism development thereby making attempts to create cross relations among actors and intending to align their motives.

iii) Learning Process

First-Order Learning

'Involves accumulation of facts and data' (Schot and Geels 2008) and *'learning about the effectiveness of a certain approach in attaining a particular goal'* (Raven 2005).

E.g.: The Kerala tourism board decided to work in tandem with the tourism industry in order to ensure the best experience to the visitors by providing top level service and

understanding that consulting with the private sector for the promotion of the State in both domestic and international market would be ideal.

Second-Order Learning

Involves enabling changes in cognitive frames and assumptions (Schot and Geels 2008) (Schot and Geels, 2008) and identification of inherent assumptions and norms in order to frame new rules (Raven 2005).

E.g. As an effect of first order learning in the previous example, the government decided to choose the role of a facilitator, instead of a promoter with acquired learning that the private sector is more efficient and knowledgeable than the government, as a result of which the PPP initiative ‘Kerala Travel Mart’ was created.

SPATIALITY

It was observed that multiple characteristics typical to the case played an important role in the framing of PPP fields differently across various sectors at its various stages. These characteristics were mostly interlinked with each other with no clear delineation between the economic geography attributes which had direct effect on the evolution of the PPP fields.

Industry base

Industry base refers to the local industrial foundation (Xue et al. 2016). The State is characteristic for existence of Small and Medium Scale Enterprises (SME) and very few large-scale industries, stagnant industrial sector with respect to contribution to the gross state domestic product (GSDP), and growing tourism industry. It is observed that the State is unattractive to investors due to multiple factors, namely lack of land availability, poor quality infrastructure and connectivity, delays in obtaining clearances, strict environmental protection due to high green public psyche in the State, troubles caused by local trade unions through illegal extortion of gawking charges and therefore there is a need to boost the infrastructure sector for rapid industrialisation of the State, but restricted with the choice of opting only eco-friendly industries (E.g. SME, Information Technology hubs etc.)

Natural Resource Endowments

High literacy levels of the State’s population, literate population that demands transparency of actions of the government, high inflow of NRI population remittances contributing towards the (GSDP), attractive tourist destinations, environmentally cautious population, added up to the natural resource endowments of the State. The lack of land resources and high density of population in the State always acted as a barrier to the State’s development specially in the case of infrastructure and industrial development.

Consumers and Local Market Formation

Both the State government and the public were ready to break conventions and try out innovative methods of project delivery provided that all actions were transparent and accountable; high need for depending on private sector for efficiency, value for money, and funding due to low levels of Foreign direct Investment (FDI) and Central government fund into the State in order to achieve the expectation of rapid development

process, need for creation of job opportunities within the State through infrastructure and industrial development.

DISCUSSION

Viewing the case study through the lens of the ‘Translation moments, Niche processes, and Spatiality’ aided in the creation of a structured way of looking at how the State dealt with PPPs across its various sectors along a longitudinal timeline. This approach helped in enabling us to understand how to identify the inefficiencies and barriers to successful translation moments; the flaws in the niche processes; and the ways in which spatiality can affect the transition process, in the case of the evolution of PPP fields.

The variation in the dynamics of the niche processes across the various sectors contribute to the identification of the hindrances behind niche development, namely lack of robustness, specificity and quality of expectations; too narrow and unaligned social networks, and inefficient learning processes. All the unsuccessful niche developments exhibited missing translation moments which complemented the poor-quality niche processes. This is best indicative in the case of the tourism sector where despite successful enrolment and good quality niche processes with respect to the actors in the tourism sector, the flaw happened due to the absence of the translation moment of mobilisation of allies, where the actors who were related to infrastructure development of the state had failed the rest of the efforts by not enrolling and working in synergy to answer the basic question raised by the prime actor – ‘how to revitalise the economy of the State?’. This argument can be complemented in terms of the niche processes where, / despite the breadth and alignment of the social networks in the tourism sector being superior to that of the industrial sector, the non-inclusion of infrastructure actors in the network had gravely affected the tourism sector by causing obstacles in achieving its final goals of attracting tourists and ensuring them the best experience.

Had the infrastructure sector been supportive enough, the PPPs in the tourism sector of Kerala could have been a classic case of success when viewed through the SNM (combined with Translation and Spatiality) lens and would have been eligible to be considered as a successful example of SNM in practice, where a technological niche turned into a market niche. The sector by itself (without considering the infrastructure sector) had displayed all three moments of translations (where mobilisation of allies was indicated by the creation of the KTM which had actors working towards a primary goal), and high quality of niche processes even in the absence of a policy back-up. In the case of tourism sector, the State had adequately framed and conceptualised its expectations across the various social networks where first and second order learning took place after which looping back towards creation and alignment of expectations happened, that eventually was meant to converge at a point where market niches would start to appear. It should be understood that this particular case of tourism has a lot to do with the spatial aspects of the State that is indicated by the governments strategy to create a State specific model of tourism PPP, instead of trying to fit in borrowed concepts from some other spatial context. We also identified that this approach that was implemented in Kerala’s tourism sector may not work in the State for the other sectors, (E.g. Transportation sector), due to the spatial attributes of the State. Therefore, we infer that bringing in more aspects of spatiality into the context of the State might

help in explaining the success and failure of the various sectors within the same geographical territory. Potential examples of other spatiality aspects could be the public psyche, human development index, priorities of the context, culture and traditions etc. For example, consideration of the eco-friendly public psyche could explain why large-scale industries that were non-friendly to the environment could not take off in the State. The spatial aspect of low Central government funds forms the reason for the government's innovative actions towards project delivery and the scanty infrastructure development across the years in spite of various attempts by the government to boost infrastructure development.

CONCLUSION

The study viewed the evolution process of PPP fields within a geographical territory through the combined lens of SNM and Translation moments coupled with a spatial perspective. The identification of the translation moments helped in understanding the process which lead to an expectation becoming a reality while the quality of niche processes helped in assessing the journey of a technological niche towards becoming a market niche by attaining stability. Therefore, analysing a niche development process would help in identifying what went wrong and thus enables us to give appropriate suggestions on what could be done based on the analysis.

It was also observed that the spatial attributes of the State contributed towards the right choice of taking an innovative path to deal with PPPs, instead of attempting to replicate a PPP implementation model from elsewhere.

The study proved that SNM can be used as a research model outside the sustainable technological innovation context and thus backing up our proposition regarding its applicability to social innovations.

We also suggest that, an in-depth study into the wider spatiality aspects of the case context, in addition to 'economic geography' could add to a better comprehensive picture of the process of evolution of PPP fields in that context.

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REVISITING THE RELATIONSHIP BETWEEN CONTRACT GOVERNANCE AND CONTRACTORS' OPPORTUNISTIC BEHAVIOR IN CONSTRUCTION PROJECTS

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REVISITING THE RELATIONSHIP BETWEEN CONTRACT GOVERNANCE AND CONTRACTORS' OPPORTUNISTIC BEHAVIOR IN CONSTRUCTION PROJECTS

ABSTRACT

Contracts act as a major tool in curbing opportunism, which is common phenomenon in construction projects. Based on Transaction Cost Economics (TCE), this research differentiates contractual mechanisms of obligatoriness, monitoring and coordination, and studies the relationship between complexity of above functions and different types of opportunistic behavior, using goodwill trust as a mediator to explain the above relationships. This research proposes that the complexity of contractual obligatoriness has negative effect on strong form opportunistic behavior, and the complexity of contractual monitoring and coordination have positive and negative effect on weak form opportunistic behavior respectively. Furthermore, goodwill trust acts as a mediator in explaining both contractual monitoring and coordination's effect on weak form opportunistic behavior. These nuanced propositions speak to the debate surrounding the relationship between contractual complexity and opportunistic behavior, elaborate the mediation mechanism, and provide insights into the contractual function view. In practical, this research provides advice for contract design in dealing with opportunism in construction projects.

KEYWORDS

Contract governance, contractual complexity, opportunistic behavior, goodwill trust

INTRODUCTION

Opportunism in construction projects that can result in disruptions and conflicts (Cheung and Yiu, 2006) is viewed as a barrier to project success (Boukendour, 2007). Contracts, using control and coordination mechanisms typically (e.g. Dekker, 2004; Mellewigt et al., 2007), serve as the main instrument for dealing with opportunistic behavior. How contract framing impacts exchange outcomes, especially opportunistic behavior, has gained considerable research attention (e.g. Cavusgil et al., 2004; John, 1984; Liu et al., 2009). However, consistent findings are far from being reached.

Some empirical studies have found that, by making the exchange contractually explicit and specifying precise behavioral boundaries before the exchange, the detailed contract is viewed as the major instrument that protects specific investments from opportunistic behavior (e.g. Parkhe, 1993; Dahlstrom and Nygaard, 1999; Liu et al., 2009). However, there are also empirical studies confirming that contractual governance has no significant effect on opportunism (Cavusgil et al., 2004). Besides, another point of view has suggested that perceptions of increased formalization and controls, like rule enforcement and surveillance, may lead to an erosion of positive attitudes and consequently to more opportunism (Ghoshal and Moran, 1996; John, 1984).

One possible reason for the inconsistent findings lies in how existing studies conceptualize the constructs. In this study, endeavors are made to investigate the above issue in a more nuanced manner by specifying different aspects and their properties of both contracts and opportunism. For opportunism, Luo's (2006) conceptual study has addressed the dimensions of strong and weak forms of opportunism, and empirical studies have strengthened the necessity of subtle research (Lumineau and Quelin, 2012; Luo et al., 2015). It is interesting and important to investigate the different effects of governance mechanisms in restraining each form of opportunistic behavior in construction projects.

On the other hand, contracts may show different features in different dimensions and previous studies may just focus on a certain aspect of contract but draw a conclusion at the overall level. Taking a step further, although some scholars analyze contractual mechanisms like control and coordination to describe the role of contracts (Lumineau and Quelin, 2012), this research argues that contractual control itself may have different effects (Heide et al., 2007) when it comes to contractors' opportunistic behavior in construction projects. Inspired by the management control literature which distinguishes between the different properties of behavior-based control and outcome-based control and receives fruitful research insights (Bai et al., 2016; Jensen and Meckling, 1992), we argue that contractual control has two different mechanisms, namely obligatoriness and monitoring, that may exert different effects on contractors' opportunism. Adding contractual coordination, the design features of construction contracts are thus examined from three aspects in this research. Contractual complexity that is widely used by contract scholars to represent the degree of detail of a contract (e.g. Barthélemy and Quelin, 2006; Reuer and Ariño, 2007; Ding et al., 2013) is employed in this research to depict the contract design features.

This research uses goodwill trust as an underlying mechanism to explain the relationship between contractual monitoring and coordination and contractor's opportunism. Trust has been confirmed as an important management tool in dealing with opportunistic behavior (Ali and Larimo, 2016; Liu et al., 2009). The complementary or substitutive relationship regarding contract and trust has received extensive research as well (Cao and Lumineau, 2015). Therefore, trust may have the potential of a mediation effect in explaining the interplay between contractual governance and opportunistic behavior, especially goodwill trust, which regards the attention of another party to behave in a trustworthy manner (Malhotra and Lumineau, 2011).

To sum up, there exist incongruent findings in previous studies, and the effects of contractual complexity on opportunistic behavior require more detailed studies. Therefore, this paper aims to fill the aforementioned gaps and address the following research question concerning construction projects:

How do the different contractual mechanisms influence the occurrence of different types of opportunistic behavior?

Taking a nuanced, functional view of contractual complexity, this research firstly elaborates the role of contracts and cross validates insights from different studies. This research also addresses the mechanism of goodwill trust regarding the interplay between contractual governance and contractors' opportunistic behavior. By analyzing the motivation and capability of implementing opportunistic behavior,

direct effects and mediation paths are elucidated, which offers a fine-grained explanation of determinants of such behavior.

THEORETICAL BACKGROUND

OPPORTUNISTIC BEHAVIOR

Defined as “self-interest seeking with guile”, opportunism is a central concept in the study of transaction cost and is especially important for economic activities that involve asset specificity (Williamson, 1985). Previous conceptualization like “lying, stealing, cheating, and calculated efforts to mislead, distort, disguise, obfuscate, or otherwise confuse” (Williamson, 1985) has been described as blatant opportunism. In contrast, the term “lawful opportunism” is used to define deceitful behavior that doesn’t pertain to the formal contract (Wathne and Heide, 2000). Similarly, Luo (2006) differentiates weak form opportunism from strong form. In this research, contractors’ opportunistic behavior is defined as “behaviors aimed at pursuing self-interest with deceit to achieve gains at the expense of the owner by withdrawing promises, shirking obligations, and breaching explicit or implicit agreements” (Das and Rahman, 2010; Lu et al., 2016; Luo, 2006), and it is viewed as a two-aspect construct. Strong form opportunistic behavior includes actions that violate contractual norms (terms, clauses, and conditions) that are explicitly codified in the main body of a contract as well as in its supplements (Luo, 2006), whereas weak form opportunistic behavior involves behaviors that violate relational norms not spelled out in a contract but embedded in the common understanding of both parties (Luo et al., 2015).

With high complexity and asset specificity, construction projects are minefields for opportunistic behavior (Pang et al., 2015). Due to information asymmetry, behaviors like underbidding or lying are common in construction projects (Wang et al., 2007), making adverse selection a serious problem. This research focuses on contractors’ ex-post opportunistic behavior, namely moral hazard problems like withholding or distorting information, shirking obligations, and renegeing on explicit or implicit commitments during the contract period. Moreover, contractors may make use of uncertainty and owners’ vulnerability to delay or even strike to receive a compromise from the owner, causing hold-up problems (Chang and Ive, 2007). It is also common to find contractors making use of the loopholes in the contract to raise claims and recoup loss due to excessive risk-taking (Pang et al., 2015). Unclear work scope, insufficient details or missing items all lead to opportunism (Pang et al., 2015), especially weak form opportunism that cheats at the margins. Thus, it is imperative for project owners to establish effective governance mechanisms to safeguard from contractors’ opportunistic behavior and reduce ex-post transaction costs.

CONTRACTUAL COMPLEXITY AND THE DIMENSIONS

Contracts are the prominent governance mechanism to safeguard against opportunism and minimize the transaction cost (Williamson, 1985). A more complex contract would offer better guidelines for solving ex-post problems (Reuer and Arino, 2007), and the complexity of contracts has long been studied (e.g. Barthélemy and Quélin, 2006; Ding et al., 2013; Reuer and Arino, 2007; Wuyts and Geyskens, 2005). In this research, contractual complexity is employed to describe the level of detail of provisions or related documents included in a project contract.

Contracts are designed to mitigate inter-organizational risks like relational risks, which refer to the possibility that partners do not act cooperatively owing to misaligned interests, and performance risks, which refer to the possibility that the objective of the transaction could still be under-realized even with full cooperation (Das and Teng, 2001). In the presence of opportunism or relational risks, transaction parties have to elaborate contracts to monitor behaviors, safeguard assets, and ensure that both parties fulfill their responsibilities. In particular, empirical research on TCE emphasizes the control function of contracts in safeguarding against opportunism (Benaroch et al., 2016; Schepker et al., 2014). However, researchers have a broader view of contracts and extend the function of contracts to coordination (Woolthuis et al., 2005; Mellewigt et al. 2007; Reuer and Ariño 2007) in dealing with performance risks. In this research, we argue that contractual coordination also has the potential of dealing with some kinds of relational risk.

Formal control features control mechanisms like ex-ante detailed contract drafting (Wuyts and Geyskens, 2005) and ex-post monitoring (Kashyap et al., 2012). And inspired by viewpoint of management control (Bai et al., 2016; Dekker, 2004) and Jensen and Meckling's (1992) control system, this research treats contractual control as a construct with two aspects, including contractual obligatoriness and contractual monitoring. Contractual obligatoriness describes the extent to which the contract party is restrained by the binding force of the contract (Luo, 2006), while contractual monitoring is defined as "the extent to which the owner's rights to observe its contractors are codified in the contract" (Kashyap and Murtha, 2016; Reuer and Ariño 2007). In addition, contractual coordination is used to define the level of detail of the contract terms incorporated to align the expectations of transacting parties, avoid "honest mistakes", and minimize inefficiencies (Mayer and Argyres, 2004).

GOODWILL TRUST

Trust is an informal governance device and researchers have argued that inter-organizational trust plays an important role in managing inter-organizational relationship (Shen et al., 2017), understanding the behavior of different parties, and facilitating cooperation (Das and Teng, 2001; Lui and Ngo, 2004).

Ability, benevolence, and integrity are thought to be main antecedents of trust (Mayer et al., 1995). Goodwill trust and competence trust are differentiated to deal with relational risks and performance risks respectively (Das and Teng, 2001; Lui and Ngo, 2004). Goodwill trust is the degree of one's goodwill and reliability in a risky exchange situation, based on benevolence, good faith, and caring about another party's welfare (Das and Teng, 2001; Nooteboom, 1996). Competence trust concerns the ability to behave or perform as expected, based on the various resources and capabilities of a firm (Das and Teng, 2001, Malhotra and Lumineau, 2011). Since opportunistic behavior is a construct related to deceitful or dishonest actions, this research focuses on mutual goodwill trust which regards the intention of another party to behave in a trustworthy manner (Malhotra and Lumineau, 2011). Goodwill, or benevolence suggests the specific attachment between the transaction parties, focusing on the perception of a positive orientation of the partner. Interactions between the transaction parties during the contracting process allow the parties to gain insights about the partner's goodwill. So, this research focuses on goodwill trust, because the relative impact of benevolence facet will grow (Mayer et al., 1995).

CONCEPTUAL FRAMEWORK

Lusch and Brown (1996) suggest that contracts will undoubtedly influence behavior. A party's opportunistic behavior results from both its motivation to do so and its capability of doing so without being detected and sanctioned (Dong et al., 2015). Nooteboom (1996) mentioned three ways to mitigate rational risks. Firstly, monitoring to detect cheating and sanctions as a measure of enforcement are essential to restrict chances for opportunism. Secondly, incentive control is necessary to limit incentives to utilize opportunities for opportunism. Moreover, benevolence based on established social norms can limit inclinations towards opportunism (Wolthuis et al., 2005). Combined with the view of contractual functions mentioned above, the conceptual framework and propositions are developed in this section.

CONTRACTUAL COMPLEXITY AND CONTRACTORS' OPPORTUNISTIC BEHAVIOR

The traditional TCE-based 'safeguarding' function is the very accepted motivation for writing contracts (Williamson, 1985). Complex obligatoriness clauses offer a way to safeguard against opportunistic behavior. Firstly, contracts define the parties' obligations in black and white, specify acceptable behaviors and unacceptable behaviors (Lui and Ngo, 2004) and set the boundaries for the judgment of opportunistic behavior (Kashyap and Murtha, 2016). Secondly, contracts play an obligatory role in coping with appropriation concerns by providing incentives or clear sanctions in case of breach of contract, like penalties or liquidated damages for delay (Woolthuis et al., 2005).

In these ways, contractual obligatoriness, or the threat of legal enforcement reduces the capability of contractors to deviate from obligations codified in the formal contract (Lumineau and Quelin, 2012). What's more, contractual obligatoriness changes the pay-off structure by increasing the cost of self-interest activities (Parkhe, 1993). When faced with opportunities of self-interest seeking, which might end up with serious consequences and loss, contractors may choose to abide by the contract after a cost-benefit analysis.

Thus, strong form opportunistic behavior, which breaches the contractual norms (terms, clauses and conditions), can be effectively curbed by detailed contract drafting in terms of obligatoriness function (Lu et al., 2016). Thus, Proposition 1 is advanced:

Proposition 1: The complexity of contractual obligatoriness is negatively associated with contractors' strong form opportunistic behavior.

Previous studies have suggested that incentives and penalties, as well as pricing and monitoring clauses like programme and quality control should be included in contracts to restrict opportunism (Barthélemy and Quélin, 2006). As the complexity of contractual monitoring increases, things related to observation and recording of performance become more convenient and transparent (Jensen and Meckling, 1992), narrowing the range around which contractors can seek self-interest with guile (Wathn and Heide, 2000). Since the motivation for opportunism still exists, contractors may be encouraged to cut corners in spaces that are left unspecified within the contracts, without being observed or sanctioned. As Ghoshal and Moran (1996) put it, "when the balloon of opportunistic behavior is poked in one place by the blunt instrument of control, it readily yields but re-emerges elsewhere in ways that

may make it more difficult and costly to detect and curtail”. If the deviation behaviors would bring benefits without punishment, then the partner may seek self-interest in this less blatant way (Liu et al., 2014). Restricting the contractors’ capability of performing opportunistic behavior explicitly, detailed contractual monitoring would divert opportunistic actions away from actions codified in the written contract and increase the frequency of weak form opportunistic behavior. Thus, the following proposition is developed:

Proposition 2: The complexity of contractual monitoring is positively associated with contractors’ weak form opportunistic behavior.

Contracts may also act as ‘knowledge repositories’ (Mayer and Argyres, 2004) which facilitate coordination and may reduce the occurrence of weak form opportunistic behavior. Firstly, coordination clauses specify task assignments in greater detail, which reduces role ambiguity and cuts down the contractor’s leeway to undertake opportunistic actions (Argyres et al., 2007). Similarly, contractual coordination helps to specify how parties should behave over time, curtailing adaptation problems and leaving little room for opportunistic interpretation. However, compared to control functions, provisions referring to coordination function are less externally enforceable, leaving little effect on strong form opportunistic behavior.

Secondly, researchers have pointed out that the curbing effect of contracts on opportunistic behavior is enhanced through detailed mutual contacts between the contract parties (Wuyts and Geyskens, 2005). If a communication framework and the interface of activities are clearly codified in the contract, the information exchange is enhanced and the transparency of the relationship is increased (Srinivasan and Brush, 2006). Thus, information asymmetry is reduced, restricting contractors’ capability of implementing opportunistic behavior (Ali and Larimo, 2016). Therefore, Proposition 3 is developed:

Proposition 3: The complexity of contractual coordination is negatively associated with contractors’ weak form opportunistic behavior.

THE MEDIATION EFFECT OF GOODWILL TRUST

Scholars assert that goodwill trust, as an important kind of social governance, reduces the perceived level of relational risk and the occurrence of opportunistic behavior (Das and Teng, 2001; Nootboom, 1996), which in turn contributes to project success. Empirical studies have supported the negative relationship between goodwill trust and opportunism (Ali and Larimo, 2016; Liu et al., 2009; Lu et al., 2015).

Formal control and trust have been deemed as important governance tools for inter-organizational relationships and their interactions have long been discussed. In the owner-contractor relationship, monitoring enhances the owner’s ability to detect the contractors’ opportunistic behavior (Heide et al., 2007). However, close monitoring may communicate a signal of distrust to the contractor, who is monitored by the owner through clauses regarding project quality or schedule. This type of surveillance-oriented governance mechanism may throw parties’ goodwill into doubt (Das and Teng, 2001; Ghoshal and Moran, 1996) and may further erode the process of goodwill trust development (Malhotra and Lumineau, 2011). This will stimulate the contractors’ sense of reactance for this obtrusive form of control (John, 1984;

Kashyap et al., 2012) and promote inappropriate actions, especially actions that cannot be specified within contracts (Wuyts and Geyskens, 2005).

Therefore, it is through reduced goodwill trust that the motivation for implementing weak form opportunistic behavior is increased. Thus, the following proposition is developed:

Proposition 4: Goodwill trust mediates the relationship between the complexity of contractual monitoring and contractors' weak form opportunistic behavior.

Unlike contractual control, which focuses on the negative facets of the relationship, contractual coordination acts as a 'meeting of the minds', and provides guidance on the positive sides, like common goals and ways to achieve it (Woolthuis et al., 2005). Contractual coordination contributes to the development of goodwill trust. Firstly, because of bounded rationality, contract parties don't plan for all potential problems initially, but set the rules of the game in detail by establishing norms and procedures to coordinate on how to conduct the project. Increased working details act as a kind of blueprint and reflect both parties' effort in elaborating on the contract, sending a signal about their preparation and intention to be loyal partners (Carson et al., 2006; Woolthuis et al., 2005) to cooperate efficiently and complete the project smoothly (Mayer and Argyres, 2004; Yang et al., 2012).

Meanwhile, by creating channels through which disagreements will be solved, coordination provisions help mitigate misunderstandings and enhance mutual goodwill trust (Malhotra and Lumineau, 2011). Common expectations and goal congruence helps to curb motivation for behaving opportunistically (Dahlstrom and Nygaard 1999), especially for actions that are unobservable or not verifiable by a third party (Lumineau and Quelin, 2012; Srinivasan and Brush, 2006).

Researchers have pointed out that the contract framing may psychologically affect how parties behave in a relationship. Therefore, there is a mediation path as proposed below:

Proposition 5: Goodwill trust mediates the relationship between the complexity of contractual coordination and contractors' weak form opportunistic behavior.

The overall framework of this research is presented in Fig. 1.

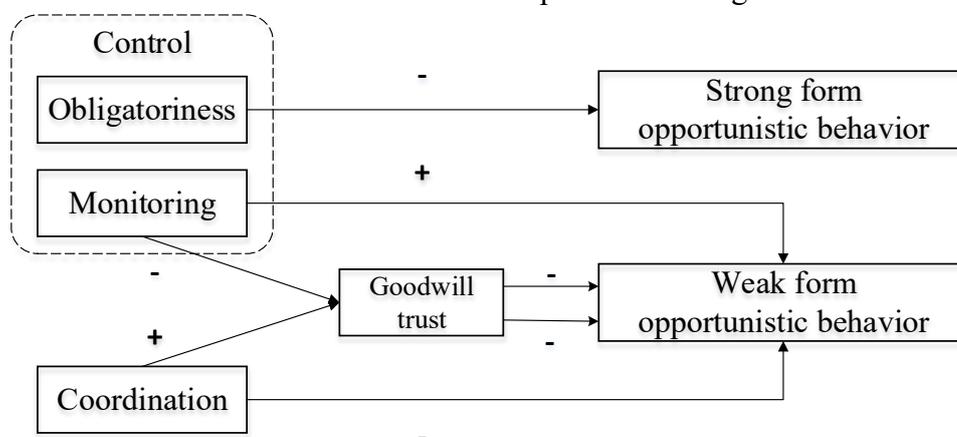


Fig. 1 Research Framework

BRIEF RESEARCH METHODOLOGY AND APPROACH

The research method is questionnaire-based survey, because this technic is particularly suitable for measuring behavior-related or perceptual variables such as opportunistic behavior and goodwill trust, as well as some control variables including expectation of continuity and prior collaboration. As for measuring contractual complexity, the authors find current measures in the literature that can be employed to objectively judge the contractual design features are not suitable for construction contracts, which are usually much more complex compared with contracts in other industries, such as information service contracts and general supply contracts. Therefore, pervasive measures cannot show enough variance of contractual complexity among different construction contracts (Chen et al., 2018). Instead, this research uses survey instruments to measure the complexity of construction contracts, benefiting from the richness of language to capture the special and broad meaning of contractual complexity in construction projects.

The unit of analysis is project or contract (one project corresponds to one contract). Data is going to be collected from contract managers working for Chinese construction companies. The main constructs are to be measured using reflective multi-item Likert scales. The scales are developed from previous research. Control variables include expectations of continuity, prior collaboration, contract price, and contract type. Once the data collection work is finished, hierarchical linear regression will be adopted to analyze the data and test the proposition. For the mediation propositions (proposition 4 and 5) specifically, Sobel test based on bootstrapping will also be used to complement the hierarchical linear regression according to Hayes (2009).

IMPLICATIONS

This research is supposed to contribute to the literature in the following ways. Firstly, differentiating effects of distinct contractual functions on different opportunistic behaviors, this research responds to previous works (Lumineau and Quélin, 2012) and speaks to the debate regarding the contract-opportunism relationship. Together with the direct effect, the explanatory mechanism of goodwill trust is verified as the indirect effect. Secondly, taking a nuanced functional view of contractual complexity, this research responds to previous studies by taking a closer look at why specific provisions are included in contracts (Woolthuis et al., 2005). Combining the view of contractual functions with management control, this research also provides new insights into contractual governance in construction projects.

This research would also have managerial implications. Firstly, it can provide guidance for contract designing. Conventional wisdom posits that managers should design more explicit contracts to curb both parties' opportunistic behavior. However, this research would indicate that construction companies should be cautious in using different contractual functions. Secondly, the model of this research suggests that contract managers should keep a weather eye on practical behaviors or conflicts derived from opportunism and employ pointed mechanism. With regard to mitigating contractors' weak form opportunistic behavior, which takes place more frequently according to the statistical data, relational governance like trust is more preferable. Coordination efforts or shared norms should be developed and enhanced through contracts or somehow else in dealing with this type of opportunistic behavior, which is less observable but more durable.

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RETHINKING ROLES AND RESPONSIBILITIES IN THE CONTEXT OF THE PUBLIC PRIVATE VALUE SHIFT FROM A CLIENT PERSPECTIVE

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RETHINKING ROLES AND RESPONSIBILITIES IN THE CONTEXT OF THE PUBLIC PRIVATE VALUE SHIFT FROM A CLIENT PERSPECTIVE

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ABSTRACT

In today's construction industry we witness an increase in public private collaboration in the delivery of public goods. New public private structures affect the traditional notion of accountability, bringing along a strong emphasis on performance and outcome. By transferring operational responsibility to the market parties in public private collaboration, there are fewer possibilities to directly influence the outcomes of these processes. Socio-political responsibilities, however, remain with public parties, requiring other kinds of safeguarding mechanisms to come into play. In this paper we aim to explore how public construction clients try to find a balance in public value management activities by rethinking their roles and responsibilities in the context of an increasing value and volume of integrated service deliveries in construction. We present results of a set of semi-structured interviews with different actors playing a part in commissioning of organisations with different degrees of publicness. The results indicate that the alignment of the client role and change in responsibilities should be rather flexible in order to balance the potentially conflicting procedural obligations as a public organisation and creating room to steer on increasingly important values of sustainability, innovation and quality. It was shown that public agents need to adopt a more facilitating and frame-setting role and build sustainable relationships based on trust. And although they are dependent of private market parties to achieve certain new 'values', their position as public client organisations actually enables them to take a forerunners' role. In order to facilitate the desired value shift roles and responsibilities need to be aligned with steering mechanisms. Further research could look more closely into the alignment of the role and responsibility change and organisational- and steering mechanisms that are flexible enough to deal with the restrictions that lawfulness brings along.

KEYWORDS

Public value management, public private collaboration, value shift, construction client, socio-political responsibility

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INTRODUCTION

Similar to other industries, a trend of cutbacks and a changing role of public administration currently shows its impact on the construction industry climate (Clifton & Duffield, 2006; van der Steen, van Twist, Chin-A-Fat, & Kwakkelstein, 2013). Both for financial, strategic and societal reasons there appears to be a growing pressure on the public sector, leading to a growing dependence of public organisations on private market parties to come up with innovative solutions to societal challenges, such as growth of the population and cities (Cornforth, 2003; Kuitert, Volker, & Hermans, 2017). Public construction clients are expected to contribute to innovation and improvement of the building sector (Boyd & Chinyio, 2008) and to ensure public value in various forms, for example by stimulating social innovation, providing safety and the protection of weaker populations (Boyne, 2003). They are, for example, more and more involved in reducing building-based emissions of harmful substance, asking for innovative solutions with higher risk profiles as a result of higher levels of uncertainty. Consequently we witness an increase in public private collaborations in the delivery of public goods (products, services, financing) with which public values are created (Benington, 2011; Eversdijk, 2013). This gets expressed in two ways (Cornforth, 2003). First, the development of an increasing number of devolved or quasi-autonomous government agencies like the Highway agencies to deliver public services (Cornforth, 2003). And second, the introduction of market mechanisms into the provision of public services through splitting the ‘purchasers’ of services from the ‘providers’ and introducing elements of competition through contracting out of services to (a mix) of private companies and voluntary organizations (Cornforth, 2003). Consequently public organizations increasingly depend on private market parties to carry out public purposes. And in the project-based construction industry various constellations of public and private market parties as public service delivery organizations are shaped for the performance of project tasks; these can either be entire firms, multi-firm consortiums or networks (Holti, 2011; Sydow, Lindkvist, & DeFillippi, 2004).

In the increasingly complex, collaborative and interdependent context of delivering public goods serious concerns have been raised both about the democratic legitimacy of governing boards and their effectiveness (Comfort, 2003). According to Comfort (2003) these concerns, however, often oversimplify the problems, passing on the seriousness of conflicting accountability expectations of different involved stakeholders and the pressure these conflicts put on for example board members (Willems & Van Dooren, 2011). In the discussion of safeguarding public values it needs to be clear which values should be secured. This needs to relate to the one to account to. The ‘degree of publicness’ to a great extent determines the expected contribution to the political or public mandate. Since public clients are both politically and socially responsible for value standards in the living environment they have different actors to account to, making acting responsible extremely complex today. Governments are being called to account by many account-holders in different public forums, including the public interest, statutory and constitutional law, the media, professional standards, community values and standards, democratic norms, and of course, citizens (Denhardt & Denhardt, 2000; Willems & Van Dooren, 2011).

Another positive experiences with public private collaborations in ensuring public services, is one where one specifically invests in stakeholder management while operating the project. In this context Verweij (2015) concludes that DBFM contracting is aimed at reducing the burden on governmental bodies in which case, public parties can be excellent intermediaries between the contractor and the local stakeholders.

Especially in recent years we see a growing percentage of integrated contracts in the construction industry, where public parties subcontract (outsources) at least a part of its responsibilities in respect to the built environment (Boyd & Chinyio, 2008). Although Public Private Partnerships are most of the time formed around common project goals of private and public parties, there are different public and private interests involved (Lundin et al., 2015). Proponents of public private partnering emphasize the ability of private market parties to deliver services more efficiently, where opponents complain about the reduction of ‘governments’ ability to adapt to changing needs’ due to the long-term contracts (Ross & Yan, 2015). In the UK public private collaborations are for example used for school development, mainly in the form of DBFM. In line with the UK government’s drive to pursue a knowledge-based economy, the ‘Building Schools for the Future’ (BSF) was launched in 2003 as a long-term programme of investment and change in England (Aritua, Smith, & Athiyo, 2008; Liu & Wilkinson, 2014). Unfortunately difficulties in BSF arise from not sorting out strategic issues and instituting appropriate organisational frameworks before engaging the private sector. Resulting in a lack of clarity about the long-term needs and end user aspirations (Aritua et al., 2008; Liu & Wilkinson, 2014).

Transferring operational responsibility by commissioning (part of) the tasks to the contractor in public private collaboration, there are fewer possibilities for the client to directly influence the outcomes of these processes (Eversdijk, 2013; van der Steen et al., 2013). Traditionally, public parties are aimed at ‘good governance’, focussing on procedural values such as non-discrimination, transparency and integrity (de Graaf & Paanakker, 2014). Private parties generally focus on delivering high product values, such as quality and innovation, and exploitation of the performance values of effectiveness and efficiency (Jørgensen & Bozeman, 2007; Smets, Jarzabkowski, Burke, & Spee, 2014; Too & Weaver, 2014). New public private structures affect the traditional notion of accountability, bringing along a strong emphasis on performance and outcome (Boyd & Chinyio, 2008). Hence, socio-political responsibilities for value standards in the built environment always remain with public parties, requiring other kinds of safeguarding mechanisms to come into play (Boyne, 2003; de Bruijn & Dicke, 2006; Moulton, 2009). So in today’s built environment with its complex tasks, a dynamic environment, the role of public clients in the process of delivery of public goods becomes more directive and facilitating (Boyd & Chinyio, 2008). This caused a value shift at public commissioning organisations, from a focus at procedural values, such as lawfulness and integrity, to steering on performance and product values, such as innovation, sustainability and quality of the public good. As the boundary- setting agent in the collaborative context of delivering public services in construction and

they need to find the right balance in their procedural obligations as a public organisation in ‘creating room’ to enable a shift in focus towards the increasingly important product and performance values in delivery of public goods in order to facilitate the value shift. .

Recent studies have shown that this shift is not yet fully embedded in the sector and asks for a more open, transparent and sustainable client-contractor relationship (Kuitert et al., 2017). This paper addresses the search of public client organisations in rethinking values, roles and responsibilities in the context of an increasing value and volume of integrated service deliveries in construction. In this paper the following question is addressed: What are the perceptions of public clients on values, roles and responsibilities in the context of the value shift in public private collaborations in construction? We start with a theoretical elaboration on public sector value thinking and public value management for public construction clients discussing different ingredients of public action that need to be balanced. Then the research approach of the interview series is explained, in order to present how public construction clients are looking for ways to facilitate the value shift and its impact on changing roles and responsibilities in the client-contractor relationship. In the conclusions and discussion we discuss the desired future commissioning profession and the difficulties in achieving the associated roles and responsibilities, and provide some directions for further research.

THEORETICAL BACKGROUND

PUBLIC VALUE THINKING – A SHORT HISTORY OF GOVERNANCE REFORM IN THE CONSTRUCTION INDUSTRY

The move towards Public Private Partnerships shows significant similarities with the public value thinking paradigm of Public Value Management (Benington, 2011; Coule & Patmore, 2013; van der Steen et al., 2013). Classifying which public values to pursue at what moment, in which situation or by what type of service delivery has become increasingly important in public governance in the past decades. Governance is about the use of institutions, structures of authority and collaboration to allocate resources and coordinate or control activity in society or the economy (Klakegg, 2009). It influences which values need to be ensured and safeguarded by public actors of public commissioning agencies and the possibilities these actors have in their commissioning role in this respect. Public value management literature describes management paradigms prioritizing certain values above others, choosing one or multiple logics, or combining specific values belonging to community and market logics (Smets et al., 2014). In the public sphere this gets (partly) reflected by successive time periods of prevailing governance models, in an ongoing governance reform. Traditional public management with an emphasis on policy laws and regulations came up as a response to the challenges of industrialization, urbanization, the rise of the modern corporation, faith in science, belief in progress, and concern over major market failures. Next, concerns with government failures, a belief in the

efficacy and efficiency of markets, a belief in economic rationality, and a push away from large, centralized government agencies toward devolution and privatization, introduced the New Public Management paradigm (Bryson, Crosby, & Bloomberg, 2014; Casey, 2014; Coule & Patmore, 2013).

A new emphasis on public value followed as a response to the fragmentation, structural devolution, single-purpose organisations, and performance management, caused by New Public Management (Bryson et al., 2014; Christensen & Læg Reid, 2007). The post-NPM reforms focuses more on building a strong and unified sense of values, trust, value-based management, and collaboration. Team building, involving participating organisations and improving the training and self- development of public servants has an important place in this paradigm (Christensen & Læg Reid, 2007). The government combines market and community logics in this collaborative Public Value Management (or New Public Governance Paradigm) paradigm (Casey, 2014; Coule & Patmore, 2013; van der Steen et al., 2013). One mechanism of this reform has been partnering between the public and private sector, often referred to as public private partnership (PPP), to deliver services previously provided exclusively by the public sector (Agyenim-Boateng, Stafford, & Stapleton, 2017). In the construction industry a shift towards aiming steering on increasingly important product-related type of values and market logics, the basis for strategy is profit maximization, dominated by performance values of effectiveness and efficiency is visible (Kuitert et al., 2017). This means a movement away from the focus on community logic, in which relations of affect, loyalty, common values and personal concern are pursued , which is dominated by procedural values that indicate the quality of the process using integrity, and associated values such as transparency, equality, lawfulness, and honesty (de Graaf & Paanakker, 2014; Smets et al., 2014). These hybrid PPP organisations are no longer under direct control of current governments (Stafford & Stapleton, 2017).

PUBLIC VALUE MANAGEMENT IN PUBLIC COMMISSIONING

The public value approach emphasises that the public domain is not just about money, but should also be concerned with requirements of the process and, next to the outputs, the outcomes of processes of delivery of public goods . With the withdrawal of public parties from direct delivery of public services, we see that achieving procedural values needs to be adopted in the processes of private market parties, next to their natural focus on performance and product. In recent times, however, the expectations of public parties are shifting towards performance, also meaning that democratic legitimacy is not enough, public clients should also perform (Willems & Van Dooren, 2011). This is expressed as the accountability paradox, which explains that in privatization of government operations there is a need to make trade-offs between accountability and efficiency (Hodge & Coghill, 2007; Willems & Van Dooren, 2011). Clients are continuously searching for a balance between procedural obligations and seemingly opposing ‘new’ product-related values of increasing importance (Bao, Wang, Larsen, & Morgan, 2013, Kuitert et al., 2017). A 'new

repertoire' to shape these changing relationships is required for the renewed division of roles, tasks and responsibilities between government, society and market (van der Steen et al., 2013). Also resulting in a need for innovative auditing, monitoring and evaluating mechanisms which focus specifically on the economy, effectiveness, efficiency and value for money (Willems & Van Dooren, 2011). Research has been done into different public concepts, but what none of these concepts or models gives much attention to the actual content of public values or criteria for judging public values (Bozeman, 2012). Furthermore, we know little about how public actors deal with public value conflicts (De Graaf, Huberts, & Smulders, 2014), expected when a new balance is sought and common when multiple logics are combined as in public private collaboration structures (de Graaf & van der Wal, 2008). Value conflicts influence the complexity of ensuring and safeguarding public values. Social scientists acknowledge that pressure on public organisations leads to unintentional deviant behaviour in reacting to value conflicts, instead of using set organisational processes (van der Wal, 2008). As public parties remain socio-political responsible, public parties need to find other, indirect, ways to achieve all values. Questions arise like : When private market parties are carrying most of the risk (related to the operational responsibilities), to what extent is it 'fair' to impose the achievement of certain procedural values by private parties? To what extent and in which circumstances is outsourcing possible and desirable? To what extent can private parties be held accountable for achieving public values when they are carrying the risks of the project?

Now looking at the position of commissioning bodies in the construction industry the OECD defines a construction client as “a natural or legal person for whom a structure is constructed, or alternatively the person or organisation that took the initiative of the construction” (OECD, 1997). This implies that the relationship between the client and contractor is central. We consider public commissioning as the way a public organization, in relation to its responsibilities in the built environment, shapes and implements its interaction with the supply market both externally and internally (Hermans, Volker, & Eisma, 2014). In this context we consider the strategic triangle of Moore (1995) as an important starting point, stressing the importance of finding a balance between different ingredients of public action; legitimacy, capacity and social objective (Meynhardt, 2009). Discussing the value shift, what we see in construction is increased focus on different (types) of values that are considered important in the context of shaping the interaction and collaboration with the market to achieve their social objectives. This implies that in order to facilitate the value shift, legitimacy and capacity need to be reassessed in order to rethink responsibilities and roles that fit this new situation. This is shown in Figure 1 and further deliberated on in the following sections.

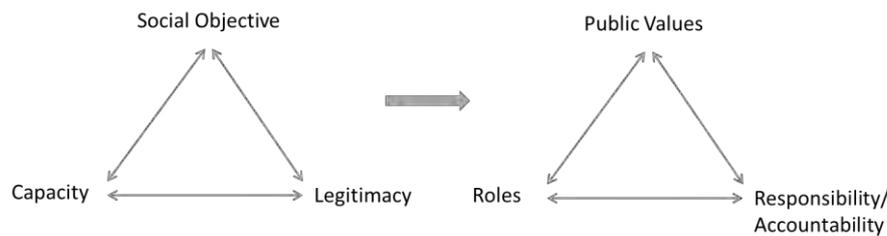


Figure 1: Three ingredients of public action in PPS

Legitimacy: responsibility division, and its influence on accountability

Due to the expansion in the use of networks of interdependent public and private parties in delivery of public goods in construction, the accountability and reliability discussion becomes more prominent (Michels & Meijer, 2008). This discussion emphasises the importance of mobilizing commitment from the 'authorising authority'; all stakeholders needed to provide legitimacy for the value proposition. In this respect one can make a distinction between an upward accountability through public sector hierarchies and processes to Parliament and a downward accountability to citizens (Shaoul, Stafford, & Stapleton, 2012). Transferring value creation tasks to a private executive party doesn't influence main responsibilities of public client organisations. Only the contractual responsibility is shared, socio-political responsibility remains with the public parties (Eversdijk, 2013). The new structures resulting from the search for innovative ways of procuring and partnerships, affect the traditional notion of accountability, and brings along a strong emphasis on performance. Emphasis is on what is expected, the way to achieve is disregarded (Bryson et al., 2014). Public parties are constrained to drawing up a set of functional requirements, providing solutions is left to the private party. Quality assurance is aimed at organizing the process, making it plausible that there is compliance with the process requirements and product requirements, or in other words the procedural values and the performance values (Jørgensen & Bozeman, 2007; Smets et al., 2014; Too & Weaver, 2014). Public accountability can be safeguarded, but only if a number of requirements have been met. The traditional, vertical, hierarchical mechanism of accountability no longer adequately fits the current social and administrative developments (Van Wart, 2013).

Where the current hierarchical presumes a principal-agent relationship, in public private partnerships clear principal and agent roles are disappearing and the typical horizontal nature of PPPs challenges this traditional notion of accountability even more explicitly (Willems & Van Dooren, 2011). Increasingly, 'leadership competencies' are being judged in terms of the ability of government, which have a special position in society, to create authority that operates successfully in horizontally dispersed power settings and is responsive to the expectations of the citizens. Public agents are supposed to be able to apply traditional hierarchical management as well as deal with informal agreements that hold networks together (Bao et al., 2013). Accountability becomes multi-faceted. In addition to the traditional, vertical, hierarchical mechanism of accountability (as in traditional Public

Administration) or more market-driven (as in New Public Management) (Bryson et al., 2014), more horizontal, informal, mechanisms of accountability should be deployed. Both mechanisms can together form a hybrid accountability arrangement (Michels & Meijer, 2008). Moreover, horizontal forms of accountability, just as vertical accountability, must meet the requirements of the democratic constitutional state, that is, transparent responsibilities, well defined interested parties, a good information supply, debate opportunities and sanctioning options (Michels and Meijer 2008). This means that public-value trade-offs need to be imitable, and decision-making should be transparent.

Capacity: enabling a changing role while remaining socio-politically responsible

The value shift and the accompanied desired change in accountability structures in the client-contractor relationship influences the role of public clients. The dependence of private parties to achieve the increasingly important product- and performance values, makes asks for changes in management of processes of delivery of public goods. The role of public clients in the process of delivering public goods becomes more directive and facilitating from a producing body to a frame-setting body, or in other words enabler and regulator (van Montfort & van Twist, 2009). Making value trade-offs, aligning operational resources to the desired outcomes, from both within and outside the organisation, and thereby providing capacity is very important (Moore, 1995). In ensuring, producing and safeguarding of public values this means a different division of responsibilities; production, distribution and supply of services became the responsibility of both public and private parties. The need for the government to steer, however, remains (de Graaf & Paanakker, 2014). Outsourcing of public tasks does not mean that the task disappears, they change. More and more the public client needs to focus on control of the executive network. In this context, public clients looks for innovative ways of procurement and partnerships. Partnering is about encouraging clients and contractors to transgress the conflicting interests that lie at the heart of their exchange relationship, by appealing to common interests centred around specific project goals and/or more strategic long term relationships. However, this presumes a level of mutual interest that is arguably unrealistic in many contracting situations, especially in short term (Bresnen & Marshall, 1999).

RESEARCH APPROACH

RESEARCH APPROACH AND SAMPLE

The main purpose of this study is to gain insight in the impact of the value shift on perception on values, roles and responsibilities of public bodies in the context of their public commissioning in construction. These values, role and responsibilities are interconnected in a way that their relation lead to certain expectations of the client-contractor relationship. Hence, and (inductive) qualitative approach was chosen to gain a profound understanding of the meaning of construction sector-specific public values and the perceptions on the roles and responsibilities of public clients in the client-contractor relationship in the context of (collaborative) delivery of public goods (Miles & Huberman, 1994). The research presented in this paper especially

concentrates on the leading, initiating, boundary-setting commissioning profession of public parties in the construction industry.

The study presented in this paper is based on 44 semi-structured interviews with 47 interviewees (due to some joint interviews) of 17 Dutch public and semi-public construction clients, using an interview guide with open-ended questions in order to discuss the sensitive topic of public values in relation to experiences in various parts of the commissioning role (Hennink & Hutter, 2011). The interviewees were chosen by expert sampling, a form of purposive sampling selecting respondents known to have certain expertise in the field, followed by snowball sampling (Hennink and Hutter, 2011). We included a wide range of public client organizations in this study in order to increase generalizability (Chi, 2016). The position of an organization on the public-private continuum, the publicness, is (partly) determined by the extent to which organizations are constrained by political control, how organizations are funded and financed, and the extent to which organizations perform public and private tasks (Besharov and Smith, 2014). The ‘degree of publicness’ to a great extent determines the expected contribution to the political or public mandate. Multiple academics elaborate on this ‘publicness’ referring to the concept of internal hybridity (Heres and Lasthuizen 2012, Jay 2013). When an organisation is more constrained or enabled by political authority, it is more public. And in line with this, an increase in constraint by economic authority increases the ‘privateness’ of the organisation (Moulton 2009). In this study we focus on the Dutch construction context, in which we can distinguish between different types public construction clients differentiating in internal hybridity. A distinction is made between organizations that are required to apply public procurement law - government and governed by the public law, - and semi-public and private organization which only have to obey to common law (Boyd and Chinyio).

We approached members of the Dutch Construction Client Forum, representing a group of large and middle sized public and semi-public clients, including the Dutch Government Building Agency, the National Highway Agency, water boards, housing associations and municipalities. Participants were approached personally, explaining the research and its relevance for the forum, and are asked to bring us in contacts of people representing different positions and decision-making levels within the organization related to public commissioning. For each participating organization the aim was to involve three to four public actors: the general manager, the director of procurement, the director of real estate and or infrastructure developments, and or the asset management or maintenance director. Table 1 shows the overview of the respondents in relations to the publicness of the organization and the position of the respondents.

Table 1: Overview of respondents

	General manager (GM)	Chief Procurement Officer (CPO)	Director of new development (DD)	Asset or maintenance manager (AM)
Public Central government (CG) 8 organizations	5	7	5	5
Hybrid Governed by law (GbL) 6 organizations	5	3	5	6
Hybrid Semi-public (SP) 3 organizations	3	2	1	

DATA COLLECTION

For each interview an interview guide was used, providing topics and some related standard questions. All interviews were conducted by the first author and each had a duration of 45 to 60 minutes. In order to discuss different aspects of the commissioning role, the interviews were divided into three parts, representing three different parts of the commissioning role. The first part referred to shaping the collaborative relationship with the supply market. The second part related to how management steered employees in ensuring values in delivery of public goods. The final part referred to the organization itself, emphasizing the way of steering on organizational values related to public commissioning, often translated into the identification of organizational goals, and whether or not the position in society - influenced by different groups of stakeholders - would be relevant in this context. Each interview started with some introductory question on the background of the interviewer and interviewee in order to ensure similar understanding of the perspective to be discussed. Accompanying the semi-structured interview guide different steps of uniting and combining value concepts from literature (e.g. Jørgensen and Bozeman, 2007; van der Wal 2008; de Graaf et al. 2013; Gann et al, 2003) were taken to develop a comprehensive, compound and inclusive list of 25 public values that could be considered of importance in public commissioning tasks, and separated in the categories of procedural, performance and product values (Kuitert et al., 2017). This list provides the theoretical basis for the interview series, and is used in the analysis of the interviews. These values were printed on value cards and used during the interviews. Using games to discuss values and norms are used is a proved method in research, for example look into the work of Gerrickens et al. (2003). To make sure that the distinction between the different values was absolutely clear to the interviewees, word clouds with interchangeable terms were included. The use of these value cards is also linked to the application of Q methodology. We applied Q-methodology to gain insight in the range of viewpoints providing a foundation for the systematic study of subjectivity, a person's viewpoint, opinion, beliefs, attitude, and thereby finding perceptions (Stephenson, 1953). In this case the cards represent the 'sample of statements' about the topic, or in other words the Q-set

(Van Exel & De Graaf, 2005). Prior to filling out the Q-sort, for the discussion on the commissioning role in shaping the relationship and steering the employees, the interviewees were asked to choose three value cards which appeal most to them when asked (a) which values they consider important, (b) which values are most likely to be traded off, (c) which values they prefer to be safeguarded, and (d) which values don't get safeguarded. The interviewee always has a possibility to add a self-made card. This choices prepared to subsequently rank order the value cards (existing + added) to the extend they are considered of interest in their commissioning role from -3 (of least interest) to +3 (of most interest). They were also requested to reflect on their ranking and indicate possible value dilemmas. To conclude interviewees had to indicate whether they expect the ranking to be the same in about ten years and to elaborate on this. In the third part of the interview we discussed the public values that are being assigned to the organization as a whole and the mutual influence with the public values discussed within the two perspectives.

DATA ANALYSIS AND VALIDATION

We adopted a systematic inductive approach to concept development as described by Gioia et al. (2013) allowing for studying social construction processes focussing on sensemaking of our respondents. We built a data structure in Atlas.ti., see figure 1 using a set of five transcripts and an additional set of another five transcripts for a second round to become familiar with the data (Altheide, 2000; Gioia et al., 2013). In the initial data coding we applied open coding as described by Strauss and Corbin (2008) , sticking to the respondents terms focussing on the means by which respondents construct and understand their commissioning experiences (Gioia et al., 2013). After reducing these first-order analysis to a manageable number of first-order concepts, axial coding was applied in order to seek for similarities and differences in a second-order analysis placing the categories in the theoretical realm (Gioia et al., 2013; Van Maanen, 1979). We then looked for overarching theoretical themes to further reduce the categories to second-order “aggregate dimensions” as added in the Gioia method (Gioia et al., 2013). Figure 1 demonstrates how we progressed from the interview transcripts, thorough sub-codes into overarching theoretically grounded themes related to the research questions.

Addressing value perceptions of public construction clients in the client-contractor relationship, we especially looked into understanding and giving meaning of sector specific public values in commissioning. Leading to the operationalisation of public values including data related to second-order concepts of the different types of public values: procedural values, performance- and product values, and additional values. In addition, an aggregate dimension was created around value interests and safeguarding of public values, containing data corresponding with the interest in different aspects of public commissioning and accompanying safeguarding mechanisms. The often reflective explanation of the interviewees led to the understanding of the shift of values as experienced by the respondent and gave a particularly good insight in the meaning and importance of the different discussed public values in the desired client-contractor relationship. To explain the impact of dynamic value interests on the perception of the public clients role in the client-contractor relationship, we included

data about both in the current situation and in the desired situation, with special attention to changing perceptions about specific collaboration and contract models. The same current and future view counts for the impact on the perceptions on the responsibilities in the client-contractor relationship, in which data is included about accountability, being a reliable partner and a sense of responsibility in relation to the publicness of client organisations. In addition another overarching aggregate dimension specifically focusses on detecting dilemma's which prove to restrict the adoption of the 'new desired' commissioning profession, making a division in first-order data about conflicts between different types of values and conflicts originating from the character of the organisation and construction sector. Completed with a second-order concept including data related to trade-offs and interventions in dealing with these conflicts. Especially the reflection on the Q-sorts gave insight in the dilemmas that clients face and increased understanding in the restrictions that certain values, mainly procedural, bring along in pursuing the desired client-contractor relationship with its distribution in roles and responsibilities. Together this led to the new interpretation of the commissioning profession, enabling the facilitation of the value shift, by alignment of the internal and external approach to commissioning. In order to also analyse differences between the client organizations, different degrees of publicness, and different decision-making levels within these client organizations, the transcripts were grouped.

To ensure reliability of the data all interviews were audiotaped and fully transcribed. Photos were taken from the filled out Q-sorts, the ranking of the value cards and the answers to the questions were included in an excel sheet and divided into these different group. This sheet was also used to validate the outcome of the analysis of the code reports, since some values might be discussed more extensively suggesting a greater importance and imposing certain ideas or thoughts. Furthermore, code reports of most of the coded transcripts were read by the second author and interpretations, also of the data structure, were compared and discussed with all authors for further validation. This resulted in a final distinction of the findings in the rethinking the client roles and a section on rethinking the client responsibilities.

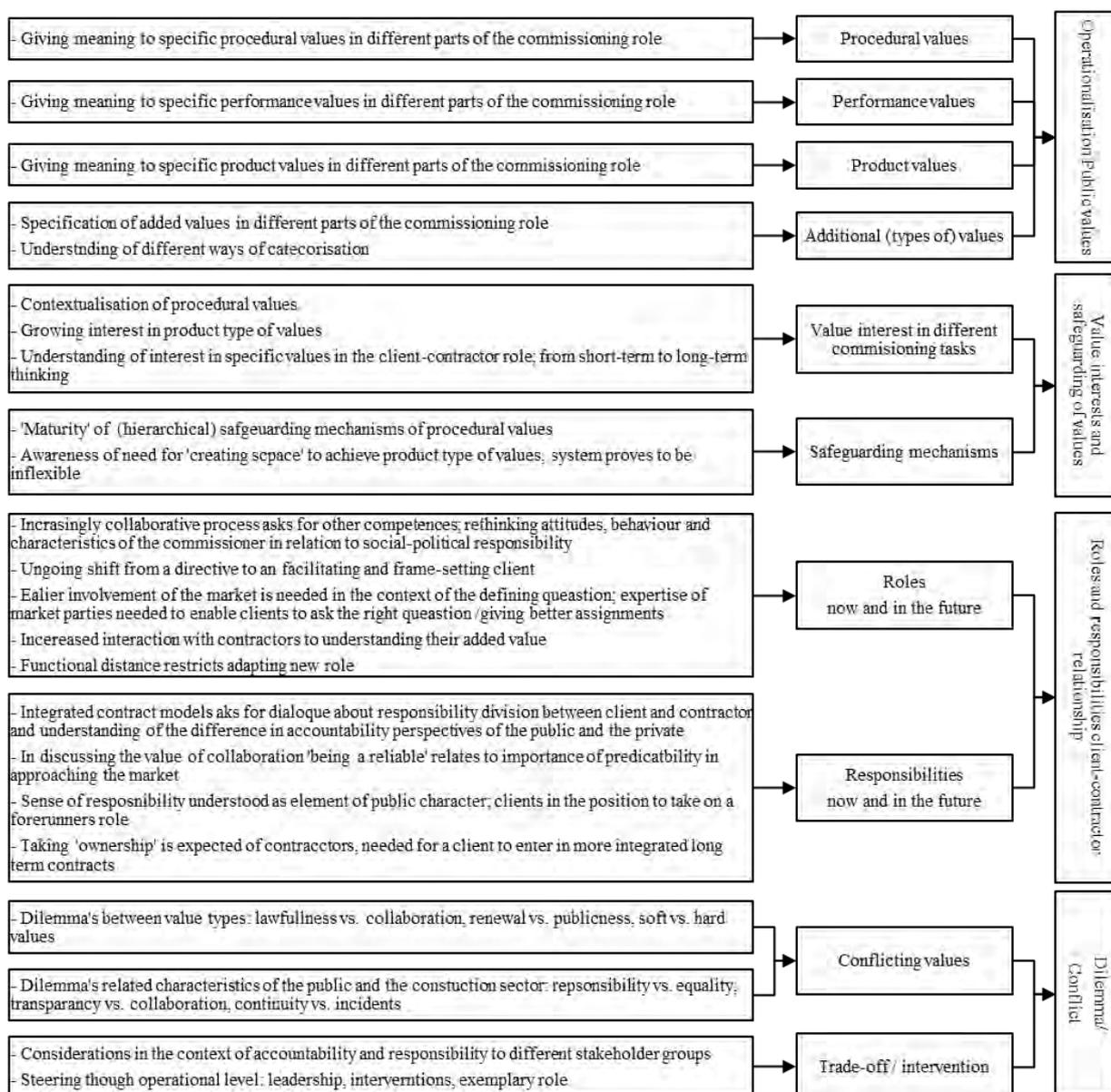


Figure 2: Data Structure

FINDINGS - A NEW INTERPRETATION OF THE COMMISSIONING PROFESSION

In general, there appears to be a strong awareness of the public task with officials of all types of public organizations. There is a general agreement on the importance of a group of procedural values strongly related to the lawfulness and the responsibilities of public client bodies represented in the values of integrity, transparency and reliability. However, results show that in the current collaborative practices of delivering public goods the procedural values of integrity, lawfulness, reliability and

equality are more and more considered as contextual. Thinking about long-term goals, linked to other values such as innovation, sustainability and quality, and long term contracts becomes more important. However, if the public character of a collaboration is leading in a certain situation, it becomes clear that ‘the system’ (e.g. procurement regulations) is inflexible, while ‘space’ (e.g. strategic partnerships) is needed to pursue increasingly important product related values such as sustainability. Hence, to facilitate the value shift, to enable clients to steer on other values than traditional procedural types of values, there is a need to rethink roles and responsibilities.

RETHINKING THE CLIENTS ROLE

We found that with the changing relationship between public client and private contractor, the public client aims to adopt a more facilitating and framework-setting role. Where the role used to be quite directive. *“You see in general, that is nice, we are now also busy with the ‘Future Agenda’ as an organisation, in which we really look at: what are the core values that we need to do something with and what kind of role do we take? In the past it was very reasonable to be very directive: we finds something, we will do that. Now it becomes much more facilitating and participatory, and sometimes initiating and sometimes an intermediary, that sort of thing.”* (DD, CG). Nowadays, there is more attention to the collaborative nature of the relationship and the resulting implications for both the approach towards the market and the interaction with contractors. Changes in playing a certain part in this collaboration are ahead, both for the client: *“We are getting a new environmental law, and that also means another role for the government. We also need to anticipate on that”* (CPO, CG), and the contractor: *“It could also strengthen each other. If we now see that market parties become more willing to take final responsibility, we are more likely to enter in longer term contacts.”* (AM, GbL). However, often the rule is not adequate for the desired behavior. Contextual changes may cause a ‘rule’ to not be sufficient anymore. For example, desired innovation may not be reached or limited because of technology that is ‘not proven’ yet and therefore may not be applied. Or because you need a certain expertise but the procedure to involve someone in the project takes longer than the actual project itself. *“Today I have to hire someone and for example, I come in with a procedure that states that it will take a month. This fits lawfully, but I have the problem and a larger risk in a project today. So the situation will be under pressure.”* (GM, CG).

The perception among clients respondents is that the clients role is about re-shifting the attitude, behavior and characteristic so one can still act according their socio-political responsibility in the changing environment. *“You see that your roles change, so your pattern of behaviour must also change.”* (DD, CG). Although the rules and regulations imply restriction the importance of acting in a compliant manner is emphasised, especially with the changing and different commissioning roles. *“ Because we have a lot of roles in our company. Sometimes we are a semi-public client, but sometimes we are also a private client. So each time we need to very well*

disassemble those roles and the compliancy regulations that there is from the perspective of that role.” (GM, SP). Often it was mentioned that the aim was to focus on trust instead of legalization of the commissioning role, which requires to approach the market in a different way, focusing on an equal level playing field instead of directive competition. Therefore clients also have to be concerned with the understandability for market parties, as public clients often are dependent of the expertise of market parties. In commissioning assignments, public clients are increasingly constraint to drawing up a set of functional requirements, and the market needs to come up with solutions. Hence, it is important to recognize the interest of the potential contractors; but also accepting their interests. *“By equality I mean that you have to recognize and recognize each other's qualities and each other's worlds and also that you have to accept that one has a different focus than the other.” (DD, CG).* The respondents thus indicated that in order to accept the perspective of the private party, it is important to understand their added value; to recognize the quality in the supply market. This also means that the level of information and expertise within the client organization needs to be sufficient, otherwise one is not able to assess this value sufficiently. Being aware, better assignments can be drawn up that are aligned with private needs and thereby enabling the public clients to use the expertise of market party to strive for the public values put in the assignments.

To deal with values involved in long-term goals, such as sustainability and innovation, it is also important to let the supply market think along in an earlier stage of the process. In particular in relation to formulation and defining, there are many unknowns. We found that the question arises how to define these ‘new’ types of values. Public clients do not seem to have many experience with this and they often need the market parties to understand these types of values.

Therefore they reach out to the market earlier to discuss the latest developments in the market. They, for example, organise market consultations, are involved with different collaborative initiatives and organise meetings with SME's in order to inform their future suppliers about possible collaborations: *“Simply by agreeing and sharing common developments, both public and private, in a client contractor relationship or in relationships to discuss general market development we increase the contact with the market.” (GM, CG).* This enables the market parties to prepare and develop in order to be able to be eligible for the future tasks. Since public parties are increasingly dependent of private market parties to achieve their goals, this is in advantage for public clients as well as it is more likely that candidates will be suitable and choices can be made with who to work, apart from only meeting the criteria. *“Yes, for example I do think that we are inadequately predictable. We do not yet succeed to make clear what we are going to put in the market the coming years. Every year it is about 100 million, we think but we cannot yet dose it. We should be able to say; well, it is totally inconvenient to put that and that on the market right now. Or talk about it with the market, or announce it, so they can prepare themselves.” (CPO, CG).* This also asks for another attitude towards the market, trusting their good intentions. Transitions in the organisation both take place at the level of the structure and processes, and the desired attitude and behaviour of employees. *“That sounds very easy, but a contract is not something you just perform. It is also really another way of*

thinking. This imposes other requirements on the organisation and the people who work there" (CPO, CG). Managing the contract, and thereby safeguarding public values as part of their socio-political responsibility, becomes aimed at managing the partnership, the client-contractor relationship. Communication not only when something content related happens, but also about how the process develops. "And the important thing is: we have appointed a coordinator for supplier management to design a kind of relationship management with the market. For example, we noticed that it works when a company calls; I haven't heard anything of tender X'. Then he says: 'Yes, but we encountered some fiscal problems here and there.' As I said process news is also news." (CPO, CG). To a large extent this also relates to managing the expectations of the different roles and responsibilities in the contract. Building these types of relationships asks for other, more soft skills, in the commissioning role. "If you observe it, than it depends especially on the collaboration, wisdom and indeed in honesty. It consists more of soft skills instead of the hard skills. It is all a part of it, completely." (CPO, SP).

However, there also is a need for a certain 'functional distance' in being a public client, making it more difficult to consult market parties. *"I am more cautious when I am in a commissioners role. So I make a distinction in general, exploration, we do not yet have a concrete object, but I want to talk to someone about developments in the construction industry, or developments of the university campus, how does he or she see my campus. These are general orientations, I think I am aloud to do that." (CPO, GbL). Therefore the alignment of the desired new approach towards the market with organisational structures, mechanisms and tools is a challenge in the often bureaucratic, traditional, slowly adapting public organisations. Missions and visions are used to embed the new way of approaching the market within the organisation and its employees: "We have mentioned a couple of values, for example being in charge, but also showing guts to develop things, integration is related to that, and having fun in your job. These are a couple of values of which we say drive the organisation forward" (AM, GbL). In approaching today's complex tasks it is important to solve the problem together and not to revert to old ways of strict contractual divisions of responsibilities. The strict approach of the distinction between the client and contractor, the idea that you pay and you will get the product is not sufficient anymore. Competences are needed from both 'sides', there is a certain interdependence of each other, a need to cooperate to come to the best solution. "Sometimes, we do have the tendency to see the market as the other side of the spectrum. We decide and when we pay we get something in return. I think it is important not to see the market as the other side of the spectrum, but that you actually search together for solutions in the middle. i.e. we have to draw upon our knowledge and skills, but we also have to trust that the others are not solely keen on the least effort for the largest part of the money." (GM, SP).*

RETHINKING THE CLIENTS RESPONSIBILITIES

In the process of changing the relationship between client and contractor through adapting the role, public client gets confronted with their public character and

corresponding accountholders. Public clients are expected to both answer to the expectation of society and the market; both regarding their role and responsibilities in collaboration with the market. This all related to reliability. Whereas the public body is socio-politically responsible, the market must be financially accountable. However together they aim for ‘Best for project’. *“And there is something of responsibility, but what I would try to see in that is the collective responsibility. I do not know if you summarize it under collegiality or something, but I do not really. Because I do not mean fraternally, but you do want to create an atmosphere of shared responsibility. The best for project. We do this.” (GM, CG).*

In the context of this reliability and accountability, it is important to think about risk allocation and distribution. The public client needs trust in their contractors since they will remain ultimately responsible for achieving public values. Public clients are increasingly concerned with ensuring that the private party shows ownership. Coming from a situation in which the public client prescribed everything and now aiming to use the broader knowledge one looks for ownership on the market side. *“A part of the emancipation of our own role, the directive role we also have and mostly developing ownership with our colleagues. That really depends on attitude and behavior: which role do you take, do you dare to make a difference, do you dare to really take the directive role with the corresponding uncertainties?” (GM, CG).* Both public and private agents need to take on more responsibility and take the risk of longer term contracts.

Since public clients are well aware of their dependence of market parties the decision about outsourcing or in house delivery is part of their accountability. This is also underlined by the current developments in the construction sector, such as the collaborative ‘Building Agenda’ which emphasises risk sharing between client and contractor. *“Because I also put in the Bouwagenda: innovation means taking risks with each other.” (CPO, CG).* To remain responsible there is a need to meet the procedural obligations and with that a certain distance between public and private is needed. It is shown that in their approach to the market public clients are concerned with their reliability and predictability. In discussing the value of collaboration, being a reliable partner appears to be discussed most often. *“It is very important that we, as a public client, are reliable and predictable, so you know what could be expected of us” (CPO, GbL).* Public clients are more and more concerned with their approachability; they are in search for connections instead of contradictions in order to build an equal, sustainable relationship on the basis of common values.

Sometimes it is more about ‘the sense of responsibility’ of public organisation themselves than the actual expectations. As a public organisation one serves the public good. The interviews show a strong sense of this responsibility. Looking into the organisations with different ‘degrees of publicness’, there appears to be a strong awareness of the public task with officials of all types of public organisations. *“Intrinsically, people working at governmental bodies feel that they are there to serve the general interest, not the interest of the organisation.” (CP, GbL)* and *“I just have to retain integrity. That is part of the public value I represent. A government official*

should always keep this in mind." (CPO, CG). The results also indicate that this feeling of responsibility relates to the complexity of the inner city and regional tasks public construction clients are dealing with and the need to increasingly incorporate values such as sustainability in order to cope with the issues (in the long run). As a public client you are in the position to be a forerunner, be progressive. "Look, we are in a period in which incredible changes take place and I think that we as an organization should have the moral duty to act as a pioneer. Also, we, as an organization towards the city because in doing so we can safeguard or even accelerate and improve the social-cultural-, the economic- and the ecological sustainability." (GM, CG). Public clients aim to take on a 'leaders role' as they feel this is their responsibility from a socio-political perspective. They believe it is their task to initiate renewal and walk ahead. "We have to be innovative as well. We also have to initiate innovation. We also have to give a good example, but also try something, making testing ground possible, asking challenging questions to the market and testing new processes and procedures." (CPO, GbL). Both the sense of responsibility and the expectations contribute to construction clients (willing to) taking on a leading role in the sector change . Hence, to some extent restricted dependence of private market parties.

CONCLUSIONS AND DISCUSSION

This study contributes to theory on public private collaborations by using public value theory to explain the importance of rethinking roles and responsibilities in construction. We found that public agents need to adopt a more facilitating and frame-setting role to build sustainable relationships that are based on trust. However, limitations exist both regarding adopting the new interpretation of the commissioning role and the transformation of the client-contractor relationship. In contrast to most literature on values in good governance (e.g. Jorgensen and Bozeman., 2007; De Graaf et al., 2013) – which remains to focus on administrative and political obligations - we found that all three types of procedural, performance and product values (De graaf and Paanakker., 2014; Bruijn and Dicke) have a role the client-contractor relationship in the context of commissioning public services in the built environment. In their attempt to find a balance between their procedural obligations as a public agent and the increasing need to steer on sustainability, innovation and quality, our results show that public construction clients aim to contextualise the procedural values related to lawfulness and their socio-political responsibilities. They are looking for a sufficient way to approach the market, as they transfer operational responsibility for achieving values to the private market parties but still remain ultimately socio-political responsible for achieving the public values. The ongoing shift of focus at public commissioning organisations from procedural values towards product- and performance values asks for a more open, transparent, sustainable client-contractor relationship. This client-contractor relationship is traditionally perceived as transactional principal-agent relationship. The assumption underlying this relationship is that the agent (contractor) is self-interested and will act opportunistically; therefore, the principal (client) should adopt a combination of instruments that will eliminate the discretionary space of the agent (Winch, 2010). Even though this theory still seems to be dominant in construction management

research, more relational approaches to client-contractor relationships are gaining momentum, promoting the development of trust (Winch, 2010).

For public clients it becomes increasingly important to recognize and accept contractors interests and recognize their added value so clients can ask the right questions. Facilitating, formulating and defining what you expect of the market seems essential when aiming for long-term relationships to realise socio-political aims. As a public client it therefore is important to develop soft skills enabling information sharing and communication with the market when defining the assignment, in other words, formulating the right question. In contrast to public value theory, which focuses on the formal arrangement of value proposition (Meynhardt, 2009), our findings thus show the importance of relational aspects. This implies that softer mechanisms may be more appropriate, since these are specifically focussed on understanding each other's interest and forming a shared goal. In the context of accountability studies this relates to adopting a hybrid accountability arrangement as described by Michels and Meijer (2008). In line with this our research shows that today's contractual mechanisms - hierarchical mechanisms of accountability - brings along an inflexibility in using the expertise of market parties in the unleashing of projects and the inability to build on earlier partnerships, showing the inability to apply horizontal, informal, mechanisms of accountability.

Our results also indicate that public construction clients are concerned with their reliability and predictability towards the supply market. As they are well aware of their dependence of market parties, the decision about outsourcing or in house delivery is becoming part of their accountability. In the context of this dependency, Strang (2018) - in his recent dissertation about surveillance and coordination in the building process – emphasizes the importance of control of different types of dependence relationships that can occur in a building process. He gives insight in the cohesion of achieving objectives and coordination in the building process by elaborating on interface risks (Strang., 2018). With the increase use of integrated contrac forms in construction attention to the connection of different phases in the construction life cycle is especially important, as transfer of responsibilities is often also part of this interface.

Next, both the sense of responsibility and the perceived expectations contribute to construction clients willingness to take on a leading role in the sector change. It was shown that although many efforts of public construction clients to work with new divisions in roles and responsibilities in public private collaborations, the 'new' commissioning role is not yet embedded in the public construction domain. And we often see public agents reverse to old habits at critical moments. The former focus on procedural obligations made public construction clients risk-averse. A cultural change is needed in the construction industry. Both public and private parties have a responsibility in this sector industry change, as in today's increased public private collaborations the private contractor can be seen as the extension of the public client. Together one should engage in conversations on public values instead of safeguarding (only) in systems, as pointed out by De Graaf and Paankakker (2014) the control of the executive network becomes central. And due to the plethora of stakeholders in different public environments - political, juridical, administrative, social - there might be overlapping accountability relationships within various negotiated environments

(de Bruijn and Dicke, 2006). Since public clients do have a special position within society they can set the example, show leadership and ownership, by guiding, coaching, facilitating, offering solutions/resolving power and/or setting a framework. Internally it is important to find appropriate management logics, skills, methods, mechanisms and strategies to create public value in various constellations of public- and private parties. It is important to be able to answer to the questions which values can and cannot be outsourced, and to what the extend steering is needed for the different (types of) public values strived for in delivery of public goods. And externally, the concern is to leave enough room to the market to use their expertise and knowledge to ensure innovation, sustainability and quality, while still making sure that certain procedural values are achieved in the process of delivering public goods. It is about how to ask the question. And which collaborative form fits best.

Further alignment of values, roles and responsibilities is needed to ensure in public values the context of increased value and volume of integrated contracts in construction. Hence, future research will have to look more closely into the alignment of the shifted roles and responsibilities and organizational- and steering mechanisms that are applied. In the search for governance mechanism and frameworks that are flexible enough and are able to deal with the restrictions that lawfulness brings along, further research will look into value trade-offs that need to be made and conflicts that are experienced by actors in safeguarding these values. In addition, in the context of the increasingly collaborative nature of public service delivery, a research from the perspective of private clients and suppliers would add to the understanding of finding commonalities.

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PROJECT CAPABILITIES AND LEADERSHIP: A MIXED-METHODS SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

The aim of the paper is to investigate the theoretical underpinnings and diffusion of scholarly debates on the two key project phenomena: capabilities and leadership. Recent project studies argue for the importance of project capabilities as well as leadership for project delivery but the two streams of research have been separate. This study seeks to understand leadership as a micro-foundation of project capabilities using a mixed-methods systematic literature review. To this end, the paper presents a combination of a bibliometric network analysis and thematic analysis of scholarly literature associated with leadership, projects and capabilities. Two areas of findings are presented along the thematic domains of project capabilities and leadership capabilities in projects. Extending the findings, the paper proposes a conceptual framework to argue for leadership as a project capability. The proposed conceptual framework extends the understanding of leadership micro-foundations for project capabilities. Further empirical work is suggested to validate and extend the conceptual framework.

Keywords: Systematic literature review, Thematic analysis, Bibliometric Networks, Projects, Capabilities, Leadership, Innovation.

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INTRODUCTION

Research has long argued for the notion of organisational capabilities (Chandler, 1990), which allow firms to perform strategic and operational functions effectively. A similar argument exists for project-based firms, whose core activities hinge upon the delivery of projects as temporary endeavours (Lundin and Soderholm, 1995; Söderlund et al., 2008). Such project-based firms must possess and develop distinct *project capabilities* (Brady and Davies, 2004; Davies and Brady, 2000) commonly defined as “*the appropriate knowledge, experience and skills necessary to perform pre-bid, bid, project and post-project activities*” (Davies and Hobday, 2005, p. 62). Building project capabilities requires a dynamic knowledge process of exploration and exploitation where managers have an influential role in supporting learning behaviours and motivating people (Brady and Davies, 2004; Brady and Davies, 2000; Davies and Hobday, 2005). Söderlund (2005) and Söderlund and Tell (2009) stress the benefit of project leadership dimension for building project capabilities and exploiting successful project operations. So far, only a few studies on project and organisational capabilities embraces the debate on leadership highlighting the importance of soft dimensions and human resources management in project-based organisations (e.g. Söderlund, 2008; Bredin and Söderlund, 2013; Isik et al., 2009).

Similar to project capabilities, leadership has been acknowledged as an element of excellence in the management of projects (Kerzner, 1987, Walker, 2015), and beneficial for achieving successful results (e.g. Davies et al., 2009; McKinsey&Company, 2017; Shenhar, 2004). In mainstream organisational literature, leadership has also been described as the ability of working through people (Walker, 2015), possessing human skills such as cooperation, sensitiveness, communication and understanding (El-Sabaa, 2001), the capability of motivating, influencing and inspiring workers (Lester, 2006) and facilitating and developing knowledge, learning and expertise (Macneil, 2001). Despite the extensive research on project capabilities and leadership, and their related competitive advantage, how leadership is operationalised in infrastructure projects is a poorly understood area (Flyvbjerg 2014; Toor and Ofori, 2008) and there is still relatively little coverage of the so called ‘soft aspects’ of their management (McKinsey&Company, 2017). Therefore, although *project capabilities* and *leadership capabilities in projects* literatures have, by and large, been developed separately from each other, there seems to be an underlying reference to leadership as a potential driver for fostering knowledge sharing and learning behaviours for operationalising project capabilities, we considered this assumption as the foundation on which we built our research.

We attempt to understand whether leadership could be tackled as a type of capability in infrastructure projects. To better understand the complementary between leadership and project capabilities, we conducted a mixed-methods systematic literature review based on elements of bibliometric network analysis, content analysis and qualitative thematic analysis to explain the overlaps, complementarities and interconnections between project literature on leadership and capabilities. While the systematic review helped us to create a framework for the literature review, the bibliometric network analysis provided additional fine-grained structure for the analysis through visual representations of the underlying body of data. The content analysis assessed how the

literature developed over time, what are prominent conversations, what is becoming relevant within the literature and the context of projects.

The core research question this study addresses is: *How do theoretical ideas and concepts of leadership and project capabilities interact and connect in research literature?*

RESEARCH DESIGN

To better understand and bring together work on leadership and capabilities in projects this research develops a ‘mixed methods systematic literature review’ as a bespoke methodological approach. This approach builds upon the systematic review of two literatures, *project capabilities* and *leadership capabilities in projects*. Systematic reviews scientifically identify, appraise and synthesise all relevant studies to develop uncertain, understudied or unknown subjects (Petticrew and Roberts, 2006). The reasoning behind the choice of two distinct systematic reviews concurrently is because we found that literature on project capabilities addressing leadership is very scarce (e.g. Davies and Hobday, 2005; Söderlund, 2005; Söderlund and Tell, 2009). We structured the analysis following Jesson et al. (2011) and Petticrew and Roberts’s (2006) practical guidelines in order to obtain reliability and synthesis of the findings.

First, we systematically searched the following terms: “project management” OR “project manager/s” AND “leadership” AND “capability/ies” OR “competence/s”; and “project capabilities”. We searched Web of Knowledge database from 2000 to 2018. This produced 152 results. Then, these items were examined according exclusion and inclusion criteria based on research categories, document and sources types, citations and relevance. More specifically, the analysis was limited to *Business, Management, Engineering* and *Planning* categories, while areas such as *Health Care, Education, Psychology, Arts* were excluded for misalignment. Documents included were Journals, Books, Editorial Materials and reviews, published in both international and national journals, books, while congresses, annuals, symposiums publications were omitted. Papers, which count a higher number of search terms both in the title and in the abstract, together with a high number of citations were included. The 60 sources, which met the inclusion criteria were then scrutinised for the abstracts and the full text and reduced to 52 papers. Lastly, 16 articles were added according to the authors’ previous knowledge of the subject matter, leading to a total of 71 sources.

Inclusion and exclusion criteria make systematic reviews more rigorous and transparent methods by way of explicating the assumptions behind the review process (Tranfield et al., 2003). Notwithstanding that, since the selection process is based on keywords, the analysis might omit literature when different terms are used for conceptually related phenomena and themes. This is the reason why we decided complement the systematic review with supplementary data analysis. To this end, the outcomes from the systematic review were used as the input for the bibliometric network analysis and thematic analysis.

The bibliometric network analysis systematically extrapolates and graphically depicts the relatedness of items (Van Eck and Watmann 2011) and identifies the core underlying subset of the literature (Van Eck et al., 2010). Through *VOSviewer*- a bibliographic network analysis software - we produced (a) network visualisations of

co-citations of references, which display the most relevant publications in the field and identify their relatedness based on the number of items, in which they are cited together, and (b) density maps of co-occurrence of sources and keywords, based on the frequency, in which the relevant terms occur together. The closer the items are located to each other, the stronger their relatedness in terms of co-occurrence and co-citation.

We conducted bibliometric network analysis on the 152 items we originally found in the systematic review. The reasoning behind this choice was because we aimed to reduce the limitations of systematic review which might neglect literature that does not use the focal key terms, yet is relevant and related. Moreover, using a substantial volume of publications, the bibliographic networks make it easier to contextualise the area of research and depict its relationships with other theoretical constructs and conversations, which might be found outside of the core knowledge domain (project and strategic management studies).

Despite the potential of this analytical approach, bibliometric network analysis can only suggest a high-level clustering of themes, but without it being explained in detail either in terms of the themes themselves or their conceptual interconnections. Since our purpose was to move beyond a confirmation of the literature and generate new theory and ideas, we then applied the inductive approach of thematic analysis, as suggested by e.g. Braun and Clarke (2006); Thomas and Harden, (2008) and others. Thematic analysis has been applied to systematic reviews in the past (e.g. Marston and King, 2006; Vrinten et al., 2016; Gulliver et al., 2010) to tackle and scrutinise recurrent themes, or patterns within a set of publications (Aronson, 1995; Guest et al., 2011; Braun and Clarke, 2006). The aim of such thematic analysis is to identify relevant concepts related to our research interest, without the intention of making them fit into a pre-conceived coding frame (Braun and Clarke, 2006), however drawing upon insights from the systematic literature review and bibliometric network analysis.

We conducted the thematic analysis coding on the 71 sources identified in the selective systematic literature review, producing distinctive codes for each literature: (1) *project capabilities* and (2) *leadership capabilities in projects*. Although the thematic analysis was informed by the thematic clusters in the bibliometric network analysis (generated by natural language processing algorithms), this was only to the extent of contributing to the conceptual build-up of the thematic structure. In other cases the automated thematic clustering had to be dismissed on the basis of algorithms' inability to capture the conceptual subtlety in the relatedness of the higher order themes. We broadly followed Braun and Clarke (2006) and Gioia et al. (2012) approaches, which start from coding relevant terms and then move on to group these terms into broader themes, or concept. Whilst Braun and Clarke (2006) conclude the analysis at this point, Gioia et al. (2012) add a further step of aggregate dimensions which identify overarching scenarios and underlying theoretical constructs. The reason for doing it is to achieve "theoretical saturation" and building a data structure which demonstrates rigor and comes back to the theory (Gioia et al., 2012). This approach led to 11 main thematic areas, of which six grouped under *project capabilities* domain and five for *leadership capabilities in projects* domain. In the last step, using the thematic analysis approach, we drew on the findings from the systematic review to argue for the interconnectedness and interdependencies across different thematic areas. The aim of this approach was to

examine overall constructs or dimensions, which could explain extant theoretical and conceptual conversations on leadership in the context of project capabilities.

FINDINGS

We next present findings from the systematic literature review analysis. In so doing, we will structure the section to cover the thematic analysis as an overview of themes within the two broad domains- (1) project capabilities and (2) leadership capabilities in projects, drawing upon the bibliometric network analysis to depict keywords and their relatedness.

1. Project Capabilities

Co-occurrence analysis of project capabilities keywords, depicting the main areas (see Figure 1 of the Appendix), highlights the relevance and connections between key terms based on the number of times they are referred to together in the documents. In support of bibliometric network analysis, we run word frequency query of the publications found from the systematic review (see Table 1 in the Appendix), which reports the same focal areas. Furthermore, the thematic analysis reveals a few more themes such as learning, routines and ambidexterity. Complementing the bibliometric network analysis with qualitative thematic analysis, six themes were identified related to project capabilities literature. The systematic review suggests that project capabilities studies both embrace project management literature, with a considerable proportion of articles published in the *International Journal of Project Management*, and approach strategic management although with only a few publications in the *Research Policy* and the *Organization Studies*.

Interestingly, the bibliometric analysis of sources (see Appendix- Figure 2) reveals instead that the project capabilities have a significant interaction with strategic management literature. Through the systematic review, we get to understand that project capabilities come from two main streams of work: (1) Penrose's (1959) Resource Based View (RBV) of the firm which acknowledges capabilities as resources and therefore sources of the firm's competitive advantage (Barney, 1991; Grant, 1991; Wernerfelt, 1984), and (2) Teece and Pisano (1994), Teece et al (1997), Green et al. 's (2008) which introduced the concept of dynamic capabilities as the firms' abilities to adapt and reconfigure themselves in response to changing environments, to an extent arguing against the RBV as static and decontextualized from the external environments. This led us to understand the importance of strategic management since most of the underlying conceptual constructs embrace the assumption that capabilities, whether project, organisational, functional, can and should be adapted, innovated, and manipulated for achieving strategic competitive advantage. Hence, projects can be understood as enablers of competitive advantage (Söderlund et al., 2008) and the primary instrument for achieving firms' strategic objectives including innovation (Davies and Hobday, 2005; Hobday, 2000).

In such a way, the themes identified can be seen as underlying conceptual constructs, which help us understand the building blocks of the development of project capabilities literature. We next present these themes.

1.1 Learning and Knowledge

The bibliometric analysis highlights a strong occurrence of the keyword knowledge. The thematic analysis recognises a significant relatedness between terms *knowledge* and *learning*. This correlation seems to be at the core of project capabilities literature. The term “project capability” was first presented in 2000 in a *Research Policy* (Davies and Brady, 2000) contribution and it appeared again only in 2004 as an *Organization Studies* journal (Brady and Davies, 2004) contribution by the same authors. The former presented project capabilities as “*the appropriate knowledge, experience and skills necessary to perform pre-bid, bid, project and post-project activities*” (Davies and Hobday, 2005, p. 62); the latter further introduced a practical model, based on knowledge management and learning organisation, for building and developing project capabilities within firms. These seminal works explain how project capabilities are built through learning mechanisms. Going more in-depth, the process consists of a double-loop mechanism. During the first phase, the exploratory learning, existing knowledge is combined the existing and then transferred to team members; during the exploitative learning, resources and capabilities are created in line with what has been explored previously (Brady and Davies, 2004). By contrast, exploitative learning is a single-loop process where firms use existing knowledge, exploiting economies of repetition of existing skills, experiences and routines, thus executing similar projects with similar costs, schedules and specification. Indeed, many projects, albeit temporarily limited, often require the similar capabilities, routines and activities (Brady & Davies, 2004; Davies & Brady, 2000). On the other hand, innovative projects investigate new opportunities, encourage changing existing routines and pursue multiple solutions (Davies and Brady, 2016). According to Söderlund et al. (2008), such *vanguard projects* specifically require relating, reflecting and routinizing learning mechanisms for project competences to be built.

1.2 Innovation and Routines

Learning and knowledge are in turn tightly linked to innovation and routines. Although the bibliometric analysis depicts the keyword of innovation, the thematic analysis reveals more in-depth how the interaction between project capabilities and other related concepts. For example, literature suggests that in order to reconfigure or build project capabilities, firms rely on both routine and innovative projects. They do so to explore new knowledge for generating innovative alternatives and to exploit existing knowledge and firms’ routines through economies of repetition. Innovation is then understood as a new arrangement of existing routines for a more effective performance (Brady and Davies, 2004; Nelson and Winter, 1982) which occurs by modifying, recombining and creating new capabilities (Davies and Brady, 2016). Routines are the building blocks of firms’ existing knowledge including capabilities to deliver innovation within project settings.

1.3 Ambidexterity and Dynamic Capabilities

Bibliometric analysis also shows a strong relevance of the keyword ‘dynamic capabilities’. Thematic analysis further reveals that authors associate the term with the notion of *ambidexterity* referring to the balancing of exploitation of established routines and exploration of new alternatives, according to changing environments. In this

process, dynamic capabilities relate to senior managers' knowledge required to understand when to exploit routines or explore innovative alternative while avoiding resistance to change (Davies and Brady, 2016). Furthermore, "senior managers have to develop a clear vision, common identity and values that justify the ambidextrous design, avoiding the possibilities for conflict, disagreement and poor coordination among innovative and routine projects" (Davies and Brady, 2016:7). Senior managers should be strong, versatile, flexible and adaptive leaders, able to value team members (Davies and Hobday, 2005). Interestingly, as suggested by Soderlund (2005) and Soderlund and Tell (2009), complex projects involve different kinds of management (bid, project, commercial, senior managers) suggesting that capabilities can be developed amongst different leadership individuals. In a similar vein, Winch and Leiringer (2016) developed the concept of *owner project capabilities* stressing the importance of capabilities required by owners to adapt and reconfigure in order to achieve competitive advantage.

1.4 Construction and Complex Projects

Although we did not mention construction in our research, it came out as a node in its own right associated with engineering in the content analysis and with complex projects in the bibliometric analysis. As construction is a project-based sector is closely linked to the delivery of infrastructure, and infrastructure projects are complex systems, this provides support for using construction and infrastructure as an empirical setting for understanding project leadership capabilities. This is a surprising finding because, by and large, there is a relatively small body of work on project capabilities in the construction and infrastructure scholarship, accounting for its size. Most of extant studies are built either on dynamic capabilities in project-based organisations, or on project capabilities in the context of complex projects, but there is much less originating in construction and infrastructure scholarship, perhaps shaped by the idea that these are mid-range theoretical domains, chiefly concerned with execution and application of the existing theoretical constructs in the specific empirical setting and much less with the development of new theories and ideas grounded in the empirical context. While the term frequency count revealed *Project Management Journal* as the leading platform of these publications, we found that Davies and Brady's (2000) work inspired studies in industries such as in the power and automation industry (Söderlund and Tell, 2009), the military sector (Melkonian and Picq, 2011), the R&D in the oil sector (Ruuska and Brady, 2011).

1.5 Resource-based View

The bibliometric network analysis shows frequency of keywords such as resource-based view and organisational capabilities. Although we consider them as underlying constructs, which contributed to the development of project capabilities literature, they are also helpful for explaining the thematic analysis in the systematic review. Whilst pioneering authors were sharpening the literature of project capabilities (Davies and Brady, 2016), another stream of research was enhancing it with new conceptualisations, with references to the human factors. For example, Bredin (2008) extended the conceptual framework of organizational capabilities, project, functional and strategic capabilities, by adding the capabilities of organisations to manage people aligning them with the strategic, functional and project capabilities and objectives. This human

resource management perspective can be understood as highly related with the resource-based view of project-based organisations, as people are viewed as an important asset for the success of the firm and. In the same vein, this view is highly relevant for the project capabilities, contributing to effective execution of project management. We also found two more direct references to leadership in project capabilities. First, Davies and Hobday (2005) stress the importance of leadership at all level of the organisation, from senior managers at strategic level, to project managers at project level. Second, Söderlund (2005) suggests a framework of four building blocks of project capabilities including project generation, teamwork, project leadership and project organising. Regardless of the insightfulness of the stream of work on project capabilities, there was a sense that very little was said about the leadership aspects and how they relate to project capabilities. This is why we next present findings from the second component of the systematic literature review, specifically addressing leadership aspects within projects.

2. Leadership Capabilities in Projects

The co-occurrence map of bibliometric network analysis for leadership capabilities in projects yields 16 main areas (see Appendix - Figure 3), highlights the more and less prominent keywords and their interconnections. Similarly to our above analysis of the project capabilities literature, we ran a word frequency query of the publications found from the systematic review (see Appendix -Table 2), which reports the occurrence of the focal areas. Through the thematic analysis, we added several more themes such as learning, context and complexity to the bibliometric network analysis, in an attempt to explain the underlying connections. We ultimately identified five main areas related to leadership capabilities in projects literature which are presented in this section.

To better understand the diffusion of the conversations on leadership capabilities in projects, we ran a bibliometric network analysis of references (See Appendix Figure 4) to appreciate where seminal debates took place. Perhaps unsurprisingly, we found that contemporary conversations on leadership capabilities in projects come from project management literature (e.g. *International Journals of Project Management* and *Project Management Journal*) and in Business and Management Journals (e.g. *Journal of Business Research*, *BJM*, *European MJ*, *Management Science*, *R&D Management*, *IJISAM* and *IJMPB*). What is more surprising, is to find a very sharp increase in the number of citations between 2011 and 2016 (See Appendix Figure 5), suggesting a high increase of interest in the topic. Literature suggests that most of the conversations focus on the importance of leadership in determining project performance (e.g., Anantatmula, 2010).

The bibliometric network analysis also suggests that a new reconceptualization of project management is at the heart of this stream of thoughts, arguably mainly driven by the need of establishing a more nuanced definition of project success (Pinto and Slevin, 1988). By early 2000s project scholarship literature was already placing human factors at the centre stage of project performance and success. Project management is increasingly considered a pivotal driver for project performance when able to deploy leadership skills, hence considering people as source of competitive advantage rather

than looking only at cost time and quality constraints (Atkinson, 1999; Cooke-Davie, 2002). This is the reasoning behind why we considered “success” and “performance” keywords, depicted in the bibliometric analysis, as underlying assumptions rather than features, thus themes.

2.1 Competences, Skills and Behaviours

Along similar lines, business and management debates on leadership capabilities suggest an understanding of leadership as a competence that can be developed rather than a naturally given or embedded ability (Ramazani and Jergeas, 2015; Shelley, 2015; Takey and de Carvalho, 2015). This helped us explaining why the bibliometric network analysis on leadership capabilities in projects emphasises debates on competences, skills and behaviour. The most prominent studies include Muller and Turner (2007, 2010, 2010b); Turner and Muller (2005); Rekonen and Bjorklund (2016); Yang et al. (2011). Interestingly, literature shows a peak in publications in 2010 when several authors asserted leadership competences and attitudes (Muller and Turner 2010a; 2010b; Skulmoski and Hartman, 2010), soft skills (Stevenson and Starkweather, 2010) and human skills, such as emotional intelligence competency (Clarke, 2010a; 2010b) as essential requirements for project managers to succeed in their mission. This body of literature addresses project leadership through specific capabilities, such as communication skills, empowering, inspirational, motivational, supportive, and empathic behaviours, and coaching and charismatic approaches.

2.2 Strategy, Context and Complexity

Authors interpret the leadership ability of creating a shared and clear vision, establishing objectives and aligning ideas as the resources and capabilities needed for achieving strategic goals (Takey and de Carvalho, 2015; Shao and Muller 2011), which explains the relation between project leadership capabilities and strategy theme. Interestingly, strategy also relates to leadership adaptability. Leadership approaches, styles or skills should be aligned according to the type of the projects, their context, and complexity (e.g. Turner and Muller, 2005, Rekonen and Bjorklund, 2016; Yang et al., 2011). The ability of adapting the approach towards the firm’s direction is meant as the strategic approach leaders should implement for gaining competitive advantage (Shao, 2018; Shenhar, 2004; Turner et al., 2009). Along the lines of the adaptability feature, leadership seems to be more collective rather than centralised as its ownership can change and swap between team members according to who is most knowledgeable during a specific project stage or for a specific project task. Leadership can also shift between vertical, project manager, and horizontal, teams of project-based organisations (Muller et al., 2018). This may also explain why literature has been looking at leadership at different level of organisations, such as contractor leadership (Suprpto et al., 2015), top management leadership (Hermano and Martin-Cruz, 2016) programme leadership (Shao, 2018), and integrated project delivery leadership (Zhang et al. 2018)

2.3 Innovation and Change

Innovation in project leadership capabilities is largely associated with creating and implementing new ideas where leadership is seen as the facilitator for supporting creativity and innovation through motivation, transparency, clear vision,

communication (Sundstrom and Zika-Viktorsson, 2009). Interestingly, innovation and creativity are also linked to themes of knowledge and learning. Other literature suggests that leadership means being able to create a shared vision and promote explorative thinking to create new knowledge and inspire learning (Hirst et al., 2004; Yang et al., 2014). Furthermore, the propensity towards knowledge sharing is strongly influenced by a shared leadership vision, where every team member takes responsibility hence feels empowered and confident in sharing knowledge (Mueller, 2014; Edmondson and Nembhard, 2009). More broadly, literature on knowledge management and organisational learning has tackled strategic incentives for innovative delivery and successful performance both in project-based organisations and construction projects (e.g. Ahern et al., 2014; Naaranoja et al., 2008; Reich et al., 2012; Hartmann and Dorée, 2015). Along these lines, leadership capabilities in changing contexts refer to the ability of fostering and influencing change acceptance while reducing resistance of team members (Lundy and Morin, 2013).

2.4 Emotional Intelligence and Transformational Leadership

As leadership has progressed throughout different stages of its understanding and schools of thought, the analysis shows reference to emotional intelligence and transformational leadership. Studies on emotional intelligence in project-based organisations often refer to seminal works by Goleman (1995). Interestingly, we found that transformational leadership is embedded in the resource-based view as a resource of competitive advantage by incentivising knowledge and managing it (Bryant, 2003). Transformational leaders are also observed as key figures for managing dynamic capabilities (García-Morales et al., 2012), widely associated with knowledge management and organisational learning by evolutionary theory scholars (Davies and Brady, 2000; Davies and Brady, 2016; Green et al., 2008; Zollo and Winter, 2002).

2.5 Construction

Bibliometric network analysis points to the high relatedness of project leadership capabilities and construction context. This can be explained by the relatively recent research efforts to redefine the “traditional perception and mind-set about leadership in the construction industry” (Toor and Ofori, 2008:1) in an effort to reconceptualise the role of project manager as a key driver for success. As other business sectors, construction industry has faced a change in its business models which have started putting soft skills at the centre of project success and performance. There is now a wide range of applied studies adopting specific leadership constructs and theories (e.g. transformational, authentic, intellectual, managerial and emotional leadership models) to understand and develop the performance of construction projects (e.g. Dashti et al., 2013; Muller and Turner, 2007; 2010; Tabassi et al., 2014; Toor and Ofori, 2008). Although these theories and concepts differ in how they define leadership as their level of analysis, they all assert the need of a new skill set and professional competences development for project managers (Edum-Fotwe and McCaffer, 2000; Dulaimi, 2005; Tabassi et al., 2014).

DISCUSSION AND CONCLUSIONS

The research aimed to address how theoretical constructs of leadership and project capabilities interact and connect in research literature. The comparative thematic analysis of the two streams of research helped us to pin point some of the driving principles behind ideas underpinning the two bodies of research. We argue that leadership and project capabilities are linked through an intricate series of associations potentially pointing towards causal relationships. On the one hand, project capabilities refer to specific strategic activities of bid preparation and project execution, which can be source of competitive advantage. On the other, leadership capabilities refer to the ability of incentivising people, motivating toward learning behaviours and change acceptance. Furthermore, we understand that project capabilities are not something naturally embedded in a company yet something that needs to be built through learning and requires inspiring approaches. As outlined by the recent McKinsey report, our literature review strengthens the notion of the so-called ‘soft capabilities’ as key, building blocks of project-based organising. More specifically, we propose that leadership is a key driver for operationalising project capabilities. We present findings in the next section (Figure 6).

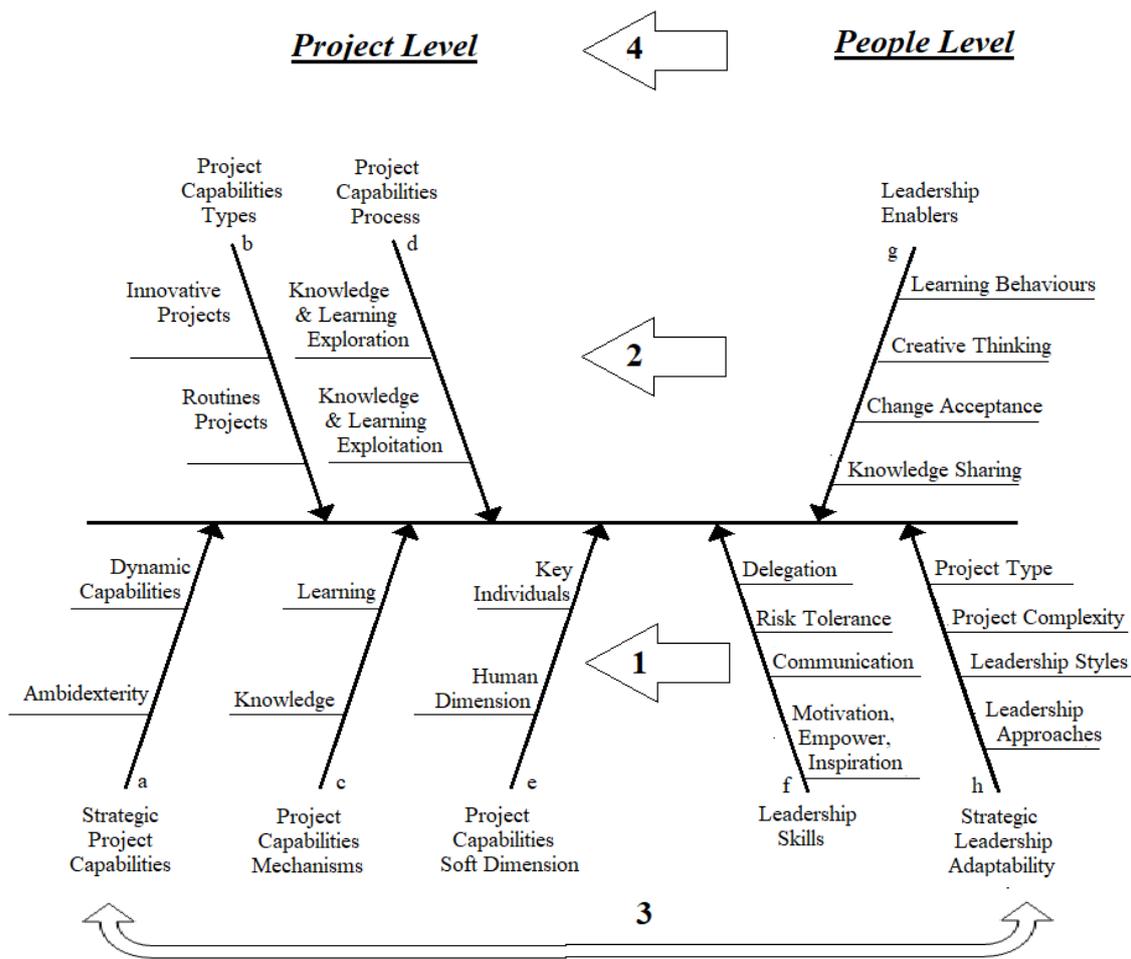


Figure 6. Conceptual Framework proposing Leadership as a Project Capability

1.1 Leadership Micro-foundations of Project Capabilities

We suggest that project capabilities are built to support ambidexterity, the ability of a firm to simultaneously explore new opportunities and exploit existing knowledge and routines. How project capabilities are mobilised based on ambidexterity refers to dynamic capabilities, the ability of senior managers of knowing when to exploit existing or creating new resources based on strategic process (a). Therefore, external circumstances and uncertainty determines whether the firm will rely on innovative or routine projects (b) (Davies et al., 2016). In the process of project capabilities building, organisational learning and knowledge management are strategic mechanisms for operationalising project capabilities and achieving success (c) (Zerjav et al., 2018). When new ideas and innovative alternatives are explored, firms undertake ‘vanguard projects’ where new knowledge is created and organisational learning is based on explorative behaviours, whereas when existing routines and process are exploited and repeated, firms undertake routine projects because of stable circumstances (d) (Davies and Brady, 2000; Davies et al., 2016).

Davies and Hobday (2005) acknowledged the importance of the soft dimension thus the human aspect, of project capabilities stressing the benefit of allocating capabilities through key individuals. Soft capabilities refer to senior managers’ capabilities of being strong, versatile, flexible and adaptive leaders, able to value team members (e) (Davies and Hobday, 2005). Senior managers should justify their strategic ambidextrous of choosing either vanguard or routine projects, by shaping a common vision, motivating team members, empowering people skills and hence avoiding conflicts (Davies and Brady, 2016; Davies and Hobday, 2005). These refer to the soft dimension of project capabilities and resemble some skills authors tackled in leadership capabilities. Indeed, the literature shows that leadership capabilities include motivating, inspiring and communication skills, ability of setting clear goals, shaping common visions, framing conflicts with clarity, tolerating risks and delegation capabilities (f).

Leadership capabilities have been argued to be able to stimulate knowledge sharing and learning within organisations (Bryant, 2003; Edmondson and Nembhard, 2009; Hirst et al., 2004; Mueller, 2014; Yang et al., 2014), to stimulate creative thinking, while reducing resistance of team members (Lundy and Morin, 2013) (g). Since innovative projects require explorative learning, creative thinking and change acceptance and routine projects require explorative learning and knowledge sharing, we argue that leadership skills are pivotal in building project capabilities (2). We break down this discussion between innovative and routine projects.

Innovative projects involve new knowledge to be explored and created. They hence require willingness to share, openness to new alternatives, and confidence in changing. In this project type, leadership capabilities can be advantageous. Inspiring, delegating and tolerating errors, promoting explorative thinking, creating innovative alternatives, motivating people towards knowledge sharing behaviours, are leadership skills that managers should develop to stimulate innovation and explorative behaviours. Nonetheless, innovative projects can be threatened by resistance to change (Davies and Brady, 2016). The analysis suggested that if managers really understand the change, they can reduce resistance by creating incentives (Lundy and Morin, 2013). We

therefore suggest that since leadership capabilities are driver for learning, creative and confident behaviours towards innovation and change, they can be an enabler for building project capabilities through innovative projects.

Similarly, routine projects require willingness to share and collaborate with each other, in order to exploit existing knowledge. However, there is a high risk that knowledge between projects is not shared (Brady and Davies, 2004). We found that learning and sharing behaviours can be enhanced by leadership capabilities such as motivating, inspiring and communicating with people. Furthermore, leadership seems to influence team reflexivity, thus the ability of reconfiguring routines when methods used should be realigned with project objectives (Hirst et al., 2004), which is essential for explicating knowledge within routine projects. We therefore suggest that leadership capabilities of inspiring confidence and motivation, are driver for sharing behaviours and learning exploitation which are key mechanisms for building project capabilities through routine projects.

To conclude, we suggest that senior managers' soft capabilities should develop leadership skills such as the ability of motivating and encouraging project teams in sharing knowledge and experiences, fundamental in routine projects, and the ability of delegating and infusing a sense of confidence to teams for stimulating new ideas, useful in vanguard projects.

1.2. Ambidexterity and leadership adaptability

We propose an interconnection between the theories based on themes of adaptability and ambidexterity (3). Project capabilities are exploited throughout different phases, each of them requiring different activities. According to Davies and Hobday (2005) in order to performance pre-bid, bid, project, and post-project activities, appropriate knowledge, experience and skills (project capabilities) are required. Similarly, leadership must be adapted to different contexts or situations to achieve successful results (h). Leadership has been argued to be highly reliant on external circumstances as well as project type and stage and evidence shows contingency between project situation and the choice of leadership styles applied in projects (Mueller et al., 2018). Leadership can be said dynamic for its capacity of renewing competences and shaping them towards the circumstances. Throughout the life-cycle, leadership should strategically exploit different capabilities and skills so to achieve best results as well as adapt appropriate approaches at each stage of the projects (Mueller and Turner, 2007; Turner and Mueller, 2005). Furthermore, beyond the concepts of styles, literature suggests it is pivotal to adapt leadership competences with different project types and requirements (Muller and Turner, 2017; 2010). Leadership can be thought of as a capability since it must be flexible, adaptive and reconfigured (Collyer, 2016). Therefore, leadership capabilities seem to be tackled in project capabilities in their ability of strategically innovating skills, competences, styles and shaped them towards the circumstances, projects stage and type.

1.3. Key Individuals and shared leadership

We advance another proposition (4). Research on project capabilities argued that leadership capabilities are more collective than individualistic and that they can be shared between top and project management (Söderlund, 2005). Indeed, leadership has been defined as being iterative and shifting in nature because its responsibility and level can change. Leadership can be either horizontal or vertical in relation to whom within the organisation should take ownership and authority to either solve conflicts, find strategic solutions, or to take advantage of the most knowledgeable group (Mueller, 2014; Mueller et al., 2018). Along similar lines, project capabilities literature argues that as senior managers need to develop vision, identity and values at the project level, project managers should play the same leadership role with respect to their project teams. Managers “should be able to recognize the strengths of individuals and align these strengths with specific responsibilities in the project team” (Ahmed and Anantatmula, 2017). This, in turn points to the importance of human resources and their management. Complex projects such as epitomised by infrastructure require high level of alignment and coordination of people prerequisites. Leadership, being the ability of working through people (Walker, 2015), provides guidance and direction, useful for aligning interests and goals. In other words, leaders must be able to effectively engage with (rather than exploit) human capital and capabilities such as knowledge, skills, competences or experiences, by shaping a common and shared vision to achieve predetermined goals.

We next suggest several possible contributions arising from this research. First, we suggest that the analytical approach based on a mixed-methods systematic literature review that was adopted for this work has significant potential as a methodological contribution. This approach helped us to better understand key themes and areas, which combine *project capabilities* and *leadership capabilities in projects* literatures as the main envisioned contribution of this work to project scholarship. Leadership was found to be a driver for operationalising project capabilities through its ability of fostering both the reconfiguration of routines, avoiding resistance to change, and of incentivising organisational learning, using leadership skills such as motivation, inspiration and cooperation. Senior managers should develop leadership capabilities in order to inspire learning behaviours and knowledge sharing and hence ensure an effective development of project capabilities. The research also pointed out benefits of capabilities of adaptation such to the project type, stage and complexity, balancing exploration and exploitation activities according to circumstances. In such a way, this study contributes to project scholarship by proposing leadership micro-foundations for the development of project capabilities. Future work should validate, expand and extend this work through an in-depth empirical treatment of ideas and concepts derived in this study.

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APPENDICES

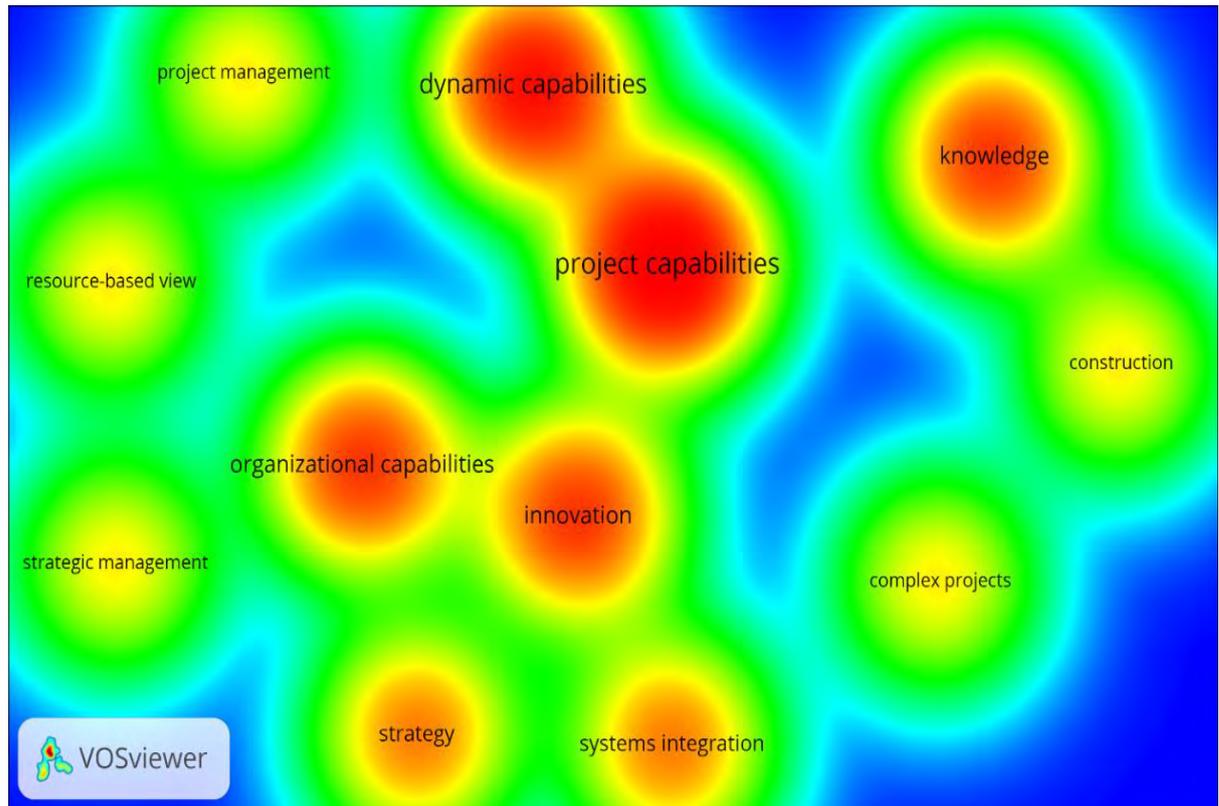


Figure 1: Bibliometric co-citation density analysis of keywords on Project Capabilities

<i>Project/s</i>	6777
<i>Capability/ies</i>	2434
<i>Management</i>	1704
<i>Learning</i>	928
<i>Knowledge</i>	644
<i>Performance</i>	549
<i>Strategic</i>	533
<i>Complex</i>	496
<i>Dynamic</i>	494
<i>Innovation</i>	468
<i>Engineering</i>	409

Table 1: NVivo word frequency of Project capabilities literature

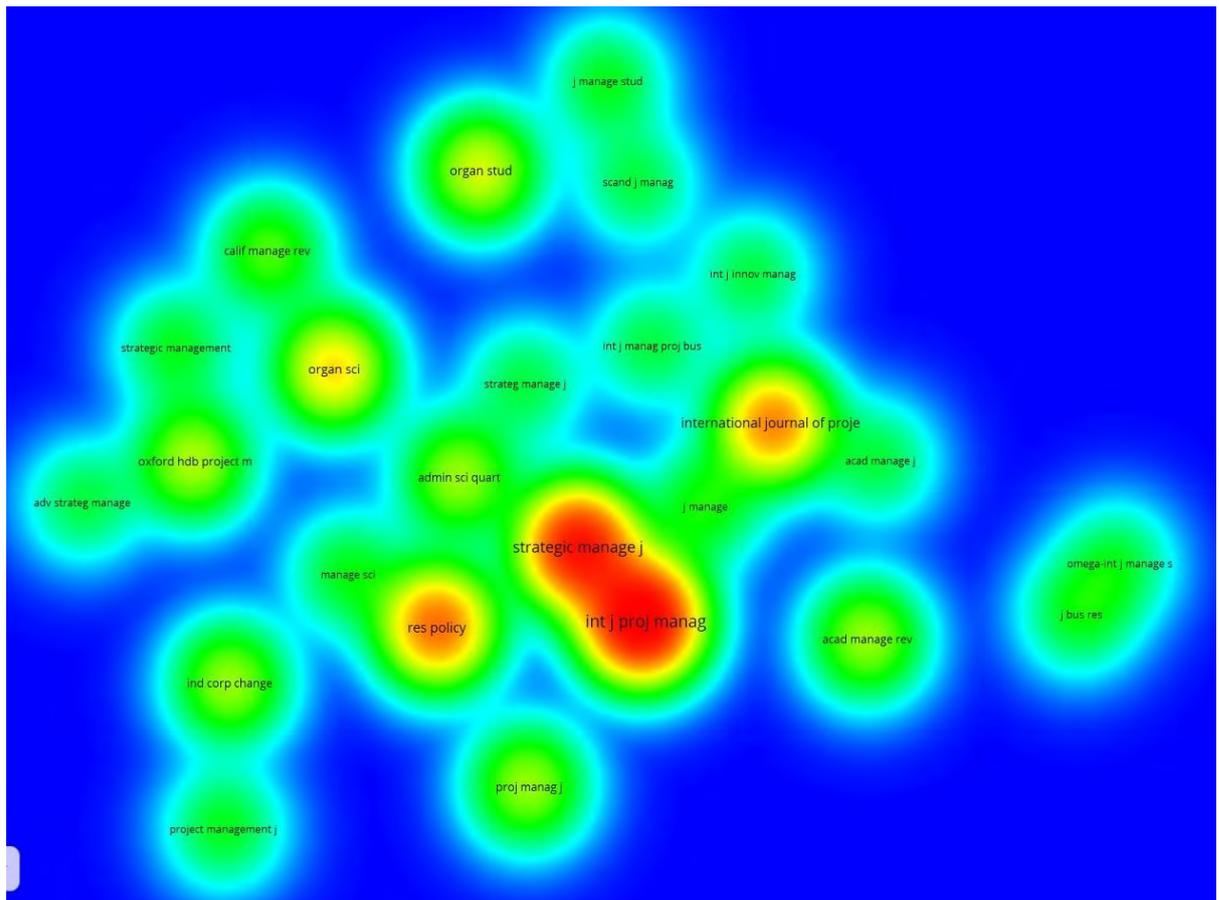


Figure 2: Bibliometric co-citation density analysis of sources on Project Capabilities

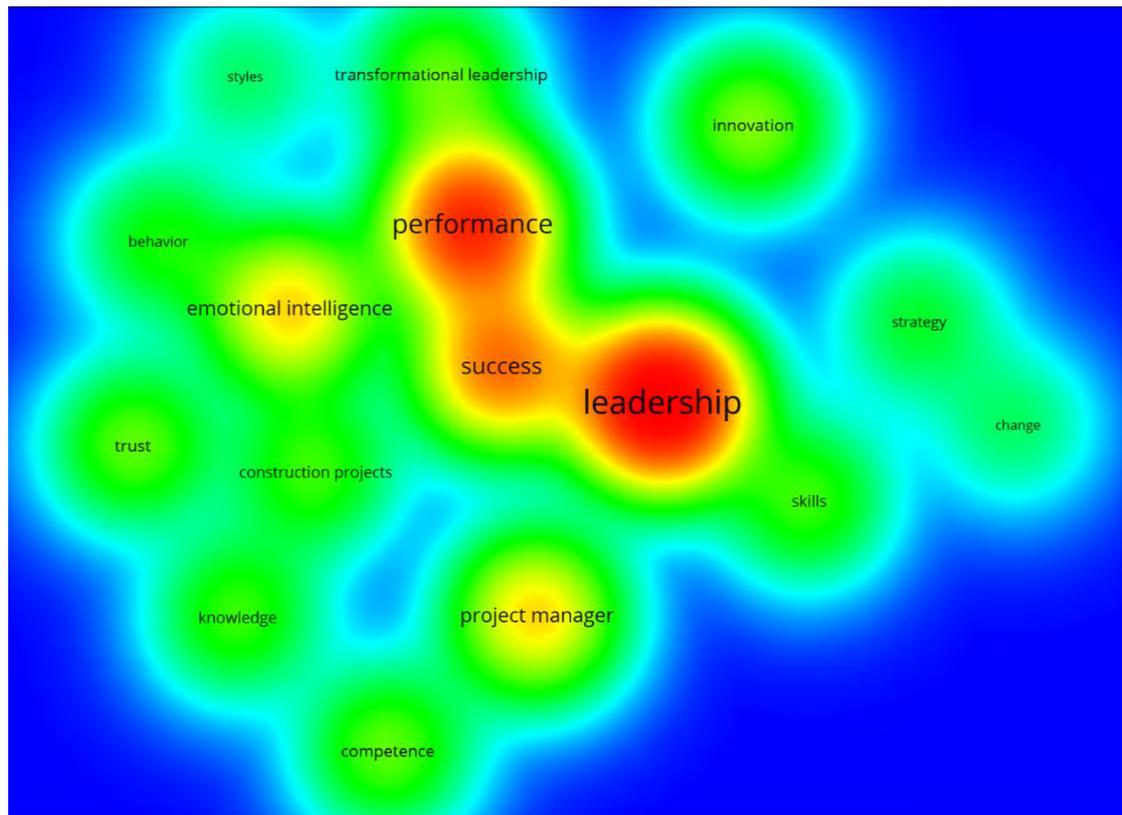


Figure 3. Bibliometric co-citation density analysis of keywords on Projects, Leadership and Capabilities

<i>Project/s</i>	<i>10760</i>
<i>Management</i>	<i>4552</i>
<i>Leadership</i>	<i>3524</i>
<i>Manager/s</i>	<i>3192</i>
<i>Performance</i>	<i>1445</i>
<i>Success</i>	<i>1381</i>
<i>Knowledge</i>	<i>1196</i>
<i>Emotional</i>	<i>767</i>
<i>Change</i>	<i>765</i>
<i>Learning</i>	<i>706</i>
<i>Construction</i>	<i>546</i>
<i>Context</i>	<i>540</i>
<i>Complexity</i>	<i>477</i>
<i>Style</i>	<i>475</i>

Table 2: NVivo word frequency of Leadership capabilities in projects literature

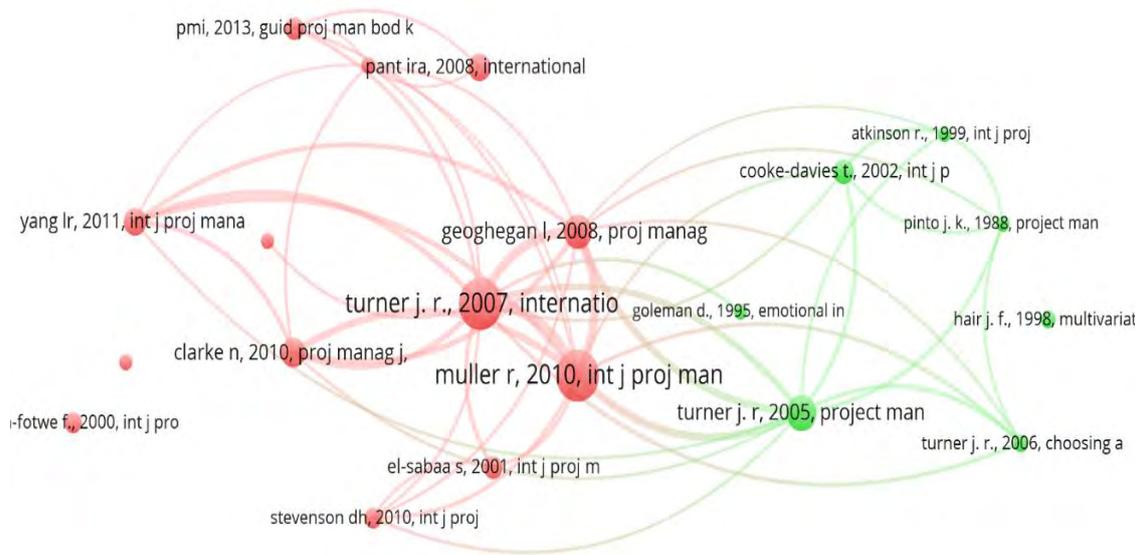


Figure 4: Bibliometric co-citation network analysis of references on Projects, Leadership and Capabilities

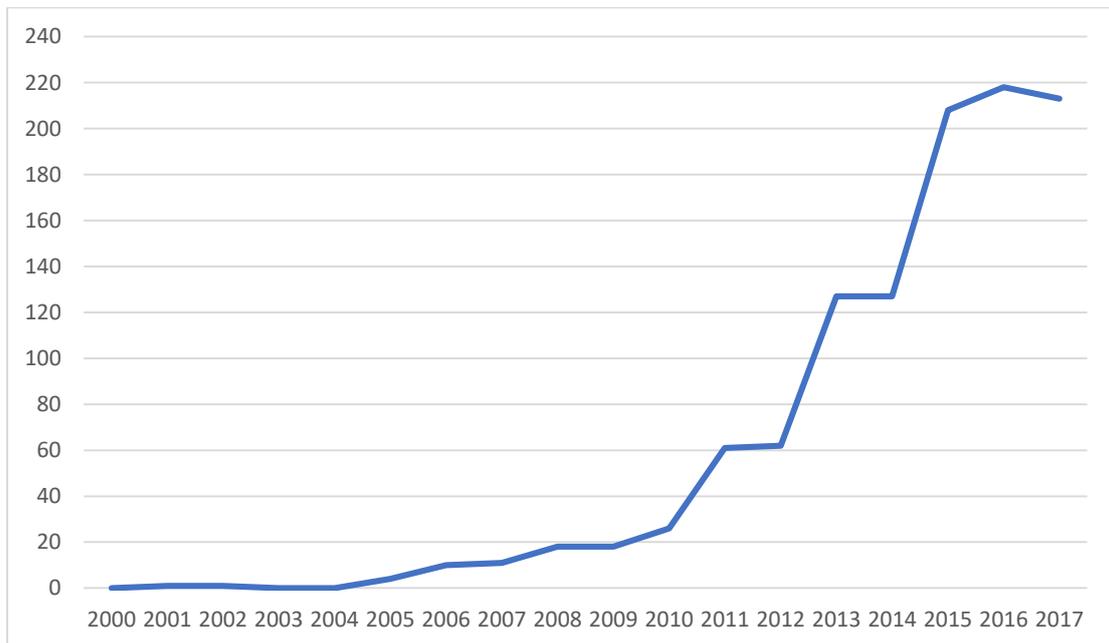


Figure 5: Citations Graph for Project, Leadership, Capabilities 2000-2017

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LEARNING IN MEGAPROJECTS: CONSTRUCTING IDENTITIES AND IMPROVING PERFORMANCE

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LEARNING IN MEGAPROJECTS: CONSTRUCTING IDENTITIES AND IMPROVING PERFORMANCE

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ABSTRACT

This article applies organizational identity theory to explore how megaprojects construct their identities as learning organizations. The study draws on 33 in-depth interviews from temporary and permanent organizations in the UK construction/infrastructure sector. Interviews were further triangulated with data from a series of industry events and workshops. The investigation explores key characteristics of learning in megaprojects and their impact on performance. The research demonstrates the shift towards informal ways of learning and importance of narratives about the megaproject mission. Boundary spanners actively engage in sharing learning through stories about lessons learned from past experiences in managing megaprojects.

KEYWORDS

Boundary spanners; identity; learning organization; megaprojects narratives

INTRODUCTION

Megaprojects are typically set up for a specific period of time to deliver innovative products or services across a range of industries such as construction, infrastructure, and engineering (Flyvbjerg, Bruzelius, & Rothengatter, 2003; Merrow, 2011). Large-scale infrastructure assets such as water facilities, airports, roads, railways are complex systems that require a large investment commitment, take many years to develop and build, involve multiple

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public and private stakeholders, and have long-lasting impact on the economy, the environment, and society as a whole (Brookes, Sage, Dainty, Locatelli, & Whyte, 2017; Flyvbjerg, 2014). Creating and maintaining complex systems in megaprojects requires the mobilization of a wide range of capabilities including contractual and relational governance, innovation, and learning (Davies, Brady, & Hobday, 2006; Flyvbjerg, 2017). This paper mainly focuses on learning capabilities in megaprojects.

Despite the growth in number and opportunities to benefit from learning in megaprojects, these temporary organizational structures continue to have poor performance records (Davies, Gann, & Douglas, 2009). Most megaprojects are delivered over time, over budget and fail to achieve users' needs (Gann, Davies, & Dodgson, 2017). It is a major challenge for megaprojects to learn throughout their life-cycle in order to be delivered on time, on budget and to specifications (Brady & Davies, 2004). The majority of extant literature emphasizes learning capability which is required during the front-end planning in seeking to reduce uncertainties (Williams & Samset, 2010). More recent studies have started to recognize the importance of the back-end operation where lessons are learned and learning is transferred to future megaprojects (Zerjav, Edkins, & Davies, 2018).

It is often taken for granted that learning capabilities in temporary organizations are not very different from those more permanent (project-based) organizations (Brookes *et al.*, 2017; Winch, 2014). The specific characteristics of megaprojects that shape learning capabilities are: (i) being bespoke (created for a specific purpose); (ii) one-off (specific end date, but usually long life-span throughout which managers keep changing; at the end megaproject members separate and not always work together on subsequent megaprojects); (iii) complexity (large scale, multi-organizational and multi-project interfaces); (iv) alliance contracting (collaborative framework, co-creative process which promotes openness, trust, risk and responsibility sharing, innovation); (v) substantial risks (financial, operational,

reputational, innovation); and (vi) with different organizational cultures merging together (e.g. clients/owners and suppliers) which shape learning practices (Gann *et al.*, 2017). Learning in permanent organizations tends to be more continuous and routinized (Hobday, 2000; Prencipe & Tell, 2001) when compared to megaprojects where learning is more dynamic due to the transient nature of the business (Brookes *et al.*, 2017; Davies, Gann, & Douglas, 2009). Hence, the frameworks and models on learning developed for permanent organizations (Duffield & Whitty, 2015; Wei & Miraglia, 2017) may not be applicable to temporary organizations, i.e. megaprojects, and further research is needed to address this gap in extant literature.

Thus, the following overarching research questions are positioned: (i) *What are the key characteristics of learning in megaprojects?* And (ii) *What is the impact of these key characteristics on megaprojects' performance?* We theoretically ground our study in extant literature on learning in megaprojects (temporary multi-organizations) versus permanent project-based organizations. When exploring the impact of key characteristics of learning in megaprojects on performance, we found that part of this impact is the ways they construct their identities as learning organizations. Hence we frame our analysis deploying organizational identity theory (Alvesson, Ashcraft, & Thomas, 2008; Gioia, Schulz, & Corley, 2000; Schultz & Hernes, 2013). Empirical findings are based on rich datasets of temporary megaprojects in the UK construction/infrastructure sector and permanent construction/infrastructure project-based firms, and senior managers' perceptions of learning in these firms.

The study offers two distinct, yet inter-related, contributions. First, the study offers theoretical and empirical insights into key characteristics of learning in megaprojects and compares them with more permanent organizations. This contributes to the temporary/permanent organization dilemma in research on learning. We also investigate the

key characteristics of megaprojects and their influence on learning and organizational performance. Second, we adopted an underutilized theoretical lens - organizational identity perspective - in understanding the ways megaprojects construct their identities as learning organizations (Grabher, 2004). This deepens our understanding of the impact of key characteristics of learning in megaprojects on performance.

In the following sections, we conceptualize learning in megaprojects and identify a set of emerging learning characteristics. We explore individual and organizational learning using organizational identity perspective. We then discuss the research method and present our data analysis. Key findings are then discussed in light of extant theory, drawing out key theoretical contributions. We conclude by drawing out practical implications, research limitations, and future research avenues.

THEORETICAL BACKGROUND

Learning in temporary vs permanent organizations

Megaprojects and their members are influenced by a focus on specified delivery focus and deadlines leaving limited time to reflect on previous experiences in managing megaprojects to, for instance, improve processes and activities, and thus vital learning opportunities might be missed (Flyvbjerg *et al.*, 2003; Davies *et al.*, 2009). Several studies argue that megaprojects often fail or underperform due to poor decisions made during the planning front-end stage (Gann *et al.*, 2017; Flyvbjerg, 2014). Megaprojects strive to drive knowledge creation throughout the lifespan from the front-end phase to the back-end maintenance and operation phase (Bakker, DeFillippi, Schwab, & Sydow, 2016; Brookes *et al.*, 2017). A megaproject improves performance over time as it gains experiences, and hence creates new knowledge. The majority of extant studies have adopted a system thinking and practice theory perspectives on learning capabilities and mainly applied to more permanent

organizations (Brady & Davies, 2004; Davies *et al.*, 2006; Gann & Salter, 2000). However, little is known about the key characteristics of the dynamic learning process in megaprojects and their impact on performance.

The majority of megaprojects operate in a context of collaborative working meaning that they move away from mainly coordinating via formal, more rigid organizational structures (e.g. rules, schedules, division of labor) towards an emphasis on more inter-personal coordination and informal communication mechanisms (Bechky, 2006; Brookes *et al.*, 2017), highlighting the importance of individuals to drive learning. In megaprojects, different interests, professions and organizations are brought together to drive and promote learning (Bartsch *et al.*, 2013). However, prior studies offer limited empirical insights into the roles of key individuals driving and promoting learning in temporary multi-organizational settings (e.g. studies calling for further research: Bakker *et al.*, 2016; Burke & Morley, 2016; Ryan & O'Malley, 2016).

Key learning characteristics in megaprojects

Megaprojects offer dynamic learning capabilities (Burke & Morley, 2016). That means, new configurations of team members based on specific expertise and experience at different phases of a megaproject's lifespan is a source of innovation that in turn improves performance (Davies *et al.*, 2009). Lessons learned from past experience in megaprojects can be stored in databases and files which can then be used by team members in future megaprojects to avoid past mistakes and deliver the final outcomes successfully (Davies *et al.*, 2017). In addition to formal approaches to learning (e.g. reports, databases, contract), individuals create a social network of relationships (e.g. events, discussion groups, communities of practices) to share knowledge and experiences.

Interactionist approaches to roles focus on the ways individuals can (re)construct social arrangements through role-taking (Bechky, 2006; Burke & Morley, 2016). The role of individual boundary-spanners is increasingly emphasized in the literature on learning, especially in the settings of multi-organizational and multi-project interfaces (Brookes *et al.*, 2017; Zaheer, McEvily, & Perrone, 1998). Boundary-spanners are vital to deal with diverse individuals and organizations coming together to deliver outcomes in megaprojects (Aldrich & Herker, 1977; Huang, Luo, Liu, & Yang, 2016). In other words, their frequent information exchange within and across organizational and project boundaries. Boundary-spanners play a key role in addressing uncertainty and equivocality stemming from a megaproject's environment and processes by crafting, receiving, processing, and communicating information (Lentonen & Martinsuo, 2008). They regularly communicate across firm boundaries and perform activities that support intra- and inter-organizational relationships (Perrone, Zaheer, & McEvily, 2003). Boundary-spanners also tend to relocate across megaprojects to transfer their knowledge and experience to other team members (Brookes *et al.*, 2017).

Knowledge and the way in which boundary-spanners interpret (sense-making) and promote learning (sense-giving) is vital to constructing learning organization (Gioia *et al.*, 2000). In other words, the ways of promoting learning by boundary-spanners entails an effort to construct learning organization (Bakker *et al.*, 2016). For instance, Huang *et al.* (2016) apply process perspective on interpersonal ties in inter-organizational exchanges, demonstrating the ways boundary-spanners perform two roles: (i) serving as a robust base for connecting and sharing information. They decode, filter and pass the received information to relevant internal users; and (ii) acting as a relationship lubricant for effective cooperation and problem solving. Yet, prior studies have not connected the informal roles of boundary spanners with organizational identity theory in terms of the ways megaprojects construct their identities as

learning organizations. This study elaborates theory of learning in megaprojects by examining informal roles and approaches to learning and the ways they construct identities.

Organizational identity perspective on learning in megaprojects

We position social identity theory in explaining the ways learning is driven and promoted in megaprojects by key individuals. Weick's conceptual ideas shed some light on the connection between learning and meaning making, suggesting that components of identity construction rise to relevance when guided by the underpinnings of learning: *“Only with ambivalent use of previous knowledge systems are able both to benefit from lessons learned and to update either their actions or meanings in ways that adapt to changes in the system and its context”* (Weick, Sutcliffe, & Obstfeld, 2005: 414). This quotation connects learning with future changes, with emphasis being placed on the importance of context and meaning making process. Limited empirical research has specifically explored learning from organizational identity perspective (Brown & Starkey, 2000; Handley, Sturdy, Fincham, & Clark, 2006). We apply a definition of organizational identity as a sense of who organizational members are, or who they are becoming, as an organization (Corley & Gioia, 2004; Gioia *et al.*, 2000). Following Schultz and Hernes (2013), we focus on identity labels and their associated meanings serving as key components of organizational identity construction. Past research has recognized the temporary nature of organizational identity construction, for example, the ways organizations re-construct their identities through time (Clegg, Kornberger, & Rhodes, 2005). To date, little is known about the ways in which megaprojects construct their identities as ‘learning organizations’. The issue of identity construction as learning organization is relevant to both permanent and temporary organizations. Yet, given the specific characteristics of megaprojects (e.g. high risks associated with reputation, high expectations from the public), it is even more critical to their performance (Brookes *et al.*, 2017). Organizations tend to self-promote themselves as learning organizations through verbal,

written and symbolic narratives. In other words, megaprojects can be socially constructed as ‘learning’ through the ways people speak, communicate, interpret, and share knowledge in the context of project organizing. Senior managers play an important role in articulating these narratives and stories. Yet, there is a gap in current knowledge in understanding of the nature of narratives mobilized by senior managers in temporary multi-organizational settings in constructing identities of learning organizations and their broader implications for performance improvement and identity construction.

RESEARCH METHODOLOGY

Data collection and analysis

Overall, 33 face-to-face, in-depth interviews with senior managers and directors from UK-based infrastructure owner, contractor and supplier organizations were conducted.

Interviewees were selected on the basis of their professional experiences and their roles as active individuals within an innovation and knowledge management system [boundary spanners] (Stamper & Johlke, 2003). They played an active role in system integration and knowledge exchange within and across multi-organizational and multi-project interfaces. On average, interviewees have more than ten years of experience working in project-based settings during their career paths. The interviews were one-to-one, typically taking place in interviewees’ offices. The duration of the interviews varied from 32 to 75 minutes with an average of 58 minutes. Appendix provides background information about the nature of the studied temporary and permanent project-based organizations.

The adopted social identity theory guided the design of the interview guide with questions focused around making sense, interpreting, synthesizing, and transferring lessons learned about past failures and successes. Interviews were taped and transcribed verbatim, whilst we assured confidentiality of participating companies and individuals. Data reliability

was further supported by triangulation of data sources including company reports, presentations, and data collected via attending a series of industry events and workshops.

The transcripts were read by researchers several times over; identifying, analyzing, and reporting patterns (themes) within the data. Analysis included broader codes such as organizations' characteristics and more specific codes zooming in on the concepts under study such as individual and organizational learning, identity construction processes. The researchers started with noticing patterns of meaning and potential interests in the data. The systematic analysis was reflective in nature by making sense of the identified themes and interpreting them in relation to theory. The themes were reviewed and refined to ensure they form coherent patterns. The reviewed themes were named and clustered under headings that relate to the research question and theoretical framework. Our analysis was concerned primarily with common patterns across different organizations (temporary vs permanent, owners and suppliers) and across individuals, where differences were noted, further investigated, and reconciled (Poole & Van de Ven, 1989). The following sections present key findings derived from the thematic analysis.

EMPIRICAL FINDINGS

Key learning characteristics in megaprojects and their influence on performance

The purpose of construction/infrastructure megaprojects is to successfully deliver assets on time and on budget (e.g. a new railway, a new tunnel, a new building), achieve organizational benefits, and create value for customers. Megaprojects (often were labelled as 'pop-up clients' by the interviewees) – from Heathrow Terminal 5, via the Olympic Park and Crossrail towards Thames Tideway Tunnel and High-Speed Two rail link – place Britain in a unique position. This was articulated especially clearly by the CEO from water infrastructure megaproject: *“London has a permanent state of temporary organizations.*

There is an industry of people that actually move from one temporary organization to another; and many of which move and start the next one not realizing they have taken the culture of the organization with them, and then they get re-shaped by the new project and move on in a new direction". The transient nature of megaprojects means that people tend to move between megaprojects by applying their past knowledge and experiences in re-shaping the culture and vision of a new megaproject. This has important implications on the dynamic process of re-learning between megaprojects and their influence on performance. Changes are at the core of the operation of megaprojects: changes in people throughout stages of the life-cycle and between megaprojects represent the transient nature of work environment within which megaprojects operate. There was a clear comparison being made between special purpose megaproject and business as usual permanent owner organizations:

"Because [Name of the organization] is such high-profile and contentious, a key part of being a leader is to actually to be able to articulate a very clear narrative around why [Name of the organization] is important. Not just for the purpose of promoting it externally, but internally as well, to motivate people. People are knowing why they are doing it, and actually make sure we are delivering the right thing. Having a very clear narrative absolutely has been very important." (CEO from rail megaproject). The clear purpose of a megaproject is at the center of what they do which distinguishes it from permanent owner and supplier project-based firms (Davies *et al.*, 2017; Winch, 2014). Constructing a strong narrative about organizational identity for internal as well as external audiences is seen crucial for the delivery of megaprojects. Table 1 presents the identified key learning characteristics in megaprojects and their influence on performance with the support from the empirical data. The transient nature reinforces the dynamics of people bringing their experiences from other megaprojects, shaping culture and mind-set. The unique purpose drives learning and performance in megaprojects. Narratives about the purpose of

megaprojects shape the dynamic process of learning and identity construction of megaprojects as learning organizations.

Table 1 Interviewees' quotations on TMO characteristics and their impact learning and performance

Characteristics of TMOs	Key learning characteristics and their influence on performance	Representative quotes
Multiple and complex temporariness	<p>Learning faster</p> <p>Temporary/permanent dilemma</p> <p>Sharing experiences</p> <p>Transferring learning internally in TMOs</p>	<p><i>"We had a sense of urgency in a business where normally we had one or two years to plan and then a year or two to deliver. We had to do all of that in '15 minutes'. And then we had a recession in 2010 with big cuts in funding. [...] And then over the last 18 months, I had to build it up again. In 7 years you change your senior team, you change people. You might change structure. [...] The world has changed very fast and we have quite demanding customers."</i> (CEO of a major road infrastructure operator, #25)</p> <p><i>"Even so projects are temporary, long-term, we consider permanency here. There is a permanency in people more than in the organization."</i> (CEO from a major water TMO, #21)</p> <p><i>"You need others [boundary-spanners] around in TMOs to share experience, to actually realize your conversation is here. How are you actually transferring all learning? [...] You have delivery managers [boundary-spanners], who transfer a lot of learning to other TMO members. It is difficult with so many emails going around and now we have social media: Twitter [...]. So, we encourage them [boundary-spanners] to come and give us ideas what they think."</i> (Head of Innovation, Water infrastructure TMO, #28)</p>
Transient nature of the business	<p>People bring past experiences from TMOs into new TMOs</p> <p>Mind-set and culture</p> <p>Key individuals and organizations engaging in the learning process</p>	<p><i>"Right from the beginning we collected the information how other high speed rails have been developed. Some of that share come from people, rather than specific knowledge sharing program. A large proportion of people have experience in past megaprojects. We had workshops on particular topics to share learning. We actually adopted a lot of things."</i> (CEO, rail TMO, #19)</p> <p><i>"Looking back is more about to say what worked and what did not [in a previous TMO] from sort of lessons point of view. How can we use the best of that and apply in the context of [current TMO] to be more creative? it comes to the point of mind-set. We all bring our experience of previous projects and previous lives into the project. And it is about looking forward: how do we organise all that experience, all that creative thinking in a context of [name of TMO] and get the best of everybody to get it delivered."</i> (CEO, rail TMO, #18)</p> <p><i>"The way we are looking at it now is that you do not want to wait until transfer, actually you want key people [boundary-spanners] and organizations to</i></p>

		<i>engage all the way through. There are learning points all the way through.</i> ” (Innovation Manager, water infrastructure TMO, #26)
Special Purpose Vehicle (SPV)	<p>Unique purpose drives learning and performance</p> <p>Constructing a narrative about TMO</p> <p>Creation of a network</p>	<p><i>“I think what you are seeing now over the last 5-10 years is when you have an ability to create a special purpose client, a ‘pop-up’ client to deliver one major program. Then they tend to do it well, because you are designing the right client organization from day 1 fit to deliver that one goal”</i> (Program Control Director, rail TMO, #27).</p> <p><i>“I am a huge believer in knowledge management system that allows people to learn. I am a huge believer in when somebody starts something they go and talk to people who have done something similar before. So, we are learning in the organization from people who have done runways before”</i> (Development Director, Airport infrastructure TMO, #31)</p> <p><i>“I am trying to create a Hub for UK infrastructure you have a really good chance to actually create value. [...] To me, it is information plus I think experience that creates value and you have wisdom. Wisdom is not something that you write down, but you need to share with other members.”</i> (CEO, transport infrastructure TMO, #18)</p>

Constructing identity of ‘learning megaproject’

Megaprojects tend to actively promote learning in comparison to permanent organizations.

They see themselves and are often recognized by other organizations as ‘learning

organizations’: *“We were far more focused on actively promoting Learning Legacy.*

Learning Legacy has been a big theme for 2017 because we are in that space now - we are the client who has the opportunity to take the time and capture everything that we have done wrong and the lessons that we have learnt along the way. You will never get [names of permanent owner organizations] doing Learning Legacy website because they are not special purpose client who will see to be upon the completion of their work. They are business as usual client who will be around for the next 20,30,40 years. [Name of the organization] is only here for 2 years. I am only here for 12 months. When the project is delivered the people will go.” (Program Control Director). This quotation clearly points to

the ways senior managers actively promote leaning legacy in a megaproject as a popular narrative.

Senior managers have a strong belief and value in constructing identity of a learning organization. This is evident from the Head of Innovation of a water infrastructure megaproject (#28): *“My ethos for the last 15 years is all about pick the right people and make sure they have got the sufficient knowledge and then get them to think in a right way. I just use the loose term collaboration, it is about sharing knowledge, sharing ways of doing things, so that we all work at big problems faced at infrastructure industry, and make a complete different to the future together.”* Of particular note is the collective and collaborative way of sharing knowledge in the infrastructure sector. Similarly, Director of Asset Management of permanent client infrastructure organization demonstrates his ambition to create a learning organization: *“One of my ambitions is to create a learning organization. Some of that is through stability, consistency of approach. But absolutely how individuals learn and make it part of collective learning rather than something they will never do again because it hurt them. They have personal consequences because of it.”*

Senior managers strive for consistent and stable approach for collective learning and creating a learning organization. This relates to the challenge emphasized by many interviewees about the next generation of project leaders: *“The biggest challenge we have got in the UK is how do we develop something that the next generation of leaders can learn from us. Because I do not think we have got the time. Actually, we are not that bad at doing projects at the moment. I feel we are not too bad at the moment because we have learnt all of that. We have a generation of people who have been through it who confidently can sell the picture, who make sure they get the right environment. But the next generation are going to be victims of our success. How could we leave them with a legacy, and capable owner has that, a framework for leadership, not management.”* Of particular note is the emphasis being

placed on ‘capable owner’ in creating learning legacy and providing a framework for leadership.

Leadership driving learning in megaprojects

Most interviewees recognized that it is quite often down to an individual’s willingness and motivation to learn from past experiences and transfer it to new experiences. This emphasizes the role of key individuals to drive learning within megaprojects and also capture information from external sources such as suppliers. The Development Director of UK major airport megaprojects shared his experience of learning from other senior management team and involvement in a community of infrastructure owners and suppliers committed to change: *“I get involved in things like Project 13. I believe what I learn will make the organization more efficient and add value. It is important to be in the conversation and actually we have something to offer.”* This quotation demonstrates a connection between individual learning driving organizational performance. It is a two-way process of improving internal performance through learning and also sharing their best practices to wider communities of practices. A number of interviewees argued that knowledge was created by boundary-spanners through capturing information, then analyzing it and being able to further develop it through *“making sense of information”*, *“applying it to our context”*, and ultimately *“communicating it effectively”* internally within and externally across megaprojects *“to stimulate learning”*.

Senior managers further reported that they found it difficult at times with so many emails and Twitter messages to *“actively participate, share knowledge, and experiences”* within and across organizations. The boundary-spanners interviewed were constantly seeking innovative ways of embedding information and driving learning to deliver projects successfully.

From formal towards more informal approaches to learning in megaprojects

It was recognized by the interviewees that most both permanent and temporary project-based organizations have some form of formal processes in place to drive organizational learning via, for instance, databases and platforms to share knowledge, but there has been much stronger emphasis on more informal approaches to learning: *“We can write case studies. We can put stuff on our webpages. I think there is a place for cataloguing experiences. People can go and read it. My experience is that people quite often do not go and read it. Increasingly, the way we are going to do it in our business is to create a very connected, organic workforce, a sustainable workforce, where Jim knows Paul works in that job; Sue knows Susan did that. Learning, I think, is more organic in our company and quite often driven by key people [boundary-spanners] who then share key learning.”* (CEO, transport megaproject). Megaprojects are temporary, even though may last many years, and they disperse after completion, so the chances of creating a knowledge platform (such as databases) is problematic. Hence, the role of key individuals (boundary spanners, self-motivated individuals) and their networks is crucial to drive knowledge and learning initiatives.

Some interviewees stated that they do not have formal knowledge management systems in place, but they have established expert groups. These groups are networks across the business that are focused around selected areas of excellence or priorities such as Building Information Modelling Group, Innovation Group, and Market-Making Group. This creates learning across a network of people meeting and collaborating who feel comfortable with each other. The CEO from a permanent construction owner firm articulated this point especially clearly: *“We have about 15 groups in the organization. That creates networks of people; they meet and collaborate. This is driven by key people. They use examples or stories to share experiences. Eventually, network and communication become the most powerful, strongest*

way of sharing the learning.” This example underlines the argument that organizational learning is driven by individuals who share knowledge through personal stories and examples from their experience. This is consistent with the emergent recognition that knowledge transfers from the project setting to the permanent organization is mainly the transfer of individual focusing more on inter-personal and individual learning than on organizational learning (Aerts, Dooms, & Haezendonck, 2017).

The data further demonstrate that permanent supplier project-based firms have many difficulties in building their learning capabilities: *“We are not really using online tools, communication tools to transfer knowledge in the right way. We started to but it is not great. It is all based on the relationships you build by speaking to people rather than being a system”* (The Business Improvement Manager, permanent supplier firm). This example places an emphasis on the need for online communities of practices where people can connect with each other when solving similar problems. The Regional Managing Director from a permanent construction owner and operator provided an example of collecting data from users based on interviews and conversations after the building project was commissioned: *“You built the building, you use all the skills, you monitor the performance for the next twelve months. You interview people how usable the building is. The most important people are users who use it on a day-to-day basis. We have to have evidence-based design. Has that worked well? If not, what has not worked well? If it worked well, let us do that again. It is about collecting the data, understanding what the data means, and use it on the next project.”* This example shows a boundary-spanner’s initiative to gathering information about users’ perceptions as a helpful way of understanding meanings, and transferring it to future projects, hence driving learning. It also shows a need for a greater integration of front-end (planning and delivery phases) of a project with a back-end (operation phase). This is consistent with the

literature on dynamic capabilities of megaprojects from the delivery to operation (Zerjav *et al.*, 2018).

DISCUSSION

Key characteristics of learning in megaprojects

The senior managers interviewed emphasized different organizing principles all of which shape learning in megaprojects: multiple and complex temporariness, transient nature of the business, and special purpose of delivery. The temporary, transient and overlapping boundaries with multiple organizations and projects of megaprojects make formal approaches to learning (e.g. databases, platforms and reports) problematic. We found the role of boundary spanners is crucial to drive learning initiatives. In order to support learning in megaprojects, it is important to pay more attention to a network of individuals and their informal roles (Bechky, 2006; Manning, 2017). Of particular note is the behavioral and cultural aspects in changing megaproject members' mind-set to become part of the identity of a learning organization. Boundary spanners play important roles in creating an environment in megaprojects where learning is valued and employees are committed in enhancing learning capabilities. We found that in permanent organizations, the speed of learning tends to be slower than in megaprojects, as there is less sense of urgency and there are established routinized learning practices that employees follow (Hobday, 2000; Prencipe & Tell, 2001).

We have found that megaprojects play an important role in driving and promoting narratives of learning legacy in the UK infrastructure sector. This is consistent with the three domains of project organizing model developed by Winch (2014). Capable owners set directions and challenges and provide support for suppliers to innovate and learn from best practices across the sector. Managers in owner organizations create an environment for learning to emerge through both formal (e.g. databases, catalogues, case studies) and informal

(e.g. conversations, telling stories, using examples) ways. The empirical data demonstrate a clear shift towards more informal ways of learning in megaprojects. More specifically, findings show the importance of boundary spanners who actively engage in driving and promoting learning in the settings of intra- and inter-organizational and project interfaces (Aldrich & Herker, 1977; Bakker *et al.*, 2016). Narratives of learning legacy are also particularly popular among senior managers interviewed.

We further found that megaprojects socially construct their identities as learning organizations via spoken, symbolic, and written forms: sharing stories, videos via digital platforms, and write reports, blogs. There was more emphasis on the importance of narratives of organizational identities of megaprojects when compared to permanent organizations. Past studies are silent about the role of narratives in identity construction, and their especially critical role in temporary multi-organizational settings. This is one of our key contribution to knowledge to the extant studies. Considering the temporary and dynamic nature of megaprojects, narratives about organizational identities motivate individuals to improve performance, but also play important role in recognition from external audiences (other organizations and public).

The impact of learning characteristics in megaproject on performance

We have found that learning in megaprojects is driven by past experiences from similar megaprojects. This empirically proves the rule outlined by Davies *et al.* (2017) that megaprojects capture prior experiences by studying past megaprojects. There has been an agreement among interviewees on the importance of sharing learning from mistakes and failures as it has impact on performance improvement in the future by avoiding past mistakes and use past examples and experiences. However, there have been some disagreements amongst interviewees about the extent to which organizations are good at learning from

failures. Whilst some interviewees take a more positive perspective, others are more skeptical (especially those from permanent supplier project-based firms) in indicating that failures are still often hidden from a public eye (due to reputation risks associated with megaprojects). It is people who bring their experiences with them from work in previous megaprojects and share their experiences with organizational and project members who face similar problems. Based on the interviewees' perceptions, sharing stories about lessons learned and support those who face similar issues impact on organizational performance improvement.

Key individuals and leaders who are actively involved in transferring learning through networks and telling stories about past success and failures play an important role in the dynamic process of learning in megaprojects. These individuals in their informal roles (e.g. boundary spanners, leaders, innovation champions and agents) are vital to drive learning in megaprojects. Some authors have warned that learning is of highly situated nature and this may make transfer from one context (i.e. one specific megaproject) into another problematic (Gherardi, Nicolini, & Odella, 1998). This is addressed by the importance of boundary-spanners in megaprojects to 'de-situate' specific domain knowledge and to communicate relevant information to megaproject's members helping to reduce uncertainty and equivocality (Ryan & O'Malley, 2016). With the help of personalized stories about past events, boundary-spanners are able to break down rich and complex content to transfer learning within and across megaprojects.

Summary of key contributions

This study contributes to our yet incomplete understanding of learning in megaprojects when compared to permanent project-based organizations. We found that narratives about the specific purpose of a megaproject play an important role in constructing identity of 'learning organization'. This contributes to a better understanding of the ways megaprojects socially

construct their identities as learning organizations via narratives. Adopting organizational identity theory (Corley & Gioia, 2004; Gioia *et al.*, 2000; Schultz & Hernes, 2013), an underutilized theoretical lens in extant studies on learning in megaprojects, this study uncovers learning characteristics in megaprojects and their impact on performance. Boundary spanners in their informal roles move across megaprojects bringing and sharing their experiences through stories about project failures and successes facilitates learning and improves performance.

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Appendix

Table List of interviewees and information about temporary and permanent organizations

#	Position in the organization	Years of experience	Label	Nature of organization*	Length of interview (in mins)
1	Project manager	30	PO2	Construction project-based organization (contractor)	61
2	Chartered civil engineer	13	PO2	Civil engineering project-based organization (contractor)	45
3	Project manager	49	PO2	Engineering project-based organization (contractor)	65
4	Group innovation knowledge manager	12	PO2	Construction project-based organization (contractor)	70
5	Business improvement manager	9	PO2	Housebuilding and construction project-based organization (contractor)	65
6	Planning manager	13.5	PO2	Construction contractor	67
7	Business development manager	11	PO2	Civil engineering project-based organization (contractor)	45
8	Design and geotechnical manager	15	PO2	Civil engineering project-based organization (contractor)	55
9	Senior advisor, development director	25	PO2	Construction project-based organization (contractor)	60
10	Principal program supply chain manager	30	TMO	Client public transport	68
11	Business director	33	PO2	Construction project-based organization (contractor)	56
12	Strategic project director	15	MP	Rail and transportation ('pop-up' client)	45
13	Managing director	23	PO2	Regional building and civil engineering contractor	32
14	Procurement operation manager	30	MP	Transport infrastructure ('pop-up' client)	60
15	Procurement director	25	MP	Transport infrastructure ('pop-up' client)	41
16	Managing director	27	PO1	Construction project-based organization (client)	47
17	Head of Building Information Modelling (BIM)	25	PO2	Construction project-based organization (contractor)	60
18	Chief Executive Officer	29	MP	Transport infrastructure ('pop-up' client)	35
19	Chief Executive Officer	30	MP	Transport infrastructure ('pop-up' client)	64
20	Procurement Director	30	MP	Transport infrastructure ('pop-up' client)	67
21	Chief Executive Officer	30	MP	Water infrastructure ('pop-up' client)	75
22	Chief Executive Officer	20	PO2	Engineering project-based organization (contractor)	70
23	Regional Managing Director	19	PO2	Construction and engineering project-based organization (contractor)	55
24	Chief Executive Officer	30	PO2	Multinational construction project-based organization (contractor)	60
25	Chief Executive Officer	40	PO1	Road infrastructure operator (client)	70
26	Innovation Manager	25	MP	Water infrastructure ('pop-up' client)	45
27	Program Control Director	15	MP	Rail infrastructure ('pop-up' client)	65

28	Head of Innovation	40	MP	Water infrastructure ('pop-up' client)	45
29	Director of Asset Management	35	PO1	Water infrastructure permanent (client)	60
30	Chief Executive Officer	40	MP	Airport infrastructure ('pop-up' client)	75
31	Development Director	25	MP	Airport infrastructure ('pop-up' client)	60
32	Director of Innovation and Continuous Improvement	13	PO1	Road infrastructure operator (client)	30
33	Project and Program Manager	30	PO1	Transport infrastructure owner and operator (client)	60

** The MPs are set up as regulated businesses created for the purpose to build and manage physical assets or facilities such as roads, bridges, buildings, tunnels and water supply. British construction, engineering and infrastructure Megaprojects ('pop up clients') are characterized by a large investment commitment; high level of uncertainty; specified timeframe; vast complexity and coalition of clients, suppliers and consultants, long-lasting impact on the economy, society, environment and society; top managers and team members regularly changing their positions within and across megaprojects. The selected PO1 are permanent UK construction, infrastructure and engineering client/owner and operator organizations responsible for operating, maintaining services or customers. The selected PO2 are UK construction, infrastructure and engineering permanent project-based supplier organizations, offering diverse services ranging from design, construction and project management services to clients. (based on Winch, 2014).*

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EXAMINING INTERNATIONAL ‘TECHNOLOGY TRANSFER’ ON CONSTRUCTION PROJECTS: INSIGHTS FROM A ‘SCOT’ ENQUIRY

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EXAMINING INTERNATIONAL ‘TECHNOLOGY TRANSFER’ ON CONSTRUCTION PROJECTS: INSIGHTS FROM A ‘SCOT’ ENQUIRY

ABSTRACT

It is well-known that technology gaps exist between developed and developing countries (DCs). Within the construction context, developing countries have over an extended period embarked on project-based international technology transfer (ITT) to improve their construction industries. However, the attempts consistently fall short in yielding the desired outcomes, and foreign contractors dominate in the delivery of vital projects in these countries. Construction project-based ITT is remarkably complicated, with multi-faceted interfaces between the social and the technical. However, existing studies tend to over-simplify the process to be linear and ignore its ingrained micro-dynamics. To understand the complicated processes the research uses the social construction of technology (SCOT) approach to explore what happens within an attempt to transfer a monolithic formwork (MF) technology on a project in Ghana. The inquiry followed the journey of the technology, capturing its development, the involvement of actors, and the impacts on the construction project. The findings underscore how a construction project-based ITT attempt is complicated and better understood from a sociotechnical viewpoint. This understanding of the process, coupled with insights about its core components (technology, actors, and the environment), raises queries about the concept of ‘TT’ on construction projects. Based on the SCOT insights the paper argues how, contrary to pervasive views in related literature, the process may be reconceptualised to understand it better *as it is* on construction projects.

KEYWORDS

Technology transfer, project, sociotechnical, social construction, SCOT, complexity

INTRODUCTION

A notable difference between advanced and developing countries (DCs) is in the use of technology in many areas, including construction (Abbott, 1985; Osabutey & Croucher, 2017). For over fifty years, the latter have embarked on project-based international technology transfer (ITT) to improve, among other things, their construction industries (Abbott, 1985; UNCTAD, 2014). DCs lack the technology needed to undertake a wide range of infrastructure projects (e.g. commercial and health facilities, and roads) vital for their development. Typically, such construction projects are large in scale, of high complexities and technological requirements, and their demands exceed the capabilities of construction firms in DCs (Ruiz-Nuñez & Wei, 2015). As a result, there is evidence of substantial reliance on foreign construction firms – considered to be advanced in the use of technology – to deliver such vital projects (Ofori, 1994). For instance, a group of Chinese firms constructed the USD 200 million

headquarters complex for the African Union (AU) in Ethiopia (AU, 2011). Other instances of dependence include the construction of energy processing plants, mass housing projects, highways, airport terminals and runways, and commercial infrastructure in Ghana, South Africa, D.R Congo and Ethiopia by a mix of Italian, Brazilian, Portuguese, Israeli and Turkish contractors and consultants (Construction Review, 2017). The reliance contributes to a vicious cycle that sustains gaps in technology between advanced and developing countries (Ofori, 1994).

Increasingly, international technology transfer (ITT) has become a preferred approach in the efforts of DCs to narrow the technology gaps. A primary goal of an ITT attempt is to realise the creation of a localised technology that can be improved and used by local actors in future projects (Osabutey, Williams & Debrah, 2014). According to the UN's Draft International Code of Conduct on the Transfer of Technology ITT is to allow 'technology-deficient' countries to obtain technology from the advanced ones (UNCTAD, 2004). The former is usually labelled as 'transferees' or 'recipients', and the latter, 'transferors' or 'givers' (Abbott, 1985; Ofori, 1994). Widespread acceptance and implementation of ITT in less advanced countries can be traced to efforts by the United Nations Conference on Trade and Development (UNCTAD), and the World Bank, which peaked between the mid-1980s and the late-1990s (Horta, 2005). The former sought to regularise and promote ITT by formulating an international code for it (UNCTAD, 2014). The latter undertook a variety of infrastructure projects (e.g. roads, oil pipeline and water treatment plants) in countries like Chad, Cameroun, Morocco and Lesotho with the aim of transferring technology from advanced countries to the former through the construction projects (Haddad & Harrison, 1993; Estache, 2006). Evidence suggests that the attempts were mostly futile (Haddad & Harrison, 1993; Ayittey, 2002; Estache, 2006). Notwithstanding, countries like Ghana, Kenya, Uganda, and Tanzania continue project-based attempts to transfer technology into their construction industries under different vehicles, including subcontracting, partnerships, and joint ventures (UNCTAD, 2003; Osabutey *et al.*, 2014). Typically, governments of the recipient countries award construction and supervision contracts to foreign firms, who are usually contractually obligated to bring in some new technology as part of delivering the projects (c.f. Osabutey & Croucher, 2017; Kumaraswamy & Shrestha, 2002). In some cases, there are local actors attached to the foreign team as part of the ITT attempt. This arrangement is based on a pervasive notion that a complete technology – limited to fixed physical construction equipment, tools and devices, or embodied in foreign human expertise – will be passed from the foreign transferors to the local transferees by the end of the project (Carrillo, 1994; Putranto, Stewart and Moore, 2003; Osabutey & Croucher, 2017).

An attempt to transfer technology on a construction project is a complicated process which entails more than merely importing physical products to be used on a project in a new environment (Sexton & Barrett, 2004). These are only technical artefacts that form part of the technology used on construction projects (Harty, 2005, 2010). The process also entails more than the importation of foreign expertise to work on a project in a new environment (c.f. Abbott, 1985). The pervasion of simplistic ideas about technology and how an idealised transfer may ensue shape how DCs approach ITT, which contribute to the failure of their attempts. Understanding the process from a perspective that unpacks its micro-level complexities holds the potential for ITT attempts on construction projects to achieve the desired outcomes in recipient countries.

To examine the microdynamics involved in an attempt to transfer technology on a construction project this paper explores “what happens when new technical artefacts are introduced and used in a new environment as part of a project-based ITT attempt?” The paper presents findings from following a set of new monolithic formwork (MF) from Portugal to Ghana, used by a Brazilian contractor working with Ghanaian locals on a Mass Housing Project (MHP) as part of a government-led technology transfer initiative. The section that follows discusses ITT in construction management research, with emphasis on conceptualisations about its core components. Against ubiquitous views in existing literature, the paper advances a sociotechnical view of ITT in a construction project-based setting as an approach to better unpack the complexities entailed. The paper progresses by presenting the social construction of technology (SCOT) as the approach adopted in the study to explore the project-level microdynamics of ITT. A discussion of the findings from a qualitative case study follows, and the paper concludes by outlining implications of the findings for the concept of ‘technology transfer’ on construction projects.

INTERNATIONAL TECHNOLOGY TRANSFER IN CONSTRUCTION

Projects are considered to form the nucleus of many agenda to improve a construction industry (Abbott, 1985) technologically. So, it is unsurprising that ITT attempts are usually project-based (Ofori, 1994; Osabutey *et al.*, 2014). Such a setting brings the dynamic and multi-faceted nature of construction projects to bear on the processes entailed in ITT and impact its core components of technology, actors, and the environment. The process of construction involves a myriad of technical artefacts (e.g. concrete mixers, formwork panels, digital devices, computer software) that are in a dynamic mix with components of the social (e.g. regulations, human influences) towards the formation of technology (c.f. Harty, 2005, Jacobsson & Linderoth, 2010).

Many studies on ITT (e.g. Ofori 1994; Carrillo 1994; Kumaraswamy and Shrestha 2002; Waroonkun and Sewart, 2008; Osabutey *et al.*, 2014), reify technology as fixed, stable, and embodied in physical artefacts, or in human expertise. However, technology on construction projects is neither rigid nor confined to any set of products or people: it develops through the interactions of actors and technical artefacts within an environment towards the realisation of the desired output (e.g., a building or bridge). The neglect of this intricacy in the literature is usually attendant with narrow ideas about how an idealised transfer may ensue. The process is pervasively conceptualised to be linear, with one group, transferors, bringing a complete technology to another party, transferees (e.g. Ofori, 1994; Carrillo, 1994; Osabutey & Croucher, 2017). Here, the literature pervasively uses ‘transfer’ to describe the movement or relocation of physical products and humans with the related expertise from one place to another. While much of studies (e.g. Ofori 1994; Carrillo 1994; Waroonkun and Stewart 2008) consider technology transfer to involve the movement of humans and physical products and slotting them into a project in a new environment, evidence from practice suggests that the process is often a clutter.

Transferring foreign technology into a new environment is not a simple, direct process and that for countries to significantly improve their construction industries, there is the need to examine ITT in a way that captures the complex layers of interactions involved. Therefore, to consider the transfer of technology to be a simple process of selection and slotting-in (c.f. Sexton & Auad, 2006) neglects the micro-

processes that define the technology, and shape the construction project delivery process. There is scarcely any study that explores the intricate micro-level processes involved in ITT, capturing the actors, technology, project deliverables and the environment. Existing studies –acknowledge, yet –barely extend to explaining the complexities involved in construction project-based ITT attempts, and there is scant research accounting for the interplay between the technical and social aspects of the process. From a sociotechnical viewpoint, this paper addresses these gaps by examining the journey of a set of construction formwork into a DC as part of a project-based ITT attempt. The section that follows discusses how a sociotechnical view of technology benefits the enquiry.

A SOCIOTECHNICAL VIEW OF TECHNOLOGY

The research examines the process of ITT as series of sociotechnical interactions involving the parties involved and the artefactual components of technology. This outlook is set in the sociotechnical studies (STS) view, which is in the broader area of sociology of technology (Harty, 2005; Orlikowski, 1992; Williams & Edge, 1996). The sociotechnical view offers approaches for exploring interactions between humans and technology. From this position, there is no pre-determination for what technology is or may look like (Bijker, 2001; Schweber & Harty, 2010). The composition of technology does not remain fixed or stable over time and are in constant, mutual interactions (Harty, 2005). Such a stance necessitates a departure from views of technology that favour compartmentalisation into human- and artefact- embedded forms, and limit technology to pre-stabilised, tangible artefacts. Instead, the view taken is that the development, identity and use of any technology are inseparable from the environment in which it is found (Rohracher, 2001; Orlikowski, 1992; Williams & Edge, 1996). Here, ‘environment’ includes humans and the socio-cultural, political and economic context within which technology is formed and shaped. Therefore, the social setting in which technology “emerges and becomes embedded” is considered essential in its composition and identity (Williams & Edge, 1996, p. 875).

Undertaking a construction project involves several human actors and an array of technical artefacts engaged towards the completion of a building, railway, or dam (Harty, 2005). Actors from different organisational and professional affiliations interact directly through integrated task executions or technical deliberations related to completing the project. Similarly, different project actors undertake designs and tasks that impact technology and how it may be suitably incorporated on a project, and how the final project deliverable may turn out (Jacobsson & Linderoth, 2010). These interactions are concurrent and lead to the emergence of a unique composition of technology that is environment-specific (Boyd, Larsen, & Schweber, 2015; Harty, 2005; Schweber & Harty, 2010). Additionally, the interactions provoke varying levels of interrelated changes with the potential to impact the composition of the technology and its development, construction routines, and the final project outcomes as well. As part of the interfaces, technology emerges as a product of social construction/shaping around specific technical artefacts (e.g. formwork). Here, the social construction or shaping refers to technology being modified by actors through multifaceted negotiations to suit several organisational and contextual requirements for effective utilisation (Bijker, Hughes, Pinch, & Douglas, 2012; Leonardi & Barley, 2010; Orlikowski, 1992).

The study carries forward the views discussed technology in the above review to examine how technology is formed in a given context as part of an attempt to transfer technology through the social construction of technology (SCOT) lens.

THE SOCIAL CONSTRUCTION OF TECHNOLOGY (SCOT)

SCOT provides a coherent and inclusive approach to empirically examine the complex realities of interactions between people, technology and organisations in a setting (Bijker *et al.*, 2012; Schweber & Harty 2010). First proposed by Pinch and Bijker (1984), it is a constructivist approach for exploring how one variation of technology develops and stabilises in a context, accounting for the role of actors.

A set of fundamental assumptions underpin SCOT. First is the ‘interpretative flexibility’ of technology. This concept establishes the premise that technology is not rigid, and that multiple possible meanings can be ascribed by different actors in the design and interpretation of technical artefacts. Thus, different actors may see technical artefacts from various – sometimes conflicting – angles and identify diverse sets of problems about them from their perspectives that are shaped by their particular backgrounds (Bijker, 2009; Bijker *et al.*, 2012). Second, under SCOT technology emerges through series of interactions between humans and technical artefacts in an environment to achieve an intended outcome. Third, the development of technology is not devoid of influences from the environment in which it emerges; the social context shapes it. Technology is therefore localised, dynamic, and evolving based on the make-up of its network in a given environment (Bijker *et al.*, 2012).

The SCOT approach is operationalised through the constructs of: Relevant Social Groups (RSGs), Technological Frames, Problems and Solutions, and Closure and Stabilisation (Bijker *et al.*, 2012). Relevant Social Groups (RSGs) refer to the parties – an individual, or group(s) of individuals – who define technology. RSGs are made up of concerned actors who “share the same set of meanings attached to a specific artefact” (*ibid*, p. 23). For every technology, the RSGs may have sets of shared or conflicting meanings, forming different ‘Technological Frames’ (TFs). A TF represents how actors understand and interpret technological artefacts, based on which they ascribe meanings that define the technology. The frames of RSGs are informed by their backgrounds and experiences (Leonardi & Barley, 2010). Through TFs, RSGs identify different problems about artefacts of technology and proffer solutions to address them. However, what one RSG may see as a problem, based on their TF, may not be a problem for another. Similarly, while a solution may address the problem identified by one RSG, it may lead to the creation of a problem for another RSG under a different TF. Through negotiations, with RSGs rallying round different TFs, specific problems are solved, leading to some closure and stabilisation. According to Bijker *et al.* (2012), “to close a technological controversy does not need one to solve the problems in the common sense meaning of the word. The key point is whether the RSGs see the problem as being solved” (p. 37). ‘Closure’ reflects the elimination of problems –in the eyes of concerned RSGs –surrounding a technological artefact, and ‘stabilisation’ is achieved when there are no more modifications to a technical artefact, and the RSGs are satisfied with the iteration they have (Pinch & Bijker 1984; Bijker 2001). Stabilising a technological network is not absolute for a given technology. Continuous sociotechnical interactions lead to commensurate modifications as and when the composition of the network changes.

SCOT AND CONSTRUCTION PROJECT-BASED ITT

The study uses the theoretical constructs of SCOT to explore the complexity of interactions embedded within a project-based ITT attempt. Transferring technology on construction projects typically involves the introduction of a new technical artefact, around which a network of technology emerges over time. The parties involved in the ITT project engage in multi-faceted interactions with each other, as well as with the technical artefact over the course of the project. Recognising the vast array of actors with different backgrounds usually engaged on such projects, several conflicting perspectives about the technical artefacts are bound to emerge. The SCOT constructs of technological frames and relevant social groups are useful to explore these developments. Through the processes of design and construction, the different parties interact with the artefacts in different ways and engage in problem-solution negotiations that contribute to the formation of technology. By following these multi-faceted interactions using the constructs of problems and solutions, the study can unpack the complicated negotiations that shape the formation of a localised iteration of technology within ITT attempts. The constructs of closure and stabilisation help explore how a stabilised iteration of technology emerges by the end of the project. Using SCOT to examine ITT on a construction project requires the research to favour neither the ‘technical’ nor the ‘social’. Relatedly, there is bias for neither the explicit nor a tacit form of technology, as commonly presented in the majority of studies (e.g. Carrillo 1994; Waroonkun & Stewart, 2008; Osabutey *et al.*, 2014; Majidpour, 2017).

APPLYING SCOT IN EXPLORING CONSTRUCTION PROJECT-BASED ITT

This section is based on how Bijker’s analysis of the bicycle as a technological configuration (comprising wheels, seats, frames, brakes and tyres) (Bijker, 1999) provides a map for the application of SCOT in this research.

The first step in applying the SCOT approach is to deconstruct the technology in focus and identify the physical artefacts (e.g. formwork panels and accessories). The next step is to identify the actors who influenced the development of each technical artefact. Actors with shared meanings about every artefact are identified and grouped. The collection of actors become known as relevant social groups (RSG), and their shared meanings about the given artefact, the technological frames (TFs). Identifying RSGs is not along formal lines of professional, organisational or contractual affiliations. Instead, the composition of RSGs is determined through the grouping of actors who share in sets of interests and concerns about the technology (Bijker, 1999). The composition of RSGs may, therefore, include a variety of actors from diverse backgrounds. For instance, a Client, Local Artisans and Foreign Consultants may share in one TF. Delineating the different TFs brings to the fore the interpretative flexibility of technology. After finding the RSGs, the next step is to identify the problems each group identifies with the individual artefacts. Concurrently, for each problem, the analysis proceeds to determine the different solutions proffered. The problem-solution identification continues until the analysis establishes a full picture of the development of the complete technological configuration.

SCOT diagrams are indispensable tools in the use of the approach. A typical schema shown in Figure 1 below, they are developed to graphically illustrate the multiple problems and solutions in a multifaceted technological network. The point of departure

in the diagrams are the artefacts, which are at the centre of the analysis. Bijker (1999) provides guidance on the step-by-step connections in the visual representation of the networks with the conventional representation of artefacts and groups of actors as hexagons and lozenges respectively. The RSG-specific problems are shown as circles, with the proffered solutions as octagons. The merit of the diagram is that it allows one to follow the sophisticated analysis of how technology develops around a set of technical artefacts, while easily identifying the social shaping processes through problem-solution interactions involving the actors.

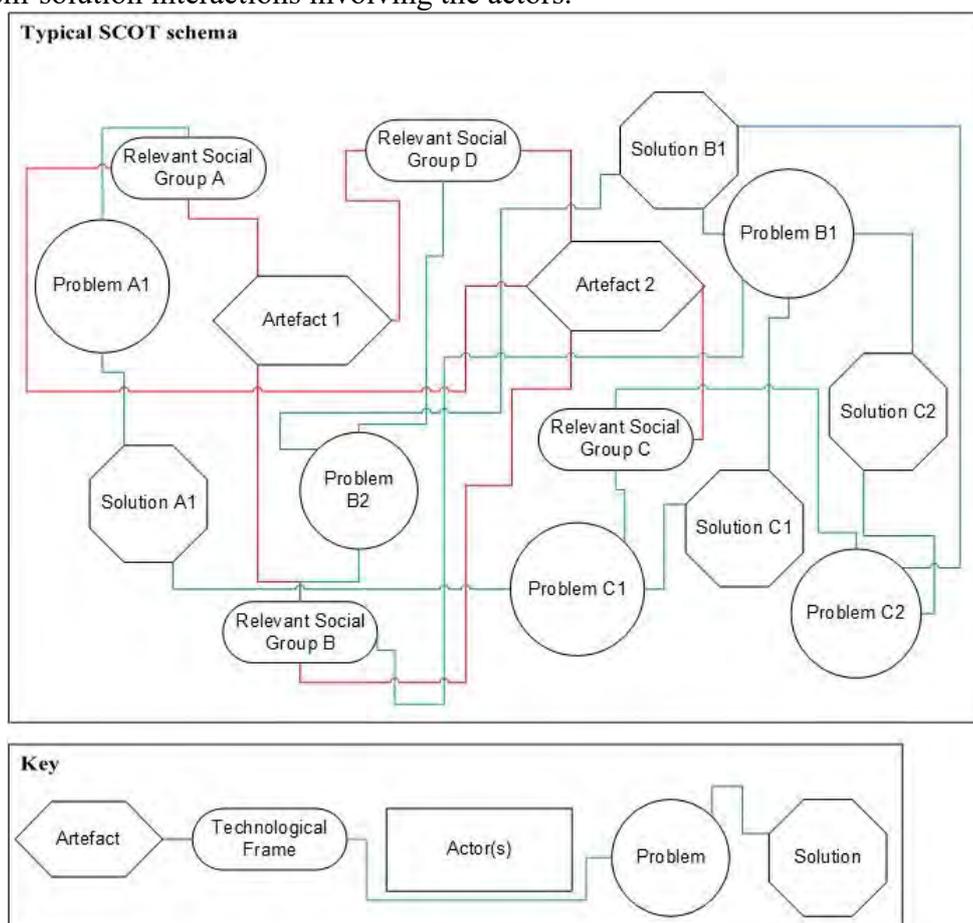


Figure 1: A conventional SCOT diagram

RESEARCH DESIGN

This paper is based on a case study of how a stabilised monolithic formwork (MF) technology developed on a mass housing project (MHP) as part of a government-led technology transfer initiative. The USD 200 million MHP contributes to plans to improve the local construction industry in Ghana technologically. The technology is a modern formwork comprising individual lightweight panels and jointing accessories that are manufactured to suit a specific design, usually for repetitive construction. Typically, the MF is used for erecting reinforced concrete structures designed as monolithic units. New in Ghana, the MF comprised the main (wall, slab and transition) panels, stairs formwork, and other accessories (struts, couplers, tie rods and connectors, etc.). The project was supervised by a joint team of Ghanaian and Portuguese Consultants, and executed by a Brazilian Contractor, working with some local

construction professionals. The foreign contractor constructed over 1400 housing units using the MF technology.

The case study presented is based on 33 qualitative interviews with a range of project actors who worked on the design, supervision and construction of the project using the MF. The interviewees included representatives of the project designers, designers and manufacturers of the MF, the client, local and foreign consultants, the main contractor, local and foreign site supervisors, and local artisans. Persons from each group interacted with the development of the MF technology to varying extents from the beginning to the end of the project, contributing to its journey of social shaping. The questions were focused mainly on the problems identified about the MF, solutions proffered, and how a localised iteration emerged. The different perspectives from the participants provided rich content needed to explore the development of the MF technology over the course of the ITT project, focusing on the role of actors and the environment. The interviews ranged from a minimum of fifteen minutes to a maximum of almost two hours, with a majority lasting about forty minutes long. A collation of relevant secondary data from project-related documents, including sections of the contract, project brief, reports, schedules, monthly and ad-hoc meeting minutes, correspondences, drawings, organisational charts and official news articles also provided rich additional contextual information for the SCOT analysis. Before analysing the data, transcripts and summarised information from project documents were coded for interests, concerns and problems held by the actors about the MF. The process of coding helped identify RSGs and their issues around specific MF artefacts for the creation of SCOT diagrams for three project stages.

FINDINGS

This section presents the findings from the case study through the SCOT lens. The analysis followed the development of the MF technology in three distinct – yet interrelated – stages. Stage 1 involved the design and preconstruction phase of the project. Stage 2 spanned when initial construction began until a major site overhaul that affected the MF technology. Stage 3 started after there was a significant overhaul of the foreign contractor's site team. Space limitations will not allow an expansive set of SCOT diagrams on the multiple problems identified over the course of the project. Therefore, the paper focuses on illustrative ones for each stage of the project.

The enquiry shows that various groups of actors shared in a variety of interests that shaped the MF technology. By identifying different sets of problems and adopting some solutions, the concerned actors shaped the emergence of a localised MF technology. Iterations of technology varied considerably based on the composition of its network at any point in time on the project. The research found two mechanisms – in the form of conjoint developments and lock-ins – that contributed to the processes of closure and stabilisation in the development of the MF technology on the housing project. Conjoint developments refer to scenarios of mutual development observed between the MF technology and the design and construction of the monolithic buildings constructed on the MHP. When such interrelated developments led to irrevocable changes in the technology and the buildings and construction processes, a lock-in was established.

RELEVANT SOCIAL GROUPS AND TECHNOLOGICAL FRAMES

The study revealed the formation of thirteen RSGs who coalesced around different sets of interests and concerns about the MF technology. The different RSGs shaped the MF technology in various ways leading to the creation of unique iterations of the technology at different project stages. Summarised below are the groups, and the different technological frames in Table 1 below.

Table 1: Relevant social groups, their interests and concerns about the MF

Relevant Social Group	Interest in or concern about the MF technology
Affordability Patron	Final building units should be affordable
Complexity Complainants	Reducing complex configurations of the MF to the barest minimum
Conventions Enforcer	The MF is adjusted to suit local design and construction practices
Coordination Crafter	The MF should be flexible to organise smooth construction sequences
Cost Sentry	The project stays within the contractual budget
Design Aesthete	The MF should not compromise the desired visual appeal of the buildings
End-User Comfort Seeker	The design and construction of the buildings using the MF produces comfortable housing units for future users
Environmental Guardian	Using the MF should not cause any form of present or future degradation to the locality
Productivity Pusher	Optimising the use of the MF to deliver the project per the contract
Safety Watcher	Using the MF does not lead to safety and health problems for workers
Simplicity Squad	Configuring and using the MF should be easy for construction
Standards Regulator	The design and construction of the buildings adhere to local and international specifications
Time Sentry	MF technology is used to deliver the housing project on time

During the first stage of the project, the central focus of interests, problems and concerns among the actors was on the MF panels and accessories, and the design of the buildings. In the second stage, there was an expansion of interests to three additional technical artefacts namely, transition panels, demoulding oil, and the monolithic staircase formwork. Around these technical artefacts the RSGs raised their concerns and identified problems through the TFs they shared in or mobilised. For instance, Design Aesthetes were interested in the ability to construct visually appealing buildings using the MF panels. Simplicity Squad were rather concerned about having the MF designed in a way that is easy to configure and use for construction. During the second stage, the technical artefacts of the MF were introduced into a new, environment (i.e., the construction project site in Ghana), and the composition of project actors consequently changed significantly. This change led to series of adjustments in the MF technology that affected the processes of its development and led to the formation of a new iteration. Here, a significant alteration was the exclusion of the stairs formwork from the MF composition for the problem of complexity (see Figure 3). In the third stage of the project, the technology, again changed, leading to the formation of another (third) iteration. There was an overhaul in the composition of the contractor's team on site, which introduced a new set of actors (including the contractor's production manager, project engineer, and project manager) into the network of MF technology

during the third stage of the project. Similar to the second stage, there was a variation in the composition of project actors, leading to a reconstitution of different RSGs and variations in the interests of the TFs mobilised. Here too, the multiplicity and fluidity of interests exhibited by project actors within the network of MF technology, as seen in previous project stages, persisted.

PROBLEMS AND SOLUTIONS

Throughout the project, RSGs associating with different TFs identified an array of problems about the MF technology and its use on the project (see Figures 2, 3 and 4). Similarly, actors at various points in time on the project proffered various solutions. Addressing the problems within the network of MF technology led to adjustments and variations in the technology, contributing to its social shaping.

In the first stage of the project, as Figure 2 illustrates, the problems identified were mainly about the design and use of the technical artefacts of the MF technology and the monolithic buildings. Relatedly, some problems revealed how the altered designs and intended uses of the technology would impact the design and construction of the buildings as well. Since the project was in the design phase, the problems raised through the various TFs of the RSGs were commonly ‘conceptual’ in nature, as Figure 2 below shows. The problems – mainly about room heights, safety, configurational simplicity and, thermal comfort – profoundly influenced the design of the MF artefacts and concomitantly, the design of the monolithic building units. Extracts from the comments of the local consultant and the contractor's Project Manager capture some of the interrelated design changes incorporated. In Stage 1, changes in design and dimensions contributed to conjoint developments and in many instances, formed a lock-in. Figure 2 below shows the interactions around these issues identified by the concerned RSGs.

“For us, we were interested in making sure the buildings were tropicalized enough for our local climate. You know, a place like Ghana has a warm climate all year round. So we couldn’t accept the short heights. And you know, those were way shorter than what our Building Regulations stipulate – instead of a minimum of 2.7metres, we earlier had about 2.4metres. With the concrete nature of the buildings something had to be done for the people who will live in them in the future.”

(Project Architect – Local Consultant)

“We presented our initial scheme drawings and designs to the Client early in the project. Some changes – specifically about heights and windows – were part of the key changes we had to make. But, we designed to the minimum limit of the local building regulations too. The local team pressed hard with the Client’s backing so we had to make the changes.”

(Project Manager – Contractor)

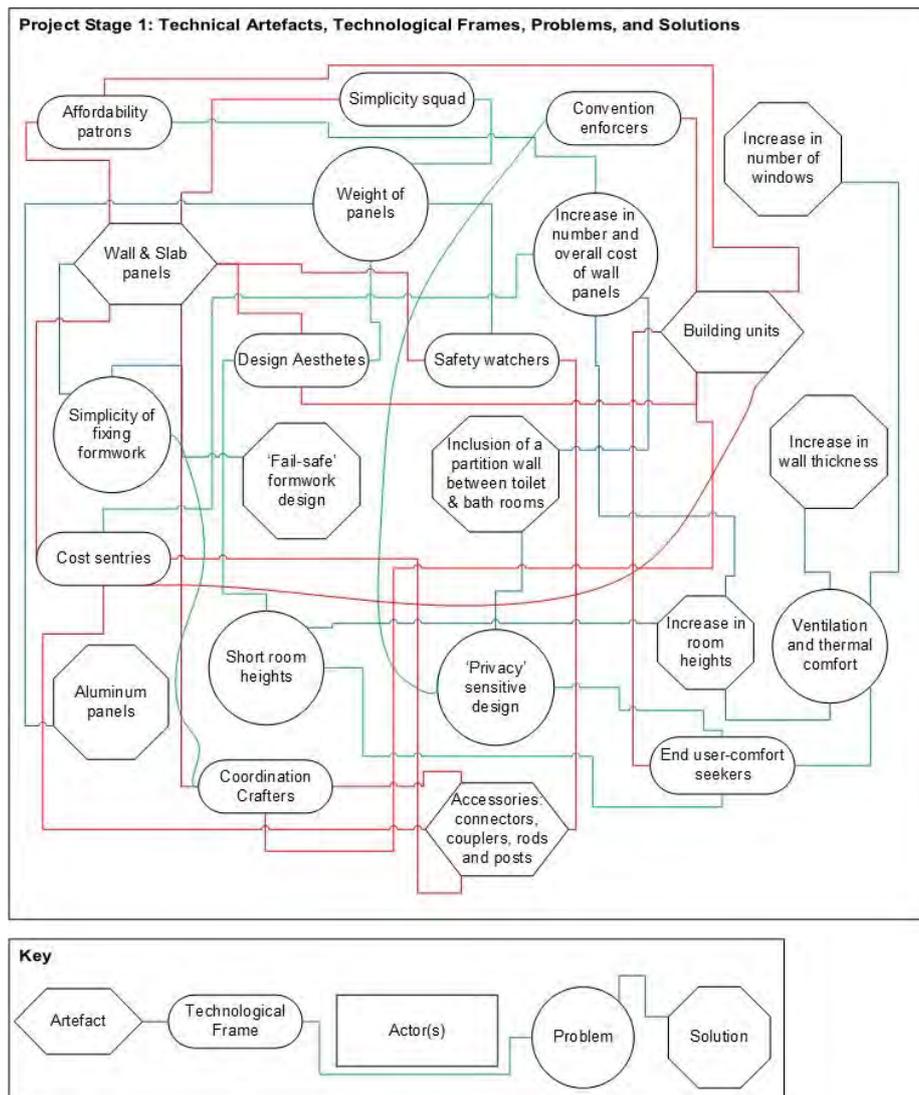


Figure 2: SCOT diagram for project Stage 1

In the second stage when the MF artefacts were introduced into the project site in Ghana, it led to changes in its network surrounding it: changes in the composition of project actors and the physical (locational) environment of the artefacts. Here, the problems emerged from the practical use of the MF technical artefacts in constructing the monolithic buildings on site. Some of the problems were related to aesthetics, and configurational complexity, and project gang clashes that impacted productivity (see Figure 3 below). The issues identified about the MF under the various TFs by the RSGs transformed into practice-oriented ones, with emphasis on additional components – like the transition panels, and staircase configuration– of the MF. Reflected in the comments of the foreign consultant’s Project Manager captured below, the whole stairs formwork configuration posed a great problem in the new network of MF technology configured when construction began (illustrated in Figure 3) and was consequently replaced with local wooden construction formwork. This significant change led to the formation of a ‘hybrid version’ of MF technology during the second stage.

“Already the contractor had spent and lost so much time learning to use and synchronise this technology to execute the project. The stairs were complex, I must admit. Even during the training, we found it hard. So, we didn’t have to waste time to go through the long and hard route of fixing it on our own. If there was an alternative, we took it. That is why we agreed to use the local way of constructing the stairs. It was easier and simpler.”

(Project Manager – Foreign Consultant)

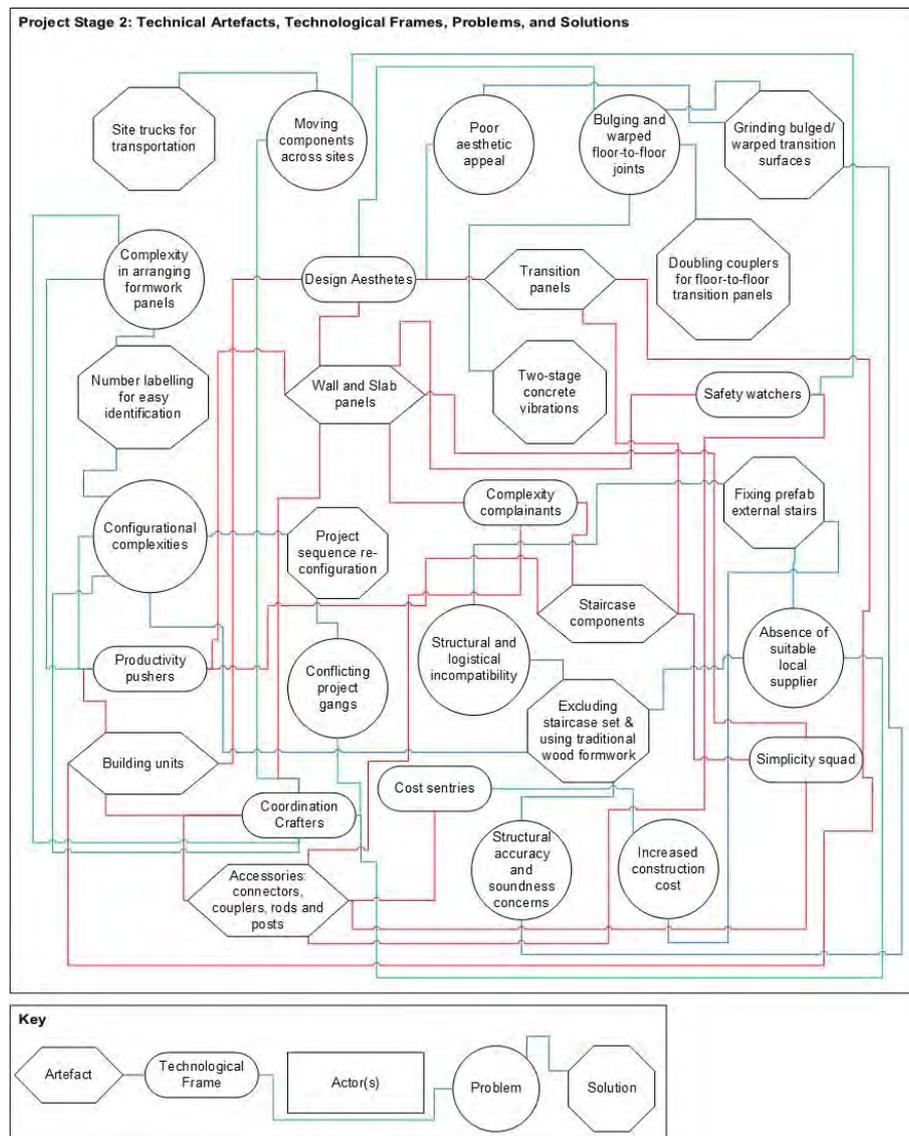


Figure 3: SCOT diagram for project Stage 2

The beginning of the third stage was marked by an overhaul in the contractor’s site project team. Project actors including the Project Manager, Production Manager and Project Engineer were replaced, with additional General Supervisors. The altered composition of actors had implications for the composition of RSGs and TFs, and new and different problems emerged in addition to others from stage 1. In the third stage, the MF was in use on the site, and that influenced how the RSGs viewed the artefacts, shaping the kinds of problems they identified. Some of the problems raised about the

technology during this stage had to do with remuneration, aesthetics of the buildings and, health and environmental concerns (captured in Figure 4 below). The multiplicity of problems about the artefacts reflected the different and sometimes contesting ideals of RSGs, revealing the SCOT tenet of interpretative flexibility.

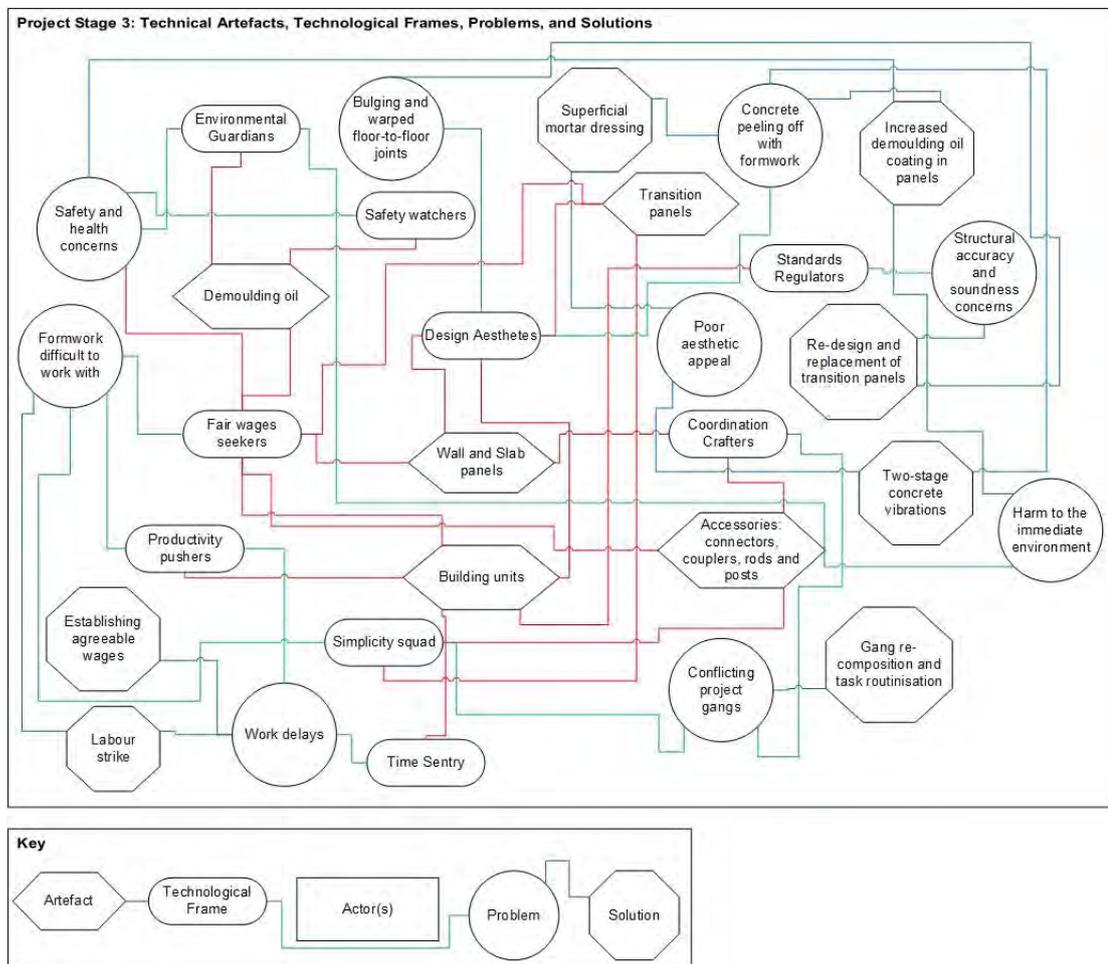


Figure 4: SCOT diagram for project Stage 3

From the SCOT diagram, two kinds of solutions were proffered over the course of the project: conceptual and practical. The former was common during the first stage of the project, and the latter in the second and third stages. Regardless of the kind of problem, actors who proffered solutions in many instances backed their suggestions by demonstrations of expert knowledge in the design of the MF (e.g., the manufacturer). Also, some resorted to referencing their contractual positions or cited social artefacts such as the project contract, building regulations and design conventions, international design standards, and planned schedules of work. Across the project stages, solutions that were incorporated in the shaping of the MF technology led to the realisation of closure, which, in some instances, helped stabilise the MF technology.

CLOSURE AND STABILISATION

Incorporating solutions for some problems closed some technological controversies surrounding the MF technology. In some other instances, attaining closure led to

stabilising aspects of the technology without further modifications to the MF. Such a situation was evinced in the exclusion of the stairs formwork set. A scenario of rhetorical closure emerged during the first stage of the project when designers merely assured concerned RSGs that a ‘fool-proof’ design of the MF panels was going to make its use in Ghana easier, despite fears of a lack of skilled labour. Closure by redefinition of the problem occurred when an explanation about the long lifespan and the property of multiple usages of the panels and components of the monolithic formwork trumped concerns about environmentally-friendly disposal mechanisms for the non-biodegradable parts of the technology. Here, the long life-span of the technical artefacts and the ability to use them for other future housing projects overrode concerns about the environmental risks it posed to the new environment.

The study found that ‘conjoint developments’ and ‘lock-ins’ were forms of closure mechanisms (c.f. Boyd & Schweber, 2018). For conjoint developments, a solution to a problem about the technology or the monolithic buildings led to integrated mutual alterations between the MF and the design of the monolithic buildings. During the first stage of the project, conjoint developments leading to mutual adjustments reflected the rhetorical closure mechanism. Other conjoint developments led to lock-ins, during which the pertinence of a problem requiring critical attention to allow the project to continue trumped the relevance of other concerns. Such instances of lock-in, linked to closure by problem redefinition, were prevalent during the first stage of the project.

The project had early lock-ins between the technology and the monolithic buildings, and that had some implications for stabilising the initial iteration of the technology by the end of Stage 1 of the project. The contractor’s choice of a monolithic formwork pre-determined some boundaries for the design and construction of the buildings on the project. The houses were designed to be constructed of reinforced concrete monolithic structures. The designs had to meet local (Ghanaian) and international structural design standards (which was the Eurocode on this project). The intention to use monolithic formwork to construct the buildings on this project also directed how the project sequencing was planned, the preparation of methods statements, and project schedules. Unlike traditional methods of construction in Ghana which prominently featured the use of wooden formwork, planning the construction tasks for this project had to be around how the MF will be used for construction.

Changes in the use of the MF technology impacted the kind of solutions that contributed to the establishment of closure and stabilisation. In the second and third project stages (when the technology was in use on site), practical, verifiable solutions had to be incorporated in addressing the problems raised by RSGs. These solutions were typically hands-on approaches that – if yielded the desired outcome – eliminated any problem/concern held by the respective RSGs about the MF technology. Otherwise, the problems persisted. Some technological controversies disappeared after there had been a ‘real’ application of a proffered solution, with which the concerned RSGs were satisfied. Some practical solutions led to closure by redefining the problem. For example, during the second stage (see Figure 3), the transition panels of the MF technology had to be re-designed and replaced due to a design flaw that affected the aesthetic appeal of the buildings. This solution was critical, as the problems arising from the flaws could not be rectified during the process of redesigning the transition panels. The resultant closure, preceded by a practical solution, stabilised the design of the transition panels and there was no further alteration for the rest of the project. In

the third stage of the project, the verifiable solutions addressed the problems of concrete slurry seeping through the panel joints, clashing project gangs, and warped floor-to-floor transitions, contributing to the dissolution of the controversies surrounding these aspects of the technology. In each of the preceding instances, closure was reached through problem redefinition.

DISCUSSION

The insights from the SCOT enquiry elucidate the complicated interfaces within a construction project-based attempt to transfer technology. The SCOT analysis reveals the intricacies embedded in a construction project-based ITT attempt. The process involves a myriad of interactions, alterations and adjustments. The findings show that technology on a construction project is not merely a fixed, stable ‘thing’ that exists, and cannot be limited to a stabilised physical product that one party can pass on to another. The deeply-woven involvement of actors in the continuous shaping of the MF technology over the three project stages shows how the formation of technology is a distinct process that is socially-embedded. The iterations of MF technology developed over the course of the project were shaped by contextual components that made the final version ‘localised’ to the project environment in Ghana. Alterations in the network of technology significantly affected the definition and identity of the technology from time to time. Concomitantly, the network out of which the MF technology emerged had some degree of fluidity. Recognising this intricate dynamic involvement of actors in the formation of technology instigates a re-think about what technology is on construction projects, and whether they can be transferred by merely ‘picking and planting’ physical artefacts or experienced actors from one place to another. The findings present new perspectives that contribute to a fresh understanding of ITT on construction projects by revealing how technology develops around technical artefacts through the dynamic involvement of project actors.

This section builds on the findings to explore a new understanding of what happens within a project-based ITT attempt. The emphasis of the discussion is on the complexity of the process and mutual developments with project deliverables, the formation of technology, and the role of actors and the environment.

CONSTRUCTION PROJECT-BASED ITT: A SOCIOTECHNICAL ENDEAVOUR

The empirical study has shown that an ITT attempt on a construction project is all but simple. The process involves series of dynamic interactions involving actors and technology, with implications for the final project outcome. Contrary to the pervasive views of ITT on construction projects being simplistic and linear (Ofori, 1994; Carrillo, 1994; Putranto *et al.*, 2003; Majidpour, 2017), the study has shown that the process comprises series of sociotechnical interactions. These dynamic interactions have far-reaching ramifications for construction routines and techniques, the composition of the technology, and project deliverables (in this study, monolithic housing units).

TECHNICAL ARTEFACTS AND THE EMERGENCE OF TECHNOLOGY

Technical artefacts, around which a location-specific technology develops, are central in an attempt to transfer technology on a construction project (c.f. Sexton & Aouad, 2006). Technology on construction projects is neither merely a fixed, stabilised identifiable object, nor found wholly embodied in experienced humans (c.f. Ofori, 1994;

Majidpour, 2017). In fact, the physical components of the MF changed (e.g. the wall and slab panels, and the transition panels) later on the project. Following the monolithic formwork, the research found that at the beginning of the project, despite the existence of the technical artefacts of the MF, there was no identifiable ‘technology’. Instead, three iterations of the MF technology developed on the project through series of negotiations and interactions involving the actors and the technical artefacts. The technology was a product of a dynamic network of actors and artefacts in the project environment. This network continuously shaped and re-defined the artefacts in the technology through problem-solving negotiations at various points in time on the project. The MF technology was shaped based on the composition of its technological network at each stage of the project. Each stage of the project showed the formation of a different iteration of MF technology arising from changes in the network, revealing its environment-specific nature, heterogeneity and dynamism. The responsiveness of technology to changes in its network reveal how its nature is ill-defined if constricted to physical products, or a combination of mutually distinct physical and tacit elements with the latter only bearing on the former when in use.

THE FORMATION OF TECHNOLOGY AND MUTUAL DEVELOPMENT WITH THE PROJECT

To attempt transferring technology by introducing a set of new foreign technical artefacts on a construction project has consequences for the overall project. Although an area explored (e.g. Jacobsson & Linderoth, 2010; Harty, 2010) in technology applications in construction in general, it remains one area less-emphasised in the construction management literature on ITT in particular. The sociotechnical developments in the formation and evolution of technology impact the project deliverables (the buildings) (c.f. Boyd *et al.*, 2015). As discussed earlier under closure and stabilisation, some modifications (arising from deliberations among actors) in the design of the buildings had commensurate implications for the MF technology. Concomitantly, adjustments in the MF technology impacted the design and construction of the buildings on the project. While some of the design and construction of the project were expected, others were unanticipated hence required on-site adjustments. The research revealed the existence of mutual adjustments between the design and construction of monolithic buildings on the project, and the artefactual components of the MF technology in the ITT attempt.

PROJECT ACTORS: FLUIDITY AND DYNAMISM

Actors who worked on the project participated in the series of negotiations leading to alterations and variations in the formation of the MF technology. Exploring the intricate processes revealed the engrained dynamic role of actors who shared in a wide array of interests that contributed to shaping the MF technology. Local and foreign project actors, regardless of organisational, professional or contractual affiliations, are deeply involved in the formation of technology in a project-based ITT attempt. Variations among actors led to changes in the MF technology. The identity of technology is linked strongly to the actor composition in its network. Thus, in contrast to existing literature (e.g. Carrillo, 1994; Waroonkun & Sewart, 2008; Osabutey *et al.*, 2014), to present technology on construction projects without accounting for the actors in its network renders it incomplete. From the SCOT findings, project actors share in a wide range of interests, and that contrasts the idea that formal categorisations bear on their (in)actions

within and around the technology within the ITT project setting (Ofori, 1994; Waroonkun & Sewart, 2008; Majidpour, 2017). The responsiveness of technology to alterations in the composition of actors in its network further supports the argument that the conceptualisation of technology on construction projects is better placed if a rigid idea is eschewed.

THE ENVIRONMENT: AN INTRINSIC COMPONENT

The project-based and broader environment of an ITT attempt (e.g. legislation and other regulatory documents, socio-political situation, climatic conditions, and socio-cultural dispositions) are crucial in the sociotechnical processes. The environment does not merely comprise stand-alone factors that come to bear on the process of ITT as a periphery. It is also not just a peripheral framework within which a transfer attempt takes place (c.f. Waroonkun & Stewart, 2008; Osabutey and Croucher, 2017). From the findings of this research, the environment shapes the formation of technology in a transfer attempt and influences the project adjustments that arise from these modifications. Indeed, the environment is woven into the shaping of technical artefacts and the formation of technology, through the role of actors who are themselves products of their past and present environments.

A REFLECTION AND QUERIES

Reflecting on the SCOT-informed insights about the formation of technology, the dynamic nature of actors, and the idiosyncratic environmental influences raise questions about the appropriateness of the concept of ‘technology transfer’ to accurately represent what ensues within a project-based ITT attempt. Does the concept accurately capture the journey of a technical artefact from one environment into another? Does the phrase depict how a dynamic network of technology emerges and evolves with a technical artefact over a period within an ITT attempt? Moreover, is technology transferred (at all) by introducing a new technical artefact in a new environment? The concluding remarks in the paper build on the findings from the SCOT exploration to address the questions. Resultantly the paper discusses how a re-think could benefit a less-misguiding conceptualisation of the series of interactions, modifications, and negotiation of interests by actors around a new technical artefact in a new environment as part of a construction project-based attempt to transfer technology.

CONCLUDING REMARKS

This study set out to examine what happens within a construction project-based attempt to transfer technology to contribute an understanding of the intricacies entailed. Using the SCOT approach for the enquiry led to the development of a coherent story to break down a project-based ITT attempt that captured the involvement of actors, the formation of technology and mutual developments with the project, and the role of the environment. The SCOT analysis emphasised one critical point: an attempt to transfer technology on a construction project is complicated. The understandings shed some light into the ‘black box’ on the ‘how’ of project-based ITT and expose the inadequacy laden in simple linear assumptions about the process. The study demonstrates that conceptualising an ITT endeavour on construction projects from a sociotechnical viewpoint holds more potential to understand other complexities entailed.

The study has shown that technology on construction projects is misrepresented if taken for granted as a ‘given’ that can be taken to a new place by a group of people. The emergent nature of technology – involving a mix of actors – in a specific location disabuses the idea that ‘technology transfer’ involves either recipient merely acquiring a fixed, stabilised piece of equipment, or merely importing foreign professionals.

The insights about the nature of technology on construction projects, as evinced in this study, prompt a re-think about the idea of ‘transfer’ beyond the pervasive meanings of ‘handover’ or ‘relocation’. Throughout the project, the different groups of actors (un)wittingly demonstrated how crucial they were in the development of the technology. Their views significantly shaped the MF technology, which evolved (thrice) into an increasingly stabilised iteration. The dynamism, multiplicity and fluidity of the interests of actors reveal that organisational, contractual nor professional affiliations do not bind actors operating on TT projects. The preceding shed light on how narrowing it is to merely study the interests of actors as under rigid binary groupings of ‘transferor’ or ‘transferee’.

Bearing in mind the preceding the suitability of the concept of ‘TT’ as an accurate reflection of the multifaceted processes comes to question. The research shows that the emergence of a localised iteration of a set of technical artefacts is project-specific. However, the development of a specific set of technical artefacts that are suited to a specific environment does not mean the formation of a localised iteration of technology. This is because technology derives its identity and composition from the network from which it emerges. This network changes from project to project, and from location to location. A variation in the network alters the nature of technology that emerges from it. Hence, a location-specific set of technical artefacts may emerge out of series of sociotechnical interactions, but the formation of technology around it is too idiosyncratic.

Considering the nature of technical artefacts, how technology evolves and the nature of the network of technology, the research concludes that ‘technology transfer’ is elusive and too loose a concept to be applied to the peculiar nature of construction projects. This realisation beckons a re-think to aptly capture the process *as it is* to avoid any form of conceptual inconsistency. Thus, an attempt to technologically improve a construction industry on a project-to-project basis is arguably more precisely considered as the introduction of new technical artefacts in a new environment to initiate the emergence and evolution of a localised technology. In contrast with ‘TT’, this proposed view presents the process as it is, without any conceptual obscurities. This conceptualisation does not take technology on construction projects for granted and establishes its emergent nature in a specific locality without given any preference to foreign or local actors in its development. Additionally, based on the premise that technology is a product of social construction, this understanding neither favours non-physical aspects of technology over physical components nor considers them as mutually exclusive of each other in the development of technology. Finally, this conceptualisation establishes some clarity about the central element of technology in attempts at technological improvements, directing the need for specificity on the part of stakeholders who embark on project-based initiatives to technologically improve their construction industries.

The findings in this paper provide a novel contribution to the construction management literature on technology transfer, by explicating the widely-acknowledged,

yet barely explored, the complexity of the process. Additionally, this study adds to the limited number of empirical applications of the SCOT approach in construction management research while revealing how the sociotechnical viewpoint benefits technology studies. Practically, the findings bear on how governments and construction firms in developing countries may re-think and organise for projects that are meant to contribute to technological improvements.

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COLLABORATIVE SKILLS AND DIGITAL TECHNOLOGIES IN TEACHING AND AEC PRACTICE – A COMPARATIVE STUDY

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COLLABORATIVE SKILLS AND DIGITAL TECHNOLOGIES IN TEACHING AND AEC PRACTICE – A COMPARATIVE STUDY

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ABSTRACT

The increased adoption of digital design tools and technologies in the highly fragmented AEC industry brings high potentials for integration of stakeholders and processes, thus enabling generation of innovative solutions along the value chain, from design to production.

However, the adoption of ICT is fundamentally changing the traditional, silo-based design, planning and construction practices. In order to enable successful utilization of digital tools in the AEC industry, building up of both skills and competencies of involved stakeholders, in realm of technology, but more over in realm of interdisciplinary collaboration is needed.

As BIM is becoming part of public procurement and integrated project delivery agendas; therefore, experiencing extensive implementation in the AEC practice, it is also increasingly becoming inherent part of university education in architecture and engineering faculties. The students and practitioners are keen in embracing of new technological skills and competencies; however there is still very little experience in teaching of interdisciplinary collaboration.

With the aim of gaining more knowledge on interdisciplinary collaboration supported by BIM and digital design tools, and thereby simultaneously implementing BIM in education, we have introduced so called Integrated BIM Design Studios (IDS) at TU Wien, where students of architecture, civil engineering and master of building science develop a building design in multidisciplinary teams using digital tools.

To find the answers to the research question: What are the major technology-, people- and process-related challenges for the successful adoption of BIM and digital tools in interdisciplinary building design projects? - we will extend the conducted research by comparing the insights from the Integrated BIM Design Studios with the ones from the interdisciplinary course Applied Computational Design (ACD), conducted within Doctoral College for Computational Design at TU Wien and the practical case study, based on the interviews with the ATP architecture and engineering company, an early BIM adaptor. The results imply on the necessity of more extensive adoption of BIM in education, but more over on need for intensified introduction of multidisciplinary courses at the university. As the AEC industry is

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adopting new digital technologies, the processes are changing from silo-thinking to fully integrated design and planning on the one hand; the software development needs specific domain knowledge in order to satisfy the needs of AEC practitioners on the other – for both aspects increased multidisciplinary collaboration is necessary and needs to become part of curriculum.

KEYWORDS

BIM, Digital Design, Interdisciplinary Collaboration, Education

INTRODUCTION

Building Information Modelling (BIM) as the digital representation of physical and functional characteristics of a facility is creating a joint knowledge and database for planning process participants thus forming a reliable basis for decisions during its lifecycle, from earliest conception to demolition. (Eynon, 2016). As BIM covers the whole lifecycle of any built asset in the environment, it includes a lot of information from every engaged discipline. BIM is not only about the plans or the design, but also about integration and exchange of appropriate information according to individual's or teams' duty which is based on an analytical and at the same time structured way of thinking.

The current management practices assume that the design-relevant information becomes available and is shared among the project participants, as it is required, either informally or formally, as far as designs and design reviews are concerned. It is difficult to find a suitable sequence that minimizes the waste of processing because designers are obstructed by the limitations of the common time-management methods – such as the critical route planning. For example, the information that is missing in the design procedure may lead to false assumptions, in this way creating the need for re-designing and further repetitions of the design procedure. The creation of BIM models has a clear capacity to help this procedure two folds – through enhancement of collaboration and as a planning tool. Providing a digital platform through coupling of various models and databases has a greater capacity to depict the correlations between design, cost, time, quality as well as energy and resources efficiency that are related to a project.

Assets, infrastructure and buildings are commissioned, conceived and built by people and are not just the result of applied technology (Eynon, 2016). Projects need people, as the technology alone is not able to stand out by itself. The planning methodology of BIM is based on the exchange and transfer of various data, which is based implies on the engagement of various disciplines, led again by different people. The engagement of people from different professional fields and backgrounds is the challenge for BIM, as well as for any methodology based on collaboration. Hence, the multidisciplinary collaboration is of critical importance, and an effective team decision-making is a mandatory prerequisite for meeting design requirements.

Despite numerous potentials of BIM, the overall BIM benefits are still difficult to evaluate, and its capabilities are not well understood (Jung and Joo, 2011; Sebastian and van Berlo, 2010; Barlish and Sullivan, 2012) especially in the context of multidisciplinary collaboration.

Through the last years, there is an upcoming demand for individual competencies in BIM projects. As BIM is becoming part of public procurement and integrated

project delivery agendas; therefore experiencing extensive implementation in the AEC practice, it is also increasingly becoming inherent part of university education in architecture and engineering faculties. The students and practitioners are keen in embracing of new technological skills and competencies; however there is still very little experience in teaching of interdisciplinary collaboration. BIM competencies particularly regarding the collaboration as demanded by integrated AEC practice are still not represented in lecturing plans and programs at universities. (Filzmoser et al., 2016; Filzmoser et al., 2017).

In order to gain more insights in the mechanisms of multidisciplinary collaboration in the BIM supported design process we will extend the conducted research by comparing the student experiments within Integrated BIM Design Studios (IDS) at the TU Wien with the ones from the interdisciplinary course Applied Computational Design (ACD) within Doctoral College for Computational Design at TU Wien. Within IDS at the Vienna University of Technology – now with its sixth iteration “BIM-bake”, i.e. an interdisciplinary building design project of a bakery – we addressed open challenges of integrated BIM-supported design and construction in education. Finally, we will compare the results gained from these university interdisciplinary student courses with the practical case study, based on the interviews with the ATP architecture and engineering company, as an early BIM adaptor.

Quantitative (questionnaires), and qualitative (focus group discussions and expert interviews) methods generate data for the analyses of the research question: What are the major technology-, people- and process-related challenges for the successful adoption of BIM in interdisciplinary building design projects?

The remainder of this paper is structured as follows: Section 2 presents the literature review on multidisciplinary courses using digital tools in education, Section 3 describes the two university courses IDS and ACD; and the practical case, Section 4 describes the study design and the data gathering methods, in Section 5 we will present the results of the comparative study and Section 6 discusses these results in light of the research questions of this paper.

LITERATURE REVIEW

BIM in teaching represents a current issue in university curriculum and research led teaching, mostly dealing with issues of interdisciplinary collaboration, interdisciplinary data exchange, software interoperability and BIM usability for further dimensions such as project management, scheduling, cost or LCA assessments. Another focus is the examination of team performance in digital networks within AEC projects as well as determination of factors for project success in through digitalisation changed AEC environment.

Crucial challenge in teaching (as well as in practice) represents the interdisciplinary data exchange within design projects. Poerscheke et al. (2010) study multi-disciplinary design (architecture, landscaping, structural, construction, mechanical and electrical engineering) where students optimize a given pre-design of an elementary school in collaborative manner for usability, sustainability etc. The intention of this research is twofold: to test BIM tools for fitness for each discipline on the one hand and the interdisciplinary collaboration on the other. They conclude that BIM and simulation tools are useful for enhancement of analysis and synthesis but do not enhance creativity, the actual driver for idea-generation is the

interdisciplinary collaboration. Plume and Mitchel (2007) test in their course the interoperability of BIM tools via the IFC interface, again using given preliminary projects. Students of various disciplines perform cost estimation, thermal simulation, and acoustic analysis using a common model via an IFC model server. This course dates back to winter term 2004, where the technical possibilities of the main modelling tool *ArchiCad* respectively the supported IFC version were still limited, and many of the addressed problems, such as versioning, have been solved. However, many of the problems of the semantic nature still remain unsolved – e.g. the definition of the “room” being different for architects and building physicist (Kovacic et al., 2013).

Regarding BIM in project management, Peterson et al. (2011) focus on teaching in single-disciplinary setting, extracting project management relevant data (scheduling, masses for costs) from architectural models and transferring the data in various project-management tools. BIM tools for scheduling, LEED certification scheduling and 4D simulation is also taught by Hyatt (2011). Both authors, Peterson et al. (2011) and Hyatt (2011), conclude that “real” tools are of significant importance – the work experience in the first case or the field trip experience in the second are crucial factors for learning or grasping of optimization potential of a project much more than technology.

Besides the technical and software-related tasks, communication and collaboration in the new interdisciplinary, virtual digital AEC platforms becomes an additional challenge for teamwork performance; which is also a topic in research led teaching. Dossick et al. (2012) focus on the analysis of communication and creation of new knowledge in spatially distributed student teams that collaborate in a virtual environment, compiling 4D scheduling and organizational analysis. In this domain modelling in real time actually supports the messy talk and thereby increases creativity. Further on, Dossick et al. (2017) propose a curriculum to prepare students for BIM-enabled globally distributed teamwork. They state that social skills and professional interaction cannot be taught in traditional lecture-based classes. Social skills are learned by interacting with others.

Several researchers focus on the teamwork-mechanisms supported by digital technologies or digital networks rather than on explicitly BIM. Iorio et al. (2012) are examining the role of a facilitator in enhancing the success of projects in student teams engaged in complex design and planning projects. Their findings indicate that when facilitators occupied highly central positions during task interactions, conflict length was observed to increase. In non-facilitated networks, highly central actors emerged from a variety of knowledge domains and conflict length was observed to decrease. This evidence suggests that while facilitators are typically viewed as information bridges in global project networks, when they are central to task discussions, facilitators may impede the development of efficient network structures.

Leicht et al. (2009) state that since the level of complexity of the architecture, structure and building systems increases, the need for coordination and communication between disciplines grows. This increased interaction has created the need for improved team and collaboration skills. According to the results of an exploratory study with ninety-five students of Leicht et al. (2013) a balance in stress management and mood and a team of similar intrapersonal focused individuals helped to create a higher performing team than predicted by the technical skills demonstrated

through examination performance. The challenge becomes defining how engineering education should address developing at least the fundamental skills need for working in team environments.

Russel-Smith et al. (2015) show another important view to let projects with various stakeholders succeed. They studied two groups of student project teams. One group was an experimental group that was given specific sustainable design targets along with a software tool to assess these impacts during building design iterations. A control group was not given these sustainability targets or software support but had a qualitative target of “green design”. Comparing projects with the same requirements, their work illustrates that setting specific sustainable targets prior to design and providing support resources that allow designers to iteratively improve and validate designs, reduces the impact of the building for each environmental indicator studied as compared to control designs. This line of research, on abstract versus concrete goals, shows that breaking an abstract goal into concrete steps helps people achieve the goal (Gollwitzer, 1999; Russel-Smith et al., 2015).

Concluding, we can identify the gap in the research led teaching involving use of digital tools and technologies, amongst others also BIM. Most of the examined literature is evolving around analysis, exchange and structuring of explicit knowledge. However, we address with our IDS and ACD the creation and exchange of implicit knowledge, which is created in the earliest design stages – the collaborative interdisciplinary design evolution and the fitness of digital tools to support this process; as well as the implementation of these aims in the university curriculum and course design.

RESEARCH DESIGN

In this paper we will extend the conducted research within Integrated Design Studios with the ones from the interdisciplinary course called Applied Computational Design (ACD), conducted within Doctoral College for Computational Design; both at the TU Wien. Finally, we will compare the results gained from these university interdisciplinary student courses with the practical case study, based on the process analysis of ATP architecture and engineering company. The focus of research was to identify the major technology-, people- and process-related challenges for the successful adoption of BIM and digital tools in interdisciplinary building design projects.

INTEGRATED BIM DESIGN STUDIOS (IDS) – UNIVERSITY COURSE

With the aim of gaining more knowledge on crucial factors influencing successful interdisciplinary design supported by BIM tools, and thereby simultaneously improving the implementation of BIM in education, we have introduced so called Integrated BIM Design Studios (IDS) at TU Wien, where students of architecture, civil engineering and master of building science develop a building design in team work using digital tools. We have been implementing BIM supported interdisciplinary design classes already for six academic years; and have gained valuable insights through qualitative and quantitative evaluation (up to now of three cycles), as already published in previous EPOC conferences (Kovacic and Filzmoser, 2015; Filzmoser et al., 2016; Filzmoser et al., 2017). The quantitative evaluation has involved evaluation of student satisfaction with process, collaboration and results;

and software-satisfaction with interoperability, usability and usefulness of the employed BIM software via questionnaire-survey. The qualitative research was carried out via focus group interviews with each discipline. The discussions were audio recorded, transcribed and then analysed by two independent coders using quantitative content analysis (Srnlka and Koeszegi, 2007).

APPLIED COMPUTATIONAL DESIGN (ACD) – UNIVERSITY COURSE

The Doctoral College Computational Design (DC:{CD}) at the TU Wien, embedded in the Center for Geometry and Computational Design, is the first PhD program in Austria that is situated at the interface of several areas of excellence in research: Computer Graphics and Algorithms, Software Technology and Interactive Systems, Computer Aided Automation, Discrete Mathematics and Geometry, Architectural Sciences, Art and Design, History of Art, Building Archaeology and Restoration, Integrated Planning and Mechanics of Materials and Structures. Within the obligatory course Applied Computational Design the doctoral students from above mentioned doctoral college were exploring the design potential as well as the performance of essential wooden structures, built entirely by utilizing the elasticity of prefabricated planar or linear elements. The course was built up as explorative design workshop, starting with drawings and physical models, and evaluation of different design approaches and principles, and by finally applying computational tools for design optimization as a team-work. The course, which is conducted in English, lasts for four hours per week and corresponds to 6 ECTS. The lecturers follow students' progress during their predefined meetings, while there are also two midterm presentations in the semester, where students present their proposed solution, are assessed and get feedback. Students are themselves responsible for the scheduling and duration of the meetings, when lecturers are not present.

In this course eight part taking-students were interviewed, thereby two with background in architecture, three in computer science, one in mathematics, one in civil engineering and one in archaeology. Six of the students answered the questionnaire; one student with architecture background and the one with mathematics is missing. Therefore six questionnaires could be analysed.

Some of them have considerable previous work experience while others do not. Each student has different background concerning not only their studies but also their job profile. According to their working experience, they can be separated in two different groups: one group for those with working experience less than fifteen months and one group for students with sixteen or more months of working.

The aim of the course was, next to design development and optimization via computational tools, to develop deeper understanding of the way of working of various disciplines, in particular regarding the intuitive design vs. scientific/mathematical explicit methodology. The course was evaluated through observations, questionnaires and open-ended interviews.

ATP ARCHITECTS ENGINEERS – PRACTICAL CASE STUDY

ATP architects engineers has more than 650 employees, which makes it one of Europe's leading integrated design companies. ATP was established in Innsbruck in 1951 as a traditional architectural office. Since 1976, the company has developed into an interdisciplinary partnership which provides clients with an integrated service

offering all architectural and engineering services from “a single source”. ATP Vienna, as the object of this study, is one of the nine independent offices in the ATP architects engineers network. Founded in 1985, the office is especially active in Eastern Europe, Central and Eastern Europe (CEE), South East Europe (SEE) and Russia. ATP offers design and planning in both greenfield as well as refurbishment in broad spectrum of typologies, primarily in production and logistics and further on in retail and entertainment, office, administration, hotels, resorts, healthcare, hospitals etc.

As general planner, ATP uses BIM platform Revit for architecture, structural design and MEP since 2008. As such ATP can be characterized as early adaptor of BIM and has invested significant resources in the implementation and adoption of BIM infrastructure and processes.

Particularly interesting in this regard is that here several disciplines work in integrated manner (architects, structural engineers and HVAC engineers) within same organization, which also results in different ways of thinking and varying needs regarding model requirements.

The practical case study involved process analysis and qualitative research through open ended interviews of eleven executives, designers, engineers and BIM managers.

The experts had different roles in the company, regardless of the discipline or professional background. There were three Users – two of them architects, one structural engineer, three Model Experts (Super Users) – an architect, a HVAC engineer and a structural engineer, two BIM Managers – a HVAC engineer and an architect, a Group Leader – an architect – and the managing director of the Viennese office (an architect). We observed the necessity of competencies according to their role in the company and the differences between necessary people competences for working on projects with and without BIM. The most important part of this research was the interview with the CEO of the company, who is the leader and the person responsible for the staff training, who provided our research with information on the cost and efficiency of investigating staff training.

METHODOLOGY and DATA

In our previous research we evaluated student experiments throughout three iterations within Integrated BIM Design Lab (Filzmoser et al., 2017) by a combination of quantitative and qualitative analyses. Besides the quantitative evaluations of the planning process and the BIM-software, focus group discussions were used for a qualitative and detailed analysis of the experiments (Krueger and Casey, 2009). Such discussions collect qualitative data, both deeper and broader than interviews or open question questionnaire data due to group dynamics, from a relatively homogeneous group on a specific topic.

The members from one discipline were grouped together, i.e. all architects, civil engineers and building scientists and discussed together. This also allowed for an exchange of information and experience among the discipline members, which worked in their separate groups during the project. All focus group discussions were recorded, transcribed and their content analysed following the procedure suggested by Srnka and Koeszegi (2007) by two independent coders. First the content was subdivided into thought units that convey single and coherent information, in a next

step a category scheme was developed based on theory and the analysed data (the categorization step). Lastly, the thought units were assigned to these categories.

In order to compare the IDS with the ACD and practical study at ATP, we have used the category scheme for the coding of the content of the focus group discussions as the base for comparison of the open-ended interviews with the students of ACD and the expert-interviews with the practitioners.

The category scheme used for the coding of the content of the focus group discussions is presented in Table 1 with a description of the categories and examples from the focus group discussions.

Table 1: Categories from focus group discussion, as base for the evaluation of the open ended interviews

CATEGORY	DESCRIPTION
BIM general	general discussion about BIM projects
Collaboration cons	negative experiences in the collaboration
Collaboration pros	positive experiences in the collaboration
Course	grading, content and organization of the course
Ease of use	ease or difficulty of the use of software functions
Interoperability	statements about import, export, interfaces
Usefulness	effectiveness of the software
Training	statements about BIM workshop and software trainings

Further on, the students of ACD were also asked to fill in the questionnaire regarding interdisciplinary collaboration, which was evaluated quantitatively.

Table 2 displays the cases, number of participants and their relevant disciplines as well as conducted qualitative and quantitative evaluations per case.

Table 2: Cases and Methodology

CASE	METHOD	INTERVIEWEES
IDS	Questionnaire Focus Group Interview	Kovacic and Filzmoser, 2014; Filzmoser et al., 2016; Filzmoser et al., 2017
ACD	Observation Questionnaire Open ended Interview	1 student architecture (ACD ARCH) 3 students computer science (ACD CS) 1 civil engineering (ACD CE) 1 student archeology (ACD ARCHEO)
ATP	Expert Interviews	3 Users: two architects (U ARCH) one structural engineer (U CE) 3 Model Experts (Super Users): one architect (ME ARCH) one HVAC engineer (ME HVAC) one structural engineer (ME CE) 2 BIM Managers: one HVAC engineer (BM HVAC) one architect (BM ARCH) 1 Group Leader: an architect (GL ARCH) CEO of the company: an architect (CEO ARCH)

RESULTS and DISCUSSION

In the following chapter the results of the interviews of the three cases are compared according the coding categories. As the ACD course was not primarily BIM oriented, but much more to multidisciplinary digital design in general, so most of the answers regard collaboration and the course.

In the category “**BIM general**” the student participants of IDS report within discussion groups:

“BIM is gains increasing importance in practice, because...”^a and
“I found it great, the design process; this is something we do not experience so often during the studies.”^b.

Interviewees from ATP said in the category “**BIM general**”:

“An advantage is, that there is one model, where everyone works with and everything has to be included in the end.”^j,

“An advantage is, that you don’t have to feed the model several times. You enter the measures once and every specific discipline has equal measures, but it is difficult to remain the level of the model.”^m,

“working in one model saves some time”^m,

“When working on a BIM model, you have to understand everything. Because you build a house completely in digital and then what is built digitally will be built in reality. So you have to understand much more how to build a house.”^k,

“If I think of my drawing as a database, not as a 2-dimensional representation, it’s the main leap.”ⁿ,
 “There has to be more technical communication, because people work on the same model for instance and it’s not that everybody is using a special software but that everybody is using one model and there has to be coordinated.”ⁿ,
 “BIM also helps avoiding and recognizing errors.”ⁿ,
 “For me, BIM is inherently an absolute change in planning philosophy. It is not just a tool.”^p,
 “quality enhancement through BIM”^p,
 “In the model there is much more visible than on plans.”^p,
 “In my opinion, BIM is a tool. If you are good at it, it can make your life or your work easier.”^q,
 “Time plays a crucial role. In BIM-projects you have to be earlier deeper in the project. In the initial period there would be more time needed.”^q,
 “You can identify problems much earlier.”^q,
 “It’s only easy to show for the outside of the building for the owner of project.”^r,
 “BIM is just a working tool. It doesn’t matter which tool you’re working with, so I think for BIM projects you need little bit higher skills than working on projects without BIM. So BIM is a little bit more advanced, demanding. That you have to think in advance and that you have to plan more steps.”^r and
 “I think for BIM you need more competencies than for projects without BIM, because more information is incorporated and more people work on the model.”^s.

In category “**Collaboration cons**” the negative statements of the participants of the IDS were recorded:

“We got our ifc file like one week ago and it’s still not the final”^b,
 “I need the geometry to go further with simulation ... they are still forming geometry ... our job depends on their job.”^c,
 “...and then there is so little time for us to develop our concept. The architects always seem to spend time on the building and geometry and this held our part back, it makes us waiting.”^c,
 “Most of our workload was at the end of the semester, like December [...] we had to wait for the architects to build the first plan.”^b and
 “There should be milestones what work should be done until when and then a part of the work has to be finished and that is given to the structural engineers or us [remark: the building scientists] and then it would work better.”^a.

The ACD members seem the most critical in this category:

“The amount of contribution to the project differed between members of the group at times, which was unavoidable due to everyone having different circumstances and work schedules, but can still feel demotivating.”^h,
 “Nobody was interested in collaboration.”^g,
 “Actually it was really hard because most of them did not understand the conceptional ideas.”^d,
 “When the people are working on something completely different from their backgrounds they do not have the same interest.”^d and
 “Time consuming - esp. finding ways to communicate needed time.”ⁱ.

The ATP company interviewees report within interviews as negative collaboration aspects:

- “many different solutions, but results are not consistent”^j,
- “There has to be more technical communication, because people work on the same model for instance and it’s not that everybody is using a special software but that everybody is using one model and there has to be coordinated.”ⁿ,
- “I repeatedly deal with project partners, which don't work with BIM-able software; then, of course, no BIM-able communication is possible”^p,
- “The problem is often that the model contains a lot but it doesn’t come to the plans.”^q,
- “through BIM communication is not necessarily easier but it is more essential”^q and
- “There is a big source of error if one in the team doesn’t work well.”^s.

In category “**Collaboration pros**” the participants of the IDS stated:

- “But with the architect it worked very well, so (..)”^a and
- “They supported me at the beginning of the project when I had not that much time.”^b.

ACD student participants stated as positive:

- “I got to know my fellow PhD students.”^e,
- “Workflow and approaches to problem solving in other disciplines. Even though I do not necessarily agree with everything, it is helpful to learn about other people's point of view during collaborative work.”^h,
- “I meet with people belonging from different fields.”^d and
- “To learn how to communicate and collaborate with various field. Ability to solve problems, coming up by interdisciplinary. Learning how unknown (for me) processes work.”ⁱ.

The ATP employees report as positive aspects of collaboration:

- “most difference is that we have only one part where everybody is working with, we do not have so much collaboration without BIM”^o,
- “satisfied with the collaboration and communication process via BIM”^o,
- “many different solutions, which sometimes lead to different results and furthermore, generate a broad range of possibilities”^j,
- “it is easier to communicate between different specific disciplines and describe and discuss problems”^j,
- “benefit is that you always have the info you need in the project”^o,
- “the progress of BIM helps the collaboration among the different parties of the project”^o,
- “BIM facilitates communication.”^l,
- “overall the communication works”^l,
- “The advantage I said is the working a live model, like everybody being up-to-date the whole time.”^m,
- “In this position it is really important to form relationships, so that all communicate sensible, targeted and output-driven.”^p,
- “cooperation comes through communication”^p,

“at the time, when everyone works with the same model, double handlings disappear; quality in communication increases, because everyone has the same communication standard everytime”^p,

“communication through the model, I receive better information”^p,

“due to the progress of BIM the communication and cooperation gets better, because there can be communicated more targeted on the model”^p,

“BIM is a lot about communication. You have to talk much more on different levels.”^q,

“The benefits are that you look at the same building or same problem from a different point of view because you have it in the model and every stakeholder looks at that. It’s not just one part, so you see that from more sides, that’s the most benefits.”^r,

“That’s more communication than before. It’s deeper communication, the content is steeper or more tense, the organization is much better than before, there’s also much more understanding of the different works of the other departments.”^r,

“If you work accurate and good, there is a high potential to select information from the model for all disciplines.”^s and

“BIM is helpful for following the processes and for a better cooperation.”^s.

In category “**Course**” the participants of IDS said that

“I think the crits were really helpful.”^b.

However the ACD members stated:

“don't feel the project was helpful for me.”^e,

“The collaboration with the other students was not negative, but we were all very frustrated by how the course was organized.”^e,

“Other than getting to know other students, this project wasn't very helpful.”^f,

“I learned to say no and walk away from things that make no sense whatsoever.”^f,

“Forming better relations with my PhD colleagues; learning about different approaches to problem solving in other disciplines.”^h,

“Especially at the beginning good climate, everybody was engaged.”^g,

“It would have been more interesting if we had known the project from the beginning because we could have shared the activities and the resulting model would have been better.”^d and

“Relationship between the members. Group dynamic.”ⁱ.

Regarding the issue of education ATP employee said

“you learn a lot through (...company...) projects during education”^j.

In the category “**Ease of use**” a participant of IDS reported

“But in SCIA changing something was super easy.”^a,

and ATP employees reported

“REVIT is not the best software for me in my case, building services, there are better ones.”^o,

“not just if you have problems with REVIT, also you have to communicate with the colleagues”^o,

“A big problem is the open BIM world and the problems, which occur due to inconsistent processes of specific disciplines or internal a specific discipline.”^l and
 “Sometimes the progress of BIM is little bit hindering, because there are always improvements.”^q.

In category “**Interoperability**” the member of IDS reported

“There was no exchange with the programs. It was not possible and if it were possible it would take too much time.”^c,

and the ATP interviewees:

“You should use one software, as we do it here with REVIT for example. That's good for BIM, but there are better softwares for each part.”^o,

“The transfer of the data is not always very successful I would say; so I think that only one software for everything is better than...”^o,

“In ATP, if you work in one model all of us, then works fine. But when it comes to exchanging with externals, then it gets more complex because we have to resort, to format and some things get lost.”ⁿ,

“From my point of view, communication with BIM technology doesn't work to 100%, when it comes to data exchange between different software types; sometimes there is huge data loss.”^p,

“The biggest effort in development lies within the smooth interaction of software-interfaces.”^p,

“I think it's easier to use one software of course but every different profession (like architects) has different means, so we have BIM and also have layout programmes; have BIM but also kind of Excel sheets but you can't unify them, you need more levels of working.”^r and

“If other companies work with different BIM-software, it is often not compatible.”^s.

In category “**Usefulness**” the members of IDS remarked

“I do not think it is good that it is possible to make a change in SOPHISTIC, or that this is changed automatically.”^a,

“... it was interesting to see what SOLIBRI is capable of.”^b,

one participant of ACD:

“I've learned how design processes work.”^g,

and two employees at ATP:

“quick change management”^l and

“elements, which can be extracted out of the BIM-model, like masses for tenders, information, workflows”^l.

In category “**Training**” the members of the IDS said

“Training helped, but I would not be able to learn a software, without a project”^a and

“Our REVIT training took two days and was very good. We learned a lot and could ask questions.”^b,

employees at ATP reported
 “The base should be formed through education and studies.”^j,
 “Only experience, but a basic knowledge is necessary; I had one whole week of education in REVIT.”^o,
 “training in your studies for BIM”^o,
 “not just new processes, also improve the old ones or the basic ones”^o,
 “Experience has way more relevance, in terms of how does it work and how it is applied in practice.”^l,
 “enhancement of the term “BIM” in school, at university”^l,
 “Experience is more important; education is the base.”^m,
 “Training should start at university.”^m,
 “training is an economic advantage”^k,
 “The education during the studies should be more focusing on the general management, the general principles, and not be training on a particular platform.”ⁿ,
 “Experience is more preferred than education in BIM; especially the experience from construction technology.”^p,
 “Training, which is needed by all means, is for BIM technology as such; for the use of software.”^p,
 “A BIM-able program should be taught during studies or education by any means, because it is the base for future work.”^p,
 “I got the REVIT-education here in the firm.”^q,
 “BIM-education is the base, after that you need experience.”^q,
 “BIM-training and interdisciplinary projects should start at university.”^q,
 “Experience is very important; I think they should really know very good the program.”^r,
 “Individuals should be trained in the job.”^r,
 “Working with REVIT I learnt with a basic training at ATP, I used AutoCAD and ArchiCAD at university.”^s and
 “A basic training should start at university.”^s.

^afocus group discussions IDS 12/13 (BIM_sustain)

^bfocus group discussions IDS 13/14 (BIM_station)

^cfocus group discussions IDS 15/15 (BIM_meridian)

^dACD ARCH – GCD 2017

^eACD CS – GCD 2017

^fACD CS – GCD 2017

^gACD CE – GCD 2017

^hACD CS – GCD 2017

ⁱACD ARCHEO – GCD 2017

^jBM HVAC – ATP 2017

^kCEO ARCH – ATP 2017

^lME CE – ATP 2017

^mU CE – ATP 2017

ⁿU ARCH – ATP 2017

^oME HVAC – ATP 2017

^pBM ARCH – ATP 2017

^qME ARCH – ATP 2017

^rGL ARCH – ATP 2017

^sU ARCH – ATP 2017

As the ACD course was not primarily facing on BIM but digital tools in general, there are no answers in category “BIM general”, “Ease of use”, “Interoperability” and “Training” which regard BIM.

The findings in the evaluation of university courses show that interdisciplinary collaboration is the largest issue in the integrated design classes.

As the IDS is already in the sixth cycle there are less complaints about the course organization, project task and execution, but much more regarding the cooperation itself. In the IDS, all of the categories of satisfaction are increasing over the courses, but the satisfaction with cooperation, which is decreasing over the iterations of the course, especially for civil engineers. The low collaboration satisfaction (e.g. perceived stress by structural engineers due to the late delivery by the architects) demonstrates that disciplines are still caught in the traditional, sequential planning process rationale (Filzmoser et al., 2017).

In the ACD however the main complaints regard the course organization, management, and lack of clear aim-setting for the project. In this context, due to high diversity between the students, some of whom are confronted with the design project for the first time, it is very difficult for them to recognize the usefulness and the purpose of the course and task itself. For some students the collaboration was a problem, while at the same time was a pleasure for others. Half of them believe that there was no problem in collaboration. At the same time, the other half faced difficulties on communication and collaboration with the other members of the team.



Figure 1: Evaluation of the questionnaire regarding collaboration with ACD students

However, the students do not believe that the collaboration issues arise from the different discipline background (Figure 1). Much more it is the difficulty of managing and scheduling communication among each other, which was main obstacle for the process of ensuring the smooth and quick development of the project, together with process related issues such as scheduling of deliverables and clear distribution of duties among students.

The analysis of the practitioners' expert interviews reveals that the majority of the interviewees admire BIM for enhancing collaboration and communication, regardless of the discipline they belong to. Much more the problems they identify are the ones regarding the BIM training and education versus the professional, discipline relevant experience and needed knowledge. There are split opinions about meaning of BIM, in

terms of BIM seen only as a tool or as a catalyst for a change in the way of designing; particularly so among the architects. The engineering disciplines, such as HVAC and structural engineers are much more convinced of the explicit benefits of the BIM tools, and are less concerned with intrinsic changes that BIM might cause in their particular way of working. The interfirm collaboration problems occur much more due to the lacking software interoperability and technical limitations of the software, rather than to interfirm interdisciplinary collaboration. This can be explained by the corporate culture of the company, which is based on process integration and incorporates this way of thinking for many years. However, different than the students, the engineers and architects cannot choose software freely as the students can, but must comply with the company standard software (due to the financial and legal reasons); which causes problems for the intrafirm collaboration due to the lack of interoperability.

The demand for new and better processes and standards, which would also improve communication and collaboration in BIM-supported projects, was addressed both by students and company employees.

DISCUSSION and CONCLUSION

Comparing the IDS with practice, our findings in terms of suitability of BIM for early design stages were confirmed; in particular, regarding the design quality. The practicing architects express their doubts on BIM changing the way of designing and design-thinking. This is what we have also found throughout six cycles – the design quality is not really improving through the implementation of BIM.

In addition, collaboration requires designed communication and organized process with clear distribution of tasks and workloads. In professional working environments there are specific communication norms, meeting strategies and project organization regarding the deliverables and task-distribution, which was not the case in ACD (process design was left to the students) and to some extent also an issue in the IDS.

Further on, the partaking students in ACD from mathematics and computer sciences were not familiar with design project procedures, which often do not follow linear development, but undergo many iterations, due to implicit nature of conceptual design; therefore for them it was very difficult to collaborate within this setting. However, as software has to reflect specific domain knowledge and support interoperability; the collaboration of AEC students and future software developers in order to develop joint understanding for the needs of the AEC industry and improve usability and interoperability of digital design tools is needed.

We conclude, that in order to change the way students and later professionals tackle the difficulties of integrated planning, fundamental changes are necessary. A semantic change in education has to occur, changing the role of particular disciplines from independent actors to being pro-active part of the design-team.

The results imply on the necessity of more extensive adoption of BIM in education, but more over on need for intensified introduction of multidisciplinary courses at the university. As the AEC industry is adopting new digital technologies, the processes are changing from silo-thinking to fully integrated design and planning on the one hand; the software development needs specific domain knowledge in order to satisfy the needs of AEC practitioners on the other – for both aspects increased multidisciplinary collaboration is necessary and needs to become part of curriculum.

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**PUBLIC-PRIVATE PARTNERSHIP (PPP)
INSTITUTIONALIZATION IN THE UNITED STATES:
QUESTIONS OF INSTITUTIONAL MATURITY,
GOVERNANCE, AND REFORM**

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PUBLIC-PRIVATE PARTNERSHIP (PPP) INSTITUTIONALIZATION IN THE UNITED STATES: QUESTIONS OF INSTITUTIONAL MATURITY, GOVERNANCE, AND REFORM

ABSTRACT

Globally, public-private partnerships (PPPs) have increased in popularity as an alternative procurement model for infrastructure development projects. While PPPs have been widely researched and remain subject to extensive debate, the role of institutional maturity and institutionalization in PPP governance has been largely overlooked in the field of engineering project organization (EPO). To address this knowledge gap, this paper evaluates how the level of institutional maturity affects the public sector's governance capacity to effectively develop PPPs. To do this, we first outline the institutional and organizational challenges involved in collaborative governance arrangements between the public and private sector. Then, drawing upon this extant theory, we define PPPs as an innovative form of collaborative governance for infrastructure project delivery. Finally, we apply Johnson et al.'s (2006) four stages of institutionalization—innovation, local validation, diffusion, and general validation—to examine the institutional maturity of the US PPP market. Through this approach, our research: (1) offers a broad institutional assessment of the public sector's capacity to effectively steward PPP projects; (2) identifies the US's current stage in the PPP institutionalization process; and (3) highlights various institutional deficiencies across the United States that require further development and reform.

KEYWORDS

Institutionalization, governance; public-private partnerships (PPPs); institutional maturity; infrastructure.

INTRODUCTION

Engineering project organization (EPO) is a specific field where “engineering, social science, business and public policy are integrated as foundational pillars within the context of infrastructure development” and used to meet multiple stakeholder objectives (Chinowsky 2011, 3). Within this interdisciplinary research domain, “there remains a bias towards project-based research over broader issues within the [EPO] community” (Sakhrani, Chinowsky, and Taylor 2017, 17). One critical area of inquiry that remains understudied in the EPO field is the role of institutional maturity and institutionalization in infrastructure project governance. Institutional maturity represents well-developed norms, rules, and cultural-cognitive beliefs involved in socio-economic development while institutionalization refers to the process in which new innovations “emerge, diffuse, and become legitimated over time” (Lawrence, Winn, and Jennings 2001, 624). Governance challenges which plague infrastructure development tend to stem from weak and conflicting institutional and organizational goals, norms, and expectations (Scott, Levitt, and Orr 2011). By their nature, infrastructure projects are burdened by economic and political uncertainty, distributional issues, and prolonged environmental impacts. The distinct project lifecycle stages, diverse stakeholder networks (Hodge, Greve, and Boardman 2010), high degrees of “broken agency” (Henisz et al. 2012), and unique, transaction-specific characteristics (Vining, Boardman, and Poschmann 2005; Williamson 1981, 1985) associated with infrastructure projects make them costly, complex, politically contentious, and inherently challenging to execute (Boardman and Vining, 2012). From planning, design, and construction through operations and maintenance, the changing composition and interaction of multiple stakeholders, skills and professions within infrastructure projects gives rise to complex organizational, political, and social governance issues (Scott, Levitt, and Orr 2011). When administered poorly, these projects are ripe for corruption and opportunism, both of which persistently threaten the governance, efficacy, and transparency of infrastructure contracting (Spiller 2011; Obermann 2007). As a result, many researchers have shown in traditionally procured infrastructure projects that:

- Infrastructure planners systematically overstate project benefits and underestimate costs (Flyvbjerg 2002);
- Engineers indemnify themselves against potential liability risks by producing overly-conservative designs (Levitt et al. 1980);
- Contractors both exploit design ambiguities to obtain contractual change orders that increase their remuneration and avoid additional investments that could improve project lifecycle costs by building cheaply to meet minimum design specifications (Henisz et al. 2012); and
- Governments favor building new infrastructure assets over maintenance investments, thereby increasing future repair and replacement costs (Bennon, Kim, and Levitt 2017).

In light of these governance challenges, collaborative institutional arrangements between the public and private sector known as public-private partnerships (PPPs)

have emerged as an alternative project delivery mechanism to procure infrastructure assets. Public-private partnerships generally refer to long term contracts between governments and private partners which “[bundle] together basic project-delivery functions, including facility design, construction, operation, maintenance, and financing, along with the transfer of significant infrastructure-delivery-related risks to private partners” (Casady and Geddes 2016, 1).

Around the world, PPPs have been widely touted for their ability to overcome some of the shortcomings of traditional infrastructure procurement and deliver benefits such as on-time and within-budget delivery, access to new forms of capital, novel financing solutions, design innovation, optimized risk sharing, and life cycle costing. However, these collaborative arrangements hold their own, unique governance challenges. While previous research efforts in EPO have examined PPP governance issues in some detail (see, e.g. Mahalingam 2010; Garvin 2010; Delhi and Mahalingam 2017), the role of institutionalization in the successful planning, execution, and enforcement of PPPs remains largely understudied.

To address this knowledge gap, this paper attempts to “broaden the [EPO] research agenda [and] break out of the confines of . . . more traditional engineering project topics” by tracking the evolution of institutional drivers affecting PPP governance in the United States (Sakhrani, Chinowsky, and Taylor 2017, 17). To do this, we first outline the institutional and organizational challenges involved in collaborative governance arrangements between the public and private sector. Then, we use this extant theory to define PPPs as an innovative form of collaborative governance for infrastructure project delivery. Next, we employ Johnson et al.’s (2006) four stages of institutionalization—innovation, local validation, diffusion, and general validation—to examine the institutional maturity of the US PPP market, including areas of reform. Finally, this paper concludes by summarizing our theoretical contribution and offering suggestions for further research.

INSTITUTIONAL AND ORGANIZATIONAL CHALLENGES IN COLLABORATIVE GOVERNANCE: AN OVERVIEW

While public and private governance systems are both inherently political systems defined by control and the use of power (Hult and Walcott 1990), these systems are governed by distinct and conflicting institutions and organizations. In the starkest terms, private organizations engage in profit-making while public agencies serve the public interest. Private firms are fundamentally guided by the market and search for business that generates a return on investment. The norms and rules of this system are governed and enforced by shareholders, corporate managers, and board representatives through business relationships, contracts, and fiduciary obligations, all in the name of commercial gain (Daily, Dalton and Cannella 2003). Conversely, public sector entities strive to maximize public utility and preserve the public interest through legislation, regulation, and adjudication (Bingham et al. 2005). Within the government bureaucracy, governance is largely administered by program managers and policymakers who must balance competing economic, environmental, social objectives. Taken together, these differences between the public and private sector are further complicated by two additional factors. First, public organizations are generally expected to provide oversight over private organizations through corrective measures and incentives. Second, government agency goals and objectives tend to be more

numerous, vague, and conflicting than those found in private systems. Policymakers and program managers working in public sector institutions define and scope problems, assess strategic options, analyze policy implications, and make decisions in the absence of certainty (Bell 1985; Chamberlain and Jackson 1987). This uncertainty and controversy incentives public sector institutions to focus on “the processes by which goals are established, challenged, and reestablished” rather than actual government outcomes (Hult and Walcott 1990, 62). Some of the primary process values exhibited by public organizations include:

1. *Structured rationality* - processes that incorporate relevant expertise and information into agency decision making;
2. *Accountability* - procedures that hold governing officials responsible for their actions;
3. *Representativeness* - processes which enable affected stakeholders to participate in the shaping of policies; and
4. *Legitimacy* – public sentiment that assumes a given policy decision has been formulated in acceptable ways, through justifiable procedures (Hult and Walcott 1990, 63-67).

In applying these processes, public agencies place great emphasis on the structure of rule-like frameworks and the development of “patterned ways in which to discover and articulate goals, select among means, and cope with uncertainty and controversy” (Hult and Walcott 1990, 36). Through these processes and patterns of decision-making, agency formation and framework development provide structure for the surrounding institutional environment. However, this also explains why government agencies, unlike private companies, appear to be governed by constraints. Their priorities favor established rules, processes, norms, and objectives more than performance outcomes and accomplishments. As a consequence, most public agencies operate inefficiently. Many lack profit-maximizing incentives which promote efficient resource allocation and institutional goal alignment (Wilson 1989).

To become more efficient, public agencies are increasingly scrutinizing and revising their administrative objectives and decision-making processes. Part of this process involves governments “reinvent[ing], downsiz[ing], privatiz[ing], devolve[ing], decentraliz[ing], deregulat[ing], delayer[ing], subject[ing] to performance tests, and contract[ing] out” some of their traditional public-sector responsibilities to private non-governmental actors (Salamon 2002, 1). Through broader engagement of private actors in public service provision, public sector organizations are seeking to promote higher levels of accountability and improve the range and depth of policy options considered in serving the public interest (Mashaw 1985). This greater reliance on the expertise and organizational proficiency of private firms to execute certain public services is forcing public sector institutions to explore collaborative governance models such as public-private partnerships (PPPs) (Andrews and Entwistle 2010). Public-private partnerships are inherently difficult to craft and execute because of extant differences in the goals, norms, beliefs of the public and private sector (Bryson, Crosby, and Stone 2006). Successful collaboration within these collaborative governance agreements thus requires reconciliation of their

conflicting institutional and organization constructs. This is especially true in infrastructure project delivery, where the public and private sectors are not exclusive spheres of action but rather co-dependent domains, working together to successfully provide public services and solve complicated public problems (Salamon 2002). In the following section, we elaborate on this blending of public and private domains by discussing the collaborative governance challenges of infrastructure PPPs. We also touch upon factors which promote the institutional maturation of PPP-enabling environments.

INFRASTRUCTURE PUBLIC-PRIVATE PARTNERSHIPS: A INNOVATIVE COLLABORATIVE GOVERNANCE FORM

Public and private collaborative endeavors are not new (Wettenhall 2003, 2005; Bovaird 2004; Hodge and Greve 2007). In fact, according to Kettl (1993, 4), “[e]very major policy initiative launched by the [US] federal government since World War II—including Medicare and Medicaid, environmental cleanup and restoration, antipoverty programs and job training, interstate highways and sewage treatment plants and even security in post-conflict zones—has been managed through public-private partnerships.” However, PPPs emerged as a popular mechanism for governments to engage private firms in infrastructure project delivery after the U.K.’s private finance initiative (PFI) during the early 1990s. Since then, governments around the world have been increasingly incorporating private-sector expertise, resources, and risk management proficiency into infrastructure project delivery through the use of public-private partnerships (PPPs). PPPs generally bundle various infrastructure project phases, including facility design, construction, financing, operations, and maintenance, into long-term contracts with private consortiums. These contractual arrangements typically involve a significant transfer of risks from the public-sector project sponsor to private, third-party actors and link remuneration to performance of the contracted service (Casady and Geddes 2016; World Bank 2017). Together, these two unique features of PPPs—bundling phases and taxpayer/private partner risk sharing—allow governments to holistically address multiple stages of the project lifecycle without developing the technical, financial, and physical resources needed to deliver and maintain these projects themselves. Depending on how public agencies construct these innovative procurement agreements, PPPs can take on a wide range of structures (see Figure 1).

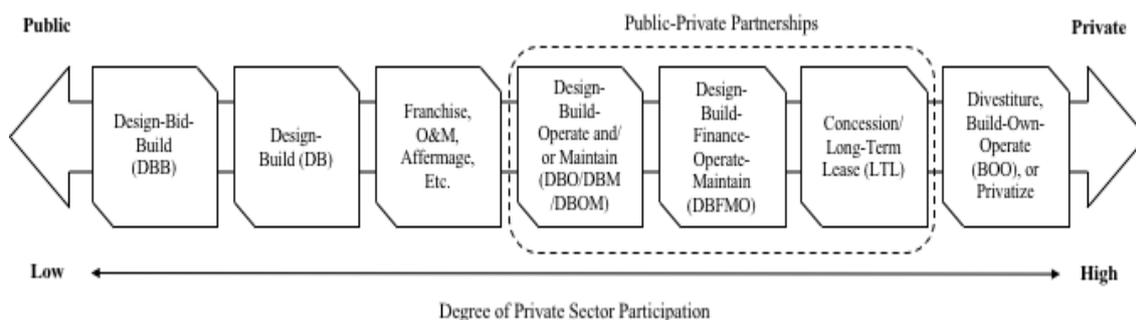


Figure 1: Spectrum of PPP Model Types

Across the PPP spectrum, governments must balance trade-offs between contractual incentives, project flexibility, and institutional dynamism (Bennett and Iossa 2006; Martimort and Pouyet 2008; Iossa and Martimort 2015). When properly executed, PPPs can deliver significant social value through life-cycle costing, asset maintenance, and allocation of complex, infrastructure-delivery-related risks to parties best positioned to manage those risks (Hodge, Greve, and Boardman 2010; Engel, Fischer, and Galetovic 2014). Some potential benefits of PPPs include design innovation, enhanced technological implementation, access to new pools of private capital, and better on-time and within-budget delivery (Hodge and Greve 2007; Raisbeck, Duffield, and Xu 2010; Lammam et al. 2013; Casady and Geddes 2016).

Despite these documented benefits, PPPs can also create issues for public agencies. For example, a longstanding concern with PPPs continues to be the loss of flexibility associated with long-term contracts (Ross and Yan, 2015). As a procurement model, infrastructure PPPs characteristically exhibit high transaction costs and long tendering periods (KPMG 2010; Reeves, Palcic, Flannery, and Geddes 2017). Moreover, PPPs may not always provide the public sector and taxpayers with adequate value for money (VfM) (HM Treasury 2012; Burger and Hawkesworth 2011). In some cases, PPPs can even create budgetary problems for governments (Hellowell and Vecchi 2015). Finally, PPPs, by their nature, force governments to engage private institutions in complex, co-dependent relationships, networks, and exchanges over the provision and maintenance of public infrastructure assets (Grimsey and Lewis 2007; Yescombe 2011). Throughout these interactions, public sector entities must activate, orchestrate, and maintain relevant stakeholder networks across the project lifecycle while modulating contractual incentives to elicit publically desired outcomes (South, Levitt, and Dewulf 2015). PPPs thus “require, rather, aggressive management by a strong, competent government” (Kettl 2011, 6). If governments lack the capacity to engage private firms in these complex, networked environments, successful planning, execution, and stewardship of PPP contracts becomes especially challenging (Geddes and Reeves 2017).

Therefore, PPP arrangements require strong political commitment and well-designed governance mechanisms that promote the public interest (Buxbaum and Ortiz 2007; OECD 2015). While successful stewardship of PPPs can be attributed to a variety of different factors (see, e.g., Grimsey and Lewis, 2007; Hodge and Greve 2005; Yescombe 2011; Levitt and Eriksson 2016), effective PPP governance generally includes:

1. Sophisticated, long-term, relational contracts to manage dynamic, multi-stage networks of diverse stakeholders such as designers, contractors, financiers, and operators (see, e.g., Wettenhall 2003);
2. Standardized procurement laws and commercial transactions which maximize competitive tendering and minimize transaction costs (KPMG, 2010); and
3. A strong institutional environment supported by international best practices (Opara et al. 2017; Martin et al. 2013).

These factors, taken together, help broadly define a government’s ability to develop a trustworthy network, regularly measure PPP performance, and successfully align

public and private interests. However, these criteria are by no means exhaustive. Successful collaboration between public and private actors in PPP projects also depends heavily on accountability. Accountability is important because surrounding networks of actors and institutions ultimately condition collaboration between the public and private sector (Bingham and O’Leary 2014). These interactions shape the institutional environment surrounding PPP arrangements and may adversely influence the government’s oversight capacity to promote fairness, transparency, and contractual compliance (Kee et al. 2007). To avoid instances of corruption and regulatory capture, Forrer et. al. (2007) suggest governments track mutual influence, participation rights, and transparency within PPPs along six dimensions—risk, costs and benefits, political and social impacts, expertise, collaboration, and performance measurement. Likewise, Delhi and Mahalingam (2017) identify 19 dimensions influencing PPP institutional environments and project characteristics, 13 strategic governance mechanisms that impact post-award PPP outcomes, and 7 outcome dimensions—financial sustainability, adaptability, legitimacy, the extent of restructuring, sustained performance, conformance to budget and conformance to schedule—that can be used to assess post-award PPP performance. Operationalizing these various frameworks, governments may be able to form an overarching alignment of public and private interests (Brinkerhoff 2002; Brinkerhoff and Brinkerhoff 2011), assess PPP performance, predict post-award outcomes, and design projects for optimal governance across the lifecycle (Delhi and Mahalingam 2017).

Overall, public-private partnerships have grown in popularity around the world as an alternative infrastructure procurement model. While many governments globally have turned to PPPs in order to break the government monopoly on infrastructure development, inject competition and flexibility into infrastructure contracting, enhance the public sector’s technical, financial, and physical capacity to deliver projects, and improve infrastructure service quality, traditional infrastructure procurement methods still offer governments, in most projects, the ability to “[internalize] transactions, [minimize] legalisms involved in complex contractual negotiations with external actors, and [provide] a more stable framework for bargaining” (Salamon 2002, 31). PPPs should therefore not be regarded as a panacea for the shortcomings of traditional infrastructure provision. Governments should rather assess “the net gains to the public offered by [PPPs]” vs. governments’ more traditional project delivery methods (Forrer et al. 2007, 482). In total, PPPs offer governments an innovative form of governance for infrastructure project delivery (Brinkerhoff 2007; Greve and Hodge 2010; Skelcher 2010), one that requires proper safeguards and a mature institutional setting to ensure “public services are not compromised for the sake of private profits” (Forrer et. al. 2007, 477). In the next section, we use Johnson et al.’s (2006) four-stages of institutionalization—innovation, local validation, diffusion, and general validation—to dissect the role of institutional maturity in the US PPP market.

PPP INSTIUTIONALIZATION IN THE UNITED STATES: AN INSTIUTIONAL MATURATION PROCESS

In markets where PPPs are successful, strong institutional platforms help shape and deliver policy, prepare and procure projects, and manage/regulate project agreements (Farquharson et al. 2011). These institutional settings generally mature over time

through an ongoing structuration of organizational fields (Scott and Meyer 1994). Organization fields, typically, are defined around a specific type of organization—in our case, a PPP project—but also include other types of organizations that importantly relate to this organization by providing resources, consuming services, expressing opposition, or providing oversight. Field “structuration” refers to the processes by which arenas of social activity are ordered. As this process proceeds, organizations engage in increased interaction, are increasingly interdependent, and exhibit greater consensus on appropriate organizational forms and procedures for doing work (DiMaggio and Powell 1983). Mature fields also exhibit higher levels of legitimacy based on “generalized perception[s] or assumption[s] that the actions of [entities involved in PPP projects] are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs and definitions” (Suchman 1995b, 574). In PPP markets, institutional maturation is also typically associated with broad facilitating factors such as “market potential, institutional guarantees, government credibility, financial accessibility, government capacity, consolidated management, and corruption control” (Yang, Hou, and Wang 2013, 301). These factors, coupled with local geography, political conditions, and capital market sophistication, drive the viable formation of partnerships (Eggers and Startup 2006). Moreover, regulative and normative interactions, characterized by legislation, agency development, and legal precedents, further underpin PPP-enabling institutions by clarifying responsibilities, interfaces, procedures, and processes both within and between market actors and the public sector.

In leading PPP jurisdictions, such as Australia, Canada, and the United Kingdom, as well as other countries across Europe, Asia, and Latin America, this long-term structuration process across decades of projects has yielded significant cross-national differences in the institutional frameworks governing PPPs. Despite global trends toward procedural standardization, contract specification, and elaboration of procurement details, many countries around the world still employ a wide variety of different PPP approaches and most lack national PPP models (Hodge 2013; Siemiatycki 2013). This diversity in the ongoing growth of PPP legislation and agency work across institutional settings has created distinct PPP-enabling fields within an elaborately networked and regulated market environment (Jooste and Scott 2012).

Within these distinct jurisdictions, significant institutional and strategic elements influence the adoption, maturation, and legitimation of PPP markets. This process can generally be described by Johnson et al.’s (2006) four transitory stages of institutionalization—innovation, local validation, diffusion, and general validation. In typical institutionalization processes, “[innovations] are first recognized, then accepted by relatively few actors, and then widely diffused and broadly accepted within a field” (Lawrence, Winn, and Jennings 2001, 626; see also, e.g. Meyer and Rowan 1977; Zucker 1987; Suchman 1995; Hall and Scott 2018). In the context of PPP market development, these stages can be defined as follows:

1. *Innovation* – the identification of PPPs as an innovative procurement mechanism to deliver infrastructure assets;
2. *Local Validation* – the successful justification or implicitly acceptance of PPPs in specific, localized settings;

3. *Diffusion* – the growing adoption of PPPs in other contexts; and
4. *General Validation* – the widespread acceptance and use of PPPs in infrastructure project delivery.

While the innovativeness of PPPs is well documented in the preceding section, the context surrounding this innovative form of collaborative governance remains important. Like other innovations, PPPs arose primarily in “response to structural conditions . . . that create[d] strategic interests or contingent events for actors in local contexts” (Johnson et al. 2006, 60). Examples of these structural conditions include endemic project cost overruns, schedule delays, and deferred maintenance. Many countries around the world are increasingly turning to PPPs to address these pervasive issues in infrastructure service delivery. In doing so, they are being forced to navigate challenging institutional dynamics involved in PPP governance, settings that can either enable or constrain the development of effective PPP programs (Henisz et al. 2012, Delhi and Mahalingam 2017). While leading PPP jurisdictions like Canada, Australia, and the United Kingdom have established “mature systems of government regulation as well as [normalized] market rules” to address these governance challenges, weak institutions and scarce institutional capacity in other nations have made governance of the PPP process especially challenging (Wang, Wu, and Zhu 2018, 296).

In the United States in particular, “[p]ublic procurement authorities often fail to appreciate the significant differences between PPPs and traditional forms of procurement and the implication of these differences for the level of resources, the unique skills, the output-based nature of the contracts, and the new processes and institutions required” (Farquharson et al. 2011, 23) Consequentially, the US lags behind many leading PPP jurisdictions in the development of sufficient PPP governance mechanisms at the federal, state, and municipal level.

This relatively slow adoption of PPPs as an innovative procurement model in the United States is institutionally rooted (Geddes 2011; Bennon, Kim, and Levitt 2017). Federal, state, and local consensus on a clear PPP policy rationale, supported by robust legal, regulatory, and investment frameworks, is inherently challenging because the distribution of powers and responsibilities of infrastructure provision in the US is significantly fragmented across different levels of government (Albalade, Bel, and Geddes 2015). For example, since the end of WWII, construction of nationally significant infrastructure—e.g. the Interstate Highway Program, Clean Water Program, Urban Mass Transportation Agency’s (UMTA)¹ transit program—has traditionally been funded using 90% federal funds and 10% local funds. At the same time, states and municipalities tasked with the funding of ongoing operations and maintenance of these projects have tended to defer maintenance expenditures indefinitely until the federal government steps in to fund the rehabilitation or replacement of deteriorating infrastructure assets (Kirk and Mallett 2013; Bennon, Kim, and Levitt 2017). This historical bifurcation of infrastructure investment priorities between federal, state, and municipal governments has created an

¹ The Urban Mass Transportation Agency (UMTA) became the Federal Transit Administration (FTA) in 1991.

unbalanced funding model which dis-incentivizes enhanced private investment in US infrastructure via PPPs.

Election cycles accentuate this misalignment in federal, state, and local investment priorities by creating political incentives that favour new infrastructure projects over adequate maintenance for existing infrastructure assets. It is not uncommon for politicians to favour launching new infrastructure projects rather than spending taxpayer dollars on maintaining existing assets beyond their elected tenure. This, coupled with federal, state and local tax exemption of public bonds have significantly tilted the playing field in favour of the government financing, operating and maintaining—albeit under-maintaining—US infrastructure projects (Bennon, Kim, and Levitt 2017).

As a result, the local validation of PPPs in the US has been relatively ad hoc. Wide variation in PPP governance exists across state lines, within specific infrastructure sectors, and amongst cities as well as some metropolitan transit agencies. The absence of cohesive project prioritization guidelines, uniform procurement procedures, standardized contracts, and robust project pipelines has created an unstable policy environment devoid of the technical capacity, regulator autonomy, decision-making predictability, and process transparency found in more mature PPP markets. Consequentially, the US has experienced limited adoption of the PPP model and a relatively uneven distribution of PPP procurements. Higher adoption has occurred primarily in more populated states where larger markets exist for potential users or customers (Albalade, Bel, and Geddes 2015). For instance, large states like California, Virginia, Florida, and Texas have each delivered upwards of ten PPP projects while many others have yet to complete a single procurement (Istrate and Puentes 2011; Geddes and Reeves 2017). Moreover, some states trying to deliver experience and build confidence in their PPP procurement capacity have only been able to procure a handful of “pathfinder” projects (Bennon, Kim, and Levitt 2017). In sum, America’s unique institutional setting, characterized by divergent national and regional priorities and dissimilar infrastructure processes, has hindered the widespread diffusion of PPPs as an alternative means of infrastructure procurement.

Despite these institutional barriers, the use of PPP projects in the United States is continuing to grow. For example, since 1993, 36 DBFOM and long-term lease projects have reached financial close across the United States, totalling \$48 billion in investments (PWF November 2017). This increasing PPP activity is largely driven by ongoing economic, political, and social consequences of America’s enormous infrastructure deficit. For instance, local jurisdiction debt-stress and tax burdens are forcing governments toward enhanced private involvement in infrastructure contracting (Albalade, Bel and Geddes 2015; Boyer and Scheller 2017; Bel and Fageda 2009). Moreover, increasing healthcare and pension obligations, declining discretionary budgets, and growing public opposition to tax increases are exacerbating declines in federal, state, and local funding for infrastructure investment (Cawley 2013; DeCorla-Souza, Lee, Timothy, and Mayer 2013; Engel, Fischer, and Galetovic 2014). Taken together, these challenging structural conditions have made the innovation, local validation, and diffusion of PPPs “a pragmatic rather than a political decision” (Albalade, Bel, and Geddes 2017, 41).

To accommodate this growing pragmatism, PPP-enabling legal, regulatory, and investment frameworks are emerging across the United States. At the federal level,

legislative measures and supporting federal institutions have become increasingly favourable toward PPP procurement (Iseki et al. 2009).² Within the US Department of Transportation, entire offices are now dedicated to promoting PPPs as an alternative infrastructure delivery mechanism. For example, the Federal Highway Administration’s (FHWA) Office of Innovative Program Delivery (OIPD) offers technical guidance and public-sector capacity support for innovative financing and project management arrangements such as public-private partnerships. Likewise, the passage of the Fixing America's Surface Transportation (FAST) Act in 2015 led to the creation of the Build America Bureau, an entity designed to “[serve] as the single point of contact and coordination for states, municipalities and project sponsors looking to utilize federal transportation expertise, apply for federal transportation credit programs and explore ways to access private capital in public private partnerships” (Build America Bureau 2017). Operating under the Office of the Undersecretary for Transportation Policy, this nascent bureau replaced the Build America Transportation Investment Center (BATIC) and assumed responsibility for streamlining access to credit and grant opportunities as well as encouraging the adoption of best practices in project development, delivery, financing, and management. Some of the Bureau’s core responsibilities include:

1. Centralized project coordination, project-level technical assistance, and alternative project delivery assessment;
2. Federal credit enhancement via Transportation Infrastructure Finance and Innovation Act (TIFIA) and Railroad Rehabilitation and Improvement Financing (RRIF) direct loans, loan guarantees, and standby lines of credit;
3. Management of the tax-exempt Private Activity Bonds (PABs) program for prospective PPP concessionaires; and
4. Administration of Infrastructure For Rebuilding America (INFRA) grants for projects that address critical issues on US highways and bridges (Build America Bureau 2017).

Together, federal institutions like the Bureau and OIPD work to encourage PPP use by addressing the aforementioned institutional barriers favoring traditional project delivery. While their role is paramount in the formation of a mature institutional setting for US PPPs, their influence should not be overstated. Because infrastructure provision happens primarily at the state and local level, “developments at the federal level are often limited in scope and effect and typically provide only general guidelines for PPP implementation” (Geddes and Reeves 2017, 159).

Naturally, the diffusion of PPPs in the US remains rooted in locally valid representations of this innovative delivery approach. Laws and agency formation at the state and local level have a more direct effect on America’s institutional capacity to engage in PPPs. This is evidenced by the ongoing proliferation of general administrative law, sector regulations, and specifically stipulated PPP contract

² See Iseki et al. (2009) for a detailed assessment of PPP-enabling federal legislation.

provisions across the United States (Queiroz and Lopez 2013). In 2017, 35 states, the District of Columbia, and one US territory had enacted PPP statutes (see Figure 2).

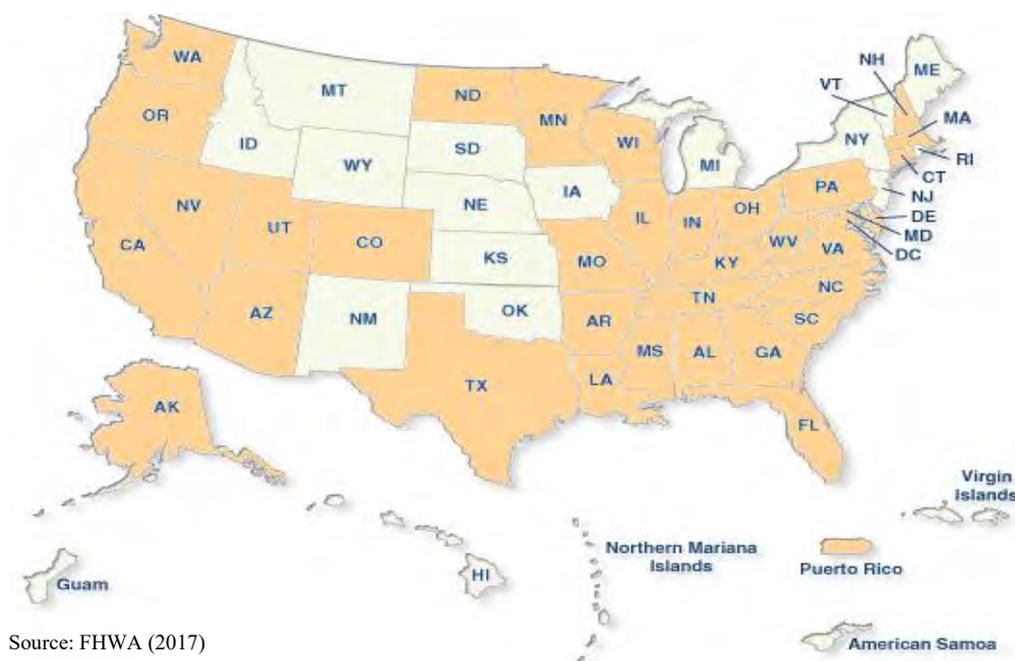


Figure 2: PPP-Enabling Legislation Across the United States

While the adoption and favorability of PPP-enabling laws has typically followed local demand side, supply side, and political/institutional drivers such as state debt and urban travel demand (Geddes and Wagner 2013; Albalade, Bel, and Geddes 2017; Boyer and Scheller 2017) rather than traditional public finance considerations, such as federal highway aid (Geddes and Wagner 2013), the implementation of these statutes has not been consistent. Wide spread variation currently exists between state-level, PPP-enabling environments. Depending on how the institutional framework surrounding PPP procurement is structured, these statutes can either provide a supportive environment for PPP procurement or undermine PPP activity. Overall, difficulties associated with balancing contractual flexibility and public-interest protections have created large disparities in PPP favorability between states (Geddes and Reeves 2017; Iseki et al. 2009). Despite these challenges, a growing body of procurement law and jurisprudence across the US is slowly laying the legal and regulatory foundation for a successful US PPP market.

To compliment these ongoing legal and regulatory developments, PPP-enabling organizations are also beginning to develop at the state and municipal level. For example, a handful of states and some municipalities (e.g. Virginia, California, Washington, Michigan, Oregon, Colorado, Georgia, and Washington DC) have established PPP units to promote procurement accountability, standardization, and transparency. Typically found in leading PPP jurisdictions, these units are designed to provide stewardship through the PPP procurement process by assisting governments with project scoping, performance specification, business case development, identification and allocation of risks, market sounding, bid evaluation and selection, and contract monitoring, among other project delivery tasks (Istrate and Puentes 2011). When appropriately structured, PPP units enable governments to navigate the

complexities of PPP proceedings with greater consistency, transparency, and legitimacy. Since the development of PPP units across states, territories, and municipalities is still in its infancy, the US should consider establishing PPP units on a regional and national level to capture some economies of scale, avoid duplicating institutional capacity across states and localities, and boost the general validity of the PPP approach (Casady and Geddes 2016).

In summary, the US PPP market continues to face significant institutional challenges. The slow development and maturation of PPP-enabling institutions, governance frameworks, and public organizational structures has created an all-too-common impediment hindering the general validation of PPPs as an alternative procurement model (Benyon, Kim, and Levitt 2017). While progress is being made in some areas at the federal, state, and local level, many private firms and public agencies still do not believe current US institutions (e.g. laws, rules, social norms, and policy) offer enough incentives, transparency, and accountability for the US to successfully deliver a coordinated PPP program (Geddes and Reeves 2017). The prevalence of inconsistent PPP procurement procedures, dissimilar legal and regulatory environments across state lines, and minimal use of PPP-enabling organizations (e.g. PPP units) are just some of the many ongoing institutional challenges affecting PPP development and governance in the U.S. PPP market.

As a result, PPPs in the United States continue to exhibit erratic diffusion patterns. While the market has matured significantly, the diffusion process has yet to produce a growth pattern reflecting widespread consensus that PPPs are an appropriate governance form for infrastructure project delivery. This temporal pattern, known as an “instance of institutionalization,” is characteristic of traditional, S-shaped institutionalization curves (Lawrence, Winn, and Jennings 2001). Figure 3 depicts the progression of PPP institutionalization unfolding in the United States as “a contested process that unfolds across time” (Johnson et al. 2006, 59). With respect to PPP infrastructure delivery, the US remains, at best, in the early phases of Stage 3.³

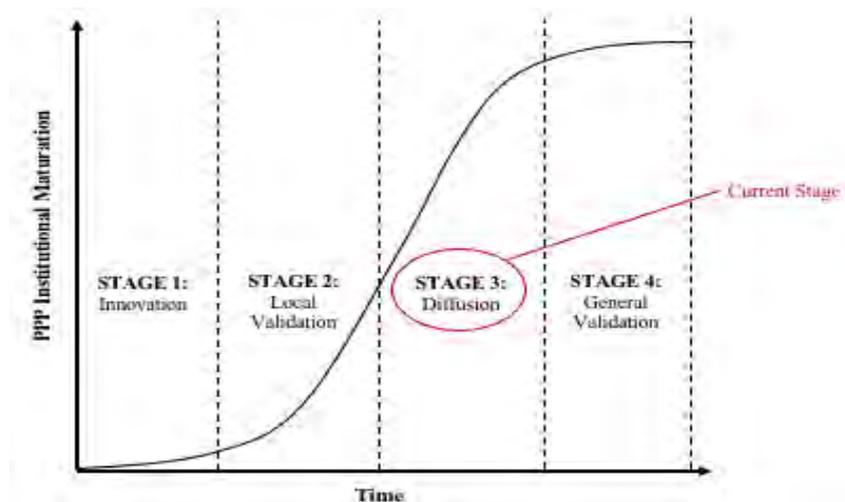


Figure 3: A General Framework of PPP Institutionalization in the US

³ These findings generally conform with the three-stage PPP market maturity curve conceived by Eggers and Startup (2006).

While “no one precise shape of curve [and length of stage] fits the dynamics associated with all instances of institutionalization” (Lawrence, Winn, and Jennings 2001, 627), this model represents a typically pattern of more successful innovations. If the US is going to begin to adhere to this institutionalization process and generally validate the PPP model, then more US public agencies at the federal, state, and municipal level will need to improve their governance capacities, address existing knowledge gaps, share and adopt international best practices, and “reform institutions or build new organizations to assess and manage new models for infrastructure procurement and assets management” (Bennon, Kim, and Levitt 2017, 24; Boyer 2016).

ACCELERATING PPP INSTITUTIONALIZATION IN THE US: LESSONS FROM INTERNATIONAL BEST PRACTICES

Successful PPP governance requires a mature institutional setting that promotes efficient and equitable delivery of infrastructure assets while safeguarding the public interest. Countries like the US which remain “at earlier stages of PPP development could benefit from the opportunity to learn from the trailblazers who have moved to more advanced stages” (Eggers and Startup 2006, 6). Leading PPP jurisdictions such as Canada, Australia, and the UK have undergone extensive institutional maturation processes to generally validate the use of PPPs. In these jurisdictions, elaborate legal structures, economic policies, and social norms have emerged to help balance the inherently conflicting interests of public and private actors. These mature settings typically have:

1. Clear policy rationales for PPPs;
2. Streamlined PPP legislation;
3. Transparent approval processes;
4. Robust project pipelines;
5. Consistent frameworks for project selection, preparation, and procurement;
6. Standardized commercial contracts;
7. Clear dispute resolution procedures; and
8. Multiple PPP units managing the preparation, solicitation, and evaluation of PPP bids (Farquharson et al., 2011).

In contrast, US institutional capacity for PPPs remains relatively underdeveloped. Currently in an early state of diffusion, the United States lacks a mature, enabling institutional environment for PPPs. This is largely driven by the public sector’s fragmentation, conflicted and inconsistent political policy setting, lack of project preparation capacity, and trust in the private sector to properly design and structure PPP projects (Mahalingam 2010). The US can improve its institutional capacity for PPPs by “establish[ing] clear, predictable and legitimate institutional framework[s] supported by competent and well-resourced authorities” (World Bank and DFID

2009; OECD 2012, 8)⁴ Institutional reforms found in international PPP markets that could immediately improve PPP governance in the United States include, but not are limited to:

1. Enhanced political commitment to PPPs as an alternative delivery mechanism;
2. Overarching policy guidance and sector-specific models “that may respond, in a logical, consistent, and consultative way, to inevitable changes in policy and the market” (Farquharson et al. 2011, 19);
3. Consistent PPP legislation and procurement procedures at the federal, state, and local level;
4. Transparent infrastructure project prioritization using non-partisan, expert panels; and
5. Adoption and utilization of PPP units at the regional and national level.

These general reforms are representative of more mature PPP markets, and the “US can capitalize on the tested experience of its international counterparts” to implement them (Garvin 2010, 402). By doing so, the US may be able to avoid mistakes in the earlier stages of maturity, adopt dynamic, innovative, and robust PPP approaches, “move up the PPP maturity curve more rapidly and leapfrog to more advanced stages of maturity” (Eggers and Startup 2006, 6).

However, careful consideration must be given to the transferability of PPP international best practices (Acerete, Gasca, Stafford, and Stapleton 2015). This is especially true at the state and local level where more research is needed on the localized development of PPP-enabling institutions (Boardman, Greve, and Hodge 2015; see also Van den Hurk et al. 2016). Additionally, successful validation of the PPP approach in the United States will require further work on comprehensive performance metrics for public-private partnerships (Boardman, Poschmann, and Vining 2005). In this regard, the framework recently developed by Delhi an Mahalingam (2017, 115) may be useful for “understand[ing] the minimum set of governance strategies that could be enacted in a given institutional environment for successful outcomes.” In general, however, the US has a unique opportunity to accelerate its PPP institutionalization process by closing the knowledge gap, adopting international best practices, and establishing credible governance processes supported by a mature, enabling institutional environment.

CONCLUSIONS

The field of engineering project organization has traditionally reserved itself to more conventional, project-based engineering topics (Sakhrani, Chinowsky, and Taylor 2017). In doing so, this interdisciplinary domain has neglected broader issues affecting infrastructure project governance. While some researchers in the EPO

⁴ For a more detailed review of PPP governance mechanisms, see World Bank and DFID (2009) as well as OECD (2012).

community have begun to “systematically develop a comprehensive typology of institutional conditions and project specific strategies that can prove significant in achieving satisfactory post-award performance of PPP projects” (Delhi an Mahalingam 2017, 131), the role of institutional maturity and institutionalization in the successful governance of public-private partnerships has still garnered relatively little attention. Our research addresses this gap in the EPO literature in the following ways. First, we document the differing institutional and organization constructs in the public and private sector that make collaborative governance agreements between them challenging to execute. Next, we use this extant theory to define PPPs as an innovative form of collaborative governance for infrastructure project delivery. More specifically, we articulate how public agencies pursuing PPP contracts must navigate diverse organizational forms, competing stakeholder interests, and complex regulative, normative, and cultural-cognitive domains, all while upholding the public interest. Finally, this paper highlights the critical role institutional maturity plays in the successful planning, execution, and enforcement of PPPs contracts. By applying Johnson et al.’s (2006) four-stage institutionalization framework to the US PPP market, our review: (1) offers a broad institutional assessment of the public sector’s capacity to effectively steward PPP projects; (2) identifies the US’s current stage in the PPP institutionalization process; and (3) highlights various institutional deficiencies across the United States that require further development and reform.

Overall, PPP projects in the US and around the world present governments with a unique governance task. Public sector institutions facing vague, competing, and dynamic policy objectives are increasingly using PPPs to overcome shortcomings in traditional project delivery and enhance their technical, financial, and physical resource capacity to execute large, complex infrastructure projects. While PPPs offer some attractive potential benefits for governments such as on-time and within-budget delivery, life cycle asset maintenance, design innovation, and enhanced access to private capital, these alternative procurement mechanisms also contain embedded challenges across many stages of the project lifecycle, from planning, design, and construction through financing, operations, and maintenance. High transaction costs, long procurement timelines, budgetary problems, and lost government flexibility are just some of issues that can arise from PPP contracting. These problems ultimately stem from a lack of maturity in the underlying institutional environment. Evaluating the institutionalization of PPP markets thus serves as a powerful tool for isolating PPP governance shortcomings and identifying areas for institutional reform. Future research should aim to further explicate this institutionalization process, map changing institutional dynamics overtime, and develop key metrics of PPP market maturity. While PPPs should not be expected to solve all of America’s infrastructure needs, these alternative procurement mechanisms have the potential to play important role to play in delivering much needed infrastructure across the United States.

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BUILT BACK BETTER? AN ANALYSIS OF PERCEIVED PERFORMANCE OF POST-DISASTER HOUSING

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BUILT BACK BETTER? AN ANALYSIS OF PERCEIVED PERFORMANCE OF POST-DISASTER HOUSING

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ABSTRACT

Houses are often significantly damaged during disasters, due in part to poor housing design and construction practices. Post-disaster, organizations and governments often aim to “build back better”, using safer designs, but little research has been done to understand how households perceive the safety of their shelters. This study examines household perceptions of post-disaster housing in terms of performance in future (hypothetical) typhoons or earthquakes, and factors that influence those perceptions. We hypothesize that household perceptions of the risks to their house will influence modification and maintenance actions. To investigate housing perceptions, we surveyed 41 respondents from a single community who had received housing assistance following Typhoon Haiyan in the Philippines. We used correlation and regression analysis to analyze perceptions and how they were influenced by gender, education, income, prior knowledge, and satisfaction with the house. Results show that households perceive worse performance during typhoons than earthquakes, and men, on average, perceive worse performance than women. Prior knowledge about construction and satisfaction were found to be significantly correlated with perceived performance, with greater prior knowledge relating to worse perceived performance, and more satisfaction relating to better perceived performance. Future work will continue to investigate these relationships and the relationship between perceived performance and actions households take to modify or maintain their house.

KEYWORDS

Disasters, Risk Perceptions, Housing Performance, Household Satisfaction

INTRODUCTION

The housing sector is vitally important for communities around the world; in addition to providing shelter, housing is linked to economic prosperity and social capital (Comerio 1997). Housing also represents a significant economic investment – in developing communities in particular, the investment required to purchase a new house is 5-12 times greater than the annual average income (Barakat 2003). At the same time, housing often serves as workplaces and is essential for livelihoods (Ahmed 2011). Thus, the loss of a house has significant physical, social, and economic consequences for individual households and the community. Yet, the housing sector remains particularly

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vulnerable to hazards, and generally sustains the most damage in disaster events (Ahmed and Charlesworth 2015).

In the aftermath of disasters that significantly damage and destroy houses, organizations, agencies, and governments provide households with assistance to rebuild their houses. Acknowledging the impact of design and construction practices on housing vulnerability, organizations and governments have recognized the need to “build back better”(Clinton 2006) or “build back safer”. To achieve these recovery goals, houses have to be designed and constructed in ways that reduce the risk of damage and collapse, with future modifications to the structure also completed in a safe manner and with necessary maintenance performed on the house.

We hypothesize that a household’s perception of the future performance of their house may be an important factor affecting plans for maintenance and investment in the home. Specifically, if a household perceives their house to be unsafe, or expects it to be damaged in a future disaster, they might modify the house, which, if not trained in safe design and construction principles and rationale for initial design choices, could actually worsen the house’s performance in a future disaster, or may lead to the household abandoning the safe house. For example, Arlikatti and Andrew (2011) found that, after the 2004 Indian Ocean tsunami, households that received improved roofing technologies often had worse perceptions of roof performance due to the new roofing diverging from traditional building practices. Another study found that households may actual abandon safe housing when superficial damage occurs, as they have a different understanding of performance than design engineers (Sucuoğlu 2013). In other words, perceptions may have a lasting impact on the long-term safety and performance of the house, challenging organizations’ goals of “building back better.” Therefore, we ask: *How do households perceive their house will perform in hypothetical future disasters?* and *What factors influence these perceptions?*

POINT OF DEPARTURE

In this research, we rely on the work of structural engineers to define building performance and relate performance in disasters to damage and risk. We also draw from the body of literature on risk perceptions to assess how households perceive the performance of their house.

BUILDING PERFORMANCE

Structures in our built environment function for different purposes, and houses, in particular, serve various roles for their occupants: as shelters providing security (Arlikatti et al. 2015), social centers for family and friends (Barakat 2003), and valuable economic assets (Ahmed 2011), amongst others. Building “performance” refers to how well a house, or other structure, can withstand disaster events and shocks, ensuring the house can fulfill its shelter role and other needs of its users after an event (FEMA 2010). FEMA (2010) defines performance as “a building’s condition after a disaster, i.e., it signifies a level of damage expected” (pp. 2-1). Although engineers have traditionally focused on performance in terms of damage of structural components, the performance-based engineering framework takes a broader view, recognizing that damage to other non-structural building components may be problematic for functionality, even if not challenging structural integrity (Moehle and Deierlein 2004). Worse performance is

linked to greater levels of structural and non-structural damage, and a house's diminished capacity to function as intended or expected by its occupants.

In previous disasters, especially in developing communities, houses have often performed poorly, resulting in considerable damage. Common sources of damage during typhoons/hurricanes (i.e., strong wind events), are inadequate connections between roofs and supporting structures (Mas et al. 2015), low-quality roofing materials, and unreinforced masonry walls that lack the appropriate support (Kijewski-Correa et al. 2017). Masonry houses lacking proper steel reinforcement and constructed with poor quality block were a contributing factor to massive destruction of houses in the 2010 Haiti and 2015 Nepal earthquakes (Gautam and Chaulagain 2016; Marshall et al. 2011; Mix et al. 2011).

Our hypothesis that perceptions of risk and performance may influence household actions and, hence, performance in future events is supported by recent events in Haiti and Chile. In Haiti, households built heavy concrete and masonry houses that often lacked appropriate connections between walls and roofs. These houses performed well under strong winds, but catastrophically during an earthquake (Mix et al. 2011). Indeed, at the time of the 2010 earthquake, the island had recently experienced four hurricanes in 2008, but had not experienced a significant earthquake since 1860 (Marshall et al. 2011). Thus, households prepared for the hazard they perceived, and these perceptions led to misguided, and consequently detrimental, construction practices. However, in Chile, where households are more aware of the earthquake risk, the 2010 earthquake, an event significantly larger in magnitude than the Haiti earthquake, caused only a fraction of the damage and loss of life (Nguyen and Corotis 2013). Thus, we turn to the body of knowledge on risk perceptions and the factors that influence perceptions to assess how households perceive the performance of their house.

RISK PERCEPTIONS

The body of literature on risk perceptions defines perceived risk as the *interpretation* of a risk based on one's subjective assessment of both the likelihood of a hazard event occurring *and* the likelihood of a negative outcome as a result of the hazard event (Gaillard 2008; Plapp and Werner 2006; Sjoberg et al. 2004; Sullivan-Wiley and Short Gianotti 2017). This differs from "real risk," which refers to the statistical likelihood of a negative consequence from a specific event (Sullivan-Wiley and Short Gianotti 2017; Wachinger and Renn 2010). Real risk can be estimated from models of physical systems that are used to assess the probability of certain negative outcomes (Wachinger and Renn 2010). While we are concerned with the real risk of a house performing poorly, or experiencing damage, during a typhoon or earthquake, in this exploratory study we focus on perceived risk, or a household's expected level of damage of their house during two hazard events (typhoons and earthquakes).

From the beginning of risk perception research, scholars have studied what factors, including individual characteristics, satisfaction, and behaviors influence how individuals perceive risk. Here we discuss individual characteristics often found to influence risk perceptions.

Risk Perception and Individual Characteristics

Gender, education, economic capacity, and prior experience are all factors found to influence risk perception. The effect of gender on risk perceptions has been

documented in numerous studies (e.g., Armaş 2008; Flynn et al. 1994; Siegrist et al. 2005), with women tending to perceive greater risk than men. This trend has been attributed to women having less power and access to resources (Flynn et al. 1994). In addition to gender, those with greater economic coping capacity, typically defined in terms of income (Sjoberg 2000; Sullivan-Wiley and Short Gianotti 2017; Wachinger et al. 2013), perceive lower risk, as they are better able to respond to hazards and their negative impacts. Education level has also been shown to influence perceptions (Moen and Rundmo 2005; Neil et al. 1994), but with contradictory conclusions as to the direction of influence. Related to education level is specific risk-related knowledge. Those with more knowledge of the hazard and potential outcomes tend to perceive greater risk (Barnett and Breakwell 2001; Kates 1971). More important than prior knowledge is prior experience. Numerous studies have found that those with experience with a hazard event perceive greater risk for future events (Barnett and Breakwell 2001; Wachinger et al. 2013; Wachinger and Renn 2010). Similarly, the availability bias, which states that events that come more quickly and frequently to someone's mind increase perceived risk, has been found to be significant (Mileti 1999 p. 139; Slovic et al. 1981; Wachinger and Renn 2010).

Risk Perception and Satisfaction

An individual's satisfaction or attitude towards the object exposed to risk is also correlated with their risk perceptions (Doria 2010; Johnson et al. 2008; Stedman 2002). Satisfaction occurs when a place or object meets certain needs (Stedman 2002). In this study, we adopt Mohit et al.'s (2010) definition of residential satisfaction as "the feeling of contentment when one has or achieves what one needs or desires in a house" (pp. 19). While satisfaction with one's house or community has yet to be examined in studies of perceived risk from disasters, satisfaction with the objects subject to risk has been found to be correlated with perceived risk in studies of drinking water (Doria 2010) and customer interactions with service organizations (Johnson et al. 2008), with those having greater satisfaction perceiving less risk.

Risk Perception and Mitigating Behaviors

While early studies of risk perception focused on the factors influencing perceptions, recent literature has examined the link between perceived risk and mitigating behaviors. We define mitigating behavior as those actions taken before a hazard event to improve housing performance, and, thus, aiming to reduce the level of damage experienced during a future hazard event (Mileti 1999 pp. 22–23; Siegrist and Gutscher 2008). Early work found that there was a strong link between perceived risk from natural hazards and mitigation behaviors (Lindell and Hwang 2008; Lindell and Perry 2000; Peacock 2003) with greater perceived risk motivating more hazard mitigating behavior. However, in recent studies, the strength of this relationship has been questioned and found to be weaker than previously presumed (e.g., Bubeck et al. 2012; Siegrist and Gutscher 2008; Solberg et al. 2010; Wachinger et al. 2013). These studies have concluded that while perceived risk is correlated with mitigating behavior, other factors, such as an individual's ability to engage in mitigation (Wachinger et al. 2013), perceived effectiveness of mitigation on decreasing risk (Bubeck et al. 2012; Paton et al. 2008), and one's belief in their ability to control of an outcome (Solberg et al. 2010) are better predictors of mitigation actions. Although the link between perceived risk

and mitigation is not as important as previously believed, it is still a contributing factor, and, indeed, individuals can only respond to hazards they perceive (Slovic et al. 1981).

While previous studies have examined perceived risks of hazards, including earthquakes (e.g., Armaş 2006), hurricanes (e.g., Peacock et al. 2005), floods (e.g., Raaijmakers et al. 2008), and volcanoes (e.g., Gaillard 2008), these studies have focused on perceptions in terms of if a disaster will occur (Gaillard 2008) or if and how a disaster would affect an individual's daily life (Armaş 2006; Peacock et al. 2005). We found only one study (Peacock et al. 2005) that asked individuals about the likelihood of their house being damaged in a disaster, but these responses were aggregated with additional responses to create a single risk perception score. The findings in Arlikatti and Andrew's (2011) study of perceptions of recovery hinted at how individuals perceived future performance of their new roofs, but did not focus on performance and damage. Thus, given the relationship between perceived risk and mitigating behavior, there is a need to specifically assess individuals' risk perceptions as it relates to the performance of their house during a natural hazard event - what we refer to as "perceived performance" or "perceptions of performance" throughout this paper.

RESEARCH APPROACH

RESEARCH CONTEXT

In November 2013, Typhoon Haiyan, known locally as Typhoon Yolanda, struck the Central Philippines, damaging or destroying 1.1 million homes (Shelter Cluster 2014). In response to this disaster, the government pledged to construct more than 200,000 houses (NEDA 2017) and international nongovernmental organizations (INGOs) provided assistance to over 340,000 households (Global Shelter Cluster 2016).

For the purpose of this exploratory study, we focus on one community, located on the island of Leyte in the Central Philippines, north of Tacloban City (the largest city on the island). The studied program was a direct-build core housing program, in which the assisting organization was responsible for the housing design, delivering materials to the site, and procuring the labor needed for construction. All houses were constructed using the same design, which is a single room, approximately 19 square meters in size, with an additional 3 square meters attached to the back of the house for a toilet and shower. The housing design consists of concrete columns, a masonry skirt wall, plywood wall boards, and corrugated galvanized iron roofing sheets. Households were selected by the organization to receive assistance using two metrics: 1) household vulnerability, (e.g., female-led or elderly households), to ensure that vulnerable populations were receiving assistance, and 2) land tenure or ability to purchase land, to ensure that the households would not be evicted from the shelters. Shelter assistance began in November 2014 (Opdyke 2017). In addition to being at risk from typhoons (Build Change 2014), the community is also in an area of high seismic risk, due to proximity to the Central Leyte Fault, as evidenced by the July 2017 magnitude 6.5 earthquake that struck Central Leyte (UN OCHA 2017).

DATA COLLECTION

The household is the unit of analysis for this study. We conducted survey questionnaires in March 2018 with households receiving housing assistance within the selected community. 100 households were identified as potential respondents, for they

were living within the selected community and received assistance from the identified organization. Convenience sampling was used to select respondents (N=41). In particular, we identified three clusters of houses within the community, and determined the number of houses within each cluster, such that we completed a number of surveys in each cluster proportional to the cluster's percentage of total houses. While the surveys were completed by an individual, in this study we take the individuals' responses to represent their households' responses. The survey questionnaire was translated into the local language (Waray-Waray) by three native speakers. Surveys were conducted in Waray-Waray in the respondent's house by one of two trained enumerators, and took approximately 30-35 minutes. Prior to this, the survey instrument was piloted in 30 households in three different communities to ensure the questions were understandable, culturally appropriate, and captured the needed data.

Survey Questions about Perceived Performance

In this study, we aimed to assess respondents' perceptions of the performance of their house in a hypothetical future disaster event. In the pilot study, we asked respondents to predict damage during a specific signal or magnitude event (typhoons are rated on a scale from Signal 1 to Signal 5, with Signal 5 storms sustaining the strongest winds; earthquakes are classified on a moment magnitude scale with larger magnitude earthquakes releasing more energy). We found that respondents struggled to conceptualize what a specific signal or magnitude event would mean; thus, in this study, we asked them to respond to two hypothetical situations: 1) a typhoon similar to Typhoon Yolanda and 2) an earthquake similar to the July 2017 Ormoc earthquake occurring near their community. We selected these two scenarios as the majority of the population would have experienced Typhoon Yolanda and the Ormoc earthquake, and respondents confirmed familiarity with these disaster events. Given the scenarios, respondents were asked *What would you expect to be the level of damage of your foundation?* and given four Likert scale response options: *1=no damage, 2=minor damage, 3=major damage, and 4=completely destroyed*. This question was repeated for each scenario for seven housing components (foundation, floor, walls, roof, structure supporting the roof, windows and doors, and household contents).

During the pilot surveys, we identified that respondents had difficulty differentiating between minor and major damage. Thus, to assist respondents in answering these questions, we provided a visual aid containing example photos of minor and major damage for each of the components. The photos used to differentiate minor and major damage to the roof are shown below.



Figure 1: Example photos of (a) minor roof damage and (b) major roof damage provided to assist respondents

Independent Variable Survey Questions

Gender, Education, and Income

Respondents self-reported socioeconomic data relating to gender, education, and income. Levels of education are elementary, high school, and university, and respondents were asked to report the highest level they attended. Respondents reported their weekly income, and according to the Philippines Statistics Authority, a family of five needs a weekly income of P1,582 to cover basic food needs (Perez 2016); the poverty level weekly income, based on ability to cover food and non-food needs, is P2,220 for a family of five (Perante 2016).

Prior Construction Knowledge

Households were asked to self-report their prior construction knowledge by replying to the statement *I had construction knowledge before Typhoon Yolanda* using a 4-point Likert scale (1=strongly disagree, 2=disagree, 3=agree, 4=strongly agree).

Household Satisfaction

We selected nine aspects of housing (lighting, air flow, temperature, bathroom facilities, kitchen facilities, size, quality, location, and overall satisfaction) identified in previous literature as contributing to households' satisfaction with their house (Canter and Rees 1982; Mohit et al. 2010; Snarr and Brown 1980). Households were asked to rank their satisfaction with each of these nine aspects of their house on a 4-point Likert scale (1=very dissatisfied, 2=dissatisfied, 3=satisfied, 4=very satisfied).

Additional Survey Questions

In addition, the larger survey had three additional objectives, presented in Table 1. In future work, these objectives will be connected to responses related to perceptions.

Table 1: Survey objectives, and example questions asked to capture objectives

Objective	Example Questions
Characterize household participation in the (re)construction of their house	How involved was your household in overseeing the construction of your house?
Assess respondents' satisfaction with their house and community	To what level are you satisfied or dissatisfied with the quality of your house?
Capture respondents' level of participation in resilience-building activities	In the last year, how often have you assisted a neighbor when they needed help?

DATA ANALYSIS

To conduct the analysis, we first normalized and aggregated our dependent variables of perceived performance during typhoons and earthquakes and the independent variable of household satisfaction. Our dependent variables each consist of seven indicators, and the satisfaction predictor consists of nine indicators. In order to calculate a single value for each of the three variables, we used the maximum-minimum method (Cutter et al. 2016; Tarabusi and Guarini 2013) to normalize a household's responses to those of the other households. In this method, the minimum value and range are calculated for each indicator. The minimum value is then subtracted from each observation and then divided by the range. After this transformation, the minimum possible value is 0 and maximum possible value is 1 for each indicator. We then summed the transformed indicator values to calculate a variable score for each household. The maximum possible score is 7 for perceived performance during typhoons and earthquakes and 9 for household satisfaction. Future work will aggregate scores using Tarabusi and Guarini's (2013) Unbalance-Adjusted Function to capture the unbalance between values for a single variable.

We then analyzed the data using standard statistical software (R). One question of interest was whether, on average, households perceive worse performance in either typhoons or earthquakes. For each household, we calculated a typhoon score and an earthquake score using the maximum-minimum method described above. We then created a difference score for each household by subtracting the earthquake score from the typhoon score. We performed a simple regression to determine if the difference score was significantly different from zero. To assess the influence of the factors discussed above on perceived performance during a typhoon and an earthquake, we calculated Pearson's *r* coefficient to measure the correlation between perceived performance and the continuous variables of income, prior knowledge, and satisfaction. For the categorical predictors of gender and education, we conducted a one-way ANOVA. After identifying the significant individual predictors, we conducted a multiple regression to determine the influence of individual predictors while controlling for other predictors. A predictor was found to be significant at $p < 0.05$.

RESULTS

In this section we present our findings of respondents' perceived performance of their house during a hypothetical future typhoon or earthquake. Additionally, we discuss how the factors identified from previous literature influence these perceptions, both individually and combined.

HOUSEHOLD CHARACTERISTICS AND SATISFACTION

In Table 2, we present the characteristics of the respondents. Most of our respondents were women, and the majority had a high school education. Nearly all the respondents had household incomes that fell below the government-defined poverty level. The majority of respondents expressed that they were satisfied with each of the housing components. Strong responses of being either very dissatisfied or very satisfied were rare. On average across the community, respondents were the least satisfied with the lighting and temperature of their house, and most satisfied with the location.

Table 2: Demographic characteristics of the survey respondents

Characteristic	N (% of Respondents)
Female	32 (78%)
Male	9 (22%)
<u>Highest Education Level</u>	
Elementary	15 (37%)
High School	18 (44%)
College	8 (20%)
<u>Weekly Household Income (PHP)</u>	
<1000	13 (32%)
1000-1500	7 (17%)
1500-2000	13 (32%)
>2000	8 (20%)
<u>Prior Construction Knowledge</u>	
Strongly Disagreed	1 (2%)
Disagreed	16 (39%)
Agreed	18 (44%)
Strongly Agreed	6 (15%)

OVERALL PERCEIVED PERFORMANCE

For each of the fourteen components (seven components x two hazard events), we calculated the community's average perceived performance, and the results are shown in Figure 2. During a typhoon, on average, respondents anticipate their house walls, roof, roof structure, and windows & doors to experience somewhere between minor and major damage and all other components to experience somewhere between no and minor damage. The elements that respondents expect to experience the most damage during a typhoon are roofs, roof structures, and windows & doors – elements we would expect to have the most damage under high wind loads. During an earthquake, respondents expect the foundations, floors, and walls to experience somewhere between minor and major damage. Again, this is similar to the damage we would expect from the lateral loads applied to a house during an earthquake.

When we compare perceived performance of specific components during the two hazard scenarios, we find that, on average, respondents expect worse performance of roofs, roof structures, windows & doors, and household contents during typhoons than during earthquakes and worse performance of foundations, floors, and walls during earthquakes than during typhoons. While respondents perceive similar performance of foundations, walls, and household contents in both typhoons and earthquakes, there is a larger difference in perceived performance of floors and windows & doors. Respondents, on average, also expect nearly an entire damage state more damage to roofs and roof structures during typhoons than during earthquakes.

We also found that, except for a few households, respondents did not expect components to be completely destroyed in either a future typhoon or earthquake event. Further investigation is needed to determine if this is due to respondents' confidence in the structural integrity of their houses, or because of a tendency to not respond in the extreme.

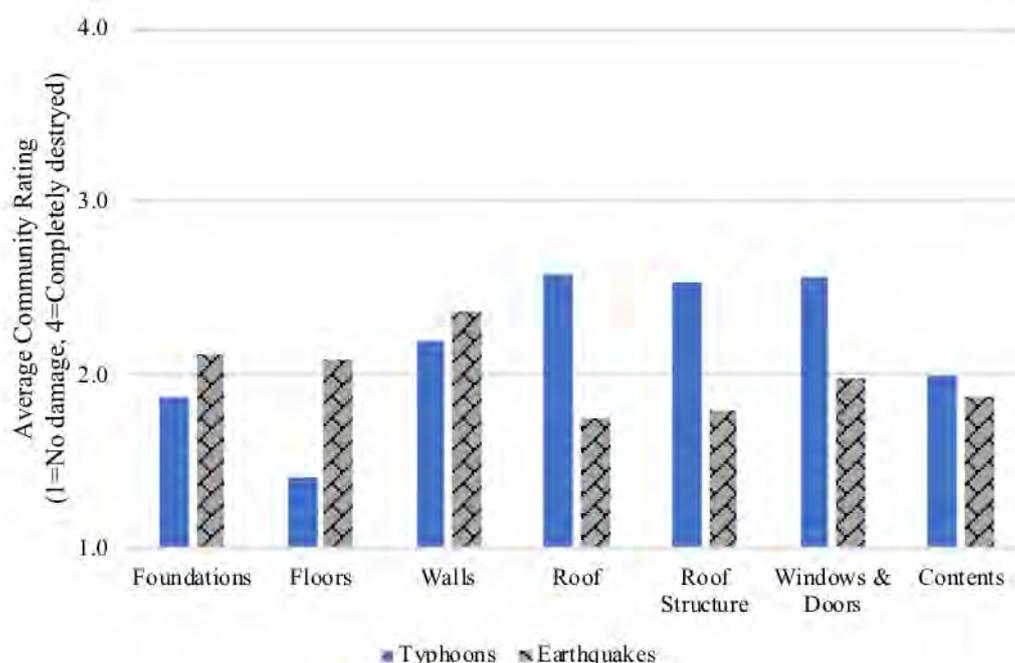


Figure 2: Average perceived damage to housing components in a hypothetical future typhoons and earthquakes

We were also interested in whether, when considering the performance of all seven house elements, households perceive their house to perform differently in typhoons and earthquakes. Due to respondents' recent experiences with typhoons, we expected them to expect more damage and perceive worse housing performance due to typhoons. However, we found that there was no statistically significant difference in perceived performance during typhoons and earthquakes ($F(1,40)=1.008$, $p=0.321$).

FACTORS INFLUENCING OVERALL PERCEIVED PERFORMANCE

We hypothesized that the factors of gender, education, income, prior knowledge, and household satisfaction influence a household's perception of performance. Pearson's r coefficient between perceived performance and income, prior knowledge, and satisfaction are shown in Table 3. We found no significant effects ($p<0.05$) on either typhoon or earthquake perceived performance from income.

Table 3: Correlations (Pearson's r) showing the relationship between perceptions of performance during hypothetical typhoons and earthquakes and dependency factors (Note: Higher performance scores indicate greater perceived levels of damage. Negative correlations indicate that as income, knowledge and satisfaction increase, respondents perceive better performance).

	Perceived Performance in a Typhoon	Perceived Performance in an Earthquake
Income	-0.027	-0.146
Prior Knowledge	0.354*	0.357*
Household Satisfaction	-0.441**	-0.284

* $p<0.05$, ** $p<0.01$; $N=41$.

We found that there was a significant correlation between self-reported prior construction knowledge and perceived performance for both typhoons and earthquakes. In both typhoons and earthquakes, the greater a respondent's prior knowledge, the more damage they expected their house to experience (i.e., the worse they perceive their house's performance), supporting the trend previously identified in literature (Barnett and Breakwell 2001).

One's satisfaction with their house was significantly correlated with perceived performance during typhoons and marginally correlated ($p=0.072$) with perceived performance during earthquakes. For both hazard events, the trend was that the more satisfied one was with their house, the less damage and better performance they expected, in line with findings from previous studies (Doria 2010; Johnson et al. 2008; Stedman 2002).

After conducting a one-way ANOVA for education level and gender, we found no significant effect on perceived performance from education level, but did find that gender had a significant effect ($F(1,39)=8.352, p<0.01$) on average perceived damage from earthquakes and a marginally significant ($F(1,39)=3.411, p=0.072$) effect for performance during typhoons. In both cases, men perceived greater levels of damage than women, predicting nearly an entire damage state higher in an earthquake than women. This contradicts prior literature, which found that women often have higher risk perceptions due to their work within the home and access to fewer resources (Armaş 2008). Assuming that men have more prior construction knowledge than women, we examined the correlation between gender and prior knowledge to see if this would explain the gap. However, we found no significant relationship between gender and prior construction knowledge; thus, further investigation is needed to understand the effect of gender on perceived performance during earthquakes.

We were also surprised to find no other significant effects from factors often identified in literature. For income, this is likely due to a lack of variation between respondents in this single community. As household vulnerability was a criterion for receiving assistance in this community, households were similar in economic status. The insignificant relationship between education and perceived performance could be explained by the significant relationship between prior construction knowledge and perceived performance, as prior literature has identified a stronger relationship between hazard-specific knowledge and risk perception (Barnett and Breakwell 2001). In this community, knowledge about construction proved to be more important than general education / knowledge in terms of how respondents perceived the performance of their house.

RELATIONSHIP BETWEEN GENDER, KNOWLEDGE, SATISFACTION, & PERCEPTIONS

After identifying the significant factors influencing perceived performance, we performed a multiple regression with perceived performance in typhoons and earthquakes as the dependent variables and gender, prior knowledge, and household satisfaction as the independent variables. The results of the multiple regression are shown in Tables 4 and 5.

Table 4: Regression of gender, prior knowledge, and satisfaction on perceived performance during a hypothetical future typhoon

Variable	Coefficient	SE	d.f.	t	Sig.
Gender	-1.2	0.7	1	-1.77	0.08
Prior knowledge	0.3	0.5	1	0.64	0.52
Satisfaction	-0.9	0.4	1	-2.12	0.04
Constant	9.3	4.3	1	2.17	0.03

Note: $r^2 = 0.27$; $F(4,37) = 4.584$; $p < 0.01$

Table 5: Regression of gender, prior knowledge, and satisfaction on perceived performance during a hypothetical future earthquake

Variable	Coefficient	SE	d.f.	t	Sig.
Gender	-2.0	0.7	1	-2.73	0.01
Prior knowledge	0.7	0.5	1	1.35	0.19
Satisfaction	-0.3	0.4	1	-0.78	0.44
Constant	3.7	4.3	1	0.85	0.40

Note: $r^2 = 0.28$; $F(4,37) = 4.823$; $p < 0.01$

In both models, we see that the trends identified above in the relationships between perceived performance and gender, knowledge, and satisfaction remain the same: males perceive worse performance than women; greater prior construction knowledge corresponds to worse perceived performance; and more satisfaction with the house correlates to better perceived performance. We also find that, controlling for any differences in gender or prior construction knowledge, household satisfaction is a significant predictor of one's perception of performance during typhoons. In the earthquake model, gender is a significant predictor of perceived performance, over and above one's prior knowledge and household satisfaction.

DISCUSSION

While these are preliminary findings and further study is needed, we begin to hypothesize the implications for organizations providing post-disaster housing. Although not statistically significant based on our preliminary data, we found that on average respondents expected their house to experience less damage during an earthquake than during a typhoon. The region has had a greater occurrence of and damage from typhoons than earthquakes in recent years, which may contribute to the greater perceived risk of typhoons. In their survey responses, some respondents indicated they wanted to increase their house's resistance to typhoons by building additional masonry walls – an action that, as shown in Haiti (Mix et al. 2011), could have serious negative consequences during an earthquake. In addition, households also reported that they are more likely to take actions to mitigate damage from a typhoon event, likely because perceived typhoon risk is greater. Thus, we suggest that post-disaster housing organizations working in areas vulnerable to multiple hazards providing training about how houses will perform in all identified hazards.

We also found that gender differences are important, with women perceiving better performance than men. If women are underestimating the risk by overestimating the performance of their house, this could lead to a lack of preparedness in a future disaster. Although there was not a significant relationship between gender and self-reported

prior construction knowledge, previous experience in nearby communities indicates that women are generally not as involved in design and construction and, thus, possess less knowledge about safe design and construction practices. While many organizations already provide specific programs that engage with women during the housing reconstruction process, these programs should strive to go beyond construction training and provide further training on hazard-resistant design and how to recognize if a component within their house has become unsafe. As women traditionally spend more time within the house, training that encourages awareness of structural changes to the house could increase disaster preparedness and encourage households to take disaster mitigating actions.

Satisfaction is also significantly correlated with lower perceived risk. While organizations should strive to encourage household satisfaction, as increased satisfaction improves happiness (Mohit et al. 2010) and community resilience (Cutter et al. 2008), they should be aware of this trend. If households that are more satisfied with their house underestimate the risk, this could make them more vulnerable to disasters. Thus, we again encourage organizations to devise training programs that go beyond construction or maintenance skills, but also provide education on hazard-resistant design, including which housing components are critical for better performance and how to protect these components.

LIMITATIONS

This exploratory study has various limitations, most notably that the data is limited to households in a single community receiving housing assistance from the same organization. The identified significant and insignificant factors are currently specific to this community and cannot be generalized further. Additional factors, such as participation during reconstruction, training in safe design and construction, social capital, and community resilience will be examined for the role they might play in influencing perceptions.

Furthermore, prior knowledge has been identified, in literature and these results, as an important factor in risk perception. However, in this study, assessment of knowledge was limited to self-reported prior construction knowledge. To better capture a respondent's knowledge level, additional questions pertaining to knowledge of hazard risk and safe design, as well as prior experience in typhoons and earthquakes, may be needed.

Lastly, we found a strong relationship between household satisfaction and perceived performance, but as discussed in prior literature (Johnson et al. 2008; Sjoberg 2000), further work is needed to better characterize the direction of the relationship between satisfaction and perceptions: is satisfaction a driver of lower risk perceptions, or vice versa?

CONCLUSIONS AND FUTURE WORK

In the post-disaster context, organizations and governments providing housing assistance strive to implement hazard-resistant housing design and construction to reduce the damage experienced in any future disaster events. As households are responsible for the continued maintenance of and any modifications to these houses, it is important to anticipate the actions they might take regarding their house and what the implications of those actions might be. The study of risk perceptions is a lens with

which to examine households' perceptions of the performance of their house. In this exploratory study, we have expanded risk perception studies to focus specifically on how households perceive the level of damage, or performance, of their house in two hypothetical future events. We found that in the studied community, households expected, on average, minor to major damage to the specified housing components, and that expected damage did not differ significantly between typhoons and earthquakes. We also found that gender, prior construction knowledge, and household satisfaction were significant indicators for differences in perceived performance.

Future work will build upon this study by surveying households that received shelter assistance in an additional eleven communities in Leyte and Eastern Samar in the Philippines. With additional survey responses, we will seek to further identify and characterize the factors influencing perceptions of performance. Additionally, we will assess respondents' plans to modify their houses or engage in resilience-building behavior within their community and then link perceived performance to these planned actions to identify how perceptions influence respondent behavior. Lastly, we will create nonlinear structural analysis models of the reconstructed houses and conduct multi-hazard structural performance assessments to quantify their expected performance in future typhoon or earthquake events using performance-based engineering methods. With this information, we will be able to compare the results of our performance assessment to the households' perceived performance and provide recommendations to disaster response organizations about how to improve post-disaster housing design and communicate these designs and how to best maintain them to households.

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MAPPING REGULATORY-RELATED INTERACTIONS OF STAKEHOLDERS FOR TEMPORARY ACCOMMODATIONS

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ABSTRACT

During temporary disruptions, synthetic organizations form to react quickly and accomplish a common goal. Germany had this type of disruption during the 2015 European refugee situation when existing temporary accommodations for displaced persons exceeded capacity and unconventional facilities, such as office spaces, warehouses and other commercial buildings, were used. Regulations do not necessarily maintain their role during these disruptions and this study visualizes the various types of regulatory-related interactions that were experienced in 2015 between stakeholders while providing temporary accommodations in four German cities. A total of 54 interviews with employees in government agencies, nonprofit organizations, utilities, and private companies resulted in 252 interactions that were qualitatively coded for both *buildings* and either *contracts* or *regulations*. These excerpts were categorized by type of interaction, or whether an actor was constrained (98), neutral (65), or facilitated (89), and by whom. Constrained interactions limit an actors' ability to engage in the temporary accommodation process, facilitated interactions allow an actor to engage more freely with the process, and neutral interactions follow typical procedure. Results show that federal building regulations and the social affairs department constrain and facilitate interactions more often than stakeholders, supporting the theory that regulations can both empower and constrain within an organization. Actors involved with government coordination, design, and facility management had high betweenness values, indicating a greater agency in the provision of temporary accommodations. These findings provide insight to government agencies about how to expedite the work within a synthetic organization by targeting key, influential actors in the network. Additionally, this study highlights the need for understanding the perception of regulations amongst specific stakeholders to better explain why certain interactions were considered constrained, facilitated, or neutral.

KEYWORDS: social network analysis, refugee, regulation, crisis, organization

INTRODUCTION

We live in a regulated world. From the food we eat, the clothes we wear, to the buildings we live in, regulations are present in some capacity. Regulations, or standards within a broader governance system, exist to provide a minimum standard in delivery of service (Busch 2011), but it is not well known as to how these standards function in an environment where extreme uncertainty exists. One such example is the European refugee situation in 2015, where countries such as Germany received unprecedented numbers of displaced persons seeking asylum (UNHCR 2015). German asylum laws guarantee the provision of temporary accommodation during the

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asylum application process (BAMF 2015); this system was functional until 2015, when capacity was exceeded in existing housing facilities (UNHCR 2016) and unconventional building types such as offices, abandoned warehouses, airports and sports halls were used. Various stakeholders including government agencies, nonprofit organizations, utilities and private entities came together to form synthetic organizations (Thompson 2017) that provided temporary accommodations. However, due to time constraints and the difference in typical usage of the accommodation facilities, it was not possible to follow standard regulatory procedures. As such, this paper analyzes the different types of regulatory interactions between stakeholders in the provision of temporary accommodations using a social network analysis (SNA).

POINT OF DEPARTURE

Synthetic Organizations and Dynamic Environments

Institutions and organizations are “relatively resistant to change” (Scott 2008, 57; Powell and DiMaggio 1991), self-stabilizing when faced with uncertainty and disruption (Thompson 2017). For example, when a city experiences a natural disaster, rebuilding efforts begin following initial response to damage to infrastructure. Disruptions are not always long-term, on-going, nor yet natural disasters. For example, Germany experienced a temporary disruption with the rapid inflow of displaced persons and subsequent lack of accommodations in 2015, and although the inflow of new arrivals was stifled through political processes, impacts of the population influx are still present today.

When temporary disruptions introduce uncertainty into a dynamic environment, the resulting organizational response has been referred to as a *synthetic organization* (Thompson 2017). This term refers to a diverse range of actors coming together to achieve a primary goal; one example being the group of stakeholders that worked together to provide temporary accommodation to new arrivals in Germany. While a synthetic organization gets the job done, it can also be inefficient, and typical standards and norms are not necessarily adhered to. This is in line with the “politics of identity” (Scott 2008, 94) which theorizes that individuals within an organization can deviate from conventional patterns when goals or identities of actors within the organization shift. Agency, power, interdependency and path-dependency contribute to this deviation and are explored in this study (Powell and DiMaggio 1991, 190). Agency refers to the extent that an actor is able to effect change within an organization and is related to the amount of power that they carry in that network (Scott 2008, 94). To what degree this power and agency exist is reliant on interdependency between actors, and is the basis for using a social network analysis in this research.

Other related studies have observed the intergovernmental coordination response to dynamic environments, such as natural disasters (Forgette et al. 2009; Nigg, Barnshaw, and Torres 2006). While a necessary contribution, there remain other unexplored types of exchanges between stakeholders. For example, in a related study, utility company employees collaborated with a professional association to clarify existing design standards to improvise for new types of temporary accommodation that did not have existing standards (Hacker, Kaminsky, and Faust 2017). There exists a need for multidimensional analysis of regulatory interactions between stakeholders involved with temporary accommodations.

Regulations and Standards

Regulations provide criteria for consistent levels of service and depending on their specificity, reduce the need for decision-making and interpretation by individuals involved with

the process (Lampland and Star 2009). For example, the Sphere Project provides minimum standards for humanitarian relief such as proportion of individuals to sanitation services and the quality of drinking water provided to individuals. For the purpose of this paper, the term *regulation* is used in the broad sense of rule-making or “a form of organized governance” (Brunsson and Jacobsen 2002, 10). Standards are specific rules and guidelines that are not necessarily required by law (Egyedi 2008, 3) yet social repercussions exist when standards are not met. Participants in the study used both terms interchangeably, as do the authors.

A conflict exists following the European refugee situation in 2015, as building regulations existed for new and renovated development but were not always applied to the temporary accommodations being provided due to the unconventional facilities used. Combined with the pressure of time to provide shelter for displaced persons, decision-makers were put in a position of improvising standards (Hacker, Kaminsky, and Faust 2017).

Hypotheses

Regulations can be used to constrain or empower social behavior (Scott 2008) and perception can influence the power or centrality of an actor within a social network (Choi and Kim 2007; Busch 2011). Having a visualization of social dynamics concerning regulatory interactions provides a better understanding of the synthetic organization and creates a framework for future studies analyzing regulations. This study contributes to understanding temporary disruptions within organizations, and the role that regulations play during those disruptions in the particular context of providing temporary accommodation to asylum seekers during mass migration. We hypothesize:

- H1. ***Actors in regulatory agencies, such as federal building regulations, city and state permitting, and the social affairs department will have constrained interactions with other stakeholders.*** Synthetic organizations function within a preexisting hierarchical structure intended for status quo conditions, meaning regulations and regulatory agencies will constrain other stakeholders’ efforts to respond quickly to an extreme situation.
- H2. ***The frequency of perceived neutral interactions will be less than constrained and facilitated interactions.*** The existence of extreme conditions/event reduces conventional protocol and causes improvisation in response to the situation. Neutral interactions represent standard operating procedure; therefore, it is expected that fewer of these interactions are expressed by stakeholders.
- H3. ***Actors involved with design and management of facilities, such as architects and building owners, will experience facilitated interactions with other stakeholders.*** Although standard procedure may be disrupted due to the extreme event, it is expected that since architects and building owners more directly interact with regulations through the permitting process and in development of contracts, they will experience facilitated interactions, such as waiving inspections or expedited review process for permits.

METHODOLOGY

Social Network Analysis

To understand the types of regulatory interactions involved with providing temporary accommodations, this study uses a social network analysis. This method visualizes actors and

interactions using mathematical representation to understand the structure and components of a network (Borgatti, Everett, and Johnson 2013). Social network analysis has shown that “decision-making effectiveness is not so much dependent on the types of behaviors produced within a discussion as it is on the sequencing of these behaviors over time,” (Chinowsky and Taylor 2012). However, emergency response to rapid population increase does not have the luxury of understanding the sequencing of behaviors over an extended period. Decision-making is forced outside the conventional regulatory processes. The social network analysis for this study includes stakeholders mentioned in interviews as well as German federal building regulations. Although regulations are not a group of individuals, they have the potential to serve as a carrier of rules for other actors (e.g. a permitting department might use federal building regulations to constrain a building owner from new development), they are also able to influence as an actor in the synthetic organization (Thompson 2017). Allowing federal building regulations to act as a stakeholder in the social network provides elaboration on the role they have and how other stakeholders interact with them.

Data Collection

Fifty-four interviews used in this study were conducted between June and September 2016 with individuals from four German cities involved with various aspects of providing temporary accommodations for displaced persons. Interviewees represent government agencies, nonprofit organizations, design firms, utilities, and private companies (Figure 1). An ethnographic approach was used to facilitate hour-long interviews (Spradley 2016), including questions about the interviewee’s involvement, responsibilities and interactions with other actors associated with temporary accommodation. Additionally, participants were asked about the conditions in the temporary accommodations and factors impacting procurement, design, construction, maintenance and daily management of the facility, depending on the participant’s area of involvement. Interviews were conducted in either English, French or German based on the individual’s preference, then transcribed and translated by a native-German or French speaker prior to analysis.

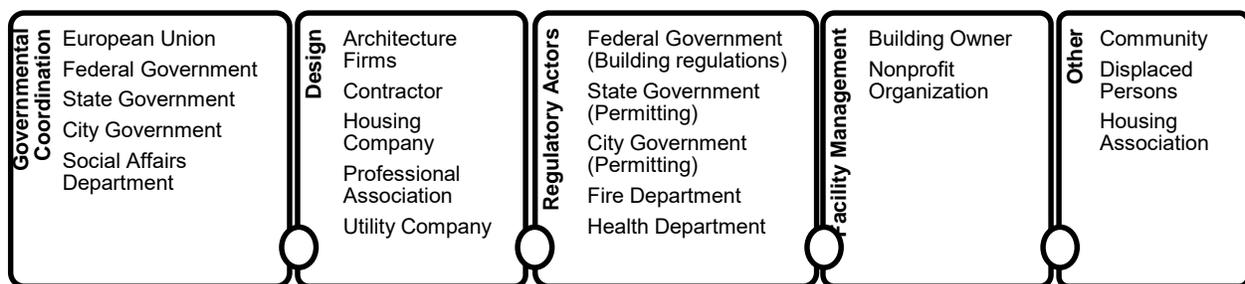


Figure 1: Stakeholders involved with temporary accommodations for displaced persons.

Data Analysis

Primary analysis was completed through an iterative topical coding process using the Dedoose software (SCRC 2016). The initial coding encompassed general groupings such as actors (e.g. *government*, *displaced persons*, *companies*), contextual codes (e.g. *challenges*, *positive impacts*, *culture*) and other more descriptive codes (e.g. *regulations*, *buildings*, *fire safety*). To create the social network, excerpts coded for *interaction* with a code co-occurrence of either *regulations* or *contracts*, as defined in Table 1, were isolated (252 excerpts).

Table 1: Social network analysis, topical code definitions

Code	Definition
Interaction	Communication or direct involvement with someone or something ¹ .
Regulations	Statements talking specifically about rules, regulations, standards relating to providing accommodation to refugees.
Contracts	Statements related to contracts between various parties. For example, housing contracts stipulating responsibilities and reimbursement between government agencies and for-profit/non-profit organizations providing temporary housing.

Source: ¹(Oxford University Press 2018)

Within this subset of excerpts, interactions were categorized by type (*constrained*, *neutral*, or *facilitated*) as defined in Table 2, and direction (which actor was creating interaction, e.g. the state government facilitated a regulatory interaction with the city government). For example, one interviewee described how they used the state standards required for temporary accommodations:

"We [the city government] had at the beginning of this situation, we had for example the standard that 7.5 m² per each refugee is obligated to have; it was only in the [city]. [The state government] only has 6 m² per refugee and we also had the standard of maximum two people per room without families. But now we change to the standard of [the state] and we can use room for four or five people. But that, we will not do in the next months. We will use the rooms with less people and then we have the possibility if in three or four months again a lot of people will come we can fill up the rooms." (Interview, City Government Employee, 8.3.16)

In this example, the state regulations were less strict than the city's requirements, allowing them to reduce the living space to design for more people. This would be considered a facilitated interaction directed from the state government to the city government.

Table 2: Social network analysis, definitions for interaction types

Interaction Type	Definition
Constrained	To severely restrict the scope, extent, or activity of. In this case, interactions that limited the actor's ability to engage with the temporary accommodation process.
Neutral	Not engaged on either side ² . Specifically, interactions between actors that neither inhibited or empowered the actor's ability to engage with the temporary accommodation process. This would follow the what is perceived as the "status quo" in actor interactions.
Facilitated	To make (an action or process) easy or easier ³ .

Sources: ¹(Oxford University Press 2017a), ²(Oxford University Press 2017c), ³(Oxford University Press 2017b)

These interactions were organized into three one-mode, directed matrices and analyzed using UCINET, an SNA software (UCINET Software 2017) for structural characteristics, including betweenness, degree and reciprocity, as defined below:

- *Betweenness*. Having power within a network through accessibility and an actor's location within the structure of the network. A higher factor of betweenness represents a greater number of interactions that would travel through that actor (Hanneman and Riddle 2005). Other sources describe betweenness as the potential to assume the role as gatekeeper in a network (Borgatti, Everett, and Johnson 2013).
- *Degree*. Accounts for the number of incoming and outgoing ties for each actor within the network. This may represent the power of an actor through available alternatives (Hanneman and Riddle 2005). A high in-degree is considered to represent a prestigious actor, or one that other actors in the network regularly interact with. A high out-degree can potentially represent an influencer in the network. For this study, influence and prestige varies depends on the type of interaction (Borgatti, Everett, and Johnson 2013). For example, an actor on the receiving end of a constrained relationship does not represent prestige, but more likely a lack of power in that interaction. Consequently, an actor with high out-degree in facilitated interactions may represent influence or the ability to use regulations for the benefit of others.
- *Reciprocity*. Represents the symmetry of interactions between actors and whether or not an interaction is reciprocated (Borgatti, Everett, and Johnson 2013). For example, in the same way that the utility company might constrain a building owner regarding some regulatory aspect, assessing whether the building owner also constrain the utility company in return.

Limitations

Several key limitations exist in this exploratory study, including perception bias and inconsistent use of terminology amongst participants. Perception can be subjective and is not always consistent across individual experience. However, the use of perception assists in better

understanding the role of regulation to improve regulatory interactions and engagement for future instances. For example, if a federal government wanted to introduce new regulations, it is essential to understand the perception of stakeholders impacted by regulations to ensure effective implementation and coordination with others. Inconsistent application of regulations and standards were expressed by stakeholders as part of the interviews conducted. In an effort to capture the greatest extent of involvement, all excerpts were included that related to regulations, standards and contracts without distinguishing between the specific definitions. The use of these three terms all relate to some level of service and are considered appropriate for this analysis, as the focus centers around the type of interactions rather than the type of specification. Future work is recommended to directly address these differences.

RESULTS

Secondary topical analysis of the data resulted in 252 excerpts containing regulatory-related interactions between stakeholders. Of these, 98 interactions were **constrained**, 65 were **neutral**, and 89 were **facilitated**. A social network analysis was created for each type of interaction and visualizations are provided in this section. Network analyses in UCINET calculated betweenness, degree, and reciprocity of the data. Different types of each metric were calculated, and trends are presented in Table 3; predominant stakeholders with the highest metric are listed in descending order. The lack of reciprocity is an interesting result which will be discussed further in the following sections but due to its low representation in the data, was given as group, dyad-based values.

Table 3: Stakeholders with the highest values for betweenness and degree, by interaction type

Type of Interaction	Betweenness	Degree		Dyad-based Reciprocity
		In	Out	
CONSTRAINED 98 excerpts	<ul style="list-style-type: none"> – City government – Building owner 	<ul style="list-style-type: none"> – Architecture firm – City government – Displaced persons – Nonprofit organizations 	<ul style="list-style-type: none"> – Federal building regulations – Social affairs department 	0.0390
NEUTRAL 65 excerpts	<ul style="list-style-type: none"> – Building owner – Utility company – Architecture firm – Social affairs department – Housing company 	<ul style="list-style-type: none"> – Building owner 	<ul style="list-style-type: none"> – Health department – State government 	0.0476
FACILITATED 89 excerpts	<ul style="list-style-type: none"> – State government – Social affairs department – Utility company 	<ul style="list-style-type: none"> – Architecture firm – Displaced persons – Building owner 	<ul style="list-style-type: none"> – City government, permitting – Federal building regulations – State government – Social affairs department 	0.0727

Constrained Interactions

Ninety-eight (98) of the 252 excerpts represent constrained interactions. Figure 2 shows these interactions between stakeholders, with line width proportional to relative frequency. Both city government and building owners had the highest levels of betweenness, which indicates that these two actors are more likely to have other stakeholders interact with them to have constrained interactions with others. Architecture firm, city government, displaced persons, and nonprofit organizations had high in-degree, meaning that these actors were more likely to experience a constrained interaction. Federal building regulations and the social affairs department had a high out-degree, meaning that they were more frequently initiating constrained regulatory interactions. One example of a constrained interaction is a conversation with an individual within city government who was describing the expectation and subsequent delay in providing accommodations due to needing to meet standards:

“We have standards provided by the [social affairs department]. Since the plan first was to build the houses and then rent them to the government, of course we had to provide those shelters according to the standards. We built them according to the standards, but we realized it takes quite a long time to finish them in that way” (Interview, City Government Employee, 9.29.16).

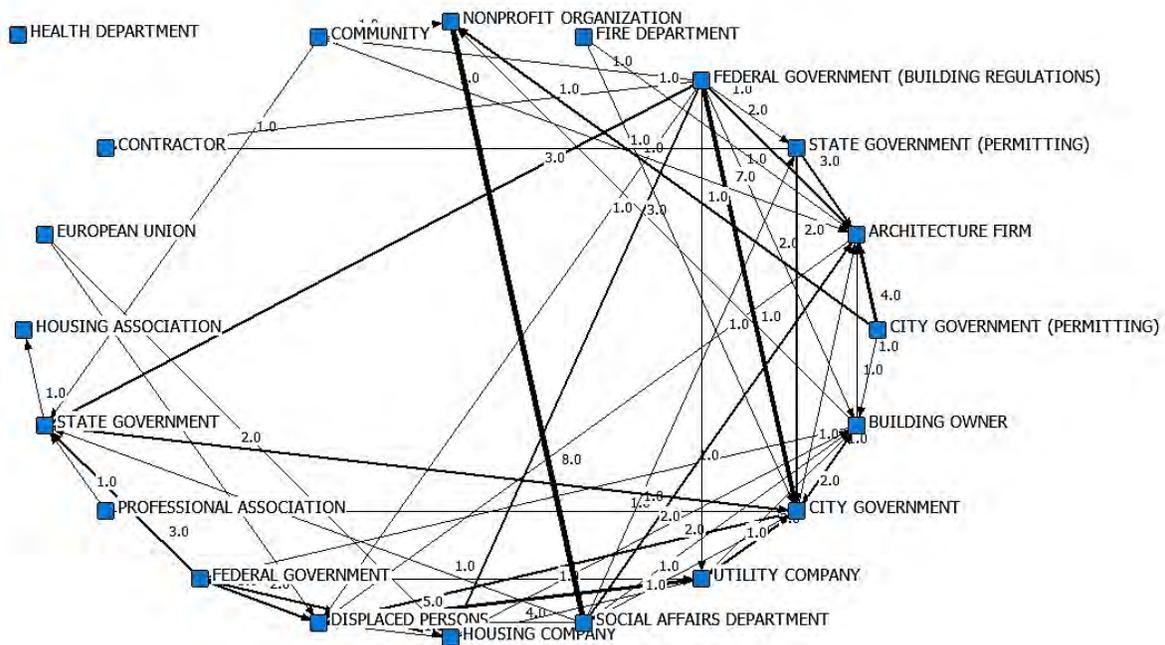


Figure 2: Visualization of constrained interactions between stakeholders involved in providing temporary accommodation.

Neutral Interactions

Sixty-five (65) of the 252 excerpts represent a neutral regulatory interaction between stakeholders. This neutral interaction is a reflection of “business as usual” or the status quo and interactions are visualized in Figure 3. One quarter of stakeholders involved with neutral interactions had high values for betweenness, including: building owners, utility company, architecture firm, social affairs department, and housing companies. Building owners had a

notably high in-degree from the other stakeholders, on the receiving end of neutral interactions. The health department and state government have a high out-degree, indicating that they initiated most neutral regulatory interactions. One example of this was in a conversation with a government employee discussing monitoring water quality in temporary accommodations:

“This all is according to [the state’s] drinking water regulation according to which every owner of a property of a certain size is responsible for having their water treatment plant tested by an independent institute and to let us, the [health department], know should it be tested positively for Legionnaire’s disease” (Interview, City Government Employee, 8.12.16)”

This is a neutral interaction coded between the state government and building owners because it was made clear that this was a standard procedure that did not depend on the dynamic environment.

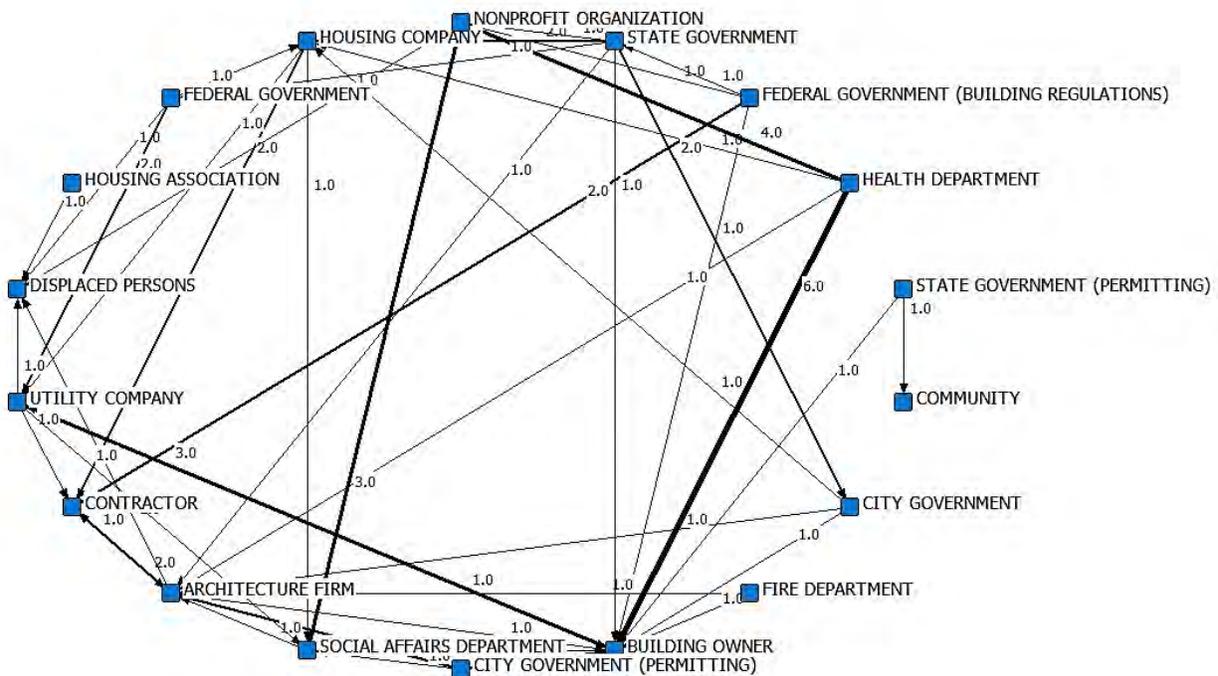


Figure 3: Visualization of neutral interactions between stakeholders involved in providing temporary accommodation.

Facilitated Interactions

Facilitated regulatory interactions represent 89 excerpts, shown in Figure 4. The state government, social affairs department and utility company had high betweenness. Actors who experienced higher amounts of facilitated regulatory interactions include architecture firms, displaced persons and building owners with the highest in-degree. Adjacently, city government, permitting, federal building regulations, state government, and the social affairs department had the highest out-degree, indicating they initiated facilitated interactions. An example of this is in an interview with the head of a construction company, an interviewee described the difference between projects for temporary accommodations and typical construction:

“We are much faster with the projects for refugees because on the federal level they changed some of the rules so that we can be much faster with the plans” (Interview, Construction Company CEO, 7.28.16).

In this example, the federal building regulations facilitated an interaction with building companies by providing exceptions specific for temporary accommodations.

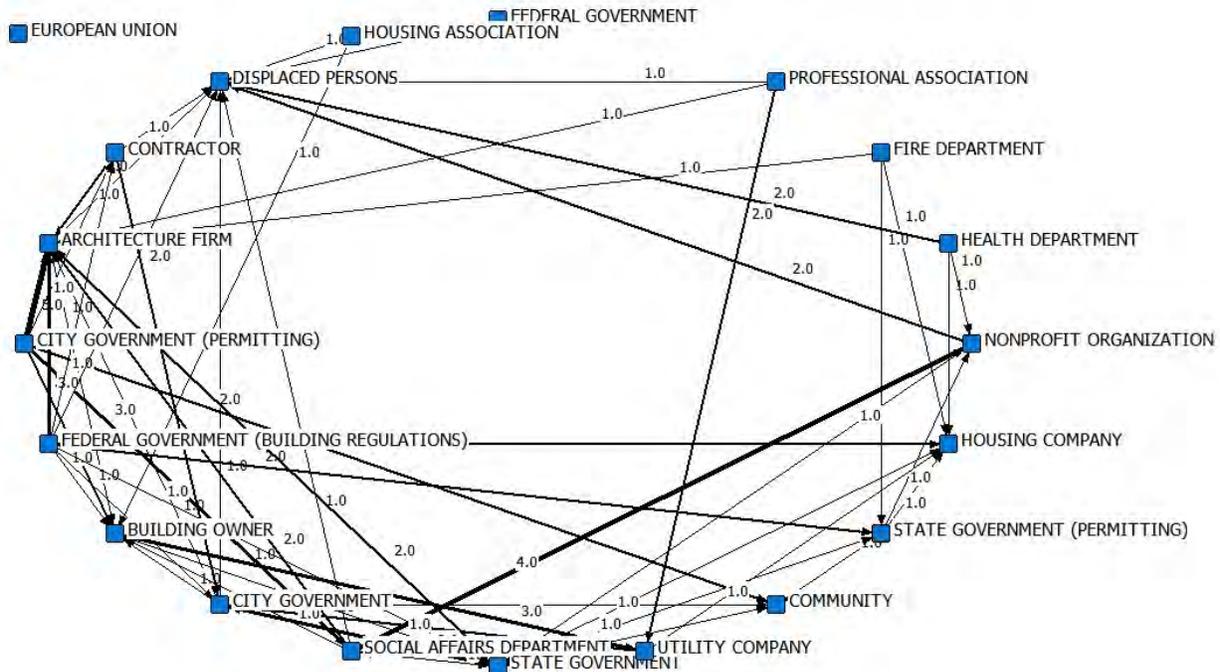


Figure 4: Visualization of facilitated interactions between stakeholders involved in providing temporary accommodation.

DISCUSSION

The resulting social network analysis conveys a representation of how regulatory interactions occur within a synthetic organization for the purpose of providing temporary accommodations. Characteristics of the network from Table 3 are discussed further in the following sections. It should be noted that all three types of interactions had very low proportions of dyad reciprocity, a measure of the symmetry between each dyad in the network, indicated by the number of arrows that are exchanged between actors in Figures 3, 4 and 5. This is as expected; in a conventional hierarchical regulatory framework, those creating regulations and standards initiate interactions with other actors by introducing and enforcing regulations. It is not expected that actors meeting regulations are also initiating regulatory interactions with regulatory agencies; this was unchanged by the rapid population influx. The following discussion sections focus on the measure of degree and betweenness in each type of regulatory interaction through the lens of the research questions posed in the point of departure.

H1. Actors in regulatory agencies, such as federal building regulations, city and state permitting, and the social affairs department will have constrained interactions with other stakeholders.

Part of this hypothesis is true; stakeholders who had the most constrained interactions included the federal building regulations and the social affairs department. Both the federal building regulations and the social affairs department had the highest out-degree values (Table 3), which indicates that they are responsible for constraining other stakeholders. One example of this interaction is demonstrated when an employee in a temporary accommodation facility expressed that changes could not be made due to contracts with the social affairs department:

“The [social affairs department,] they run these places and for sure we are not allowed to make here another new bathroom or a kitchen or something like that. Because the contract, like I think, I didn't read the contract, but I think we take this place for a short time, like 6 months or however how long. And after that they will get it back” (Interview, Nonprofit Organization Housing Manager, 6.15.16).

However, other regulatory agencies, such as city and state permitting departments did not have a high out-degree. It is possible that this is because both federal building regulations and the social affairs department are the source of regulations and standards; the federal building regulations are typical standards for new development and the social affairs department creates and manages contracts that are accompanied by standards for temporary accommodations (AIDA 2016). This was expressed by a city government official,

“I think that our standards for building apartments are very, very high. We have a very high quality, but I think we need to cut down a bit in order to responsibly create affordable living space” (Interview, City Government Employee, 8.12.16),

Both the federal building regulations and social affairs department hold influence, which has been associated with out-degree (Hanneman and Riddle 2005). Although regulations and the social affairs department have more influence in constraining other stakeholders through regulations, city government and building owners have a greater betweenness (Table 3), indicating that they might be gatekeepers for constrained interactions, or have a greater agency in the network (Scott 2008). One example is that to meet federal building regulations, a city government might institute specific standards for building owners, or architects (i.e. other stakeholders involved with design of accommodations). Although these actors do not experience the most constrained interactions (Table 3), they are still constraining actors in the network. Stakeholders go through these two agencies to constrain others, which provides insight into which actors to target when implementing new standards or when trying to expedite a process.

H2. The frequency of perceived neutral interactions will be less than constrained and facilitated interactions.

This hypothesis is proven true; of the 252 excerpts describing regulatory interactions, only 62 were neutral; or what the participant considered to be a standard interaction between stakeholders. Building owners had the highest in-degree (Table 3), indicating that they were more frequently experiencing neutral interactions. The health department and state government both had the highest out-degree, indicating that they are initiating neutral interactions more often than other

stakeholders in the social network. Examples of these interactions include water quality inspections, as one participant described:

“And they have free access to the housing facility. They can come and go when they want to. And I believe the health department comes regularly and does tests – probably also for the water quality” (Interview, City Government Employee, 8.23.16)

If the health department is most likely to initiate a typical, or neutral, interaction, it is understandable that the building owner would have a high in-degree since they would be responsible for coordinating and responding to inspections of the facility. The health department is regulatory, regularly conducting environmental inspections of facilities, and yet participants regarded these types of interactions as normal, rather than constrained or facilitated. This could possibly be due to the perception of water services during temporary disruptions as a human right (Kaminsky and Faust 2017); if water is considered a right, then stakeholders may perceive that inspection of facilities is part of standard operating procedure, rather than a provided service such as permitting and inspections for specific types of buildings. More research would be necessary to confirm this explanation of the observed data.

While constrained and facilitated regulatory interactions had two or three stakeholders with the highest betweenness, neutral interactions are more evenly distributed amongst five stakeholders: building owner, utility company, architecture firm, social affairs department, and housing company. This indicates that these actors are more likely to act as gatekeepers in neutral interactions, or that when uncertainty exists, stakeholders’ agency increases to meet the need of the synthetic organization (Thompson 2017). To provide temporary accommodations in a short period of time, more actors are needed to maintain normal interactions. More work is needed to understand how these specific actors interpret regulatory processes and what specific aspect of the temporary housing accommodation process requires their involvement.

H3. Actors involved with design and management of facilities, such as architects and building owners, will experience facilitated interactions with other stakeholders.

This hypothesis is true; architecture firms and building owners experienced more facilitated interactions than other stakeholders. Actors involved in design (architecture firms), management (nonprofit organizations) and occupants within the facility (displaced persons) exhibited a high in-degree (Table 3), indicating that they are more likely to experience facilitated interactions compared to other actors in the network. One example of such an interaction is from an architect, where they describe the regulations used to complete a housing project for the social affairs department:

“There are a lot of regulations... But the main important point was that everybody was open for new solutions and for easier solutions. Also, the fire brigade or the fire men who are involved in this has the order to go down with the standards...And that’s actually what made this project very interesting for us. Because you had more freedom with thinking.” (Interview, Architect, 9.15.16)

The standards were lowered for building projects in order to expedite the process, which in turn helped architects feel freedom in the design process. The inclusion of displaced persons in this social network and their high out-degree was an unexpected observation, as displaced persons were not interviewed for this study but were still referred to by other stakeholders in the process. A high out-degree represents prestige or receptivity; in the context of regulatory interactions, this

could also represent importance in interactions. An example of this type of involvement was given by one of the same architects:

“And always two apartments share one toilet and the bathroom. And so that’s the thing. And I think that’s quite humane. I mean it’s OK” (Interview, Architect, 9.20.16).

This statement expresses support for regulations because they provide a humane quality of living within the facilities. Displaced persons had a high in-degree for both constrained and facilitated interactions (Table 3). This shows that other stakeholders consider the involvement of displaced persons in the role of regulations. However, their perspective is not always solicited. Out of all 54 interviews, only one participant mentioned that they reached out to people seeking asylum to capture their needs in designing temporary accommodations. The results in Table 3 and Figure 4 show that displaced persons are involved with regulatory interactions – they are impacted by regulations and standards, yet do not have as much agency in the regulatory process which might be due to their asylum status. As Scott has described, “all actors, both individual and collective, possess some degree of agency, but the amount varies greatly among actors as well as among types of social structures” (Scott 2008, 95). For logistical and ethical reasons, displaced persons were not included in interview participants for this study. However, it is strongly recommended for future work, as evidenced by the inclusion of displaced persons in regulatory interactions (Table 3). Results may show how directly connected displaced persons are with federal building regulations (typical development standards) and standards given by the social affairs department (situation-specific guidelines for contracts associated with temporary accommodations).

Government agencies (city government permitting, federal building regulations, state government and the social affairs department) had a high out-degree (Table 3), indicating that these actors facilitated regulatory actions. This high out-degree indicates that the way that government agencies used regulations in interactions benefitted, or enabled, other stakeholders in their specific role during the accommodations process. One example of this is demonstrated in an interview with an architect expressing the major differences between their typical interaction with permitting departments in comparison to during the refugee situation:

“It was quite fast the permitting process for the refugee housing. As it’s or at least it was a priority, this area...” (Interview, Architect, 9.20.16)

The city government’s permitting process prioritized refugee housing, which empowered the architect to finish their project more quickly than otherwise. City government (permitting) and state government facilitated more interactions with these stakeholders rather than constraining them (Table 3). This might indicate the extent of both actors’ agency in the synthetic organization. All participants expressed the need to provide housing quickly; intermediate government agencies, such as the permitting department and state government, used their position in the network to effect change in expediting the design process for other actors as expressed in the quote above. More work is needed to understand the perception of government agencies regarding the role of regulations in addition to the visualization that is provided in this study.

CONCLUSION

In synthetic organizations, stakeholders come together to achieve a common purpose in an unusually uncertain and dynamic environment. The social network analysis provided in this study visualizes the regulatory dependencies within this synthetic organization whose goal is to provide temporary accommodation for displaced persons. Federal building regulations and the social

affairs department hold the most power in this network. Given their high out-degree (Table 3), they are able to influence other actors through constrained or facilitated regulatory interactions which supports the theory of the power gap that exists between standard writers and those implementing such standards (Lampland and Star 2009, 118). Regulatory interactions impact all stages of providing temporary accommodations: coordination (city government), design (architecture firms), management (building owners, nonprofit organizations) and occupancy (displaced persons). All of these areas had a high in-degree in the social network, demonstrating the impact of regulations throughout the entire process and extent of path dependency between actors. Interdependency was also evident at the coordination and management steps in the provision process. Government agencies and building owners both had the highest amount of betweenness in both constrained and facilitated regulatory interactions. Betweenness represents the centrality of actors through interdependence amongst other stakeholders and is considered a gatekeeping position in the social network. In general, the regulations themselves and actors responsible for contracts hold the most power in the social network and engage with both constrained and facilitated interactions. All aspects of the provision process are impacted by both constrained and facilitated regulatory interactions, but actors involved with coordination of facilities are positioned as the gatekeepers in these interactions. These results visualize the organizational relationships of agency, power and interdependence in an environment faced with extreme uncertainty. The extent of these characteristics are dependent on the positioning of actors within the network as well its social structure (Scott 2008, 94). This study has mapped the social structure of the synthetic organization and identified key actors in the network, but future work is needed to understand how specific actors perceive regulations in these interactions. Knowing this information equips societies and governments in responding to extreme uncertainty, and informs decision-making regarding regulatory processes to ensure the safety and dignity for those occupying temporary accommodations.

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BUILDING A COOPERATIVE CULTURE THROUGH THE CONSTRUCTION SUPPLY CHAIN

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BUILDING A COOPERATIVE CULTURE THROUGHT THE CONSTRUCTION SUPPLY CHAIN

- CONFERENCE-LENGTH PAPERS -

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ABSTRACT

Relational project delivery arrangements are becoming increasingly popular as a means to improve the performance of large and complex construction projects. Like most construction management research in general, the research (and the practices) on such arrangements focuses on the owner-contractor dyad, although research already long suggested that relationships with sub-contractors and -suppliers may have large impact on the low productivity development in the sector. The question is how various formal and informal mechanisms used to build a cooperative culture actually extend beyond the owner-contractor relationship. This research-in-progress aims to present a framework for studying these issues.

KEYWORDS

Supply chain management, Cooperative culture, Collaboration quality

INTRODUCTION

Establishing a cooperative culture seems to lie at the center of so called relational project delivery arrangements (Lahdenperä, 2012) and collaborative procurement arrangements (Walker & Lloyd-Walker, 2015). These arrangements focus on bridging the gap between designers and building contractors, on the one hand, and building contractors and owners, on the other. Hence, they are predominantly adopting a dyadic perspective on relationships in the construction supply chain. An abundance of literature focuses on a dyadic level of the owner and contractor relationship (Lena E. Bygballe, Jahre, & Swärd, 2010). Considerably less research has investigated how cooperative mechanisms and culture extend the boundaries of the owner and contractor relationship in construction projects, and how a contractors' intent and contractual incentives for relational cooperation are extended to subcontractors and -suppliers.

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This paper addresses the question of how a cooperative culture can be established and sustained throughout the supply chain in design-build contracts. A recent report by the McKinsey Global Institute (MGI, 2017) points out the fragmentation of the construction supply chain into specialised and separate trades is among the key reasons for the low productivity development in the sector (cf. Eccles, 1981). According to the report the productivity difference between the large-scale players and the fragmented specialized trades is remarkable (20-40%). Yet academic research in construction management is mostly focused on the owner-contractor relationship, that is, typically the “large-scale players”. However, there seems to be an increased concern for sub-contractor and SME (small and medium-sized enterprise) perspectives on various supply chain integration efforts in the construction industry (Dainty, Briscoe, & Millett, 2001; Pala, Edum-Fotwe, Ruikar, Doughty, & Peters, 2014; Tezel, Koskela, & Aziz, 2018). The literature is still very scarce and to our knowledge no previous study has explicitly focused on the owner’s role in collaborating with the extended supply chain.

We approach the topic through two inter-related concepts: collaboration quality and cooperative culture. Collaboration quality, defined as “the extent to which buyer and supplier groups synergistically exploit shared resources while minimizing wastes through interacting during project planning and execution” (Yan & Dooley, 2014, p. 61), has been found to explain success and performance in NPD (Yan & Dooley, 2014) and information system projects (Boughzala & de Vreede, 2015). A cooperative culture, in turn, is seen to be built upon mutual respect and good faith, open and active communication, and commitment to improvement (Lahdenperä, 2012).

LITERATURE REVIEW

SUPPLY CHAIN MANAGEMENT IN CONSTRUCTION

The interests in various relational project delivery arrangements such as partnering, alliancing and integrated project delivery (IPD) has been growing since the 1990s (Lena E. Bygballe et al., 2010; Lahdenperä, 2012). It seems that such arrangements has had a positive impact on the performance of projects as reported both in famous case studies (Brady, 2008; Gil, 2009) as well as more extensive reports (Walker & Lloyd-Walker, 2015). Yet this seems not to be reflected in the productivity development in the industry as a whole (MGI, 2017). Critical voices argued very early that such arrangements overlook issues beyond the owner – main contractor dyad (Dainty et al., 2001; Miller, Packham, & Thomas, 2002). Dainty et al. (2001) called for an attitudinal change towards smaller companies and argued that it is the owner’s responsibility to implement that change.

Using a single case study approach, Eriksson, Dickinson, and Khalfan (2007) found out that the client’s procurement procedures indeed affect sub-contractor involvement and integration in the construction process. They, however, also found that for that to have an impact on innovation and value creation a longer-term perspective would be required. Hence, a supply chain management and/or network approach to construction should be furthered (Lena E. Bygballe et al., 2010). Supply chain management approaches in construction aiming at longer term benefits such as supplier development are already recently reported (Gosling, Naim, Towill, Abouarghoub, & Moone, 2015; Noorizadeh, Rashidi, & Peltokorpi, 2018). These

studies typically and quite naturally assume a (main) contractor perspective. The owner perspective appears to be lacking.

A long-term perspective is challenging in a project-based industry such as construction, where clients, for good and for bad, use different contractors from one project to another. Likewise, each contractor typically decides on and brings its own supply chain in each project. Hence, there is still a demand for means to bring about a cooperative culture in the short-term. For example, in a recent study, Swärd (2016) shows how informal means can be used to signal incentives in the form of a shadow of a bright future.

In a multiparty arrangement the client is typically the driving force. There seems to be a variety of different approaches to partnering in construction that share a number of features, such as early contractor involvement and special contracts (Lena E. Bygballe et al., 2010; Lahdenperä, 2012). This and procurement procedures in general that Eriksson et al. (2007) studied are, however, but one means to achieve a cooperative culture in projects. Some of them clearly have to do with procurement procedures and contracts, whereas others are applicable to the construction process itself.

COOPERATIVE CULTURE AND COLLABORATION QUALITY – TOWARDS A FRAMEWORK

In this work, collaboration quality is something resulting from a cooperative culture and resulting in improved performance as indicated in Figure 1.

In essence, a cooperative culture is brought about through the use of a mix of formal and informal mechanisms (Lena E Bygballe, Dewulf, & Levitt, 2015). For example, Lahdenperä (2012) identified six main categories of so called “key integration features” (KIFs) found in literature that are used to establish a cooperative culture, among them both formal and informal ones: team formation, administrative consistency, commercial unity, planning emphasis, teamwork premises, and operational procedures. Typical formal mechanisms constitute things like contracting approach, structure and contract form (i.e. delivery system), incentives, risk sharing and so forth.

Planning emphasis is a KIF that encompasses the use of advanced information and communication tools. With the adoption of BIM and Industry 4.0 technologies in general, collaboration is expected to become easier and more effective. The question, however, still remains: will these use of these also involve sub-contractors and -suppliers?

Overall, the mix of formal mechanisms constitute what can be referred to as a delivery model. A delivery model is hence seen as a broader concept than that of delivery system that refers to the contractual scope arrangement between an owner and the sub-contracting market (Barrie & Paulson, 1992). The interplay between formal and informal mechanisms and their joint impact on collaboration quality is at the heart of this paper. In addition, we note that the effect may or may not be what the owner initially intended when selecting the mix of mechanisms. Figure 1 shows the preliminary research framework for our study. The specific aim of our study is to uncover some of the organizational mechanisms and their relations involved in this framework.

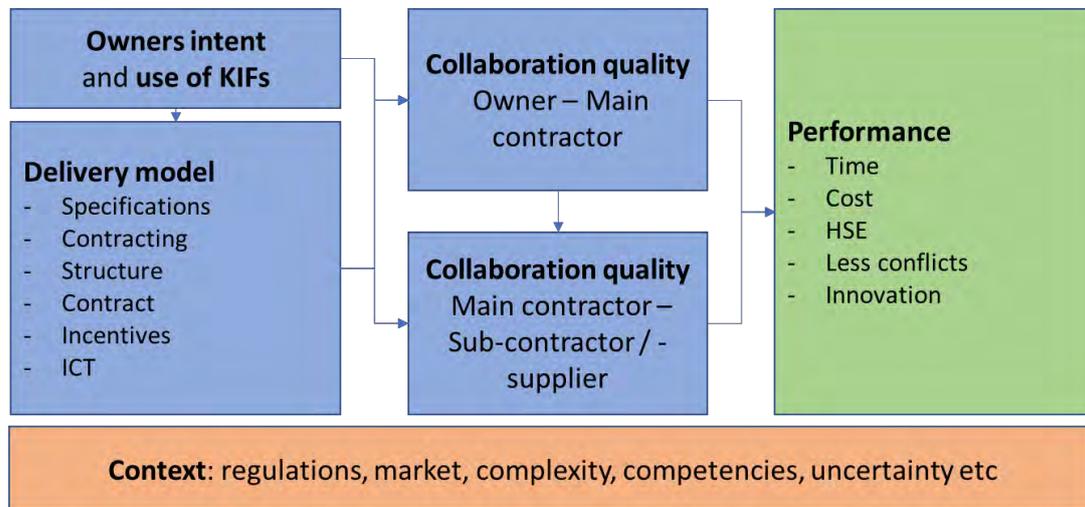


Figure 1: Preliminary research framework of the study

METHODOLOGICAL APPROACH

Due to the scarce amount of research on collaboration quality along the wider construction supply chain and especially that between main contractors and sub-contractors, we have adopted an explorative research approach. We use a case study setting and report from a study on a road construction project, where the owner pursues design-build contracting, but with an early involvement of building contractors.

In our study, we focus on how the quality of cooperation is established in the early phases of the projects, how it is maintained during the project, and, most importantly, how the quality of cooperation unfolds between the general contractor, sub-contractors and sub-suppliers during the execution phase of the project. For this purpose we have collected and analysed documents from the projects early phase and we are now in the process of interviewing contractors and suppliers.

PRELIMINARY FINDINGS

We foresee two kinds of findings. Firstly, we report on how collaboration quality established in the early phases of the projects was maintained during the execution phase, that is, to what extent the integration measures taken has played out. Secondly, we aim to report on how the same measures shaped the relationships between the contractor, its sub-contractors and -suppliers given the minimal involvement of the owner.

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**“IT’S JUST PAINT, RIGHT?” AN EMPIRICAL
EXAMINATION OF INSTITUTIONAL MISMATCH, SOCIAL
MANAGEMENT, AND BUREAUCRATIC COORDINATION**

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“IT’S JUST PAINT, RIGHT?” AN EMPIRICAL EXAMINATION OF INSTITUTIONAL MISMATCH, SOCIAL MANAGEMENT, AND BUREAUCRATIC COORDINATION

Brittany N. Montgomery¹

ABSTRACT

The political economy of painting streets is far from the grandiose aspirations of megaprojects. Paint is an accessible, “simple” tool for local governments to change the use of existing infrastructure. In the transportation sector, for example, it is a fast and cheap way of implementing city-wide policies for prioritizing bus-based public transit. Yet the technical simplicity of paint projects belies their growing social and organizational complexities. Similarly overlooked are the extant norms and habits that underpin the behavior of project stakeholders and the effects they may have on project implementation. How can we understand the institutional and organizational complexity of a technically “simple” public sector project and how to manage (through) that complexity?

From the perspective of a fully-embedded participant observer within the current administration of the Capital District of Bogotá, Colombia, I adopt an ethnographic approach to understanding this question. Through deep engagement in a transportation project under my supervision as a top-level adviser to the Secretary of Mobility for over 13 months and by way of discussions with the various parties involved, I illuminate the processes by which a preferential bus lane project (essentially street painting) evolved into a project of high institutional and organizational complexity. Initial conditions of mismatch between regulative institutions and the norms of appropriateness and routine parking behavior spurred a government-led effort to realign the institutional pillars governing the use of public space. Mass protest over the violation of perceived *de facto* rights initiated a process of “social management”. Together these processes catalyzed a significant expansion in the project’s scope and organizational field, as well as heightened the need for bureaucratic coordination within and between agencies of the city government.

KEYWORDS

Complexity, informal institutions, bureaucracy, politics

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INTRODUCTION

It was an ordinary Tuesday morning around 10:30 AM. I was sitting in my government office in Bogotá’s transportation agency reviewing the fliers for my priority bus lane project. Suddenly, my WhatsApp² blew up with photos of throngs of people swarming the project scene. More photos rolled in of a mob surrounding the team of human-sized traffic cones that I had sent to encourage better parking behavior. Another few minutes, and the number of angry people blocking the streets swelled into the hundreds. My team of “cones” stripped their costumes and fled. The most important east-west corridor on the south side of the city was blocked off with a mass of people carrying an outstretched Colombian flag that spanned three lanes of traffic.

I had done nothing but enforce the law. Not even that. I had sent out a team of six people dressed as traffic cones with a megaphone to sing and dance around illegally parked cars in an effort to publicly shame violators into following the law. Issuing a traffic ticket was the last straw - a sort of three strikes and you’re out model.

How had a preferential bus lane project³ that seemed so simple - essentially paint plus police - turned into a monster? Painting streets is a low-key, fast, cheap, and easy way of implementing city-wide policies for prioritizing bus-based public transportation. Yet painting an 11 kilometer priority bus lane was clearly not going to be as easy as anyone had thought.

The project’s “success” would depend on coordination with others: other divisions of my own agency, other agencies within the Mobility Sector, and agencies that typically had nothing to do with transportation or infrastructure. Whether they would help (or not) was an outstanding question. It would also depend on dealing with local stakeholders who were not so much angry about the project itself, as the fact that it catalyzed law enforcement. Law enforcement that threatened to change their routine business practices that relied on unenforced on-street parking rules.

The technical simplicity of small-scale infrastructure projects like this one belies the growing social and organizational complexity of their implementation. Similarly overlooked are the routine behaviors and norms that underpin the everyday activities of some project stakeholders and the ways in which these “informal” institutions may affect project implementation. How can we understand the institutional and organizational complexity of a technically “simple” project and how to manage (through) complexity? Painting streets is an idealized example that allows a sharp focus on the institutional and

² WhatsApp is a free, encrypted messaging platform for smartphone users. It is the primary mode of communication between government officials in Bogotá.

³ A “preferential” bus lane, also known as a “priority” bus lane, reserves one lane of traffic per direction for the almost-exclusive use of public transportation buses. Taxis and other private vehicles can use the lane for momentary stops or right turns but cannot use the lane for transit.

organizational dimensions, since the technical one is trivial. Through what processes did a paint project evolve to elicit “district-level political risk” and mushroom into a monster involving 18 government agencies, survive implementation, but ultimately fail in the operational phase?

THEORETICAL FRAMES

Scholars of projects suggest that the bedrock of complexity is the combination of a project’s inherent institutional and technical features (D. Lessard, Sakhrani, and Miller 2014). The emergent properties of projects depend as much on this foundation as on “project shaping” - “the episodic process in which stakeholders make strategic moves to manage or resolve exogenous risks, uncertainties and forces acting on the project” (D. Lessard, Sakhrani, and Miller 2014, 171). Yet the empirical evidence describing the mechanisms of project shaping focuses primarily on large, technically complex megaprojects and on the interactions between public and private sector sponsors (Orr and Scott 2008; Mahalingam, Levitt, and Scott 2011). Government is often treated as a monolith. What is going on *inside* and *between* the various branches and divisions of government remains unobserved in this literature.

Furthermore, studies of the complexity of large infrastructure projects focus almost exclusively on what Douglass North labels the formal “rules of the game” (North 1990), neglecting to explain the ways in which extant norms, perceptions of legitimacy, and other “informal” institutions affect project outcomes (see D. R. Lessard and Miller 2001; Lundrigan, Gil, and Puranam 2015). In cases that do examine the role of informal institutions, scholars focus on institutional clashes between private and public sector or local and “global” project sponsors (see Orr and Scott 2008; Mahalingam, Levitt, and Scott 2011), rather than the informal institutions held by the affected public that may directly influence project implementation. Additionally, prior discussions of the institutional environment in which projects are situated considers them to be a static element of complexity (D. Lessard, Sakhrani, and Miller 2014). In some cases, such as high-income countries or even high-income neighborhoods in low-income countries, where enforcement of particular laws is the “norm,” this premise may not be incorrect.

However, the enforcement of extant laws and regulations is not a given anywhere. It may be especially uneven in cities with low income levels, due to factors ranging from weak institutional capacity to corruption (see Roy 2005, 2009) and intentional forbearance (Holland 2016). This common reality requires a fresh look at informal institutions, or what Scott characterizes as the “normative” and “cultural-cognitive” institutional pillars (Scott 2014), and their relationships with the formal, “regulative” pillar of institutions. According to Gibbons, “...institutions - that is, the formal and informal ‘rules of the game’ (North 1990, 3) - must be equilibria: they must provide

everyone, including enforcers, with an incentive to behave appropriately (Gibbons 2001). Although scholars of projects identify the importance of institutions for project performance (e.g. Miller and Lessard 2000), informal institutional change catalyzed by a project is not studied in detail. Scott suggests that the misalignment of the institutional pillars will result in conflict (Scott 2014, 71) - a situation that might directly affect project costs and schedules. How does the State attempt to induce *informal* institutional change, in order to lay the groundwork for the operational phase of projects?

In projects where the inherent technical features offer little-to-no opportunity for participation⁴ or project shaping, affected communities may turn to mobilization. Mobilization creates new challenges for the State, particularly in the case of projects that provide basic public services. Social movement scholar Doug McAdam characterizes reactive mobilization as the “primary threat to global infrastructure projects” (McAdam 2011), yet most literature on “global” or “large” infrastructure projects focuses on private rather than public sector response to resistance against projects (e.g. Amengual 2018). Aside from examples of repression of protests, we have relatively little understanding of the nuanced process by which the administrative branches of the State are beginning to cope with and mitigate the uptake in resistance to projects or to the enforcement of longstanding rules essential to project viability.

What none of these literatures address directly are the ways in which the institutional and organizational features of low technical complexity, government-led projects combine, iterate through the process of implementation, and ultimately affect project outcomes. How does a “simple” project evolve into one of high organizational and institutional complexity? How do the norms and routine behaviors of a segment of affected stakeholders influence the processes that governments adopt during project implementation? What are the unseen, internal workings of the bureaucratic agencies charged with project implementation?

RESEARCH APPROACH

Having sat at the table with multiple Latin American governments as an engineer and planner only to watch carefully planned projects fizzle, I wanted to explore the processes and relationships of project planning and implementation from within the State. Developing a deep understanding of the informal institutions that shape behavior

⁴ By “participation” I refer to co-creation or co-design of the project. In the case of a narrowly-defined priority bus lane, the only immediately visible decision to be made is that of painting / designating the lane for transit, offering little opportunity for public participation. A broader project definition may allow for greater community participation, but a rich discussion of participation is beyond the scope of this paper.

within the public sector and the internal processes that shape projects requires an intimate familiarity with the everyday goings-on of an administration and the projects it attempts to deliver. I adopt an inductive, ethnographic approach to generate insights about infrastructure projects and the public sector organizations that undertake them, following in the footsteps of a rich literature that employs a similar approach in studying organizational processes and informal relations (see review in Van Maanen 2001).

Although broad areas of inquiry were defined before going into the field, my questions were defined inductively through my full immersion in a government organization. As with many deep-dive, inductive studies, I focus on one site or “case” of an organization. Scholarship on infrastructure projects has long employed a case-based approach, due to the relatively unique, one-off nature of most infrastructure projects (Morris and Hough 1987; Miller and Lessard 2000). Similarly, insights into organizational behavior and institutions frequently derive from deep, within case or cross-case analysis (see Van Maanen 1973; Weick 1993; Ostrom 1990).

CASE / SITE SELECTION

My prior professional experience as a transportation engineer and city planner in Latin America surreptitiously paved the way for a personal invitation to work for the current (and second) administration of Mayor Enrique Peñalosa in the Capital District of Bogotá, Colombia - an offer I accepted based on the condition that the position would serve as fodder for my doctoral research. This location allows me to unpack the interplay between bureaucratic agents frequently overshadowed by the mayor himself. Domestically and internationally renowned for the infrastructure projects implemented during his first administration (1997-2000) (see Dávila 2005) and lauded as a rare beacon of “political will” in recognition of his track record of politically unpopular initiatives, he is known for bringing a technocratic (versus clientelistic) approach to governing Bogotá (Flóres Fernando 2016; Arenas 2016; Durán G. 2016). In recognition of his capacity for project implementation across multiple sectors, Peñalosa was recently voted #25 on the list of “100 Most Influential Urbanists” (Planetizen 2017).

Promises of restoring, improving, and expanding infrastructure services in pursuit of “urban democracy” fueled Peñalosa’s 2015 mayoral campaign and underlie voters’ expectations of the administration. The “urban democracy” pillar of the administration’s development plan contains goals related to the implementation of infrastructure projects, particularly in the transportation sector (Gabinete Distrital 2016, 231). As compared to the types of projects studied in the megaprojects literature, these are one to two orders of magnitude lower in cost and technical complexity. Furthermore, the resources for several transportation projects were certain. Thus, from the outset of my fieldwork, the expectation of a rich set of projects to draw from was high.

The characteristics of the administration of the Capital District of Bogotá also contribute to case selection.⁵ Bogotá is representative of the broader trend “agencification” (Pollitt and Talbot 2004). Responsibilities for the urban transportation sector are divided between seven entities, six of which fall under the umbrella of the “Mobility Sector”⁶ and the seventh of which is a stand-alone cabinet-level bureau. The fragmentation of responsibilities offers an extreme perspective from which to observe organizational complexity. Furthermore, this constellation of agencies has been relatively “successful” in continued expansion of the Bogotá’s Bus Rapid Transit (BRT) system, a feat that has not been realized by half of the Latin American cities that have adopted BRT.⁷

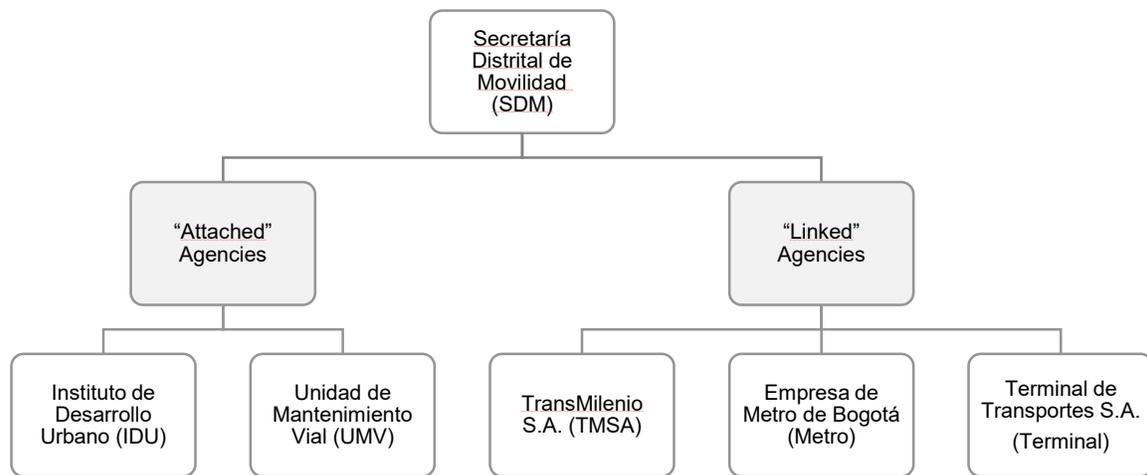


Figure 1: Organizational Structure of the Mobility Sector of the Capital District of Bogotá, Colombia. Adapted from (El Alcalde Mayor de Bogotá, D.C. 2006).

Within the administration, my specific position offered an excellent vantage point

⁵ Bogotá’s designation as a “capital district” gives the city the same level of autonomy as regional departments within Colombia.

⁶ The Mobility Sector includes “attached” and “linked” agencies, per Article 107 of Agreement 257 of 2006 of the Bogotá City Council. “Attached” entities include: the Road Maintenance Unit (*Unidad de Mantenimiento Vial*) and the Urban Development Institute (*Instituto de Desarrollo Urbano*). “Linked” entities include Transport Company of the Third Millennium TransMilenio S.A. (*Empresa de Transporte del Tercer Milenio - TransMilenio S.A.*), the Metro Company (*Empresa de Metro de Bogotá*), and the Bus Terminal Company (*Terminal de Transportes S.A.*).

⁷ A “Bus Rapid Transit” system is mass transit system with many of the characteristics of subway or metro lines that operates on the surface with buses and exclusive lanes, rather than rails. As of 2016, approximately half of the BRT systems in Latin America had only implemented a single BRT corridor. This mode of transportation relies on economies of network, which implementing a single corridor does not achieve. (Author’s calculation based on data from (BRT Centre of Excellence et al. 2016)).

from which to observe the inner-workings of the administration, as well as interactions with project stakeholders outside of the administration. For 13 months I served as a top-level adviser to the Secretary of Mobility (SDM) - the legal head of the “Mobility Sector”. As a high-level adviser, I gained an unusually large degree of access to cabinet members and top-level decision-making forums, as well as the opportunity to manage and collaborate with over 300 public sector employees from 18 government agencies. Although my experience in this role includes work on 10 projects, in this paper I highlight the trajectory of one project that illustrates the evolution of institutional and organizational complexity on a technically “simple” project.

PROJECT IMPLEMENTATION

In the following sections I recount my experience implementing a preferential bus lane on Av. Bogotá⁸, thereby illustrating the processes of growing institutional and organizational complexity and the processes by which the State managed these complexities. When appropriate, I use an “abductive” approach to link empirical evidence with theoretical concepts (see Dubois and Gadde 2002).

CHANGING PRIORITIES - A CATAPULT TO THE TOP

When I arrived in Bogotá in early 2017, Mayor Enrique Peñalosa’s approval ratings were so low that journalists compared them to those of neighboring dictator Nicolas Maduro (Alarcón 2017). Just one month prior, a political opponent launched a movement to revoke Peñalosa’s mandate⁹ by gathering signatures from thousands of citizens. According to news outlets, one of the primary reasons behind his unpopularity was failure to meet the “excessive expectations” promised by his campaign (Semana 2017), particularly in the areas of transportation and infrastructure. After one year in office the public had seen no results. Of the entire cabinet, the head of the Mobility Sector - my new boss - had the lowest approval rating.

Arriving at the SDM at this moment was like being dumped into a pressure cooker. Blinded by the desire to show results, boost approval ratings, and avoid the *revocatorio*, leaders bargained on actions that would improve their standing in the press. Just five work days after walking into the office for the first time (and not yet officially employed), I met with the Secretary to define my role in the agency. The conversation began with “*dime*” (talk to me) - not a great foot to get off on. “I have reviewed all of the project *fichas* (descriptions) and have met with the leaders of the projects. I think I can be the most useful on the projects related to public transportation. I understand that you

⁸ For the purpose of protecting human subjects, I have chosen fictitious names for the locations and subjects of this paper, with the exception of elected officials and cabinet members.

⁹ This movement was known as the “*revocatorio*”.

need highly visible, quick-to-implement projects. I think the preferential bus lane project is what you need right now, and I would like to lead that. Let's see how many kilometers we can implement and do what Mayor Haddad did for Sao Paulo here. We need an entire network of these bus lanes, not just a random project here and there.”

Not only did I get what I asked for - the leadership of a tangible, fast-tracked project in the implementation stage - I negotiated a fairly dormant project to the top the priority chain. Why? Because it was one of the fastest, easiest, most visible, and least controversial projects. Or so we thought.

The agency had been studying three preferential bus lane corridors, plodding along in the “technical study” phase without a project champion. My boss chose to move ahead with the corridor that had the most advanced “technical study”. This was not a politically strategic decision, one that responded to political or community demands, or even one that was discussed (to my knowledge) with the mayor. It was a technical choice of the “most needed” corridor - one with the highest number of public transport passengers. No analysis of project stakeholders had been made. So seemingly unnecessary were the ‘social’ aspects of the project that even the signed and approved technical study misidentified the boroughs (*Alcaldías Locales*)¹⁰ in which the project would be implemented.

During the following week, a flurry of activity within the agency ensued to finish the technical report. Since I had not yet been officially hired, I received an “FYI” copy. It was a purely technical exercise, in which paint and rearranging bus stops were the only elements necessary to transform a main transversal avenue in the city into a faster, better corridor for local bus routes. The justification was limited to explaining the microsimulations of bus operations at one critical point along the 11 km corridor that would benefit from a reorganization of bus stops and an exclusive lane.

Meanwhile, the Secretary ordered a redesign of the paint scheme to improve the visibility of the lane markings. Colors, solids, and stripes were discussed, drawing on examples worldwide. The final scheme settled on a fat orange stripe down the center of the bus lane - a decision made by the mayor himself via renders sent by WhatsApp chats. By the end of February, we had a technical study and a paint design. My job: implement it.

ORGANIZATIONAL STRUCTURE

Contending with the organizational structure within the agency presented the first hurdle. My “team” had one full-time person besides myself, and even that one person

¹⁰ Bogota is divided into 20 boroughs (*Alcaldías Locales*), each headed by semi-democratically chosen local “mayor” that reports to the mayor of the Capital District (*Alcalde Mayor*).

was without a contract ¹¹for approximately three weeks during my first month on the job. The rest of the roughly 130 people that worked on the project ducked in and out as need be. As a top-level adviser, I had the soft-power of proximity to the head of the agency, but, technically speaking, no one worked *for* me. Everyone on my project officially reports to division directors or “office” heads¹² based on the statutory hierarchical org chart.

This simultaneous overlap of uncoordinated powers - the power to manage projects via soft power and formal hierarchical power - creates a management mess, whereby workers’ loyalties are torn between different masters. It is almost impossible to get these “team” members to do anything without first going through a painful negotiation of their time with their bosses on the official org chart, regardless of the project’s “priority” or importance to the Secretary. Even that may fail. At the first project meeting I scheduled, only 10 of the 38 invited people showed up. Department directors with little-to-no-knowledge of the project frequently undermined the project by reassigning their human resources to other projects or giving contradictory instructions to my own. In contrast to the newfound urgency of the project to the Secretary (who sent an email in all caps ranting about how slow the project was moving - “*NO PUEDO ESPERAR MAS*”¹³ before I was officially hired), the rest of the agency was out to lunch.

KICKSTARTING A PROJECT

While traffic engineers hurriedly finished the street striping plan, I began designing the critical path to full operation. Unlike the agency’s engineering-dominant stance, my social science training asked how to broach this project to the public. From my own perspective, there was no room for deliberative participation. What would people decide? We either painted a lane, making the small complementary regulatory change to its legal use, or we did nothing. Bus stops are a type of “locally unwanted land use,” so opening their locations up for debate was a nonstarter. Alternatives to the corridor location were also a geometric impossibility, given the bizarre cross-cutting arc

¹¹ In Colombia there are three main classes of public sector employees: career civil servants (selected based on Weberian principles), political appointees, and independent contractors. This last category of employees are hired via short term contracts (3-12 months) under the premise of delivering specific, pre-determined contractual objectives. They make up 59% of the Capital District government (Gabinete Distrital 2016, 481), and, while contract renewal is possible, district legal departments build in gaps between contracts of inconsistent and unknown length in an effort to evade an accusation of corruption from the control entities.

¹² Positions on the official org chart are typically hired as political appointees. They carry high “administrative burden,” where I define “administrative burden as the combination of liability and risk (or level of exposure to findings by Colombia’s oversight agencies) assumed by political appointees and career civil servants.

¹³ I CANNOT WAIT ANY LONGER

made by Av. Bogotá across the city. Furthermore, adding additional elements to the project, such as improved lighting or security cameras at bus stops, were out of our agency’s statutory scope of action and would depend upon the good will of other government agencies.

Yet, given the current context of criticism of the administration for neglecting to listen to the “public,” we had to do something that would at least indicate an effort to listen to those who would be affected by the project that seemed to have a negligible margin for public participation. It needed to be simple and fast enough to implement without delaying the “socialization” of the project¹⁴. A survey of frequent bus users along the corridor that gauged knowledge of the existing preferential bus lanes and indicated the top improvements to make at bus stops would do the trick. At the time, we thought nothing of the fact that this effort omitted potential opponents of the project - who would oppose this anyway? It was a simple redistribution of existing traffic lanes.

While planning the survey, I met Paco, a contractor that had worked closely with the Secretary in the previous administration. Unlike the division of the agency devoted to citizen services and community participation, he had a deep knowledge of the community we would affect. Unbeknownst to the Secretary or the engineer on my project, the prior administration studied the same bus lane, but the former Secretary determined that the political risks of the project were too high, given the magnitude of illegal uses of the street and sidewalks, and abandoned the project. Completely new information. Neither the technical study, nor a single conversation about the project had surfaced the social or political risks involved.

The technical study had been just that. A purely technical exercise led by someone with limited experience outside of academia. The idea that real people might object to this technically robust reconfiguration of traffic lanes did not appear on the horizon. But even upon explaining the situation to my boss, he blew off the risk potential as trivial. Despite the remarkable base of bottom-up support held by the previous administration, its leaders nixed the project due to the intense social challenges. Now, in an administration with a tenuous hold on legitimacy and a recall on the mayor in process, the task seemed insurmountable.

THE SETTING

The first time I laid eyes on Av. Bogotá, I was in the front seat of a pickup listening to Paco explain the litany of problems ahead. We drove slowly, as I hurriedly scribbled notes and snapped few photos. The corridor straddles four low to middle-

¹⁴ I had been informed by my one employee that dissemination of public information regarding the project - referred to as “socialization” in Spanish - was required at least one month prior to the project’s opening day (operation).

income boroughs, each with its own distinct physical challenges and constellation of political actors. With the exception of the westernmost stretch, the roadway section is in a state of disrepair. Sidewalks are practically nonexistent – inconsistent patches of asphalt, brick, concrete, or dirt, replete with gaping holes. Vehicles of all types, from small freight trucks to motorcycles, straddle the sidewalk and lane #3¹⁵, going about their everyday activities as if “public space” were nothing more than an ephemeral idea invented by distant bureaucrats. Sofas and recliners - the vinyl kind reminiscent of fast food booths – spill onto the sidewalks, narrowing the available pedestrian space. Motorcycles are everywhere. Cheap cafes sit next to motorcycle repair shops, brothels, car washes, crowded furniture display rooms, dive bars, small lumberyards, and a handful of regional destinations like medical centers.

The only common characteristic throughout the four boroughs is the high incidence of the invasion of public space. The longer we drove, the more parked cars on the street we saw. The right hand lane in each direction was effectively a free, but technically illegal, parking lot. It was clear that this was not going to be easy. I was embarrassed by the fact that it had taken me two weeks to clear out enough time for a site visit. The overwhelming pressure to produce results, the endless stream of people that poured into my office, and the litany of meetings at which I did not necessarily need to be present had blinded me to the most obvious and basic initial step of any project: trying to figure out what was actually happening on the ground. The pickup ride screamed, “you don’t know what you’re getting yourself into!”

A GROWING PROBLEM

My first visit to the field made it clear just how far away we were from achieving better bus operations along Av. Bogotá. We lacked the basic conditions for implementing the bus lane. Not only did we need to enforce proper use of the preferential lane - a confusing set of regulations to explain at best - we also needed to enforce existing laws regarding arterial street and sidewalk use that had been “on the books” for decades¹⁶. Based on multiple site visits, the liberal use of public space was a deeply ingrained routine behavior that was the normal state of affairs for the businesses that lined the corridor. These “informal institutions” stood in complete contrast to the National Traffic Law, which had prohibited parking and other invasive uses on arterial streets since 2002.

At first glance, this might seem like a case of intentional non-enforcement of the law. Alisha Holland labels this forbearance - a condition in which the State intentionally

¹⁵ I call the right-hand lane in each direction lane #3. It is the third lane in a road section of three lanes per direction.

¹⁶ The *Código Nacional de Tránsito*, was passed in 2002 in Law 769 and reformed in 2010 by Law 1383 (Poder Público - Rama Legislativa 2002).

neglects enforcement of regulations in exchange for votes or rents (Holland 2016), and development scholars note the legal exceptions that are made for wealthy or politically influential citizens (see Roy 2005). Or it might appear to be a case of “weak capacity,” whereby the State lacks the capabilities necessary to enforce the law. Neither of those seemed quite right. On the opposite, wealthy side of the city, some streets are clear of illegally parked vehicles, and there is no evidence of a 20+ year-long relationship between locals and the police. Paco and others from the branch of the agency with “control” in its name attributed the problem to a simple lack of concentration on that area of the city. Their recommendations: levy the heavy hand of government and enforce the law.

A singular focus on the street, however, was doomed to fail. We would simply move the problems to the sidewalk. The ultimate “success” of the bus lane project hinged upon upending deep-seated norms and routine behaviors of the appropriation of public space for private use and bringing them in-line with extant parking laws. However, the SDM lacked the legal competencies necessary to do anything beyond the curb, much less a relationship with the Metropolitan Police (the agency empowered to sanction sidewalk infractions). Even worse, the competencies that the SDM *does* have over street space are anemic. The contractual mechanisms and incentives available to the SDM to discipline the contracted-out Traffic Police favor their monopoly on coercion and limit their effectiveness based on sheer availability.¹⁷

PREP TO PAINT

To keep the project moving I needed to simultaneously attack multiple fronts of the project. I began with an agency within the Mobility Sector whose actions were next in the critical path. If the roadway surface is in poor condition, fresh paint will rapidly deteriorate, and, according to the signage group in the SDM, Colombia’s formidable administrative oversight agencies¹⁸ will pursue the individuals responsible for the paint job. The “ías,” as these agencies are known colloquially, in such a case could accuse the agency of failing to plan or coordinate between branches of the public administration, possibly even levying the charge of *detrimento patrimonial* - the misuse of public funds. Such an accusation presents a real possibility of jail time¹⁹ for the head of the agency or

¹⁷ The Capital District of Bogotá, with a population of approximately 8 million and a land area of over 1,500 square kilometers, annually contracts the services of only roughly 1000 traffic police.

¹⁸ In Colombia, multiple national and local-level administrative watchdog agencies oversee the technical activities and expenditures of other branches of the public sector. These agencies include: the *Procuraduría*, *Contraloría*, *Fiscalía*, *Defensoría del Pueblo*, y *Personería*.

¹⁹ According to conversations with colleagues at the SDM, the former director of IDU during Peñalosa’s first administration is serving jail time due to incorrect concrete test specifications. Everyone knows of a public servant that has gone to jail based on a control entity’s “findings”.

the last person to sign the work orders for paint (i.e. the individual with administrative burden).

Thus, our simple little project faced another challenge: adding yet another actor to the organizational field and amplifying the transaction costs of coordination. All of the legal functions associated with road construction and maintenance belong to the Institute for Urban Development (IDU), which, despite falling under the umbrella of the Mobility Sector, has almost complete fiscal and legal autonomy²⁰. We would have to wait for IDU to fill potholes and resurface small stretches of the corridor before spilling a drop of paint. Coordination began at the top with a phone call between the head of my agency and that of IDU and was reiterated in weekly high-level coordination meetings of bus-based infrastructure projects.

The “help” that followed, however, proceeded in a less than fluid manner. It took an entire month to receive a roadway repair schedule. Technical expertise mixed with bureaucratic autonomy and a paralyzing fear of the control entities stymied the working relationship between the two entities. Although the technical team at IDU claimed that we could paint ten days following the termination of pavement repair, the engineering team at the SDM requested an additional 18 days (28 total) of asphalt cure before beginning to paint. Both sides claimed that their technical expertise trumped that of the other side. I was caught in the middle, failing at my attempt to negotiate between the parties.

In order for the paint contractors to start, we would need a consistent flow of information from IDU, as well as adjustments to their schedule to facilitate our paint job. Within the passing rainy weeks, IDU fell behind and proceeded with a modified schedule without notice, absent an assault of questions sent by email and WhatsApp. We received information that “they were finished, except...”. “Finished except” did absolutely nothing for us other than fester frustration. In the first segment of the corridor, we received written confirmation that their activities were complete, only for *our* (SDM) contractors to stumble upon *their* (IDU’s) contractors sealing cracks in the asphalt at night. Our attempt to paint turned into a fit of starts and stops, deepening the existing risk aversion of all parties involved. If we painted after freshly sealed cracks, the paint peel off in a spider web of cracks. This would not only tarnish the reputation of the current administration, it had large potential for raising the eyebrows of the “*ías*”. If this had been a one-time occurrence, it might have been less egregious, but it just kept happening.

²⁰ Despite the formal organizational hierarchy that establishes the sector (Decree 567 of 2006), the Secretary of Mobility (entity and its head) lacks the formal levers necessary to determine project prioritization, budgetary allocations, or personnel decisions within other entities (El Alcalde Mayor de Bogotá, D.C. 2006).

Their replies by email and WhatsApp denied the problem. We sent emails and an *oficio*²¹ with photos to IDU, in attempt to clear the agency’s name of the “lack of planning label” and blame that might be attributed to our *own* agency based on IDU’s negligence.

RECOVERING PUBLIC SPACE

While I was wrangling with IDU over the time it took for asphalt to dry, progress also needed to be made on the issue of recovering public space. I was advised by the citizen services director that some of the most important political actors to get on-board with the project were the local mayors of the four boroughs that the corridor traversed. In the first meeting with Borough 21, the scope of the problems we faced grew again. While touring the corridor, we had overlooked the yellow stripe on the sidewalk that split it in two between the curb and building facades. The former mayor of the borough painted it in an unauthorized attempt to legalize motorcycle parking on the sidewalks, despite having zero jurisdictional authority over such matters. For locals, it was as good as legal. For the current borough mayor, this was the opportunity he had been waiting for to lay down the (real) law. “Control” was again the word of the day.

Dismayed by the hole I seemed to be digging myself into with an ever-expanding project scope, I wound up at the door of the Secretary of Government (SDG), the most powerful branch of the mayoral administration and the agency responsible for working with local mayors. Like my technocratic counterparts in the SDM, I had also conceived of this project as a fast paint job coupled with enforcement. It had worked that way in Sao Paulo, right? How else had Mayor Haddad implemented 416 kilometers of priority bus lanes in just four years (Fernandes 2016)? I had no idea how to proceed.

Broadening the vision of the project, as well as making sense of how to move forward, was largely the result of input from SDG and from the newly-formed “social management” group of three social scientists in the SDM. In order for the project to become self-sustaining (not relying exclusively on police enforcement that we lacked the capacity to provide), we needed to think beyond painting bus lanes. We would need to solve problems along the corridor that local stakeholders, not simply bureaucrats, deemed pressing, as well as catalyzing long-term behavioral change with respect to the use of public space along the corridor. This idea was an anomaly within the Mobility Sector. My boss saw any effort *not* explicitly directed at paint as a waste of time and frequently reprimanded me for my efforts beyond just paint.

Together we transformed the goal of painting bus lanes into an effort to visually and operationally transform Av. Bogotá to such an extent that further illegal use of public space would become normatively unacceptable. In other words, the paint project was

²¹ An *oficio* is an official form of both internal and external communication with public sector entities. It requires the signature of someone with administrative burden, usually a political appointee.

now one of government-induced informal institutional change. It would require full recovery of the public space along the corridor. This implied actions as diverse as transforming the corridor of informal vendors into formal employees via alternative employment programs offered by the district (Institute for Social Economy-IPES), making similar offers to homeless inhabitants of the corridor (Secretary for Social Integration-SDIS), and using a combination of soft warnings, pedagogical tools, and sanctions to eliminate other invasions.



Figure 2: Public entities within the project's organizational field. The blue box indicates the four entities originally inside the organizational field, prior to its expansion due to the recovery of public space.

After a couple of unsuccessful attempts at organizing meetings with other agencies - no one showed up - we shifted the burden of meeting invitations to our counterparts at SDG (the only agency with convening power). These working meetings unveiled long-standing confusion about the division of responsibilities among agencies and a general “this is not my problem attitude”. More importantly, how could we change their attitude on the project to one of support? Were we not all working for the same administration?

Who was responsible for which elements of public space, and which entities could enforce the rules? The baseline assumption was that the chief burden of recovering public space lay in the hands of the aptly named “Defender of Public Space” (DADEP), whose head was famous for having cleared off sidewalks in Peñalosa’s first

administration and had recovered sidewalks in upper-income neighborhoods over the past year. They were entirely uninterested. They even denied our joint request (with SDG) to participate in a confidential exercise to identify the risks potentially encountered during the “operation” to recover public space²².

Despite the slow start and lack of support from DADEP, we managed to make headway with other entities. Both IPES and SDIS began the characterizations of their target populations - prerequisites for the public space operative to be carried out by borough mayors and the Metropolitan Police. Secretary of the Environment launched an initiative to clean up over-sized signs littering the corridor’s sidewalks. Borough mayors reluctantly agreed to support the project, but only three weeks later three of the four of them renounced their charges and were replaced by new appointees. Conspicuously absent from these forums was TransMilenio, the agency responsible for contracting out bus operations and who stood to gain the most from the improvements the bus lanes would provide.

INTERNAL GRUMBLINGS

Complaints about coordination with other entities, however, should be tempered with a discussion of internal coordination problems. Another project bottleneck was finishing the paint striping plans. The signage team epitomizes what I call “blame throwing.” It is *never* their fault or responsibility, and they can *never* do or try something that is the slightest bit out of the ordinary or not codified in a design manual. The new orange stripe paint design had to come as an edict from the Secretary in order for them to complete the design. Before receiving that direct command, it “couldn’t be done.” When a problem arose with an inter-municipal bus stop location, the signage group launched an email war with the division of the agency that sites bus stops, emphasizing that it was all someone else’s fault. There was no effort at reconciliation or attempt to solve the problem - it was simply an exercise in attempting to shift the blame to someone else.

Even worse was the triangle of coordination between the signage group, the contractors, and the independent supervisor. When we finally began to paint - roughly one month behind schedule - not once was anyone from this triad able to deliver a most basic request: a chart indicating the contractors’ planned work schedule and work completed. It was always the other party’s fault. Rainy days, low efficiency, and a lack of consistent pressure from the contract supervisor and signage group stretched the originally-estimated 20-25 days to completion to four months.

²² An “operation” to recover public space is the last resort when previous efforts of persuasion to follow the regulations regarding public space have failed. During an “operation” violators are fined and, in some instances, their merchandise is confiscated by the Metropolitan Police.

SOCIALIZATION AND PEDAGOGICAL ACTIVITIES

Our communication plan with local stakeholders involved a sequence of phases designed to kill two birds with the same stone: nudge behavioral change and inform “the community” of the upcoming bus lane project. “Socialization” in the typical vein of activities within the SDM boils down to what Arnstein labels “tokenism” on the ladder of citizen participation (Arnstein 1969): handing out fliers about the project to local businesses and residents along the corridor and holding informational meetings. According to the community participation department of the agency, allegedly the “experts” in community work, we needed to target “political” actors (neighborhood councils and borough-level city councils) and “social” actors (residents and business directly lining the corridor). However, the “social diagnostic” they prepared for me was useless, misidentifying the project, containing little more than the Wikipedia sidebar information on each borough, and leaving me with little confidence in their proposed strategy.

Based on this paltry definition of actors, the participation group’s plan for “socialization” of the project included two activities: door-to-door visits along the corridor, and community meetings (scheduled on an ad-hoc basis). Our first behavioral nudge would be the gentle mention of street and sidewalk invasions with an imploring request for “collaboration” in making public space available to *everyone*. But that was completely out of the norm for the community participation group, whose task it was to knock on doors. Instead of allowing me (as the project manager) and the psychologists from the social management group to formulate the approach and train the team, the group’s coordinator rejected any field methodology, instructed his group to listen to him only, and negated the instructions we gave. Tension and animosity grew as the month of “socialization” progressed because the participation group was not meeting their “goals” - a predefined number of community meetings entirely unrelated to the priority projects of the agency. The coordinator instructed field workers to rush through the socialization process, so that they could hurry back to their offices and work on their “goals”. Failure to meet the “goals” (in this case 4000 “community encounters” per year) threatened the wrath of the control entities, regardless of whether the activities completed were of benefit to the communities and the administration’s projects.

We were also confronted with a distinct group of individuals from the participation group every day, as a result of management and contractual problems that were beyond my control. Almost every day someone’s contract ended and a new contract belonging to someone else began. According to a colleague from TransMilenio’s social management group, we needed a team of 30 people for the door-to-door socialization process. Yet, in our agency, all of the employees in community participation group were hired under the independent contracting regime, and at that moment, only seven of the

40-45 employees had active contracts.

Somehow we limped through a month-long door-to-door effort and four meetings with local community action committees. We encountered minimal resistance and even weak support for the project from local groups of senior citizens. The informative tasks seemed to be on track, even if the paint job was running a bit behind. Nothing indicated an impending eruption of social unrest.

The next step in the plan was continuing with more direct “pedagogical” efforts, although to the psychologist in the social management group, labeling any of the actions then undertaken by the SDM as “pedagogical” was a bit of a stretch given their punitive (rather than instructive) tone. Instead of modeling what “good” behavior looked like (in the vein of “civic culture” activities developed by former mayor Antanas Mokus), the cones only shamed people. To be true to what *others* in the agency would label these actions, I will call them “pedagogical.” These activities were intended to shift individual behavior, as well as the general public’s perception of appropriateness, in the administration’s desired direction in a softer manner than an immediate jump to “control” via police. We had already begun raising awareness of infractions during the door-to-door socialization process, albeit in an inconsistent fashion. The following sequence of steps included: 1) highly visible social persuasion via human traffic cones, 2) “pedagogical” traffic tickets²³, and finally 3) “real” traffic tickets.

In the first step, instead of police-issued parking tickets, a team of six people costumed as traffic cones would sing and dance around illegally parked vehicles, creating a public spectacle of the infraction. “*Que la mueva, que la mueva, que la mueva!*”²⁴ Those who complied with the social pressure would be encouragingly cheered on by the cones, but those who, after three calls of the license plate number via megaphone, failed to move their vehicle would be levied a traffic ticket by the police. Although this was the first time the agency would use the cones outside of the city’s wealthiest neighborhoods, there was no foresight that the mocking chants of the cones would engender a violent reaction. In fact, the hunch of my team was quite the opposite. Rather than jumping straight to “control,” which was what the department control and surveillance as well as the Secretary vied for, this sequence would smooth the transition from rampant infractions to adherence to existing traffic laws.

We chose five strategic locations for dispatching the cones - locations with the highest incidence of street invasion via illegally parked vehicles. The cones were to begin in the borough with the lowest density of parked cars and gradually work their way into more hotly contested zones. Days 1-4 of cone action sailed along. Day Five exploded in

²³ “Pedagogical” traffic tickets require recipients to attend traffic behavior courses for a lower fee than a standar traffic ticket.

²⁴ Move it, move it, move it!

our faces.

MANAGING THROUGH PROTEST

PROTEST 1 - FURNITURE MAKERS

The first hour of Day Five of the cones was the tipping point for roughly 300 people to take to Av. Bogotá. In addition to my WhatsApp blowing up, suddenly my office was filled with the directors of citizen services, transport and infrastructure, control and surveillance, and the head of the communications office. It was *my* project, after all. In true SDM fashion, these colleagues shifted all of the blame to me. I had no idea what to do. There was no contingency plan.

The head of the communications office had nothing useful to offer. Her only position was that we were never sending cones to work on my project again. I texted the Secretary. No response. I waited a while, texted again. No advice, just a vague unhelpful comment that he had already spoken with the agency's traffic police coordinator and that "we were not going to permit the blockage of a street just because of a ticket". No help from the top, no lateral help. It was not like I had any experience reacting to street protests.

Another hour passed, and I received a phone call from the director of citizen services demanding that my team show up to a meeting with the protesters that afternoon - just two hours away. What were we going to talk to them about? And who was going to do the talking? IT SHOULD NOT BE ME. "*No tienes que hablar - puedes solamente sentar y escuchar lo que dice la comunidad*" (you do not have to talk - you just have to sit and listen to what the community has to say). Right. As if that were going to work with a group of protesters that it took 15 Metropolitan Police (MEBOG) squads and the riot police²⁵ to calm down. But there was no one else, and so it fell to me.

Given the points that I anticipated hearing about based on our site visits - complaints of the elimination of on-street parking and freight loading - I gathered members of the infrastructure department to accompany me. Later that afternoon we arrived at the scene of the protest and were ushered into a small clearing on the fourth floor of a furniture making factory reeking of paint fumes where roughly 30 people were gathered, sitting on palettes or other makeshift seats. What did they want? Free parking on the street. Freight loading zones directly in front of their storefront. If not, their clients would move elsewhere and their businesses would die. They followed the rules and paid their taxes. Why were we intent on punishing them? Why did we send out costumed adults to make fun of them?

²⁵ EMSAD: the "mobile anti-disturbances squadron".

“*Queremos escuchar la Doctora!*”²⁶ That meant me. As the highest ranking member of the administration in the room, not only were all eyes and video cameras on me, it was up to me to offer some sort of conciliatory remarks. I began by explaining that the agency had conducted a technical study, admitting that it had deficiencies and that we were in the process of remedying them. I introduced my two companions from the SDM: the experts in freight and parking. First the freight engineer launched into an explanation about the rules but was quickly drowned out by the crowd’s comments that freight was not their main concern - parking for clients was. So I turned to the parking expert - someone I barely knew - and asked him to explain the regulations governing parking. After a long and unintelligible list of laws and decrees that regulate parking he explained that the option of “flexibilizing” (“*flexibilizar*”) the national traffic code in order to allow these activities on the project corridor was a legal impossibility, given that it was a *national* level regulation (thus entirely out of our legal jurisdiction). He then listed a series of options that SDM could study in order to provide relief from the enforcement of the “no parking” law on Av. Bogotá: converting neighboring small streets into one-way only to permit parallel parking, eliminating lanes from streets, and creating special parking zones in the neighborhood. Although I was internally panicking about who was going to do these studies, they seemed like our only option to avoid further disturbances. We would somehow find a way to study alternative locations for the conditions the furniture makers perceived as critical to their commercial viability, despite the fact that legally we owed it to no one to make concessions regarding the application of existing parking laws. Making legal alternatives available for them might be the path to reaching a new institutional equilibrium.

Thus began the process of “social management”- a delicate balance of managing perceived rights with real ones in an effort to complete a vision of city development.

During the two weeks following the first protest, the expanded technical team visited the neighborhood and devised “alternative solutions” that we could implement on other streets to meet the demands of the furniture makers. We invited the people who had been present at the first meeting to a workshop, in which they would hold the decision-making power on how to prioritize these measures. The participatory planning exercise designed jointly by the “social management” and technical groups - a new method of interdisciplinary collaboration in the SDM - was not meant for the 100 people that showed up (instead of the 30 we invited). It quickly devolved into a forum where the furniture makers took over. Two contradictory points of “consensus” were reached: 1) *all* of the potential parking zones and all of the potential freight zones should be implemented and 2) we would not be solving their problems until we “flexibilized” the

²⁶ We want to listen to the Doctor! (“Doctor” is often used as a salutation of respect.)

parking laws on Av. Bogotá.

MOTORCYCLE SALES

While the team from the SDM scrambled to develop mitigation measures that would appease the furniture makers and allow the project to move forward, another opposition group burst onto the scene. Upon request of a borough-level city council member, we organized a special project “socialization” meeting for the leaders of motorcycle sales and repair businesses. Like the furniture makers, they claimed that by removing on-street parking, we would destroy their earnings and crush their businesses. Not only was this group allegedly involved in the resale of stolen parts, weapons, and other illicit activities, it was strongly backed by both local and district-level council members. In response to their negative reaction, we held out the same offer we made to the furniture makers - a study of alternatives to meet their demands, including the consideration of their innovative solutions like motorcycle-only parking. Internally, I buffered a fight between the infrastructure branch of the agency that was open to innovative solutions and the signage branch who claimed that something as simple as painting a rectangle with a motorcycle icon in the middle for parking was impossible because it lacked a standard design in the national manual. The law did not permit it, but neither did the law reject it. To my boss and me, that meant “let’s go with it,” but to them, it was a red flag waving in front of the control entities.

With both interest groups, our task beyond the initial meetings was to establish the legitimacy of the administration, as well as that of the project goals. In a dramatic aberration of protocol, the Secretary himself met with leaders of both groups on multiple occasions, listening to their requests and attending to borough and district-level elected legislators. Even at the disagreement of the technical team, he threw in an additional behavioral carrot for both interest groups: the design of a new plaza in their neighborhoods. Detailed explanations of extant laws, site visits by engineers, and colorful satellite maps identifying mitigation measures demonstrated technical legitimacy. The project’s main goal of prioritizing public transport went relatively uncontested, possibly due to the history of planning documents that adopt the same goal. However, both groups responded that the solutions were not worth anything “*no sirve para nada*” because they did not permit parking directly on the project corridor.

These efforts failed to stop further protests. One month after the first protest, the furniture makers shut down not only the project corridor but also Av. Norte-Quito-Sur, a 12-lane urban highway that carries the highest transit passenger demand in the city (52,000 passengers/direction/hour). Our meetings with both interest groups continued. Another month passed and Protest #3 erupted, this time from the combined efforts of both groups. In both instances, colleagues from Secretary of Government and Secretary

of Security, Justice, and Coexistence, rather than from the direction of citizen services (responsible for the gaffed response to the first protest) restored social order on the ground and laid the foundation for future dialog. Another round of “working meetings,” in which the Secretary, this time accompanied by higher-ups from three other branches of the administration, listened to the same round of complaints.

What conclusions did the leaders of the public agencies at the table reach in these meetings? One, the project was not going to be canceled. Two, the laws that governed parking would remain in-tact - we had no power to change them (not to mention that parking on arterial streets was undesirable from a traffic engineering perspective). Three, we would *not* tell the police to stop enforcing the law; however, we would give instructions to extend the period of pedagogical tickets. Four, we would implement the feasible on-street parking and freight loading zones that had been presented in meetings, as well as install temporary signage permitting these actions while the paint projects for these zones were prepared. Five, the SDM would serve as a bridge to other district-level agencies in order to meet the demands of these groups that were out of our legal jurisdiction (e.g. economic development trade fairs, security cameras).

Short of canceling the project and authorizing free on-street parking along Av. Bogotá, there seemed to be little the administration could do to appease these groups. From their perspective, maintaining the current use of the street was a *de facto* right based on decades of little-to-no enforcement of the law. Routine behavior, not formal institutions (i.e. the regulatory pillar), ruled. Even with the best effort to mitigate what they perceived as a taking, the continued threat of social unrest was imminent.

OUR PARTNERS?

Painting the street continued straight through the protests. Given that it was a nighttime activity, blocking implementation would have presented considerable difficulties for opponents. At the same time, TransMilenio’s role in implementation - eliminating one bus stop and adding extra modules to others - unfolded on the street. Standard procedure for this agency (that should have been our partner, given that all of the benefits would accrue to the private sector companies that it contracted for operations) included “socialization” of stop location changes. Although the optimization exercise had been conducted jointly, the agency’s discourse on the street was to blame the SDM for the changes. The preferential bus lane was the SDM’s “fault,” and any complaints over it should be directed to the other agency. Blame throwing at its finest.

PREP FOR OPENING DAY

In the week prior to opening day, we distributed over 25,000 fliers with information about the proper use of the bus lanes, as well as the proposed alternative on-street parking and freight zone locations. Radio advertisements alerted drivers to the

project. The communications office begrudgingly sent the cones back to the “safe” zones of the corridor to continue punishing illegally parked motorists.

But who would imagine that a freshly painted priority bus lane would require a strategic plan of police detail, based on the anticipated level of mobilization risk along the corridor? Two days before opening day, I called a “control” meeting to iron out the last details of the plan. Secretaries of Security and Government, the Metropolitan and Traffic Police, and the commander of the SDM “Guide Group” sat around the table. The intelligence branch of the National Police reported to MEBOG obtaining intelligence indicating that a protest was planned for the day of the event.²⁷ We walked through the previous months of working meetings with protesting groups, given that these would influence police reactions in territory.

The police forces ticked off the list of personnel confirmed for opening day. For the 11 km stretch, we had requested 50 transit police, 80 Metropolitan police, ESMAD (riot guard), and the presence of roughly 100 members of the SDM’s “guide group”²⁸. And then someone at the table ordered tanks. TANKS. Like tanks from Desert Storm. Not to be “used,” but for a “persuasive exercise” that would drive home the fact that this is *real*, that this is an “*exercise of government*.”

OPEN FOR TRANSIT

OPENING DAY

Sunny and sporting free-flowing, eye-popping orange bus lanes, opening day arrived. The entire 11 kilometers were crawling with police, but I could not have been more pleased that the Metropolitan Police had ignored the suggestion of tanks. Buses were running more than smoothly. Not a parked car was in sight. Speeches were made and photos taken. Newspapers published flashy press releases. Finally, the administration had done something to improve the zonal bus service.

For the next three weeks, large police squads issued “pedagogical” traffic tickets to violators. Bus running speeds increased by 12%. To the heads of the administration, it was a rousing success.

²⁷ It turned out that the “intelligence” had been misunderstood between branches of the police. My conversation later in the day with someone from SIPOL - the intelligence branch of the police - indicated that they knew of a desire to protest, but that neither union was aware of the opening date nor had planned a protest specifically for that day.

²⁸ The “guide group” is the jack-of-all-trades subdivision of the Direction of Control and Surveillance. In general, the team is responsible for facilitating traffic detours, clearing out intersections, and being on-call for a variety of similar duties. Often, however, they pick up the slack of the Direction of Citizen Services, handing out fliers, explaining projects to roadway users, and conducting surveys.

WHAT CANNOT BE FOUGHT IN THE STREETS WILL BE FOUGHT IN THE COURTS

Meanwhile, my phone was a non-stop shop for complaints from leaders of the opposing groups. Despite a total of eight meetings with the two groups opposed to the project, two official requests for information (*derechos de petición*) from both groups (four total) arrived at the SDM requesting additional meetings and “real” solutions to their problems. Accusations ranged from not having studied the corridor at all to not completing an economic study and precipitating a drop in revenues that endangered industries already on precarious economic footing. One group accused the agency of violating their constitutional right to work implementing the preferential bus lane and eliminating parking. Denying on-street parking was, in their eyes, the equivalent of an economic taking.

Except that legally - as confirmed by multiple SDM attorneys - it was not. We were simply *choosing* to enforce the decades-old regulatory institution that no prior administration had pinpointed as a target of enforcement. The mismatched constellation of institutions was clear. Not only did enforcing parking rules run against the grain of routine behavior, it also violated the logic of appropriateness (normative institutions) held by the several interest groups along Av. Bogotá.

SIDEWALK REPAIR

As the days following the project opening turned into weeks and respect for both the lane and the adjacent sidewalk space began to deteriorate, my team began investigating whether it might be possible to make improvements to the (non)existing sidewalk infrastructure, so as to encourage better behavior. Instead of eliminating the invasion of public space all-together, efforts to keep the preferential lane clear resulted in a direct shift of the problem from street to sidewalk²⁹. Given the difficulties with continued police presence, the next-best remedy was to make a physical change to the sidewalks that would not only improve them for pedestrians but also make it physically impossible for vehicles to hop the curb. Since maintenance fall under the purview of IDU, another painstaking process of coordination began.

I directly requested help from the sub-director of the agency, who indicated the possibility of using emergency funds to make the necessary repairs. The SDM team prepared a technical analysis, justification for repair, and request for maintenance based on top traffic accident locations and sidewalk invasion hotspots. By the time the *oficio* landed on the desk of a lower-level engineer at IDU, any possibility of repairs was wiped off the table. As he explained to the SDM team, IDU has its own internal logic for determining when public space will be repaired. Data on accidents, street classification,

²⁹ Although traffic police have the authority to penalize vehicles parked on sidewalks, empirical evidence indicates that they focus almost exclusively on street space.

and existing conditions are plugged into an independent algorithm (unknown to the SDM) that is entirely unrelated to the priorities or other projects of the administration. Although the avenue was slated for complete reconstruction, it was not high enough in the priority list. In other words, it made no difference what the plans of the administration included (e.g. the development plan approved by the city council), the results of the algorithm were not to be budged. Using emergency funds was somehow off the table, given plans for the elevated metro line that would soar over Av. Bogotá. (If a sidewalk were repaired and subsequently reconstructed by the metro project before having exhausted its guarantee, the case would be a surefire finding of a “lack of planning” by the administrative oversight agencies.)

MID-TERM RESULTS

After opening day, how did operations fare? Police presence along Av. Bogotá was high for approximately two weeks and moderate for roughly one month. It dropped dramatically after the first month of operation to random, sporadic visits to the corridor, despite formal memos and meetings with the “coordinators” of the police to develop a long-term plan for sanctioning vehicles parked in the bus lane. The agency’s communications office had zero interest in sending the cones back to the corridor, given that the splash in the newspaper had already been made. To the Secretary, it was time to move on to other projects. “Success” had been achieved during the opening day ceremonies. But without enforcement or persuasion of behavioral change, any hope for genuinely shifting norms and behaviors was lost. By November, the situation in the corridor had digressed to its original state of invasion plus orange paint.

The behavior of bus drivers also detracted from a normative shift. Community members consistently complained that bus drivers use all three lanes per direction rather than staying in their own designated lane. We had trained the trainers of the private operating companies, but the message did not trickle down. If the bus drivers did not respect the rules - being the theoretically easiest population for the State to control - why would anyone else?

Coordination both within the SDM and between other agencies also fell flat. Shortly after opening day, the bus lane team received a request from another branch of the agency (which had participated in the technical study) to move a bus stop for safety reasons, something we clearly could not do after just finishing the paint job, given the hawk eyes of the oversight agencies. Despite innumerable hallway meetings with the director of the department responsible for paint and consistent assurances that the work would be complete, as of April 2018 - nine months after the head of the agency committed to these actions - only four points of the 37 committed to local interest groups had been painted. Even worse, the written excuse of the signage group was that we had

not discussed these actions with the community.

Efforts to recovery sidewalk space were similarly limited. SDM-led coordination of the agencies involved in recovery of sidewalk space fell flat following personnel changes beyond my control. Interest dwindled at the top of these agencies, particularly after their recognition was omitted from the ceremonies. Only one of the four boroughs actively developed and pursued a strategy beyond an initial site visit to recover sidewalks.

PRELIMINARY CONCLUSIONS AND IMPLICATIONS

This abbreviated recount of the preferential bus lane project illustrates areas for further exploration and theory building. In it, a seemingly “simple” project mushroomed into one of high organizational and institutional complexity. The initial conditions of “institutional mismatch,” which pitted longstanding regulations against norms and routine behaviors, played out as predicted by Scott in a situation of “confusion and conflict,” manifest by three traffic-paralyzing protests (Scott 2014, 71). An attempt to induce normative and cultural-cognitive institutional change, as well as manage social unrest as a result of this process, catalyzed a dramatic expansion in project scope and the size and composition of the organizational field. Rather than simply filling potholes, painting streets, and writing traffic tickets, the endeavor to foster broad a behavioral shift incorporated everything from offering employment to informal vendors to relocating homeless people, eliminating over-sized signage and painting parking spaces. This State-led effort at realigning the institutional pillars in such a way as to be mutually reinforcing grew a project that initially involved four government agencies to an organizational field of 18 agencies. Through a process of “social management,” project sponsors attempted to trade mitigation measures for behavioral change, but low levels of bureaucratic coordination within and among government agencies stymied regulatory enforcement and the implementation of mitigation measures.

These bureaucratic coordination roadblocks indicate that it may be necessary but not sufficient to rely on “political will,” a powerful executive, and “strong” government agencies - variables often touted as the keys to transportation project success (Ardila Gómez 2004; Kumar, Zimmerman, and Agarwal 2012). Formal organizational structure that promotes the autonomy of entire agencies and their internal branches, combined with individually-levied administrative burden, contributes to atomized (as opposed to coordinated) decision-making. Factors ostensibly unrelated to small-scale infrastructure implementation, such as the public sector employee contracting regime and the pervasive fear of Colombia’s public sector oversight agencies appear to influence bureaucratic coordination, through the loss of institutional memory (high turnover) and blame throwing. Ultimately, coordination (or the lack thereof) within and among branches of

the bureaucracy influences which aspects of projects come to fruition and the process of project implementation.

For project sponsors and planners, this case illustrates the complexity of seemingly simple projects. It suggests that an analysis of the initial constellation of institutions and history of regulatory enforcement is critical during the project shaping phase and may dictate alternative approaches to project implementation and stakeholder engagement that go beyond traditional forums for public participation. Finally, it provides a concrete example of what Sanyal dubs “planning for resistance” *within* the bureaucracy and identifies new variables that hamper bureaucratic coordination. Further exploration of the three primary themes of institutional mismatch, the process of social management, and bureaucratic coordination will rely on this case, as well as experiences from additional projects observed while working for the district, in an attempt to develop richer explanations of the processes of and barriers to implementing “simple” projects³⁰.

³⁰ This paper is a work in progress toward a doctoral dissertation and will be included in whole or in part in the final dissertation and future publications derived from the dissertation.

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CIVIC CROWDFUNDING: ADDRESSING PRINCIPAL-AGENT ISSUES DURING LOCAL INFRASTRUCTURE DELIVERY

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CIVIC CROWDFUNDING: ADDRESSING PRINCIPAL-AGENT ISSUES DURING LOCAL INFRASTRUCTURE DELIVERY

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ABSTRACT

Public service delivery requires principal-agent relationships between local governments and community members. This is exemplified in local infrastructure delivery, where the project's scale and geographic nature results in concentrated impact within a specific community. For "public goods," in which no one is excluded from using the asset and use of the asset does not deplete the asset, the community has ownership of the good as a collective, and must manage the resource allocation collectively. Regardless of community ownership, the community cannot collectively manage the complex process of delivering local infrastructure. Therefore, the community must rely on an agent, commonly the local government, to oversee infrastructure design, construction, and maintenance. But, as with many principal-agent relationships, the local government is not a perfect agent for the community and can misrepresent the community when making decisions during the infrastructure delivery process.

At a time when local governments are struggling to pay for infrastructure construction, operations, and maintenance, tax dollars are being wasted on late changes to design and construction due to principal-agent issues between local governments and community members. During infrastructure delivery, misalignment between the principal's interests and agent's decisions can result in community opposition. Without early, comprehensive and meaningful engagement with the principal (community) to better align the community's interests with government's decisions, projects can fail. Civic crowdfunding, where an individual can donate to specific infrastructure projects (Davies, 2014a), can provide a necessary means for better aligning communities and local governments. The project sponsor, often a local civic organization, leads the civic crowdfunding campaign and acts as a boundary spanning intermediary who aligns the community's interests with the government's interests and constraints. As such, the project sponsor can mitigate many principal-agent issues between local governments and their communities.

KEYWORDS

Civic crowdfunding, local infrastructure delivery, principal-agent.

CAPACITY BUILDING FOR LOCAL INFRASTRUCTURE DELIVERY

Boulder, Colorado was once lauded as one of the most progressive cities for bicycle infrastructure in the United States. As part of the city's plan to increase bicycle facilities, a protected bicycle lane was constructed on Folsom Street in 2014. Only 11

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weeks after the protected bicycle lane was constructed, extreme opposition from community members forced the local government to remove the project. Despite transport and safety improvements along the Folsom Street corridor, community members argued that the project was a disaster. Letters to the city council cited insufficient stakeholder engagement with businesses and community members as one of the main reasons the project was poorly designed. This project might have been an anomaly in a bicycle-friendly city like Boulder, but three other cities (within the same year) also removed their protected bicycle lanes for similar community opposition reasons.

While bicycle infrastructure is only a small fraction of total dollars spent on infrastructure, the Boulder case highlights the relationship between local governments (a primary stakeholder in infrastructure delivery) and their constituents *and* it presents an example of late-stage stakeholder opposition that commonly arises in infrastructure projects. At a time when local governments are struggling to pay for infrastructure construction, operations, and maintenance, tax dollars are being wasted on late changes to design and construction due to emergent community opposition. We assert that new, participatory technologies that bring together crowdsourcing science and online payment capabilities can address the principal-agent issues that arise when local governments fail to represent the needs and interests of their constituents accurately. Because, even as infrastructure development becomes more efficient and safer due to better design and technical expertise, public opinion (and its unpredictability) is a factor that continues to impact project success.

One such participatory technology is civic crowdfunding. It allows individuals who are impacted by or benefit from a project to contribute financially to the project in question. Even though crowdfunding bridges social and financial support for a specific project, civic crowdfunding campaigns do not contribute significantly to funding city infrastructure. In recent years, crowdfunding campaigns for local infrastructure projects can represent anywhere between 2% (with donation-based crowdfunding) to 50% (with equity and debt-based crowdfunding) of the project costs. However, crowdfunding can serve as an important source of community validation for a project, and thereby result in the creation of a boundary spanning intermediary to represent citizens' voices in subsequent project decisions. In the case of crowdfunding infrastructure projects, this intermediary is the "project sponsor", often a civic organization who understands the community and will launch the crowdfunding campaign.

This paper explores the theoretical underpinnings of using civic crowdfunding (primarily donation-based crowdfunding for infrastructure projects) to repair broken principal-agent relationships between local governments and their communities. The first section of this paper reveals principal-agent issues in relationship to local infrastructure delivery by drawing on theory from public administration and project management literature. The next section discusses the ways in which civic crowdfunding can repair different parts of a broken principal-agent relationship. The last section shines a light on the limitations of civic crowdfunding in addressing principal-agent issues and outlines future research to complement this analysis.

PRINCIPAL-AGENT RELATIONSHIPS BETWEEN COMMUNITIES AND LOCAL GOVERNMENT

As seen in the Boulder, Colorado case, there was misalignment between the community's interests and the local government's design and installation of an infrastructure asset. Without early, comprehensive, and meaningful engagement with the community to better align the community's interests and the government's design, the project failed. Understanding this case requires a deeper analysis of the relationship and expectations between the local government and the community. Past researchers have created theories about the role of government in providing public services to a community. Frederickson's theory of the public suggests that there are five imperfect ways to look at the relationship between government and the public (Frederickson, 1991).

1. The Pluralist Perspective: This perspective explores the possibility of the public as one interest group, based on the idea of pluralism.
2. The Public Choice Perspective: This perspective treats the public as a consumer, taking a utilitarian perspective. In this case, individuals pursue their own self-interests and do not think about the greater good at times.
3. The Legislative Perspective: This perspective views the government as representative of the public, enabled by interest groups and voting outcomes. Although it is necessary to view the public in this way, there are some issues with this because interest groups and outcomes do not properly represent the entire community.
4. The Cliental Perspective: This perspective acknowledges the public as a group of clients to whom bureaucrats respond via public services.
5. The Citizenship Perspective: This perspective considers the public as a citizen public where the public is characterized with strong citizenry participation in policy and administration.

In the case of Boulder, Colorado and in the context of local public goods (including infrastructure) delivery, some of these theories are more applicable than others. Because local governments have a relatively small constituent base, we consider the third perspective to be the most relevant. As a representative government, government officials make decisions that attempt to reflect the wants and needs of the public. In the Boulder case, the inability of the government to adequately represent the wants and needs of all constituents of "the public" resulted in a failed project.

PRINCIPAL-AGENT RELATIONSHIPS IN INFRASTRUCTURE DELIVERY

Considering the representative government's perspective, we can see how the relationship between the government and the community is a principal-agent relationship. In other contexts, principal-agent relationships highlight the dependent nature of one stakeholder on another. For example, a shareholder depends upon the business' management to maximize the value of their holdings. And, a community member relies on their local government officials to allocate their tax dollars towards infrastructure and other programs that will improve their quality of life. In both of these cases, there are reciprocal actions that hold agents (management and government, respectively) responsible to represent their principal's interests. If business management performs poorly and shareholders lose value, the management can be replaced. Similarly, citizens are able to vote an elected official out of office if

the individual does not serve the best interests of the community. In each of these cases, the principal owns capital assets while the agent manages day-to-day responsibilities of the asset (Mayston, 1993). In many ways, we encounter principal-agent relationships in our daily lives. Principal-agent relationships are common because many assets we own and services we require cannot be provided or carried out by ourselves or by any one individual. Instead, principal-agent relationships exist to address “tasks that are too complicated or costly to do oneself” (Sappington, 1991).

The principal-agent relationship is a powerful and necessary part of life because agents have strengths and skills that make them more adept at producing or managing assets. At the same time, the principal lacks the necessary knowledge and perspective to oversee the asset in a beneficial way. In a perfect relationship, the principal and agent have equal access to information, share risks, have sole responsibility to their respective principal or agent counterparts, and have aligned priorities. Additionally, the agent is bound by a contract and can be publicly observed, and the principal is not distracted by other agents and the agent is not derailed by other principals (Guesnerie & Laffont, 1984; Mayston, 1993; Sappington, 1991). But, as we will see in the case of local government and infrastructure delivery, the local government is not set-up to have a perfect principal-agent relationship with their principal, the community.

Local infrastructure delivery is one such task that requires a strong principal-agent relationship between the community and local government. Public goods, in which no one is excluded from using the asset and use of the asset does not deplete the asset, are owned by the community as a collective, in the sense that tax dollars pay for the asset construction and maintenance and the community must collectively manage the resource allocation (Ostrom & Ostrom, 1977). In this case, the community is the principal. Similar to other principal-agent relationships, the community lacks the knowledge and decision-making power to manage infrastructure delivery. Decisions to construct, maintain, and operate infrastructure assets require substantial amounts of financial capital, complex stakeholder engagement, and technical expertise. No single community member can pay for, design, construct, and operate/maintain an infrastructure asset. Moreover, coordination of the entire community without a structured organization is too expensive as an undertaking. Hence, the government acts as the agent in these decisions and represents the community’s interests during the infrastructure delivery process. Similarly, because the government must rely upon more knowledgeable stakeholders, such as designers and constructors, to provide the infrastructure asset effectively, the government is also party to other principal-agent relationships. In traditional infrastructure delivery, the stakeholder network (as it evolves during the planning, design, and construction phases) is comprised of multiple principal-agent relationships (Ceric, 2013). But, at the end of the process, the government still maintains the overriding responsibility to operate and maintain the infrastructure asset for the community well.

PRINCIPAL-AGENT ISSUES

In general, principal-agent relationships are vulnerable to a variety of challenges, including information asymmetries, limited commitment from both parties, divergent interests, and inability or high costs to observe and measure an agent’s performance (Ceric, 2013; Jensen, 2000; Mayston, 1993; Sappington, 1991). But, governments are inherently different from their private sector counterparts because they are subjected

to a principal-agent relationship with constituents. Therefore, governments in democratic societies are increasingly subjected to public visibility and accountability, not just administrative and legal accountability, to uphold their commitments as agents (Bovens, 2005). In the case of local governments, and especially with the representative government framework, it is difficult to enforce a perfect principal-agent relationship because:

- Agents do not feel a strong tie to the principal (the community) because not everyone votes and the government creates new principal-agent relationships with other interest groups (Kalt & Zupan, 1990; Kein, 1988; Papadopoulos, 2007),
- Agents do not sign a formal contract with principals (Kalt & Zupan, 1990),
- Agents do not need to compete with other agents on a regular basis, and therefore the principal has limited agent options (Kalt & Zupan, 1990),
- Agents do not operate in a transparent environment (Leruth, 2012; Papadopoulos, 2007), although this is changing quickly in government as services like OpenGov.com become more pervasive; and,
- Agents participate in a multilevel environment that further decreases transparency (Papadopoulos, 2007).

Emerging trends in the last few decades have intensified these principal-agent challenges for provision of infrastructure services. In the 1990s, decentralization trends shifted more responsibilities and power to local governments (Oates, 1999). Unlike their federal counterparts, local governments often lacked the technical know-how and resources for delivering successful infrastructure assets and operating infrastructure services. As a result, project stakeholder networks expanded beyond governmental agencies and communities to include private sector providers that have technical expertise and financial capacity (Alm, 2015). Understanding the limitations of local government, the United States government passed the Federal Acquisitions Reform Act in 1996. This policy allowed local governments and government agencies to extend decision-making power to the private sector through innovative contracting practices (Ghavamifar & Touran, 2008), creating new principal-agent relationships.

As the stakeholder network expands (introducing new principal-agent relationships), the principal-agent relationship between the government and community becomes further diluted, especially as the government has to act as an agent to multiple principals (Posner, 2004). Additionally, when more stakeholders are contractually bound to the project, benefit from information circulation and pursue their own priorities, the original principal(s) becomes vulnerable (Leruth, 2012). This trend has exacerbated other issues such as the diffusion of administrative action, multiplication of administrative partners, and proliferation of political influence outside of governance circles (Kettl, 2010) that prevents local governments from acting in the community's best interests (Pratchett, 2004).

The consequences of poor principal-agent relationships in infrastructure delivery are reflected in growing community opposition to new development, inequitable service provision, and unjust tariff increases (Forrer, Kee, Newcomer, & Boyer, 2010; Ortiz & Buxbaum, 2008). These cases of community opposition occur when the community, as the principal, realizes that local government, as its agent, has not acted in the community's best interest. Moreover, community members cannot pay for the monitoring costs to ensure the government's actions are aligned with their priorities.

Thus, the community members are only able to evaluate the status of the principal-agent relationship and engage effectively as principals when an outcome occurs (the project is constructed) (G. J. Miller, 2005) or begins operation. As it turned out in the Boulder, Colorado case, some powerful community members discovered, only once the project was constructed, that the agent had not behaved in their best interest. If these community members had been able to monitor the local government more effectively during the infrastructure delivery process (primarily during design), then it might have been possible to mitigate future opposition.

REPAIRING PRINCIPAL-AGENT ISSUES

There is high potential for community opposition when an agent does not act in the best interest of powerful community members' (as seen in the Boulder case). But, the principal-agent issues between the government and community, as well as the principal-agent issues between different stakeholders during infrastructure delivery, are not novel. Academics have long proposed, developed and/or assessed a variety of strategies to resolve principal-agent issues. The following is a list of strategies to help repair weak principal-agent relationships:

- Agent implements participatory tools such as public participation, collaborative governance, and deliberative democracy (Koliba, Zia, & Mills, 2011; Posner, 2004),
- Agent is selected using a third party to ensure hierarchical accountability (Forrer et al., 2010; Posner, 2004),
- Agent is subject to administrative oversight with technical standards and both informal and formal oversight (Forrer et al., 2010; Koliba et al., 2011; Posner, 2004; Turner & Müller, 2004), and
- Agent's actions are tracked and measured against previously established metrics (Posner, 2004; Turner & Müller, 2004).

The principal in the case of infrastructure delivery is comprised of many individuals with only partially aligned interests. It is thus difficult for the principal to implement these tools collectively to strengthen the principal-agent relationship. The most comprehensive solution would be for a better aligned party to implement these tools and act in the principal's best interest. This occurs in other industries. For example, within the financial industry, the principal (an investor) selects a fund manager that will monitor the agent (the business) and advise the principal in making investment or divestment decisions. In doing so, the fund manager (who is acting as a better aligned, and often more capable, representative of the principal) signals to the agent that they must implement changes to maintain or grow their return on investment, subject to their risk preference and other goals. With new technology and a trend toward re-intermediation of principal-agent relationships, there is a new tool that can be used to mitigate principal-agent issues by bundling multiple previously cited resolution tools.

CIVIC CROWDFUNDING AS A WAY OF REPAIRING PRINCIPAL-AGENT ISSUES

Civic crowdfunding, made popular by recent trends, capitalizes on new trends in participatory technology to improve principal-agent issues in public infrastructure delivery. A project sponsor identifies a project that the community needs, which has

been determined through previous community planning events, ongoing public participation and observation, and tactical urbanism instances where community members make temporary changes to the build environment to gauge interest and make quick design changes. In past cases of civic crowdfunding, the identified project has been small and geographic in scope, impacting one particular community. Protected bicycle lanes, community centers, neighborhood gardens, renovated parks, and local sanitation systems have been crowdfunded via platforms that cater to civic infrastructure projects. During the early design phases, the project sponsor launches a crowdfunding campaign. At its most basic level, civic crowdfunding allows individuals to contribute to or invest in specific projects. More broadly, civic crowdfunding can democratize the infrastructure delivery process and allow individuals to have more agency in deciding which projects they prefer. If the campaign reaches its target funding/investment goal, the project moves forward.

After a successful crowdfunding campaign, the project sponsor manages the community's investment and acts as the aligned and capable agent for the community. The principal-agent relationship between the community and the project sponsor spurs another principal-agent relationship between the project sponsor and the local government. The local government is the project sponsor's agent and delivers the infrastructure project. In both relationships, the project sponsor is able to better maintain these relationships because of its unique offerings. In regards to the community, the project sponsor dedicates time to disseminating project information, contacting potential investors, and creating the system, process, and tools for the civic crowdfunding campaign. As the conduit between the local government and the community, the project sponsor provides information to both parties and engages the community throughout the delivery process. In this position, the project sponsor is a boundary spanning intermediary.

A boundary spanning intermediary connects two entities that would otherwise not interact with each other (Aldrich & Herker, 1977; Fleming & Waguespack, 2007; Tushman & Scanlan, 1981). This role captures two primary responsibilities: information processing and representation. Unlike brokers who provide information in one direction (primarily, giving information), boundary spanners engage with multiple networks in two directions (giving and receiving information) to exchange knowledge and mediate interactions (Long, Cunningham, & Braithwaite, 2013). Successful boundary spanners are well connected internally and externally to build capacity through information pooling, introduce incentives by establishing shared norms, and provide accountability through grassroots participation (Sturm, 2010). The project sponsor through leading the crowdfunding campaign takes on the role as a boundary spanning intermediary, acting as a better agent for the community and becoming the principal for the local government during the infrastructure delivery process. The following table summarizes the principal-agent issues, tools, and how the application of civic crowdfunding and the presence of a boundary spanning intermediary can help remedy these issues.

Issues	Solutions	Civic Crowdfunding	Section
Agents do not feel a strong tie to the principal (the community) because not everyone votes and the government creates new principal-agent relationships with interest groups (Kalt & Zupan, 1990; Kein, 1988; Papadopoulos, 2007)	Agent implements participatory tools such as public participation, collaborative governance, and deliberative democracy (Koliba et al., 2011; Posner, 2004)	Community selects projects and can communicate their preferences via the project sponsor	Project Sponsor Understands the Principal's Preferences
Agents do not sign a formal contract with principals (Kalt & Zupan, 1990)		Financial donations increase the expectation the project will be delivered and gives stronger voice to the crowdfunders through an aligned and capable representative of their interests in the project	Project Sponsor Meets the Principal's Expectation
Agents do not operate in a transparent environment (Leruth, 2012; Papadopoulos, 2007)	Agent's actions are tracked and measured against previously established metrics (Posner, 2004; Turner & Müller, 2004)	Project sponsor must provide a clear description of the project requirements and constraints (including scope, timeline, service levels)	Project Sponsor Communicates Project Outcomes
Agents participate in a multilevel environment that further decreases transparency (Papadopoulos, 2007)	Agent is subject to administrative oversight with technical standards and both informal and formal oversight (Ferrer et al., 2010; Koliba et al., 2011; Posner, 2004; Turner & Müller, 2004)	Project sponsor acts as a stronger and more capable stakeholder during project delivery and has access to more information.	Project Sponsor is More Transparent
Agents do not need to compete	Agent is selected using a third	Project sponsor is typically a civic	Project Sponsor Remains

<p>with other agents on a regular basis, and therefore the principal has limited agent options (Kalt & Zupan, 1990)</p>	<p>party to ensure hierarchical accountability (Forrer et al., 2010; Posner, 2004)</p>	<p>organization that has aligned interests and doesn't need competition from other agents</p>	<p>Focused on the Project</p>
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PROJECT SPONSOR UNDERSTANDS THE PRINCIPAL’S PREFERENCES

Traditionally, government has used relationships with interest groups to access information about the community for a specific project. Even though this type of participation strengthens principal-agent relationships between government and interest groups, interest groups rarely represent the priorities of the entire community (Forester, 2006). In the presence of civic crowdfunding, the project sponsor focuses on one issue and the constituent group who will benefit from and/or be impacted by the project in question (Grossman, 2012). With local infrastructure projects, identifying this constituent group and working with them is facilitated by the project’s relatively small geographic footprint. And, often times the project sponsor has a deeper understanding of all stakeholders within the impacted community because of their relationships with neighborhood associations, grassroots leadership, and business groups prior to the crowdfunding process (Charbit & Desmoulins, 2017). Hence, the project sponsor relies heavily upon public participation, collaborative governance, and deliberative democracy to further understand the community’s needs and engage them during the project planning phase and civic crowdfunding processes.

At a basic level, public participation is vital for involving users and community members in decision making processes and knowledge exchange. Local knowledge is defined as the privately-held knowledge and shared expertise that transfers only through networks of interactions (Malecki, 2000). As a boundary spanning intermediary, the project sponsor has internal access to local knowledge that can better inform the decision making process for infrastructure. When a local government holds mandated public meetings to review project details and construction plans, there is often times a lack of sincere public participation and excluded community groups (Hou & Kinoshita, 2007). Without involving users and community members in decision making processes, the local government can make poor project decisions that result in community opposition. In traditional project delivery, local governments often lack the capacity and resources to achieve all the benefits of public participation by implementing strategies that are legitimate, representative, and transparent (Hillier, 1998).

In the case of civic crowdfunding, public participation processes are not confined to mandated public meetings. Informal public participation, conducted outside of public meetings, can yield more genuine engagement experiences for both community members and the project owner. Because civic crowdfunding is able to take advantage of social networks, there is more potential for a civic crowdfunding campaign to utilize informal strategies to connect individuals towards a common goal using “shared meanings and common heuristics [to] guide their actions” (Booher & Innes, 2002). First, strong relationships between the project sponsor and the community are developed over years of community planning sessions and strengthened in project planning/conceptual design phases when the community is consulted to varying degrees about the project. Second, the process of asking for donations to a project can be very personal. The individual “ask” provides a platform for project sponsors to engage genuinely with community members about the project and seek their continued feedback on the project design and construction plans. In pursuing informal and formal public participation strategies, the project sponsor is better able to understand the principal’s preferences.

PROJECT SPONSOR MEETS THE PRINCIPAL’S EXPECTATION

The representative government perspective reflects political accountability systems that ensure local governments deliver on the promises that they make. Accountability as “a relationship between an actor and a forum in which the actor has an obligation to explain and to justify his or her conduct, the forum can pose question and pose judgement, and the actor may face consequences” (Bovens, 2006). This can be a strong feedback loop for public service delivery. When political accountability falters, constituents can vote elected officials out of office; or, in regards to local infrastructure delivery, communities can oppose the construction of the project, delay or obstruct it and thereby damage an official’s reputation. But, using civic crowdfunding can create more mechanisms, both informal and formal, for accountability that can substitute for weak political accountability.

We have explored how informal mechanisms can help when formal public participation is insufficient. Likewise, informal mechanisms can create another avenue by which local government is held accountable for its actions. For example, a project sponsor, in engaging the community and seeking financial contributions, creates a group of constituents that are interested in a similar goal. This group can be referred to as a solidary group. It is both encompassing and embedded and able to hold project sponsors accountable for delivering the project (Tsai, 2007). The encompassing component allows any person that is interested in the project or will be impacted by the project to join, regardless of the size or presence of a financial contribution. The embedded component reflects the group’s eagerness and capacity to involve the local government stakeholders within the group. The embeddedness feature is important because of the need for the project sponsor to coordinate with local government during infrastructure delivery. Together, these components, allow the solidary group (because the members share a common interest) to impose moral standings on those that oppose the project, especially local government.

Civic crowdfunding not only provides an informal mechanism for putting pressure on stakeholders opposed to infrastructure delivery, civic crowdfunding also provides formal accountability mechanisms for the project sponsor. One mechanism is the presence of financial contributions and the crowdfunders’ ability to influence the project sponsor. The project sponsor becomes more powerful as more community members contribute towards the crowdfunding campaign. From the project sponsor’s perspective, lack of crowdfunders and donations can result in the project sponsor losing leverage to influence local government and deliver the project. Therefore, the project sponsor attracts more crowdfunders by appealing to the community’s preferences. By funding a project, each crowdfunder has the expectation that the proposed project will be delivered. Further, if the project is not carried out as initially presented, there are grounds for the crowdfunders to bring their concerns to the project sponsor and sway public opinion in a negative way for the project sponsor and the civic crowdfunding investment process.

PROJECT SPONSOR COMMUNICATES PROJECT OUTCOMES

There are several issues when we look at how the community (principal) is able to track the local government’s (agent) decisions to carry forward a design that meets the community’s needs, a budget that responsibly uses tax payer dollars, and a schedule that is cognizant of community norms (when is school in session, during

what times does construction noise and traffic need to cease, etc.). The scope of the project, once shown to the community within a public meeting setting might never be shown to the community again. The budget has very little transparency and may never be shared with the community, although it might be reflected in publically accessible financial documents. And, while the schedule has the most transparency because construction activities can affect traffic patterns and the local environment, the community must rely on public relations specialists to get accurate information about schedule updates. While traditional projects offer limited transparency, civic crowdfunding has the potential to increase transparency for projects because of the knowledge exchange that occurs during the crowdfunding campaign and the infrastructure set-up during the crowdfunding campaign to communicate information. Making sure project information is communicated in an accurate, accessible, and timely manner is not only critical for maintaining relationships between the project sponsor and crowdfunders, it is a critical part of raising money for the project (Miglietta, Parisi, Pessione, & Servato, 2013).

First, the project sponsor must advertise the project in an accessible format that allows the community to understand the project details. While this occurs primarily in one-on-one interactions, the project information is also displayed on the online crowdfunding platform where interested community members can donate financially to the project. The crowdfunding campaign page on the platform will often times include the project budget, scope, and schedule, including what the campaign dollars will be going towards. In providing these details, the platform goes through a round of verification, certifying that the project budget aligns with what is being asked of potential crowdfunders and has obtained the necessary approvals to be implemented. As such, the project sponsor is able to use this knowledge exchange to communicate the project goals and objectives to a much higher degree than a typical public announcement. These early lines of communication (especially communication that is open, trustworthy, cooperative, and respectful regardless of the content or recipient) can lead to a greater chance of project success (Olander & Landin, 2005).

The civic crowdfunding process does not only establish a communication infrastructure between project sponsor and community. The process also requires the project sponsor to solidify the project details and communicate project objectives with a level of credibility to attract interested community members. The amount of detail and project metrics communicated online and in person should provide enough detail to convince interested community members that the project will be beneficial to the community. With this information, community members can choose to be community investors and approve of the project by contributing money. By opening up these lines of communication prior to infrastructure delivery and informing community members about project details, there is less potential for community members to oppose the project when construction begins because they are knowledgeable about the project's timeline and scope (Dainty, Moore, & Murray, 2007). The project sponsor, as a boundary spanning intermediary, is able to collect and market project information in a way that allows the community to hold the project sponsor accountable for the project budget, scope, and schedule.

PROJECT SPONSOR IS MORE TRANSPARENT

The project sponsor, as a boundary spanning intermediary, is better at communicating project outcomes at the beginning of a project *and* using the established communication infrastructure to be more transparent during project delivery. During traditional project delivery, local governments often suffer from bureaucratic procedures that can prevent transparency with constituents. Bureaucracy, including budgetary powers, elected official oversight, and influence from interest groups, give the government and its agencies the power to act. But, at the same time, bureaucracy can unnecessarily and negatively influence project decisions thereby deviating from community planned infrastructure solutions. Informal and formal oversight can track local government's project related decisions; but, this oversight is often times very costly. In civic crowdfunding, the project sponsor serves as a representative for the government and can, at times, replace the government's role in making key decisions and overseeing the delivery of the project in question (Aldrich & Herker, 1977). Yet, unlike the government agency, the project sponsor is more transparent because they are less bureaucratic and have established communication conduits during the crowdfunding campaign increasing the community's satisfaction (Leung, Ng, & Cheung, 2004).

Because the project sponsor has established lines of communication via in-person conversations and an online presence during the civic crowdfunding process, it is easier for the project sponsor to maintain communication and make project decision-making more transparent (Miglietta et al., 2013). And, in cases where the project sponsor is local to the community, the community can interact with the project sponsor on a frequent basis. As such, the project sponsor becomes a key point of contact for community investors during the project delivery process. At the same time, the project sponsor is able to influence project decisions because they provide resources for a specific project, have access to local knowledge, and are the perceived representative of all community investors (Friedman & Miles, 2002). As the boundary spanning intermediary between the community and other project stakeholders during the decision making process, the project sponsor can operate transparently.

On one hand, the project sponsor is best situated to collect project specific information, mediate resources from other project stakeholders, and distill project information for community members (Pajunen, 2006). In coordinating with other project stakeholders, particularly government entities, the project sponsor screens information and reorganizes it in a way that is manageable for community members to understand. In these cases, the project sponsor, while communicating through the civic crowdfunding platform, acts as an infomediary (Latham, 2003). On the other hand, the project sponsor is also situated to aggregate local knowledge for design and construction decision making. As a boundary spanning intermediary, the project sponsor is able to use their position to vocalize community concerns in support or opposition to project elements which strengthens the ability for the project sponsor to act on behalf of the community in a more efficient way (Miglietta et al., 2013).

PROJECT SPONSOR REMAINS FOCUSED ON THE PROJECT

The project sponsor's commitment, as shown through their management of the civic crowdfunding process, provides the basis for a boundary spanning intermediary. In

the case of traditional infrastructure delivery, which requires a level of technical knowledge and high resource aggregation, government agencies cannot always allocate personnel exclusively to oversee a project from planning through maintenance. Therefore, the government personnel may be acting as agents for multiple principals and projects. With civic crowdfunding, the project sponsor, often times a civic organization with roots within the community, takes on the project because of the history and dedicates resources exclusively to champion a project from planning through maintenance. This ensures enough attention is paid towards project details. Because the project sponsor is responsible for funding and marketing the project, they have even more incentive to make sure the project is completed successfully.

Despite the lack of competition for the project sponsor role, the organization that takes on this role has a lot of responsibility (and therefore risk) for delivering the project. As such, the project sponsor is a project champion and can wield “strong influence on the evolution of projects” (R. Miller & Olleros, 2000). As the project champion, the project sponsor is public facing and interacts with media and politicians to ensure that public opinion is reflected in decision-making processes (Olander & Landin, 2005). The project sponsor works closely with community prior to and during the crowdfunding campaign so that they can rely on and leverage the community’s knowledge during interactions with external stakeholders. This proves to be an important part of the crowdfunding process. Even though crowdfunding campaigns do not fund the entirety of a project, the money and support coming through a crowdfunding campaign sends a strong signal to other funders, such as foundations, local businesses, and even the local government. Attracting and managing these other funding sources ensures that the project sponsor stays focused on the project goals and aligned with the community’s ideals. This alignment is maintained even as more funders join the project because the outside funders are interested in supporting the community’s vision, not changing it. And, the project sponsor, as a civic organization with strong roots in the community, is dedicated to seeing the community’s vision realized.

POTENTIAL HAZARDS OF CIVIC CROWDFUNDING

Based on theory, civic crowdfunding and the presence of a project sponsor has the potential to change principal-agent relationships during infrastructure delivery. The premise of civic crowdfunding allows the principal to have a stronger voice during infrastructure delivery as facilitated by the presence of a boundary spanning intermediary, as an agent for the community and a principal for local government. While in theory, this may be true, the ability for civic crowdfunding to repair principal-agent relationships is heavily dependent upon the project sponsor’s use of meaningful public participation strategies prior to, during, and after a civic crowdfunding campaign. In doing so, the project sponsor can more accurately identify, engage with, and understand the community and the community’s needs.

One such hazard of civic crowdfunding is how the project sponsor identifies the community (Charbit & Desmoulins, 2017; Davies, 2014b). While it is relatively easy to identify impacted community members for local infrastructure projects, the goal of civic crowdfunding is not strictly to engage the community in a more meaningful way. Instead, the funding component can shift the project sponsor’s attention towards

community members who are financially resourced. Or, the project sponsor may seek a larger population of crowdfunders who reside beyond the project's radius of impact to reach the crowdfunding goal. While these crowdfunders may indirectly benefit from or be impacted by the project, they might not represent the views of the community members who directly benefit from or are impacted by the project. This can then weaken the principal-agent relationship between the project sponsor and the community because the agent does not have a strong tie with the principal and isn't able to accurately reflect the principal's needs (Kalt & Zupan, 1990; Kein, 1988; Papadopoulos, 2007). The project sponsor can circumvent this problem by increasing local engagement with the principal (community members who benefit from or are impacted by the project) during the project selection, initiation, and design phases. This helps the project sponsor build the crowdfunding campaign around a project approved by the principal, instead of building a campaign around a geographically located set of crowdfunders.

One of the main benefits of civic crowdfunding is the continued communication and engagement that occurs between the project sponsor and crowdfunders throughout project delivery and operations. In cases in which the project is prolonged, the project sponsor might change as individuals leave their roles and new people are hired into the project sponsor role. With these personnel changes, ties between the project sponsor and principal might fray, especially if informal engagement strategies were used to build trust with community members (Charbit & Desmoulin, 2017). If the new project sponsor is unable to maintain the principal-agent relationship, it will become more difficult for the project sponsor to accurately reflect the principal's needs, communicate changes, and seek input. Together, these failings might jeopardize the project (Leruth, 2012; Papadopoulos, 2007). This can be prevented from occurring by having a smooth transition between project sponsor personnel and using formal (as well as informal) engagement strategies that provide consistent opportunities for community members to interact with the project sponsor.

Local infrastructure projects are traditionally paid for and managed by the local government because these projects result in public goods. Civic crowdfunding has often been cited as a privatization of public goods that can replace public funding. Instead, we argue that civic crowdfunding requires government support and most of the project's funding (Brabham, 2017). Regardless of the use of crowdfunding, the government still needs to be involved to ensure that the project does not conflict with existing or planned infrastructure assets, the land for the project can be easily acquired, and the right permits are approved for the project. Local government involvement provides oversight and technical standards to facilitate project delivery (Forrer et al., 2010; Koliba et al., 2011; Posner, 2004; Turner & Müller, 2004). Because of the grassroots nature of civic crowdfunding, and the project sponsor's initiative in planning and funding the project, there is a chance that local government is not involved early enough during the project delivery phase to ensure that the project sponsor understands the limitations and constraints of the government with respect to the given project, and thus promotes unrealistic expectations for the project. Without early partnership between the project sponsor and local government, the project may go awry. If this occurs, the project sponsor, as the boundary spanning intermediary, will not be able to work effectively on behalf of the principal. Therefore,

the project sponsor should build relationships with local government prior to and during the civic crowdfunding campaign.

PROPOSITIONS FOR FUTURE CIVIC CROWDFUNDING RESEARCH

This research makes several claims about the role of civic crowdfunding in resolving principal-agent issues between the government and communities by involving a project sponsor during infrastructure delivery. We have written this paper as an introduction to the idea of using civic crowdfunding and alerting interested parties to potential hazards. The benefits and advantages of using civic crowdfunding for infrastructure delivery can be boiled down to these four propositions about the boundary spanning intermediary:

1. Eliminating knowledge asymmetries can improve project decisions, and project sponsors have more intimate access to local knowledge,
2. Project sponsors can champion the delivery of a project,
3. Project sponsors are held more accountable to communities than governments, because of expectations that come with a financial contribution, and
4. Project sponsors are in a position to communicate more project details to community members and to communicate impacted community members concerns to governments throughout a project's lifecycle.

This paper brings together a diverse set of literatures to explore the implications of civic crowdfunding in resolving principal-agent issues. The future of this research should seek to understand how civic crowdfunding, and more specifically the project sponsor, shifts the relationship between governments and communities during infrastructure delivery. The propositions set forth in this paper can be used as a foundation for case studies and deep qualitative studies on individual projects that use civic crowdfunding. Forthcoming research will use case studies of crowdfunded and traditionally funded projects to test these propositions and introduce considerations and implications for civic crowdfunding for local infrastructure delivery.

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ROTATING LEADERSHIP TO BUILD RELATIONAL CAPITAL AND ENHANCE COLLABORATION IN PROJECT ALLIANCING

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Rotating Leadership to Build Relational Capital and Enhance collaboration in project alliancing

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ABSTRACT

Project alliancing has been extensively used to stimulate collaborative relations between different participants as well as improve the project performance in the construction industry. Scholars have identified that the leadership roles in such context are distributed and rotated among multiple project team members rather than embodied by a single person/partner. Employing shared leadership in alliancing context provides more chances for the alliance partners to engage in positive social exchanges and interaction with each other, thus enhancing the relational capital – mutual trust, reciprocal commitment and information exchange, as well as promoting the interorganizational collaboration. However, shared leadership and relational capital evolve over time as the alliances develop. To test the dynamic development of shared leadership and relational capital, a longitude cross-case study consist of two highway alliance projects is to be conducted. The data collection and interview will be conducted in three stages through the middle-later project alliancing life cycle. The overarching aim of this paper is to move discussion from the traditional centralized leadership from specific project participant to the dynamic shared leadership in project alliancing. This will help both researchers and industry practitioners to adequately advance alliance collaboration.

KEYWORDS

Project alliancing, shared leadership, relational capital, interorganizational collaboration

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INTRODUCTION

Nowadays, alliances have been increasingly applied across the construction industries (Lu & Yan, 2007), the engineering industries (Huo et al., 2014) and the high-tech industry (Lee, 2010). A strategic alliance is a voluntary arrangement in exchanging or sharing resources between two or more independent organization entities (Lahiri & Narayanan, 2013). Project alliancing is a project delivery strategy where owner and non-owner participants are allied in sound trust, acting with integrity and achieving consensus, managing all risks of project delivery jointly, and sharing outcomes (Ross, 2003). Alliancing driven by different construction organizations intends to achieve ideal short or long-term goals that would not be attainable as entities working independently. Thus, the leadership roles are distributed and shifted among multiple representatives from different organizations rather than embodied by a single partner in project alliancing, and the rotating of leadership responsibilities lies in which participants' expertise is most relevant and crucial to the project.

According to Ralf Müller (2018), distributed leadership emerged while project team members contribute their views and communicate with each other in a project context. A related concept of distributed leadership which is most prominent is shared leadership. Shared leadership is defined as “an emergent team property that results from the distribution of leadership influence across multiple team members” (Carson et al., 2007). It is considered as a more effective form than traditional centralized leadership or vertical leadership to enhance team performance under certain conditions (Pearce & Sims 2002). The importance of leadership being shared among team members have been realized by leadership scholars (Serban & Roberts, 2016; Liu et al., 2014). Thus, the first purpose of this study is to enable shared leadership in the project alliancing and predict the effect on boosting alliance outcomes.

Project alliancing strives for overcoming the adversarial relationships existed within construction industry (Walker et al., 2014). Thus, the relationship development process adds considerable value through the alliance contracting (Davis & Love, 2011). That is, relational capital which referred to a relational rent generated in an exchange relationship acts as an important binder in project alliancing. Scholars have argued that shared

leadership can help to facilitate caring, minimize the power differences and thus improve the relations between group members (Houghton et al., 2015). However, the effect of shared leadership on alliance performance is indirect due to the complexity and uncertainty of both project and participants' behavior. The process of shifting responsibility among representatives from different alliance members can boost mutual trust, which is an important embody of relational capital. Mutual trust for one another can be signaled as alliance partners manifest their willingness to share power and responsibility. This can also be supported by empirical study finding that collectively leadership behaviors were positively linked with trust and commitment (Avolio et al., 1996). In addition, shared leadership can foster team learning and cultivating effective knowledge exchanges among members (Liu et al., 2014). Rotating leadership among alliance participants helps enhance the inter-organizational communication and information exchange, enhancing the alliance performance.

Thus, relational capital including three key aspects - mutual trust, reciprocal commitment, and information exchange will be established through the rotating of leadership at the level of inter-organization alliances. The second purpose of the paper is to study the mechanism of shared leadership effect on relationship capital and alliance collaboration.

LITERATURE REVIEW

SHARED LEADERSHIP IN ALLIANCES

Leading multiple teams, groups, or organizations posed a great challenge to leadership research since power in such situation is often distributed among different members. It is suggested that a collective form of leadership, such as shared leadership, can be a critical factor to boost inter-organization collaboration in which members play distinct but tightly-knit and complementary roles (Bolden, 2011). Compared with the traditional vertical leadership, shared leadership emphasizes on a horizontal *relational* phenomenon at a team-level (Mehra et al., 2006). In project context, shared leadership emerges when project team members take on the leadership roles on behalf of the project manager to interact with others (Ralf Müller, 2018). Pearce & Conger (2003) has defined shared leadership as “a dynamic, interactive influence process among individuals in groups for

which the objective is to lead one another to the achievement of group or organizational goals or both”. Shared leadership is a team-level leadership practice, wherein multiple individuals share influence with other partners to make decision and solve problems, as well as shape collective activities among different entities. Accordingly, shared leadership is an informal leadership that intends to share influence with their partners in decision-making and problem-solving, as well as share responsibilities for outcomes (Hoch, 2012). This form of leadership may be more potentially successful in a situation where power is diffuse but partners are highly dependent on each other in terms of their unique knowledge, skills and abilities (Bligh et al., 2006).

Scholars suggest that shared leadership is an emergent property of a group evolving over time (Aime et al., 2013). Thus, shared leadership derives from dynamic interactions among different members within the group and takes time to develop. Focusing on the dynamic characteristic is critical, because the leadership roles may experience the dynamic construction, deconstruction and reconstruction over time with the contextual forces evolving and the “leadership role constellation” members intervening (Denis et al., 2001). On one hand, shared leadership tends to increase as groups develop the information and knowledge sharing (Kozlowski & Chao, 2012), and as trust among different members grow (Drescher et al., 2014). For example, group members are apt to engage in shared leadership when they share mental models of the working situation (Burke Fiore & Salas, 2003). Similarly, Serban & Roberts (2016) observed that shared leadership can be intensified under a high level of change-oriented communication, due process and social support condition. On the other hand, shared leadership may be restricted or decrease if the alliancing encounters adverse environmental demands or relationship conflict. Research on shared leadership has often gained positive outcomes, which predicts a positive relationship between shared leadership and performance (Hoch & Kozlowski, 2012). Moreover, Ensley et al. (2006) demonstrated that shared leadership is more effective even than vertical leadership. However, some studies have found a negative relationship between shared leadership and performance (Boies et al., 2010). The inconsistencies in these researches may be attributed to the static view of shared leadership (Drescher et al., 2014). As such, the study of shared leadership should be in the light

of its dynamic development.

Most researches used aggregation theories to study shared leadership. However, such approach is deficient for two reasons (D’Innocenzo, et., al, 2016): First, important details may be ignored since different members emphasize on different components. High level shared leadership can be rated when a team member focuses on two strong leaders, while the poor shared leadership can be concluded when the team member concentrates on the individual who has the social loafing tendency. Second, researches employing aggregation theories of shared leadership often adopted traditional hierarchical leadership concept. This may lead to the miss of the very nature of shared leadership and failing to explain situations outside of downward leadership influence. Accordingly, shared leadership scholars have turned to social network approaches (Carson et al., 2007), which begins to focus on the relationships among interconnected individuals. Furthermore, social network analysis can help to investigate how leadership is distributed among different (Fransen et., al, 2015) and identify the emergence of multiple leaders (Emery et al., 2013)

Therefore, our analysis differs from the traditional shared leadership research in three ways. First, we view shared leadership activities in alliancing as a collective phenomenon to which different project participants can contribute in different ways and being carried out by some key persons who work on the organizational boundary at different levels primarily. Thus, these persons are main “spokesman” of leadership actions and their behaviors can reflect the leadership sharing extent in project alliancing. Secondly, shared leadership is regarded as a dynamic process in which leadership roles evolve as the project advancing and basing on participants’ expertise and skills. Thirdly, shared leadership in this paper is a supra-organizational phenomenon (Denis, Lamothe & Langley, 2001) since leadership roles and influences in project alliancing extend beyond the organizational boundaries.

RELATIONSHIP CAPITAL IN ALLIANCES

It is suggested that successful alliance contracting lies in the relationship development between different partners (Davis & Love, 2011) and some empirical support for this relationship has been found (Liu et al.,

2010; Sambasivan et al., 2013). Relational capital in project alliancing is generated as a relational rent during the interaction and exchange of different organizations. It acts as coordinating mechanisms among different alliancing members, thus contributing to the collaboration quality. Researchers have argued that relationships between alliance partners can be characterized as mutual trust, commitment and communication (Sambasivan et al., 2013). We identified three key aspects of relational capital essential to alliancing collaboration: mutual trust, mutual commitment, and information exchange.

Mutual trust. Interorganizational trust, which is regarded as a “fundamental relationship building block” (Wilson, 1995) and is expected to facilitate the understanding for cooperation and planning in relational contract, is argued to be crucial to the development of alliances (Liu et al., 2010). In alliancing context, trust refers to an expectation of good faith efforts by different partners through their reciprocal commitment. It is suggested that sound trust building within project teams is an important factor in project alliancing relationship (Fu et al., 2015, Buvik & Rolfsen, 2015). What ’s more, mutual trust is emergent constructs that evolve over time (De Jong 2010) and is created through social network processes. Although there is a limited degree of trust in the early life of alliances, it can be an important reference for the choose of right partner and an important impact to mitigate uncertainty. Mutual trust may begin to develop as the partners become familiar with the alliancing norms and behaviors that have been established (Wong et al., 2005). And trust will keep increasing as the consequence of perceived economic or social nature investment in the formative phases of alliance relationship. In the next stage of alliancing development, trust which is more stable can help to improve the reciprocal commitment (Davis & Love,, 2011) and resolve conflicts in an amicable way (Sambasivan et al., 2013). Then the implicit trust can be expected to emergence as the degree of interorganizational interaction increases, leading to a stable alliancing relationship.

Reciprocal commitment. Reciprocal commitment has been realized as an important factor in forming a positive relationship because future outcomes is expected to enhance reciprocity and maintain stability (Kingshott, 2006). The commitment phase is so intensive during the alliancing life cycle that it involves the

continual discussion and negotiation and mutual learning. When the levels of reciprocal commitment among the alliancing partners are high, the partners are more likely to achieve goals due to the effective exchange process and activities or relationship coordination (Cai et al., 2010, Sambasivan et al., 2013). As partners become increasingly involved in their alliance they may support mutually beneficial activities and pay more attention to the shared goals rather than the individual interest (Davis & Love, 2011). Accordingly, the reciprocal commitment is conceptualized as the degree to which both partners intent to invest requisite resources and establish enduring, reciprocal obligations in the alliance.

Bilateral information exchange. Scholars have argued that information and social exchanges shaped the inter-organizational contact patterns and horizontal relationships (Santos & Baptista, 2016). One of the most important reasons for forming the alliances with other competitors is the knowledge acquisition, sharing and the transfer of experience (Soekijad & Andriessen, 2003; Ingram & Simons, 2002). In turn, bilateral information exchange between alliancing partners helps them share both know-what and know-how, thus making possible certain “economies of expertise” (Sambamurthy & Subramani, 2005). Furthermore, high degree of information exchange can help break down the “thought worlds” produced by people with different expertise, thus encouraging them to work together to solve problems (Ganesan et al. 2009). Kale and Singh (2009) stated that effective information exchange facilitates collaborative performance because shared interests and common goals are stressed during the increasing information exchange. Accordingly, the timely, quality information exchange acts as a bonding mechanism between partners and is argued to have a positive effect on alliance outcome.

SHARED LEADERSHIP RELATIONAL CAPITAL AND ALLIANCE COLLABORATION.

Alliancing projects call for a collaboration and cooperation internal environment to achieve the shared purpose and attach importance to voices from different participants. This demand is consistent with the proximal factors that influence the development of shared leadership—internal team environment, including the shared purpose, social support and voice (Carson et al., 2007). Furthermore, recent research

often found positive relationships between shared leadership and team performance (Hoch & Kozlowski, 2012; D’Innocenzo, et., al, 2016). Additionally, some scholars hold on that shared leadership is a better predictor of performance outcomes than vertical leadership (Ensley et al., 2006). As such, shared leadership can be a great try to transform the diffuse sub-organizational self-interest and detrimental competition between organizations into collaboration and cooperation that optimize alliancing performance.

Trust has been viewed as the result of repeated interaction between different members since their behavior represents their trustworthiness on each other. Alliances partners are demonstrating their trust for one another when they show their intentions to share responsibility and power, and the shared leadership behaviors would further cultivate trust. Drescher et al. (2014) stated that as more team members involved in sharing the leadership functions, there are more opportunities to boost trust in the team. Similarly, trust established among team members may break up when a single member attempts to lead the collectively managed team (Druskat & Pescosolido, 2006). Furthermore, scholars have found empirical support for a positive relationship between shared leadership and trust (Bergman et al., 2012; Wang et al., 2014). Hence, shared leadership facilitates the mutual trust between different partners (Hoch & Kozlowski, 2012), which is an important antecedent of alliance success.

When it comes to collective leadership, the major sharing of leadership functions focused by scholars are information search and structuring, information use in problem solving, managing personnel and material resources (Hoch & Kozlowski, 2012, Drescher et al., 2014). These sharing leadership behaviors provide more chances for the alliance members to engage in positive social exchanges and interaction with each other (Aime et al., 2013), thus contributing to the information exchange. Every alliances partner can take the leadership roles to influence other members during these exchanges process, which can create a balance situation of power between different participants. To keep balance, the less powerful member would enhance their commitment by providing valued resources in return. That is, the acquisition, sharing and development of knowledge can be promoted between alliance members when the leadership is rotated among them, which

leads to a better understand and trust between them.

Accordingly, as more alliance partners assume the leadership roles, there are more opportunities for them to interact with each other and thereby form trusting bonds, change information and enhance reciprocal commitment. The relational capital can be built through the development of shared leadership, which contributes significantly to the high collaboration outcomes.

METHODS

A cross case study of two alliancing highway projects is to be conducted to examine the effect of shared leadership on relational capital and alliance outcomes. The investigated project I is Ji Tai highway project, one of the most important projects of the latest expressway network planning in Shandong Province, China. The project includes the basic subgrade and pavement engineering and the whole line adopts the two-way six-lane standard. The project scope also includes the establishment of tunnels, bridges and highway culverts. The original budget is 11.3 billion and the original project schedule is about 3.5 years. The investigated project II is Jiqing highway reconstruction project, which intends to broaden the original roads into the eight lanes to moderate the traffic congestion. The project includes the bridge reconstruction, culvert reconstruction and the service area reconstruction. The original budget was 30.0 billion and the original project schedule is about 3 years. The study mainly focuses on the middle and later periods of these two projects.

RESEARCH STEPS

To investigate the dynamic development of shared leadership and relational capitals, the case study was conducted as shown in Fig. 1:

To pick up the appropriate key persons who may engage in shared leadership activities, the measurement of shared leadership behaviors was developed based on the four functions of group leadership (Fleishman et al., 1991); a focus discussion with academic experts and practice professionals was also developed. The study firstly consulted several managers of the top management team (TMT) and asked them to provide a list of core members from all stakeholders based on their titles, qualifications, and work experience. The selected

team members include the typically project managers from different alliance partners (eg., owner's senior manager, construction and program management executives). And we also included the lower level representatives in charge of regular communication with other members via the regular alliancing sessions. These key persons are asked to answer the shared leadership behaviors questionnaire. At last, the final shared leadership performers can be determined to join our tracking survey.

The formal data collection periods are divided into three stages. The respectively interval of two stages are 3 months and 5 months. The questionnaire survey on shared leadership, relational capital and performance are continual through the later alliancing life. Besides the questionnaire survey, a 15 minutes interview is conducted at stage 2 with 3 open-ended questions: 1. "How did you feel about the leadership role at the start of alliancing?" 2. "What difference and challenge do you find in the alliances with traditional project delivery in terms of leadership. Give examples?" 3. "What actions were taken to influence other members who communicate a lot with you /your team in the alliances?" At the last stage, a 15 minutes interview is also conducted with 3 open-ended questions: 1. "What changes occurred compared with former stage? Were any measure taken to solve the problems?" 2. "What do you think the leadership emerge in the alliances look like? Give some advice?" 3. "Were you happy/unhappy with the final collaboration performance? How did the alliances working process lead to this feeling?"

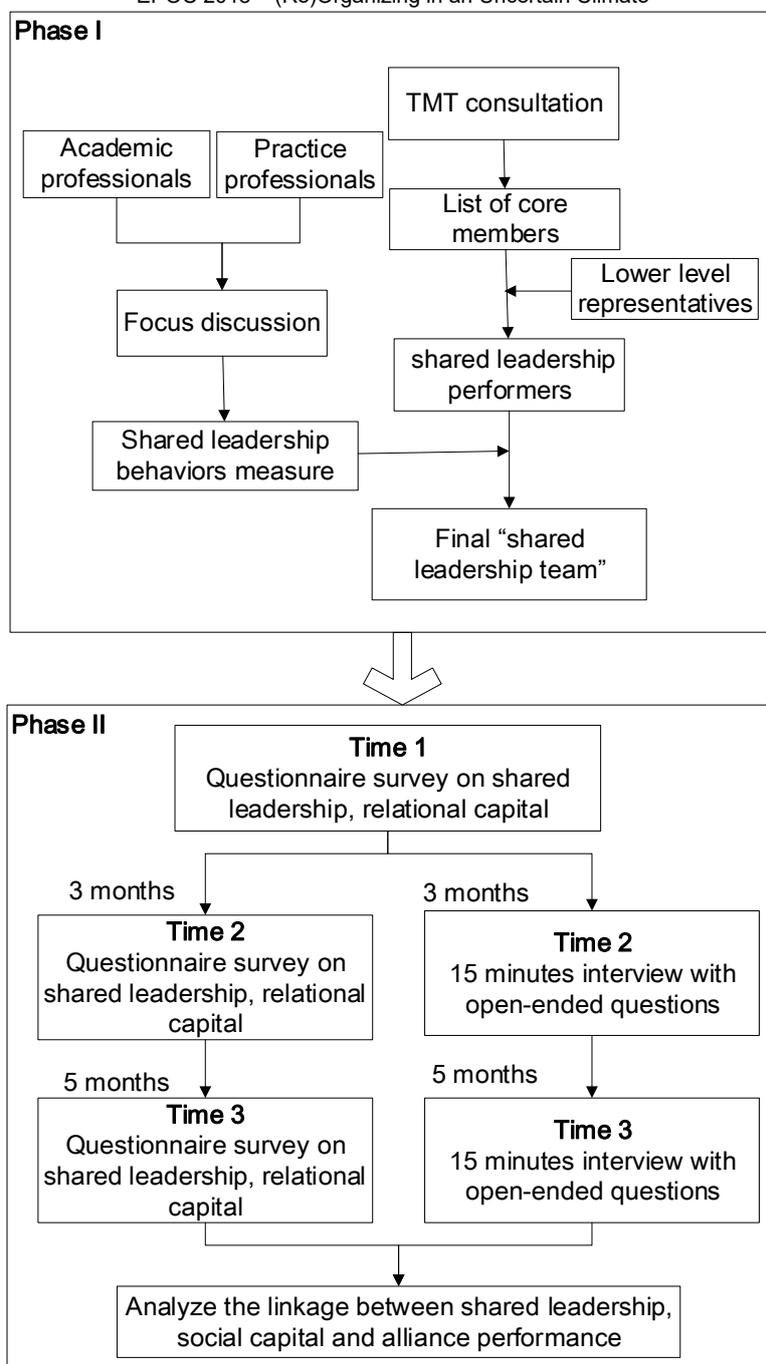


Figure 1. Research steps

MEASURES

Shared leadership. The “shared leadership team” identified in phase I are selected to measure the shared leadership level using a social network approach (Carson, 2007). The final shared leadership performers are required to rate other members in the “shared leadership team” (1, “not at all”, to 5, “to a very great extent”) on the following question: “To what degree does the alliancing project development rely on this individual or his team for leadership?” Shared leadership is measured using density, which is calculated followed the

measurement approach for valued relations (Sparrowe et.al, 2001). The leadership sociogram is to be created for the “shared leadership team” as Figure 2.

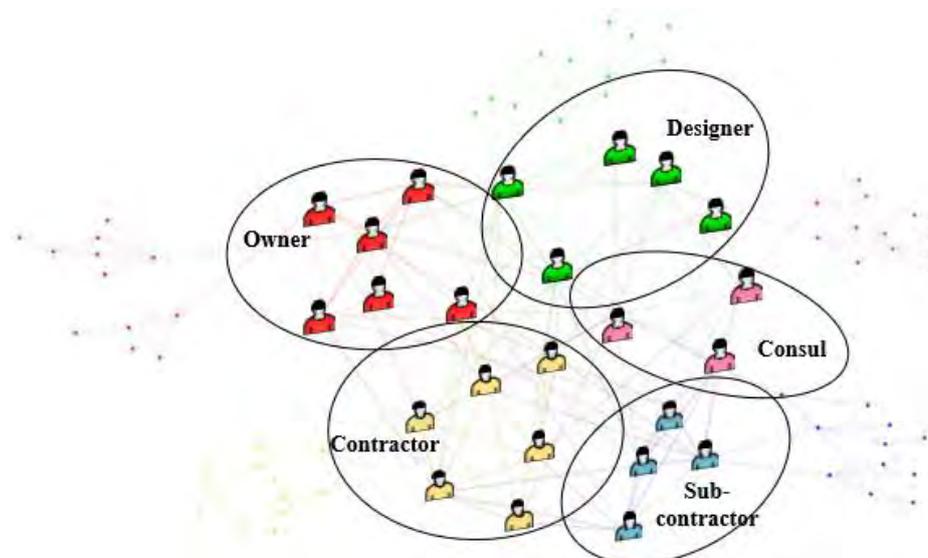


Figure 2. shared leadership sociogram in project alliancing

Relational capital. The intensity of interaction among project alliance partners can be reflected by relational capital, which is divided into three dimensions- mutual trust, reciprocal commitment and information exchange in this paper. Mutual trust was measured assessing the moral integrity, fairness and dependability in the relationship. The items involve “Both alliancing partners were generally honest and truthful with each other”, “Both alliancing partners treated each other fairly and justly” “Both alliancing partners found it necessary to be cautious while dealing with each other” “Relaying on each other was risky for both alliancing partners”. Reciprocal commitment plays a central role in relational exchanges between different organizations. Reciprocal commitment was borrowed from the organizational commitment study to measure the willingness of each partner to invest required resources into the alliance. The representative items involved “Both partners were willing to dedicate whatever resources and people to make this project a success.” “Both partners provided experienced and capable people to the project.” Bilateral information exchange measures were adopted from Heide and John (1992), involving the items “There was frequent visiting, meetings or telephone and written communications between different partners” “Information exchange during the alliancing life cycle took place frequently and informally”. These three dimensions were rated on a five-point scale

(“strongly agree to “strongly disagree”). Higher scores indicate high level of relational capitals between different alliance partners.

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CRACKS IN THE MIRROR: CONCEPTUALIZING THE ONGOING AEC INDUSTRY RE- ORGANIZATION

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CRACKS IN THE MIRROR: CONCEPTUALIZING THE ONGOING AEC INDUSTRY RE-ORGANIZATION

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ABSTRACT

The architecture, engineering and construction (AEC) industry structure is characterized by extreme industry fragmentation and decentralized project organization. As a result, the industry suffers from an overly strict mirroring of knowledge with task dependencies. This ‘mirroring trap’ prevents firms from seeing opportunities to change its boundaries and/or restructure its industry. Existing firms are unable to adopt or even perceive the advantages of systemic innovations that require knowledge and task efforts outside of the accepted modular product architecture. However, there are several emerging examples of re-organization attempts within the AEC industry that represent ‘small cracks’ in the prevailing dominant model of product architecture. This paper presents a conceptual model for four emerging re-organizational efforts. We show how these emerging re-organization efforts represent strategic actions by AEC firms toward ‘partial mirroring’ or ‘breaking the mirror’. The four categories include partial mirroring using supply chain integration practices, strategic mirror breaking using relational contracts such as IPD, and strategic mirror breaking using pre-emptive re-modularization – either through an integrated hierarchical firm or through a core-periphery platform structure.

KEYWORDS

Industry Structure, Systemic Innovation, Mirroring Hypothesis, Organizational Design, Modularization, Relational Contracts, Industrialized Construction

INTRODUCTION

The prevailing product architecture and paradigm can only change through disruptive “systemic” innovations that overturn the current product architecture paradigm! What will be the disruptive paradigm for construction? Will it be related to new products, new processes, and organizations, or some combination of all three?

Ray Levitt, 2007

Over three decades of scholarship, Prof. Raymond E. Levitt has highlighted how the architecture, engineering, and construction (AEC) industry is held captive by the characteristics of its own structure. The horizontal and vertical fragmentation of the AEC industry coupled with temporary project-based organizations presents a ‘never

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ending stream of problems that require local incremental innovations’ (Levitt 2007). However, innovations with the most significant impact on productivity require simultaneous changes by multiple firms in the fragmented AEC supply chain (Levitt 2007; Taylor and Levitt 2004a). These ‘systemic’ innovations are passed over for localized product innovations that offer less global benefit but fit within the existing modules of work and specialization (Sheffer 2011).

The prevailing ‘modularization’ of the product architecture into standard interfaces and work packages eases the difficulties of coordination for complex projects. However, this paradigm also traps firms into the prevailing product architecture and resists attempts to innovate at the system level (Hall et al. 2018; Levitt and Sheffer 2011; Sheffer 2011; Taylor and Levitt 2004a, 2007). Organizational design and strategic management scholarship has theorized this problem as a mirroring ‘trap.’ The overall productivity of the AEC industry struggles to improve because ‘it cannot access new opportunities involving technical architectures that do not mirror the current industry structure’ (Colfer and Baldwin 2016). Arguably, the mirroring trap is one explanation for why the built environment has not embraced the full potential benefit of digitalization and building information modeling (BIM) (Eastman et al. 2008; Whyte and Hartmann 2017). When industries enter periods of technological change, mirroring organizations often are unable or unwilling to perceive of innovations that offer global benefits but do not match the prevailing modularization of the dominant industry structure.

There is some current evidence, however, that new ‘disruptive paradigms’ for the industry are emerging to break free of the mirroring ‘trap’. This paper briefly summarizes extant literature and/or examples of four such re-organization attempts. They are:

- new collaborative modular clusters that utilize collaborative supply chain integration practices such as colocation and lean construction (Hall et al. 2018);
- new ‘virtual’ project-based companies in emerging project delivery models such as Integrated Project Delivery and Project Alliancing (Hall and Scott 2018; Lahdenperä 2012);
- new integrated hierarchical firms that industrialized construction to derive value from a technical building system platform and a streamlined design, off-site fabrication, and assembly process;
- new core-periphery platform structures built by digital system integrators that derive value from an industry 4.0 platform approach linking design and fabrication.

This aim of this paper is to offer a conceptual overview to explain why, how, and where these ongoing re-organization attempts are occurring. We do so specifically through the theoretical lens of the mirroring hypothesis. Drawing from the recent work of Colfer and Baldwin (2016), we argue that each of the above efforts can be understood as strategic actions taken to break free of the mirroring ‘trap’ that has long held the AEC industry captive and resisted attempts at systemic innovation. We suggest the forward-thinking firms and organizations presented here are attempting to enlarge their knowledge boundary beyond their operational boundary, an important strategy during this period of technological change and increasing complexity. The four re-organization attempts achieve ‘partial mirroring’ or strategically ‘break the mirror’

(Colfer and Baldwin 2016) thus allowing new prevailing product architecture and paradigms to emerge.

The paper proceeds with an overview of three decades of industry structure research, with emphasis placed on the scholarship led by Levitt and his research team on fragmented industry structure, decentralized project organization, and their effects on innovation adoption. Next, the paper describes the theory, background, and development of the mirroring hypothesis. Third, the paper conceptualizes the four the re-organizational efforts that are currently employed by project organizations and/or firms in the AEC industry. Brief examples of emerging firms and project arrangements are given for each of the four conceptual models. The paper concludes with a discussion of the intersection and categorization of these four efforts and proposes directions for future research on the topic.

CHARACTERISTICS OF AEC INDUSTRY STRUCTURE

The AEC industry is characterized by extreme fragmentation in three dimensions: horizontal, vertical and longitudinal (Fergusson 1993). Horizontal fragmentation occurs in the trade-by-trade competitive bidding environment of traditional project deliveries. Because it is difficult to cross-subsidize changes across trades, globally-optimal innovations cannot compete with traditional solutions that are more cost-effective from the perspective of a particular building element or phase. Vertical fragmentation occurs because each project phase has a different set of stakeholders, decision-makers, and values. This creates displaced agency – also called ‘broken agency’ - where involved parties will engage in self-interested behavior and pass costs off to stakeholders in a subsequent phase to the detriment of the long-term user (Henisz et al. 2012). Longitudinal fragmentation also occurs in North America and other liberal market economies. Project teams that disband at the end of projects and are selected on future projects by competitive bidding. They are thus unlikely to work with the same set of partner firms on future projects. Consequently, team members lose tacit knowledge about how to work together effectively and organizations are unable to build upon ideas that cross firm boundaries (Dubois and Gadde 2002). Taylor and Levitt (2005) term this knowledge breakdown as an industry “learning disability” that slows innovation diffusion. In addition, the high demand fluctuations within the industry creates a reluctance by firms to invest significant capital in innovation development (Sheffer 2011). The system of tort liability in North America holds firms responsible for design and construction mistakes and further encourages technological risk aversion.

AEC PROJECT ORGANIZATION AS DECENTRALIZED MODULAR CLUSTERS

The fragmented construction industry structure leads to the organization of large construction projects as ‘decentralized modular clusters’ (see Figure 3) (Sheffer 2011). The vertical fragmentation of the industry splits the role of the systems integrator between two very different actors – the principal contractor and the principal architect (Winch 1998). As a result, ‘mediating and championing roles essential to successful innovation are less likely to be carried out effectively’ (Winch 1998). The majority of project work is governed through standardization (Langolis and Robertson 2009) and ‘craft administration’ (Stinchcombe 1959). The institutionalized product architecture

and design rules act as the coordination standards to ensure that modules produced by separate firms fit together (Langolis and Robertson 2009; Sheffer 2011).

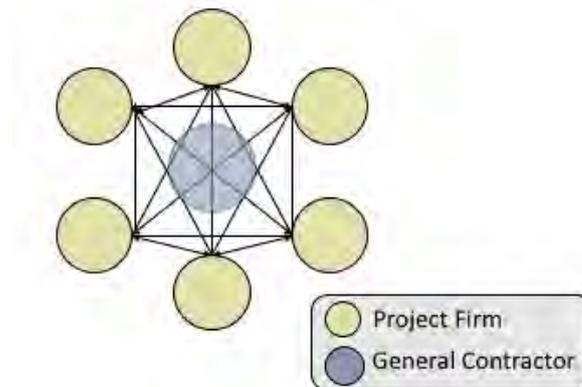


Figure 1 – Project Organization as Decentralized Modular Cluster (Sheffer 2011)

In the end, the general contractor acts as a weak systems integrator but typical work can be designed, coordinated, and constructed as independent pieces with relatively little system integration required. The general contractor is in large part a broker of subcontractor services and less of a system integrator on typical small building projects than an equivalent automobile or aircraft prime contractor. General building contractors in a decentralized modular cluster lack the necessary overhead cost structure and capacity required to coordinate systemic innovations.

IMPACT OF AEC INDUSTRY STRUCTURE ON INNOVATION DIFFUSION

Incremental and modular innovations that fit within the existing divisions of work and specialization tend to proliferate because they do not cross traditional discipline boundaries. These modular innovations such as energy-efficient light bulbs and water-efficient toilets fit within the existing supply chain and have standardized interfaces. They do not alter the interface of adjacent construction products or the process of installation within the building. Implementing a modular innovation can be as simple as removing the old component and installing the new one.

By contrast, architectural and radical innovations change the linkage between concepts and modules. They are difficult for firms with strict mirroring to perceive or adopt. Taylor and Levitt explore this effect in the AEC industry, using the term *systemic innovation* instead of architectural innovation² (Taylor and Levitt 2004a). Systemic and radical innovations reinforce the overall product function but redefine the boundaries between the units of work traditionally provided by each firm in the supply chain. Systemic innovations require multiple firms in the supply chain network to change their design, prefabrication and/or assembly practices in a coordinated way (Taylor 2006). They alter the interfaces between the modules or the overall system architecture. Systemic innovations can create increased overall product value or delivery

² This is likely because using the term architectural innovation in the AEC context might connote an innovation driven by the project Architect, not the product architecture as intended by Henderson and Clark (1990).

productivity but will typically induce switching or start-up costs for some participants while reducing or potentially eliminating the role of other participants. Examples of systemic innovations in AEC include radiant floor heating, smart building management systems, and prefabricated wall frames with integrated components. These innovations may introduce a change in the interfaces or design criteria between two or more modules, a change in the process (e.g. schedule, sequencing, etc.) of the overall system, or both. They cross professional and trade specializations, redefine how work is done in the industry, and break industry standards. For these types of innovations, there is a fundamental mismatch between the AEC industry structure and the characteristics of the innovation (Levitt and Sheffer 2011; Taylor and Levitt 2004a).

Table 1 – AEC Innovation Framework
(Henderson and Clark 1990; adapted by Taylor and Levitt 2004b)

		Core concept	
		Reinforced	Overtuned
Linkage between core concepts & components	Unchanged	<p>Incremental innovation <i>Example: Lumber wall truss frame replacing conventional stick-built lumber wall frame</i></p>	<p>Modular innovation <i>Example: Extruded metal truss frame replacing conventional stick-built lumber wall frame</i></p>
	Changed	<p>Architectural (Systemic) innovation <i>Example: Prefabricated wall frame with HVAC, plumbing & electrical components replacing conventional stick-built lumber wall frame</i></p>	<p>Radical innovation <i>Example: Geodesic dome frame replacing conventional stick-built lumber wall frame</i></p>

EFFECT OF INDUSTRY STRUCTURE ON INNOVATION DIFFUSION

As described above, systemic innovations require major changes in the design interfaces and/or installation processes. As a result, systemic innovations are passed over for localized product innovations that offer less global benefit but fit within the existing divisions of work and specialization (Sheffer 2011). Research by Sheffer (2011) demonstrates the link between project organization, industry structure, and the adoption of systemic and radical innovations. Looking at LEED certified building scorecards, Sheffer finds that projects with high levels of horizontal and vertical integration are two and a half times more likely to implement ‘green’ systemic innovations than a project with no vertical or horizontal integration, even after controlling for the cost of the innovation. Furthermore, project integration makes no difference in the adoption of modular or incremental innovations, emphasizing that systemic and radical innovations are the types of innovation actively resisted by the fragmented AEC industry structure and decentralized modular cluster project organization.

DIGITALIZATION AS DRIVER OF INDUSTRY STRUCTURE CHANGE IN AEC

Levitt has argued as early as the late 1980’s that the pending digitalization and technological change would need to be met by changes in industry structure, arguing that ‘integrated design and construction will require new organizational structures and perhaps new institutional arrangements in which to conduct facility engineering’ (Howard et al. 1989). Yet the pace of organizational change has been slow; the existing industry structure is entrenched and reinforced by extreme industry fragmentation

among firms and projects that are organized as decentralized modular clusters with weak systems integrators. Recent scholarship has demonstrated that BIM-based digital technologies affect relationships within and across firm boundaries (Papadonikolaki and Wamelink 2017) has emphasized that the full benefit of digitization (e.g. BIM) cannot be achieved without thoughtful restructuring of organizational processes (Eastman et al. 2008; Whyte and Hartmann 2017). In theory, as the rate of technological advancement mature for digital assets and tools such as BIM, it will in turn drive increased changes in organizational structures and processes made possible by the technologies.

THE MIRRORING HYPOTHESIS

The mirroring hypothesis in organizational design and strategic action scholarship is generally stated as follows: because the coordination of complex, interdependent tasks is challenging, the ‘formal structure of an organization will (or should) “mirror” the design of the underlying technical system’ (Colfer and Baldwin 2016). The mirroring hypothesis has emerged as a summary of several works predicts that ‘organizational ties within a project, firm, or group of firms (e.g. communication, collocation, employment) will correspond to the technical dependencies in the work being performed’ (Colfer and Baldwin 2016). Given the challenges of coordinating complex interdependent tasks (Thompson 1967, Galbraith 1974), the mirroring of technical dependencies and organizational ties is an organizational solution that allows firms to conserve scarce cognitive resources (Colfer and Baldwin 2016).

The mirroring hypothesis predicts correspondence but does not impose causal direction. The concept of the mirroring hypothesis with causal effects running from technical dependencies to organizational ties has been suggested by organizational and product design scholars, initially led by Thompson (1967) and Simon (1957). Its implications can perhaps best be described by Sanchez and Mahoney (1996) that ‘although organizations ostensibly design products, it can also be argued that products design organizations, because the coordination tasks implicit in specific designs largely determine the feasible organization designs for developing and producing those products.’ The mirroring hypothesis also finds its origins in computer science, as summarized by Conway’s Law. Conway (1968) argues ‘organizations which design systems (in the broad sense used here) are constrained to produce designs which are copies of the communication structures of these organizations.’ This is also the mirroring hypothesis but causality runs from organizational ties to technical dependencies (Colfer and Baldwin 2016).

The mirroring hypothesis is predicated on the presence of product modularization and information hiding (Baldwin and Clark 2000). Modularity³ describes ‘the degree to which a given system can be broken apart into subunits (modules) which can be assembled and recombined in various ways’ while modularization is a ‘structured learning and design process aimed at making a complex system more modular’ (Baldwin 2015). Modularity enables *information hiding* to control complexity, a fundamental principle of the mirroring hypothesis. Each module in a technical system

³ The idea of modularity as described here is a definition from organizational science; this concept of modularity should not be confused with the emerging trend of *modular construction* (although the movement to modular construction *is* one example of re-modularization of the AEC industry, as discussed later in the paper).

is informationally isolated from other modules within a framework of system design rules (Baldwin and Clark 2000) so that ‘independent individuals, teams, or firms can work separately on different modules, yet the modules will work together as a whole’ (Colfer and Baldwin 2016). Systems with many technical interdependencies will require tight coupling while discrete modules can be implemented by loosely coupled organizations (i.e. separate firms) (Langlois and Robertson 1992).

THE MIRRORING TRAP

Colfer and Baldwin (2016) conducted a comprehensive study of the mirroring hypothesis by analyzing and coding 142 empirical studies in which ‘both technical dependencies and organizational ties were observed and their correspondence assessed in a rigorous quantitative or qualitative fashion.’ The studies were classified by their organizational form (industry-level, firm-level, or open-ended collaboration) and were drawn from a wide range of technical industries. In addition to formally defining the mirroring hypothesis, they conclude that the concept of mirroring adequately captures the central relationship between technical dependencies and organizational ties in complex technical systems. Firms use mirroring to conserve scarce cognitive resources; mirroring is an economical way to set up complex technical systems because it places problem-solving resources in strategic places where these problems are likely to appear (Colfer and Baldwin 2016).

However, Colfer and Baldwin also find evidence of a ‘mirroring trap’ for organizations. Loosely-coupled organizations must be wary of ‘strict mirroring’ that can be imposed with regards to technical knowledge. Under strict mirroring, technical tasks *and technical knowledge* of a complex system are partitioned into modules, reducing the amount of knowledge needed by any one person or group. In theory, this should be the most economical way of conserving cognitive resources; team members are only responsible to acquire knowledge about the work within the boundaries of their own module. In practice, when an ‘overly strict mirroring of knowledge with task dependencies’ is implemented, it is ‘likely to prevent a firm from seeing opportunities to change its boundaries and/or restructure its industry’ (Colfer and Baldwin 2016).

In particular, strict mirroring prevents firms from perceiving innovation opportunities – such as systemic innovations – that cross product architecture boundaries. Henderson and Clark (1990) distinguish between innovations that induce changes to components within a product and innovations that change the linkages between product modules. They suggest that organizations tend to lose their abilities to innovate at the architectural (e.g. systemic) level, because over time organizations develop organizational structures and information channels that are focused on component-level activities. Thus, strict mirroring can cause firms ‘not only [to] resist innovative threats, but actually resist all efforts to understand them, preferring to further entrench their positions in the older products’ (Utterback 1996). Therefore, while mirroring conserves scarce cognitive resources and can be efficient in the short run, strict mirroring can be a trap (Colfer and Baldwin 2016), especially in periods of dynamic technological change.

Colfer and Baldwin specifically point to the AEC industry as an example of an industry stuck in the mirroring trap. In 9 out of 10 cases of longitudinal industry-level studies, Colfer and Baldwin find that within mirrored industries, the firms are well-aligned with the dominant product architecture. When ‘a new architecture was

discovered with a better value proposition,’ incumbent firms had to adapt their organizational structure (i.e. become mirrored) or exit the industry. Yet Colfer and Baldwin note the 10th industry – the AEC industry – by drawing from the work of Levitt and Sheffer (Sheffer 2011; Sheffer and Levitt 2010). Colfer and Baldwin point to the AEC industry as an example of an industry stuck in a mirroring trap. In this case, the mirroring prevalent in AEC industry structure is ‘performing poorly in that it cannot access new opportunities involving technical architectures that do not mirror the current industry structure’ (Colfer and Baldwin 2016).

PARTIAL MIRRORING AND STRATEGIC MIRROR-BREAKING

When industries enter periods of technological change, mirroring organizations often are unable or unwilling to perceive of innovations that offer global benefits but do not match the prevailing modularization of the dominant industry structure. To counteract this, firms ‘must scan both new technologies and current contracting arrangements to identify “bottlenecks” that may be controlled by changing technical dependencies and organizational ties to create new institutional arrangements’ (Colfer and Baldwin 2016). Firms in technically dynamic industries can achieve competitive advantages through ‘strategic manipulation of its boundaries’ (Colfer and Baldwin 2016) and its industry structure (Cacciatori and Jacobides 2005). This can be successfully accomplished through either partial mirroring or strategic-mirror breaking.

Using *partial mirroring*, firms explicitly invest in knowledge of technologies beyond their task boundaries. These firms are often systems integrators who are responsible for the performance and evolution of an entire technical system and its network suppliers. However, when the rate of technical change increases and systems become more complex, ‘firms taking on the role of systems integrators must have system-wide knowledge extending beyond the tasks they perform in-house’ (Colfer and Baldwin 2016). These firms must increasingly develop competencies that span a wide range of technical fields and their knowledge must exceed the scope of their tasks (Brusoni et al. 2001; Colfer and Baldwin 2016).

When technical change and complexity increases, firms may choose a strategy to ‘break the mirror’ through *relational contracts* or through *pre-emptive modularization*. Firms can use relational contracts to seek to foster high levels of communication and cooperation across their boundaries in an attempt to increase technical interdependencies in the context of a long-term, mutually advantageous relationship (Colfer and Baldwin 2016). Single firms can also attempt pre-emptive modularization by creating new, modular technical architectures within vertically- and horizontally-integrated boundaries. While this re-modularization risks premature development that overlooks latent interdependencies, it also enables architectural and radical innovations to be driven at a high rate of technical change (Baldwin and Clark 2000; Henderson and Clark 1990), possibly with the intent to pre-empt rivals and push the limits of technical change required to compete in the market (Colfer and Baldwin 2016). Finally, when the nature of the products is more digital than physical, mirror-breaking firms can adopt pre-emptive modularization in the form of a core-periphery technical and organizational system. This organization form is often found in the emerging trend to transform products into platforms. The platform organization can take advantage of ‘different degrees of modularity, interdependence, and cognitive complexity in different parts of a large system’ while enabling methods for inter-organizational

collaboration (Colfer and Baldwin 2016). Figure 2 demonstrates the theorized relationship between technological change (y-axis) and the nature of a system components (x-axis) as physical, digital, or mixed.

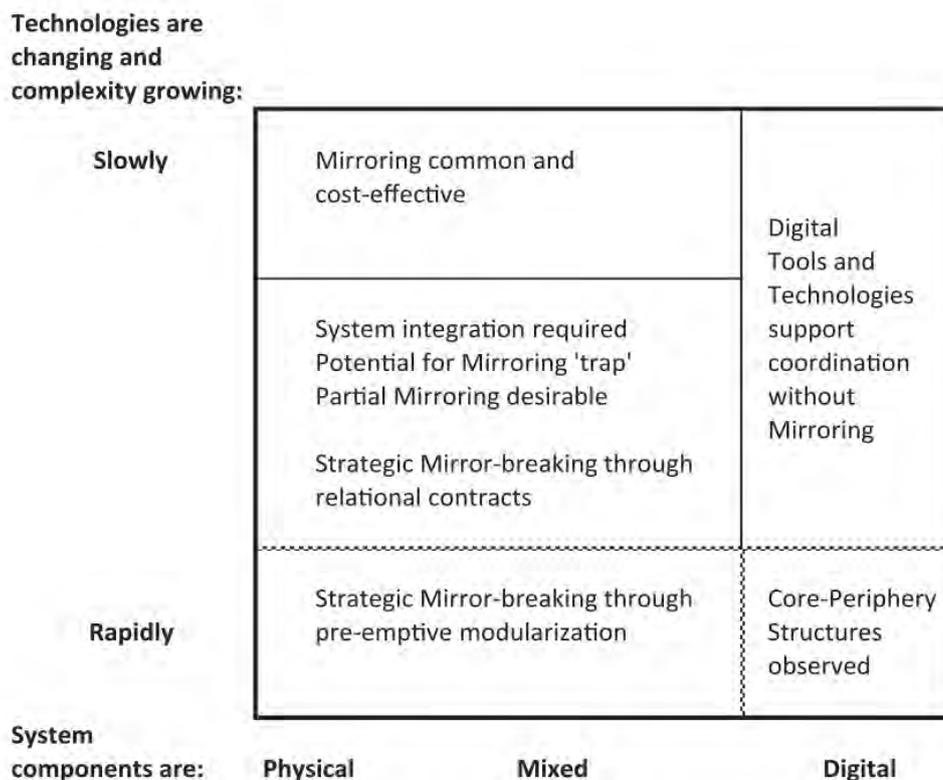


Figure 2 - Boundary conditions on the mirroring hypothesis (Colfer and Baldwin 2016)

ONGOING RE-ORGANIZATION IN THE AEC INDUSTRY

Below we offer a conceptual overview of four emerging re-organization efforts within the AEC industry. The categories are not meant to be comprehensive; it is possible (and likely) that other categories exist. This section proceeds with an overview of the ongoing re-organization, relates the re-organization within the context of the mirroring hypothesis, briefly touches on benefits and drawbacks of the effort, and provides emerging examples from an industry context.

COLLABORATIVE MODULAR CLUSTERS

Recent scholarship emphasizes that systems integrators (e.g. architects, general contractors) are increasingly implementing supply chain integration practices (SCIPs) to increase collaboration within the project supply chain (Bygballe et al. 2014; Hall et al. 2018). Supply chain integration practices can be defined as ‘a project-wide (e.g. not individual or intra-firm) practice implemented to organize information, processes, people and/or firms for the purpose of collaboration and integration within the supply chain’ (Hall et al. 2018). Examples of SCIPs include building information modeling (BIM) coordination, the last planner system, early involvement of key participants,

liability waivers among key participants, team co-location, and/or target value design among others. These practices, when employed together, are sometimes referred to as ‘progressive design-build’ or ‘integrated project delivery (IPD) – ish’ (Sive 2009).

SCIPs allow the project organization to move from a decentralized modular cluster to a ‘collaborative modular cluster.’ The enable firms in the supply chain to achieve informal horizontal and vertical integration without contractual or structural change. For example, the use of a colocated ‘Big Room’ enables participants from multiple firms to work alongside of one another, leading to increases in coordination, communication, and trust. SCIPs are typically driven by the general contractor who – as systems integrator - benefits from increased informal coordination. While firms do complain about the resources dedicated to these SCIPs, the firms also are able to explore new interdependencies that they can slowly absorb into practice for their future projects.

VIRTUAL PROJECT-BASED COMPANIES

The use of relational contracting such as Integrated Project Delivery (IPD) and Project Alliancing has significantly increased in the past decade. The project delivery methods incorporate many of the SCIPs above, but formalize the arrangement into a multi-party relational contract. As many as 17 firms are formally joined together to share the associated financial risks and rewards of the project. In essence, the firms are bound together to create a ‘virtual, project-based company (Thomsen et al. 2009). As described by Thomsen et al. (2009) this company is not so much a ‘legal entity but more like a temporary social organization. People remain employed by their respective companies, but assume one or more roles based on individual skills and project needs, rather than the nature of the employer’s business.’ The structure of these virtual project-based companies creates vertical integration (including the project sponsor/owner, designers, general contractor, and trade contractors) and horizontal integration (between traditionally separate trade contractors and system designers). This integration offers opportunities to co-create technical interdependencies and systemic innovations in the context of a mutual relationship (Hall et al. 2018; Lavikka et al. 2017). Studies have also demonstrated that IPD leads to increased level of trust and communication necessary for these mutual relationships to thrive (Pishdad-Bozorgi and Beliveau 2016; Sun et al. 2015). Despite some discussion that IPD teams should remain together from project-to-project to form a highly functional team, this has not yet been documented in practice. Thus, these project-based companies still suffer from longitudinal fragmentation at the conclusion of each project.

INTEGRATED HIERARCHICAL FIRMS

A new generation of firms have emerged with the intent to link downstream manufacturing and assembly activities with upstream design constraints. Because they tend to be united in efforts to industrialize the construction process – through the use of off-site manufacturing, prefabrication, modular construction, automation, and/or robotics, they are termed here industrialized construction firms. Industrialized construction should not be confused with (only) a prefabrication strategy to move work offsite. It also typically includes an integrated organizational strategy and new business model with developed technical platforms, long-term relationships between participants, supply chain management integration, design for manufacturing and

assembly, a new customer focus, and a product/platform -based mindset (as opposed to a traditional project-based mindset) (Lessing 2006, 2015).

Industrialized construction firms often redefine the business model of construction through horizontal, vertical and longitudinal integration. They are structured as integrated hierarchical firms, keeping the control of product architecture and processes in-house. These firms do not outsource production but instead operate as an integrated hierarchical firm, typically by moving construction activities to their own large offsite factory. Design, manufacturing, transport, and assembly are all coordinated within the same integrated firm. These new firms often focus on the delivery of housing as it offers repeatable modules and the ability to scale across the market.

Longitudinal continuity comes through the development of a technical building system, often referred to as the ‘kit of parts.’ This technical building system acts as the platform in which organizational knowledge can be embedded. Versions of the building system are released in a similar way to versions of mobile phones or software are released (e.g. version 1.0, version 2.0, etc.) The knowledge embedded in the development and maintenance of this technical building system platform can be considered a strategic asset (Johnsson 2011). Products that are not built by the firm are procured using long-term partnerships with others in the supply chain instead of through competitive bidding.

Industrialized construction has seen significant investment in recent years. Existing industry leaders have moved toward vertical integration by taking on more responsibility in the value chain. Examples of this include RAD in the San Francisco Bay Area, California, USA, the firm BoKlok (a joint venture of Skanska and IKEA) in Sweden (1,300 housing units per year) and Laing O’Rourke in the UK (which led an industry coalition that received 22 million pounds) which is constructing an off-site factory that can delivery 10,000 housing units per year.

Table 2 – Industrialized Construction Venture Capital Investment (CrunchBase, 2018)

Firm Name	Total funding raised	# of funding rounds	Year of first round
Katerra	1100.0 Mil. USD	4	2016
Blu Homes	197.5 Mil. USD	5	2011
Kasita	11.6 Mil. USD	3	2015
Blockable	7.5 Mil. USD	3	2016
Plant Prefab	3.0 Mil. USD	1	2016
Acre Designs	1.7 Mil. USD	2	2015
Cover Technologies	1.6 Mil. USD	1	2017
Cazza	1.0 Mil. USD	1	2017
Full Stack Modular	1.0 Mil. USD	1	2017

In addition, there is currently significant and unprecedented investment from venture capital into industrialized construction. These integrated hierarchical firms are headlined by the start-up firm Katerra in the US. Katerra has raised 1.1 billion USD in venture capital since it was founded in 2015. While Katerra remains a headliner, one

must not ignore that several other firms are also emerging that use the same business model. A preliminary review of the nine largest industrialized construction firms found in the CrunchBase database of start-up funding is shown in table xx. Even excluding Katterra and an early forerunner Blu Homes, these industrialized construction firms have raised 27 million dollars of venture capital investment since 2015.

Core-Periphery Industry 4.0 Platforms

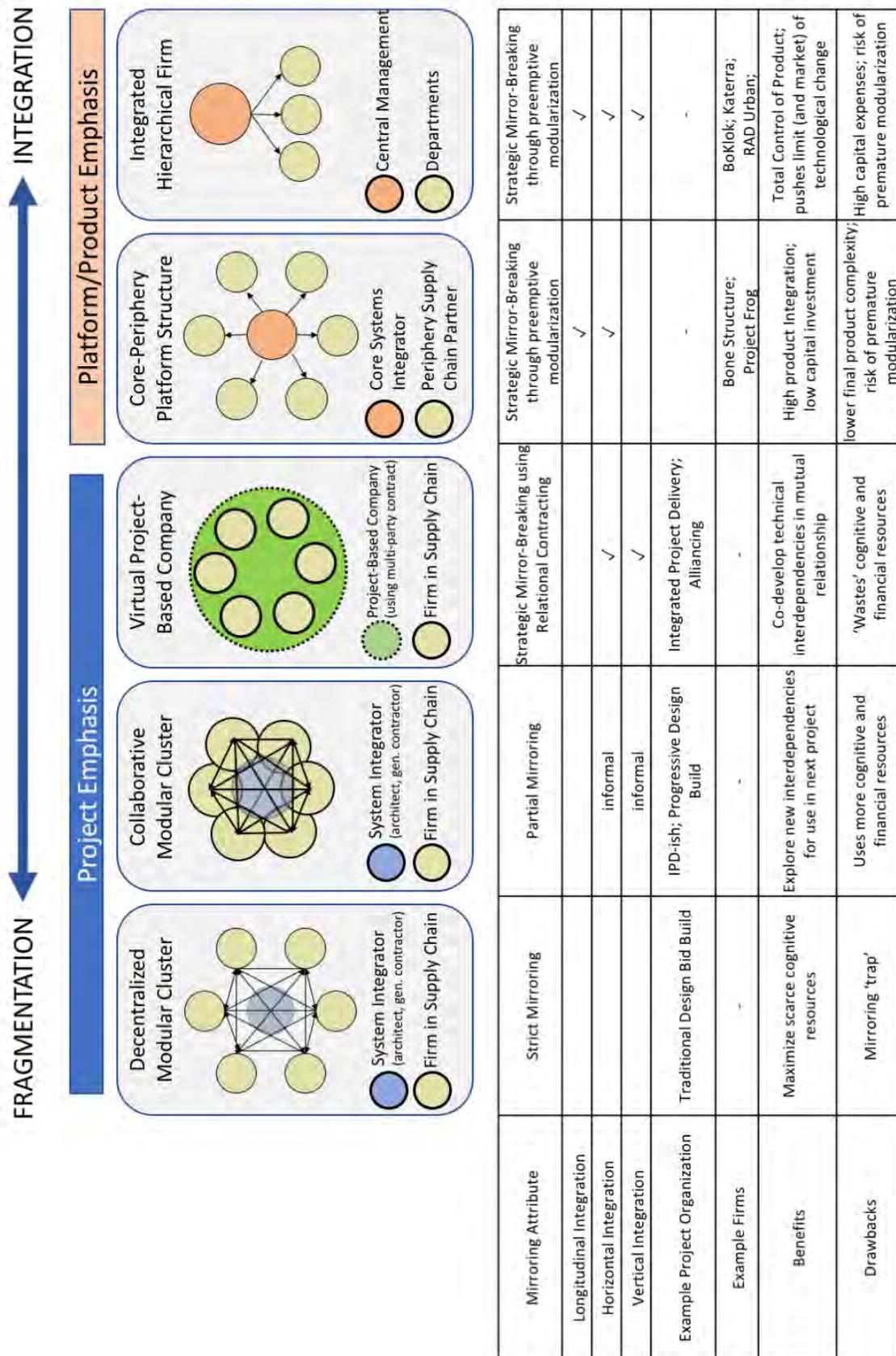
A less common form of industrialized construction organization exhibits the organizational characteristics of a core-periphery platform structure. Core firms are *digital* systems integrators; they design and integrate a new system or product architecture but do not manufacture the products themselves. They instead leverage the integrated cloud-based design platform to configure projects. They then utilize the principles of capital-light industry 4.0 supply chains to precisely mass-customize manufactured parts from periphery supply chain partners suppliers such as the automotive, aerospace, manufacturing or industrial sectors. Core-periphery firms are longitudinally integrated through their digital platforms, and often have horizontal integration in order to create their new and improved product architecture. Core firms also build long-term relationships with partners in the design, procurement, fabrication, and assembly stages. The benefit is a capital-light digital firm that can create a new ecosystem around its digital platform integration. However, this type of platform requires configuration engineering solutions where projects are constrained to limited choices within their product platform. Because control of the product architecture is not confined within the core firm’s organizational structure, more time is needed to innovate with long-term periphery partners.

Examples of core-periphery industry 4.0 platform structures include the startup companies Project Frog and Bone Structure in the San Francisco Bay Area. Project Frog began as an integrated firm offering to build off-site modules for schools. The initially raised 70 million USD from venture capital. However, a pivot in recent years has seen them develop a cloud-based configurator⁴ for architects to easily understand and design with Project Frog’s proposed system architecture. The configurator is linked to automated generation of permit drawings, structural calculations, and a bill of materials.

DISCUSSION

The ongoing re-organization efforts above offers firms the opportunity to deliver buildings ‘in a more integrated manner across their lifecycle—either through more vertically and horizontally integrated firms, or through long-term alliance partnerships’ (Levitt 2007). A summary diagram of each industry and table comparing the four emerging re-organization categories can be found in Figure 4. The categories are shown on a continuum from fragmentation to integration. At the fragmentation end of the spectrum, the current organization of decentralized modular clusters exhibits no characteristics of longitudinal, horizontal or vertical integration. At the integration end, integrated hierarchical firms include horizontal and vertical integration in their

⁴ Available for viewing at www.myprojectfrog.com



organizational model and achieve longitudinal integration through the development and continuous improvement of technical building system platforms. It is important to note that we do not imply increased integration is necessarily better. The benefits and drawbacks for the re-organization categories discussed above are also shown in Figure 4.

CRACKS IN THE MIRROR

Looking at the four re-organizational categories, we argue that each of the efforts represent small ‘cracks in the mirror’ for the AEC industry structure. They represent organizational configurations undertaken by forward-thinking firms to re-organize and compete in the market through the development of new product architecture paradigms. In other words, each of these efforts can be understood as strategic attempts to avoid the mirroring ‘trap’ currently prevalent in the AEC industry.

The use of supply chain integration practices to create collaborative modular clusters is an example of an organizational shift toward partial mirroring. Firms that utilize SCIPs are typically general contractors that acted as weak systems integrators. Ostensibly due to technological change, these systems integrators now have interest in expanding knowledge boundaries. The use of SCIPs are an ‘effective way to explore and understand latent interdependencies that are not apparent under the current technical architecture’ (Colfer and Baldwin 2016). The use of SCIPs is not the most economical strategy for organization, as partial mirroring violates the principle of information hiding and increases costs of participation. Indeed, this may explain why some firms and individuals critique the high overhead costs associated with a dedicated co-located project trailer, bringing on trade contractors earlier in the process, or creating a dedicated BIM team. However, the partial mirroring strategy can be effective long-term for existing firms as it allows them to view the current technical architecture in a broader context and potentially learn to mirror the interdependencies appropriately in their next project (Colfer and Baldwin 2016) without investing in significant change to institutionalized contracts, work routines, and supply chain arrangements.

Virtual, project-based companies are examples of strategic mirror breaking through the use of relational contracts. Inter-organizational arrangements seek to foster high levels of communication and cooperation across boundaries using informal and formal mechanisms. While the overhead costs and change in work processes are initially much higher than in partial mirroring, the firms can benefit by increasing technical interdependencies in the context of a long-term, mutually advantageous relationship (Colfer and Baldwin 2016). While the idea of ‘long-term’ is relative in the AEC industry, this might offer an explanation as to why virtual project-based companies work best for large, complex projects that span several years.

A new generation of integrated hierarchical firms have used industrialized construction business models to undertake strategic mirror-breaking through pre-emptive modularization. These re-modularizations of the platform architecture allow for the development and adoption of systemic innovations that provide the greatest global benefit. They are coordinated by the integrated firms that benefit from total control of product architecture and the ability to push the limits of technical change. However, integrated hierarchical firms face risks of high capital investments for factory production coupled with the risk of premature re-modularization that fails to correctly understand latent interdependencies (Colfer and Baldwin 2016).

Figure 3 – Conceptual overview of emerging AEC industry structure models

Finally, a few core-periphery industry 4.0 platform firms have begun to emerge. These digital system integrators also engage in strategic mirror-breaking. However, as their delivered product is primarily digital, they exhibit some characteristics of a core-periphery structure. The digital systems integrator provides the ‘core contributions’ by setting up the platform ecosystem. Meanwhile, connected suppliers and trusted partners provide contributions to smaller, localized components. This proposition that the industry 4.0 platform demonstrates a core-periphery organizational structure is based on very small set of emerging firms. Future work should study the examples provided in greater depth in addition to other firms to see if this proposition holds true.

The four re-organizational efforts and the existing industry structure can be mapped to Colfer and Baldwin’s (2016) boundary conditions of the mirroring hypothesis. Figure 5 includes:

- a) decentralized modular clusters;
- b) collaborative modular clusters that use SCIPs;
- c) virtual project-based companies such as those that use the IPD method;
- d) integrated hierarchical firms; and
- e) core-periphery platform structures.

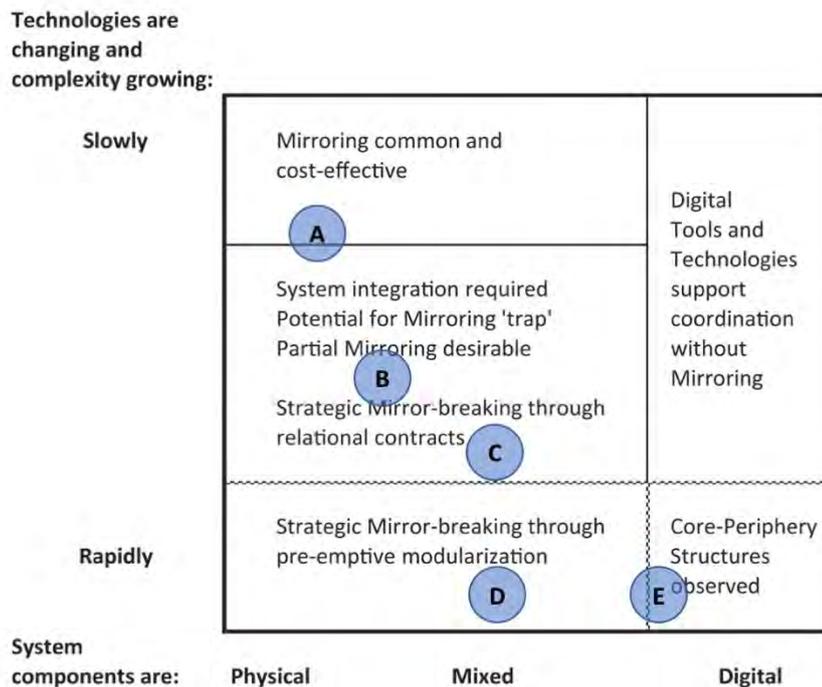


Figure 4 – Positioning the AEC industry within the boundary conditions on the mirroring hypothesis (adapted from Colfer and Baldwin 2016)

An important note is that re-organization and re-modularization should be understood as a dynamic process. It requires firms to map new functions to new components and

then understanding how the new components can be correctly designed with interfaces that account for the new interdependencies (MacDufie 2013). It takes time and iterations for these new arrangements to formalize and institutionalize (Colfer and Baldwin 2016). Here we see a snapshot of how an industry - long-entrenched in the mirroring trap - can simultaneously respond with significantly different organizational models during a period of technological change.

PROJECTS AND PLATFORMS

Finally, the re-organization categories can be interpreted to show a growing divide between project orientations and platform/product orientations (see Figure 4). Collaborative modular clusters and virtual project-based companies are more integrated versions of the existing project-based organization. While they represent novel organizational approaches, they still fail to achieve longitudinal integration and sufficiently address the industry-wide learning disability identified by Taylor and Levitt (Taylor and Levitt 2004a). Integrated hierarchical firms and core-periphery industry 4.0 platforms are relatively new re-organizations. They offer platforms as a means of longitudinal integration. This rise of ‘platformization’ – a term referring to massive networks built in the form of platforms to connect suppliers and customers – is still only relevant to a very small segment of the market. Yet they might offer the seeds of what has been termed the ‘innovator’s dilemma’ (Christensen 2013). These platforms tend to be startup companies that focus on smaller, repeatable projects such as housing. These small projects do not interest or attract the core business of entrenched industry players, who primarily are adapting through partial mirroring or relational contracting for larger and more complex projects. Yet should re-modularization be successful for start-up firms at the lower end of the value chain, it seems possible that one or both of these organizational forms might eventually be able to move up the value chain to more complex projects.

CONCLUSIONS AND FUTURE RESEARCH

This paper presents a conceptual model for four emerging re-organizational efforts currently ongoing in the AEC industry. The paper’s point of departure comes from the mirroring hypothesis of organizational scholarship, which suggests that the formal structure of an organization will match the underlying technical system. Evidence is provided to demonstrate that the AEC is currently caught in a mirroring ‘trap’ caused by extreme fragmentation and decentralized project organization. The industry is unable to adopt or even perceive the advantages of systemic and radical innovations that require knowledge and task efforts outside of the accepted modular product architecture. However, emerging organizational models and strategies offer small signals of ‘cracks in the mirror.’ These include partial mirroring using supply chain integration practices, strategic mirror breaking using relational contracts such as IPD, and strategic mirror breaking using pre-emptive re-modularization – either through an integrated hierarchical firm or through a core-periphery platform structure.

Future research should conduct comparative case studies from each of these four categories, in order to develop a richer description of the characteristics and differences among the emerging organizational models. The propositions put forth here are based on literature and theoretical categorization. Future work should empirically test and validate these propositions to determine if they hold true.

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DURABLE INNOVATION: A CASE OF ENGAGING WITH PUBLIC BODIES IN THE NUCLEAR DECOMMISSIONING SECTOR

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DURABLE INNOVATION: A CASE OF ENGAGING WITH PUBLIC BODIES IN THE NUCLEAR DECOMMISSIONING SECTOR

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ABSTRACT

The role of innovation intermediaries has recently become a prominent area of research in innovation studies. While much has been written about what innovation intermediaries do, the value and impacts of intermediaries is under-examined. Furthermore, researchers have tended to study innovation intermediaries in the private sector rather than the public sector. Treating the search for technological solutions as a project, we analyse how Alpha – a public body acting as an innovation intermediary in the UK nuclear decommissioning sector – engages with value chain actors and to what performance impacts. Our case study analysis makes three related contributions, including the need to consider the multiplicity of the role of public sector intermediaries, the need to refocus attention towards demand for innovation, and the need to reframe the impacts to consider not only the acceleration of technology adoption but also the need to develop durable innovation.

KEYWORDS

Demand, Innovation Intermediaries, Nuclear Decommissioning, Open Innovation, Public Sector

INTRODUCTION

Ever since Chesbrough (2003; 2006) coined the term ‘open innovation’, there has been a growing body of scholarship that moves beyond seeing innovation as an activity done within an organisation, to a conceptualisation of innovation as a distributed process of managing knowledge flows across a network of organisations (see e.g. Lichtenthaler, 2011). Consequently, the role of intermediaries as knowledge agents or brokers in driving innovation across the distributed network has come under increasing scrutiny (Howells, 2006), with much research emphasis on how innovation intermediaries can facilitate acceleration of innovation, manage the risks associated with the development of new technologies, products and services, and thus secure competitiveness (Marangos and Warren, 2017).

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Although there is a substantial body of literature that explains the functions of innovation intermediaries in the private sector, far less is known about the specific workings of intermediaries in the public sector (e.g. Bakici *et al.*, 2013; Edler and Yeow, 2016; Gascó, 2017). Moreover, while the literature has provided quite detailed explanations of what intermediaries do, how intermediaries generate value in what they do remains relatively under-examined (Hsuan and Mahnke, 2011). In this paper, we examine the role of public bodies as innovation intermediaries in the generation and diffusion of innovation. By following a public sector innovation intermediary in the UK nuclear decommissioning sector, Alpha, we analyse the engagement activities undertaken by this intermediary with actors across the value chain.

In what follows, we will present a brief theoretical review of innovation intermediaries and their engagement activities to make a case for examining what intermediaries do in driving innovation in the context of megaprojects in the public sector. We then describe the case study organisation, Alpha, and explain the methods and data sources used in this study. Our conclusions then point to three main points of departure. First, while the literature indicates a variety of roles that an innovation intermediary can occupy, our analysis of the case organisation Alpha shows that an intermediary can simultaneously occupy several of these roles; this multiplicity of roles, along with the potential tensions it creates, are rarely examined in the literature. Second, although innovation intermediaries are known to match suppliers of technological innovation with end-users of such solutions, the emphasis in the existing literature on innovation intermediaries tend to focus on supply-push rather than demand-pull strategies. Third, and related to the previous point, much research on innovation intermediaries considers how an intermediary might accelerate innovation and technological adoption. Yet, our case analysis highlights the argument that, in the context of megaprojects such as the nuclear decommissioning programme in the UK, it is more critical to search for innovation that works for and exploited by the end-user (and preferably over a long period of time) – or what we term as ‘durable innovation’.

THEORETICAL ORIENTATION: INNOVATION INTERMEDIARIES AND ENGAGEMENT ACTIVITIES IN THE PUBLIC SECTOR

Under the open innovation paradigm, focus has turned from analysing how innovation happens within the confines of an organisation to examining innovation across networks of organisations (Chesbrough, 2003; 2006). In a seminal, longitudinal study of patenting activities in 97 leading firms from the chemicals industry in Western Europe, Japan and the United States, Ahuja (2000) found in her analysis of interfirm collaborative networks that indirect ties mattered as well in boosting the number of patents filed by each firm in the network in a given year (see also Salman and Saives, 2005). Innovation intermediaries are one such indirect tie as they act as a bridge between organisations in the crosspollination of ideas and technologies (Howells, 2006). As Winch and Courtney (2007) argue, these innovation brokers can play an important role not only in promoting new ideas but also to turn these ideas into adoption of new physical products and technical processes.

Unsurprisingly, a number of typologies have emerged in the literature to characterise what innovation intermediaries do. For example, van Lente *et al.* (2003) indicated that innovation intermediaries play three key roles in articulating options and demand, aligning actors and possibilities, and supporting the learning processes and absorptive capacity of client organisations in the innovation process. In another example, Lee *et al.* (2010) identified three roles of network database, network construction and network management; these roles have differing levels of engagement where the intermediary as network database simply performs a match-making function, whereas the intermediary as network constructor or network manager plays a more proactive, strategic role in orchestrating relationships in managing the innovation process. In another typology, Guo and Guo (2013) studied how innovation intermediaries facilitate knowledge spillovers within the knowledge systems of industrial clusters in China to find that intermediaries can play four distinct roles: the role of technology gatekeeper in acquiring new technologies, the role of technology spanner to enable the diffusion of new technologies, the technical problem solver in applying new technologies, and the innovation resource integrator that plays an integration function across the value chain. As Howells (2006: 720) explained, innovation intermediaries can cover a range of activities including “helping to provide information about potential collaborators; brokering a transaction between two or more parties; acting as a mediator, or go-between, bodies or organizations that are already collaborating; and helping find advice, funding and support for the innovation outcomes of such collaborations.”

How innovation intermediaries engage with what Chesbrough and Brunswicker (2014) termed as the ‘searchers’ of knowledge and technological innovation and the ‘solvers’ who possess the technological solutions have also come under the spotlight. Macchi *et al.* (2014), for instance, highlighted three engagement strategies through their study of business incubators in the ICT sector in Italy. These include a central gatekeeping strategy where the intermediary adopts a top-down approach in organising relationships and guide the innovation process of tenant companies in the incubator; a bottom-up strategy where tenant companies have maximum freedom in the ways they interact with other firms, and; a cross-fertilisation strategy where the intermediary facilitates by organising networking opportunities for tenant firms.

In another study, Colombo *et al.* (2015) through an integrative review put forward a typology of four possibilities of brokering, mediating, collecting and connecting strategies. The broker chooses the most appropriate sources of knowledge to provide a ‘turn-key’ solution to their clients. The mediator selects the most appropriate solvers based on the fit between their capabilities and the client’s problems. The collector seeks out solutions regarding specific problems faced by their clients, and the intermediary in turn helps their clients select the most appropriate solution. The connector receives information about the experience and competencies of members of their network that are willing to collaborate with their clients and the intermediary then allows the client to choose the most appropriate parties to collaborate with given a specific innovation problem.

In these typologies, scholars have identified that intermediaries can play a neutral role of the ‘honest broker’ who facilitates and matches relationships between searchers and solvers on the one hand, to more engaged innovation process management where the intermediary evaluates and manages the innovation portfolio

for end-users (Katzy *et al.*, 2013; Klerkx *et al.*, 2015). In some cases, the intermediary also plays the role of ‘innovation capitalist’ that funds the innovation process (Nambisan *et al.*, 2012). Studies have also considered the knowledge and competencies that innovation intermediaries should have or develop. Janssen *et al.* (2014), for instance, analysed 14 collaborative multi-party ICT-enabled open innovation projects between 1999 and 2008 to identify the intermediary competences at different stages of the innovation process. They highlighted how it was important for the intermediary to look beyond company boundaries and have knowledge about social networking technology during the ideation phase; develop sourcing, sharing and learning capabilities during the translation of ideas phase, and; possess an ability to manage the balance between risk and reward and to focus on impacts during the technology diffusion phase. Janssen *et al.* (2014) also observed that developing the capability of reaching outside the immediate boundaries of the technological domain and industry sector, particularly in the ideation and translational phases were critical to the success of an intermediary.

With growing interest in the concept of innovation markets, the role of intermediaries in facilitating technology exchanges, especially in the context of Internet-based marketplaces (Chesbrough, 2006) have grown in prominence. Intermediaries play a critical role in understanding the situated contexts of the innovation markets in which the organisations they serve operate, and to develop ambidexterity by balancing between exploration and exploitation (Lichtenthaler, 2011). In Bocquet and Mothe’s (2015) study of two French SME clusters, they found that industries that have longstanding know-how and a deep industrial culture characterised by secrecy, low absorptive capacities and price-based competition such as the machining and tooling industry will tend to have a focus on exploiting tried and tested technologies. Conversely, in a sector that orientates towards new ideas, innovation opportunities and rapid evolution of markets such as the creative industries, the focus is more on exploration of new ideas, new technologies, and new markets. Thus, Bocquet and Mothe (2015) argued that intermediaries play a vital role in balancing these emphases so that they can support firms to become more ambidextrous in the exploitation-exploration continuum.

More recently, Lopez-Vega *et al.* (2016) studied an innovation intermediary based in the USA with subsidiaries in Belgium, Japan, Korea, Australia, South Africa and Brazil orchestrating over 2,500 open innovation projects and handling over 35,000 unique proposals from solution-providers to examine how and where to search for ideas for innovation. They created a typology of search paths based on search space (local or distant) and search heuristics (experiential or cognitive), and distinguished between situated, analogical, sophisticated and scientific paths. Lopez-Vega *et al.* (2016) argued that knowing the local sectoral context (situated) and finding similar experiences from elsewhere (analogical) were more useful for problems that exploit feedback from the problem at hand, a routine development process, or learning-by-doing; conversely, using more sophisticated and scientific approaches were more appropriate for exploring novel solutions to complex problems.

Despite considerable research into what intermediaries are and what they do, there are a number of gaps that persist in the literature. First, we know far less on how innovation intermediaries add value to the innovation processes of their clients and end-users (Hsuan and Mahnke, 2011). Researchers have nevertheless offered some

hints as to how innovation intermediaries can accelerate the innovation process. So, Ahuja's (2000) study was based on the premise that the frequency of patenting activity in a given year was desirable. Winch and Courtney (2007) implied that innovation brokers could accelerate the uptake of new technologies – in their case, the adoption of sustainable technologies in construction. Lee *et al.* (2010) also considered success to mean the swift construction of a production system and speed of commercialisation of a new idea. In the context of the Tapiola project of regenerating the Finnish City of Espoo, Peltokorpi *et al.* (2017) argued that the megaproject – which can be conceptualised as a systemic innovation intermediary (see e.g. van Lente *et al.*, 2003; Klerkx *et al.*, 2015) – offered an organising platform that brings together a diverse range of ecosystem actors to accelerate the development lifecycle and lead to scalable solutions.

More recently, however, scholars have questioned whether the benefits of engaging with innovation intermediaries have been established. Kovács *et al.* (2015), for instance, pointed out in their bibliometric analysis that far less attention is paid to examine broader performance implications of open innovation beyond innovation performance (e.g. patenting activity). Besides, as Chesbrough and Brunswicker's (2014) survey of CEOs and CTOs of large firms show, the use of innovation intermediaries is ranked lowest in terms of preference for boosting innovation performance. Indeed, as Klerkx *et al.* (2015) noted, the value of innovation intermediaries is often difficult to pin down since intermediaries are often regarded as missionary workers working behind the scenes; value is more often than not merely a perception (or a leap of faith). By studying the role of consultants as innovation intermediaries (see also Bessant and Rush, 1995) in three innovation contest contexts (in transportation, aerospace engineering and communications sectors), Lauritzen (2017) also argued that the intermediation process can so often be fraught with tensions and contradictions that innovation intermediaries can often increase rather than reduce uncertainty in the innovation process; she highlighted a number of control-openness paradoxes, including finding a balance between utility (i.e. meeting the client's current needs) and creativity (being open to 'crazy ideas'), and the dilemma between protection and sharing of intellectual property, which can de-value the contribution of innovation intermediaries.

A second gap relates to the over-emphasis on analysing innovation intermediaries in the private sector, although there is growing interest in the role of public-sector intermediaries (Chesbrough, 2017). Related to the first gap above, a number of researchers have argued that the performance of public sector innovation intermediaries deserve special attention. For instance, unlike the private sector where the goal is often to gain competitive advantage by producing novel and better products and services, Bakici *et al.* (2013) noted that performance outcomes and what generates value in the public sector is often less clear. Kankanhalli *et al.* (2017) also noted that the value of public sector innovation intermediaries is typically not found in a physical product, but through less tangible improvements in service performance. In a study of the living lab as a public sector intermediary, Gascó (2017) also stressed that it was difficult to demonstrate the return on investment in the intermediary. Unlike the private sector, process such as methods of citizen co-creation and participatory methods mattered much more than obtaining specific innovation results; she also added that the performance challenge of public sector innovation

intermediaries related more to sustaining innovative projects and scalability beyond the demonstration phase.

A third and final gap relates to the over-emphasis on supply-side perspectives, often at the relative neglect on demand-side issues (see Kovács *et al.*, 2015). In Bakici's *et al.* (2013: 321) study, for instance, even though there is recognition of the need to shift towards more demand-side considerations, the benefits of intermediaries is still focussed mainly on the private sector gaining visibility and publicity for their projects rather than the satisfaction of end-users. Indeed, supply-push strategies do not always work in the context of public sector innovation intermediaries. In a recent case study research in the UK health service, Edler and Yeow (2016) found that acquisition of new technology did not always take place as broadly envisaged despite going through the steps of identifying the technological requirements, scanning the field and selecting the most appropriate solution. This is because of institutional barriers that can serve to render problematic the demand for new technologies – in their case, the need to considerably transform organisational practices and actor capabilities can stymie innovation diffusion. Moreover, in the public sector where service improvements matter much more than physical products, the introduction of innovative processes can be even more challenging. Edler and Yeow (2016) found that articulating a concrete need for a new process was often very difficult. As Chesbrough and Brunswicker (2014) noted in their survey, organisational change appears to be an insurmountable challenge. Thus, to reap the promising rewards of engaging with innovation intermediaries, there is a need to refocus attention towards demand for innovation.

RESEARCH CONTEXT AND METHODS

In the preceding section, we argued for the need to study the value generated from engaging with public sector innovation intermediaries in balancing supply and demand for innovation. To do this, we draw on a case study organisation, Alpha, a public body that fulfils a strategic role in delivering nuclear decommissioning projects in the UK. We analyse how and why Alpha engages with the value chain in order to access technological innovation, especially from small-to-medium-sized enterprises (SMEs) to answer the question of what (valuable) outcomes are generated through such engagement. Like Lopez-Vega *et al.* (2016), we conceptualise the search for technological solutions in an open innovation context in the public sector as a project. Nuclear decommissioning thus presents a very useful context for theorising the project of searching for technological innovation in two counts: first, project studies have hitherto paid more attention to construction rather than decommissioning (see Invernizzi *et al.*, 2017), and; second, while studies on the role of intermediaries in open innovation tend to focus on the need to accelerate innovation, nuclear decommissioning in the UK is a drawn-out process that is estimated to last over the next 120 years (Nuclear Decommissioning Authority, 2017), and so this provides a unique temporal context to examine the forms of engagement of a public body like Alpha in the creation and diffusion of innovation.

The approach taken is case study research (Eisenhardt, 1989; Eisenhardt and Graebner, 2007), supported by the selection of a number of 'nested' innovation projects (Miles *et al.*, 2014). The case study is informed by qualitative data collected through 20 semi-structured interviews, and analysis of documentary evidence that

includes inter alia organisational policies and ‘guidelines’ on research and development and records of engagement with both end-users and suppliers of a selection of recent technological innovations designed and/or procured in the process of decommissioning nuclear power plants and dealing with nuclear waste (see Table 1 below). The interviews were conducted with a range of key stakeholders (e.g. SME supply chain, end-users known as Site License Companies) across different levels of the organisational hierarchy (e.g. directors, research and development managers, technologists). The interviews were guided by a semi-structured protocol designed to elicit the participants’ experiences of engaging with Alpha as the innovation intermediary. Questions included how, when, where and what Alpha did in order to search for, generate and share technological innovation across the value chain. The interviews also explored the impacts (i.e. ‘so what’) of Alpha’s engagement strategies and practices as an innovation intermediary in nuclear decommissioning. The interviews were also supplemented by other documentary evidence, including internal memos, transcripts of videos from networking events and online marketing materials. Fieldnotes from observations of supplier events and innovation competitions organised by Alpha were also collated and analysed.

Table 1. List of interviewees.

Organisation	Organisation	Participant	Hierarchy	Discipline Focus
Public Body	PBI (Alpha)	Participant A	Senior Manager	Technology
		Participant B	Manager	Technology
		Participant C	Manager	Programme
Other Publicly Funded Organisations	OPF1 (Beta)	Participant D	Manager	Business
		Participant E	Manager	Technology
	OPF2 (Epsilon)	Participant F	Manager	Business
	OPF3 (Lambda)	Participant G	Senior Manager	R&D
	OPF4 (Gamma)	Participant H	Manager	Business
Tier 1 SLCs	SLC1	Participant I	Senior Manager	Technology
		Participant J	Senior Manager	Technology
		Participant K	Manager	Operations
		Participant L	Manager	Technology
	SLC2	Participant M	Senior Manager	Operations
		Participant N	Manager	Technology
Tier 2 (Large/Primes)	Lrg1	Participant O	Senior Manager	Business
Tiers 3 & 4 (SMEs)	SME1	Participant P	Board	Technology
	SME2	Participant Q	Manager	Operations
		Participant R	Manager	Business
	SME3	Participant S	Board	Technology
	SME4	Participant T	Board	Technology

RESULTS

KEY ENGAGEMENT ACTIVITIES

As Chesbrough and Brunswicker (2014) found in their survey, the three most common engagement activities include customer co-creation, university collaborations on research and networking events. Furthermore, as Natalicchio et al. (2014) and Kovács *et al.* (2015) suggested, innovation competitions are becoming more popular. Table 2 below summarised the key forms of engagement observed in Alpha, which are in line with the common forms of engagement identified in the literature.

Table 2. Forms of engagement by Alpha.

Form of engagement	Example	Outcomes
Supply-side (lower technology readiness level)	Industry-funded PhD research	Pushing the frontiers of foundational knowledge Building of skills, knowledge and capabilities in the long-term
Connecting supply and demand (middling technology readiness level)	Industry-academic networks and competitions	Proof-of-concepts to identify demonstration projects for scaling up breakthroughs
Demand-side (higher technology readiness level)	Embedding technology in business-as-usual	Embedding new technologies and creating new demand for proven technological breakthroughs in Site License Companies

CONTEXT OF INNOVATION AND INNOVATION INTERMEDIATION IN ALPHA

“Reprocessing operations will come to an end within the next three years and so the site is already going through and will be going through a significant change in focus moving from that reprocessing organisation into a decommissioning site remediation organisation” (Manager of an End-user organisation, transcript of a video recording of presentations at a networking event, 14 February 2017)

According to the Annual Corporate Report 2017, Alpha invests more than £85 million a year in research and development across the estate. The bulk of this is focussed on addressing challenges associated with decommissioning work on sites. Around £7 million is spent directly by Alpha on technological innovation (e.g. robotics and other autonomous systems, sensors and detectors, imaging and virtual reality) that can be applied across numerous sites. As the quote above from the manager of one of the end-user organisations served by Alpha explained, there is an

urgent need to find technological solutions to meet the needs of this transformation from a reprocessing organisation to a decommissioning and site remediation organisation. It is worth noting, nevertheless, that this end-user represents one of seventeen end-user sites – which consumes 60% of the decommissioning budget – that Alpha works with across the UK.

Alpha supports the end-users in the innovation process in several ways. As mentioned above, Alpha provides direct funding on the development of technological innovation. In one example, Alpha organised an innovative technology scheme where a university partner worked alongside an end-user to help businesses develop technologies that can help accelerate the decommissioning mission on site (Funding for Decommissioning Technologies information leaflet). For technologies that go beyond the proof-of-concept phase, Alpha also runs competitions so that technology suppliers, many of which are small-to-medium sized enterprises (SMEs), can demonstrate new technologies for decommissioning hazardous nuclear processing cells. An example of this was a competition organised in 2008 where Alpha allocated £1 million of funding to demonstrate the effectiveness of laser technology widely used by non-nuclear industries to explore the possibilities of cutting up metal and removing contaminated concrete surfaces; this journey resulted in the development of a new robotic equipment following 4 years of development and involving collaboration between developers, the end-user and ongoing support by Alpha and UK government departments and agencies (Annual Corporate Report, 2017).

Thus Alpha plays, simultaneously, several intermediary roles including that of a funder or innovation capitalist (Nambisan *et al.*, 2012), a network database and constructor (Lee *et al.*, 2010), a technology spanner and innovation resource integrator (Guo and Guo, 2013). As an innovation intermediary, Alpha's involvement is largely in the ideation and translation phases of the innovation process. Therefore, in line with Janssen *et al.* (2014), Alpha has strong competence on reaching outside the immediate boundaries of the technological domain. As a senior manager of the Technology Strategy (Participant A) commented,

“Our role is to strategically find out what the issues are that will help us complete decommissioning in total. So those might be innovation things, they might be commercial, they might be supply chain development. So our role is to facilitate all of those all the way through really. Even at the announcing of the competition, you know, our role is to make sure that we try and communicate it with as many people as possible and try and bring in as many different types of people as possible and try and bring in as many [end-users] early on as well.”

Thus, while researchers into public sector innovation intermediaries have often suggested that the focus, unlike in the private sector, is on less tangible service elements (Bakici *et al.*, 2013; Kankanhalli *et al.* 2017; Gascó, 2017), Alpha can be seen to engage in both the development of physical products and technologies, and in the development of less tangible processes (e.g. through advanced skills development in the nuclear decommissioning supply chains in collaboration with universities).

IMPACTS OF ALPHA’S INNOVATION INTERMEDIATION

“[...] what is success in the innovation space, if we are diversifying and making more of a resilient supply chain, so when those services are required to be called upon it’s there. Is that a success? And I would argue – yes, it is. So, if we are investing in suppliers and innovators that have the potential from the outset to solve a challenge for the [end-user’s] estate, I think we should look into it and should fund it. If it doesn’t actually come off and some of them will and you usually use the law of a third, so 300 ideas, 100 funded, 33 will get so far and you might end up with 5 that actually work. But those 5 that actually work might make a massive impact that will dwarf the initial investment we make” (Participant H, Programme Manager, Gamma)

There are multiple, often-competing drivers of performance that Alpha has to meet in facilitating the innovation process in the UK nuclear decommissioning sector. On the one hand, and as indicated by one of the end-user sites, there is a push toward “accelerating deployment” of technological innovation (Alpha’s Strategy, 2016). On the other hand, there is also recognition that searching for and developing technological innovation that works can take a long time. Yet, there is also the pressure of public accountability, and of ensuring that the decommissioning programme delivers value for money for taxpayer. Thus, Alpha mediates in a context that is fraught with tensions and contradictions (Lauritzen, 2017). In what is “a very conservative sector” (Innovation lead, transcript of a video of a networking event, 14 February 2017), there is also a need to demonstrate that the technology works not only in accelerating the decommissioning programme, but also in reducing the cost and risks and in making the operations safer (Online promotional material in the ‘Game Changers’ initiative at one of the end-users’ site). Thus, as the manager (Participant R) of an SME supplier remarked,

“[...] it is the race to be second. So, everybody wants to be second and nobody wants to be first. As soon as you have done something that is proven, everybody wants one.”

This interesting quote about the first-mover disadvantage is an illustration of the need to shift away from supply-push to demand-pull strategies. As a Programmes Manager (Participant C) of Alpha explained, while Alpha can facilitate network construction by incentivising activities, it does not have the power to compel the end-users to deploy the technological innovation

“I incentivised the [end-user]. I didn’t tell them then what to do. They came up and said, ‘We’ve been thinking about these Remotely Operated Underwater Vehicles (ROVs) and we can, we reckon we can lift a fuel rod with it.’ I got some money there for incentivisation and so ok, incentivise you [...] so it encouraged them then to really start to think about driving the technology and taking it from ‘Oh, that’s an interesting little side thing’ to actually ‘I have got to be a lot more operational about this.’ Necessity drives innovation, always has.”

Without working with end-users to drive demand, the development of technological innovation can lead to frustration and disenfranchisement among the suppliers, especially for SMEs. An example of this can be found in another story of

translating a technology from another unrelated sector into the nuclear decommissioning context.

“He is sort of, kind of frustrated because no one is really taking up his technology. ‘I’ve put all this money in it so why can’t you force someone to take it?’ The answer is – we have other answers. So, would you have invested in that in the first place if you really thought about it? Not unless you have got a good sponsor, with the end-users who have seen a real need for it and done your market research and that and taken it beyond asking R&D – will this be good?” (Participant C, Programmes Manager, Alpha)

So far, the focus on Alpha has been on outside-in, rather than inside-out activities in the innovation process (Chesbrough, 2017). As the Programme Director of an end-user site noted in the promotional video of an advanced vacuum drying system in 2013, the collaboration between the end-user and the technology company resulted in more than the technical artefact; it delivered

“a good understanding of industrial application of vacuum drying technology and they have brought to us a state of the art solutions to the problems we were trying to solve, be it hydrogen generation or trying to limit the amount of secondary waste arising that are produced and [...] we will see that benefit resounding for a number of years to come.”

In a similar vein, a senior member of the Nuclear Industry Council wrote,

“[the] potential is not only the next generation of nuclear power, to replace our current ageing infrastructure, but is also the development of new technology and fostering innovation that will impact decades into the future.” (Proposal to the UK Government for a Nuclear Sector Deal, 2017).

Thus, the durability of the technological innovation or, what works and what lasts, can sometimes be privileged over what can be deployed quickly. This emphasis on durability can also be seen in an inside-out example. As the manager of a supplier commented, game-changing technology developed for the Alpha estate can sometimes have application potential in other sectors such as the oil and gas sector and in the navy. Indeed, as a Technical Manager of Alpha (Participant B) noted,

“We do recognise there are benefits associated with our mission of technology that is developed here, could go out to Fukushima, be further developed in Fukushima and come back to us as a better technology.”

Chesbrough (2017) suggested that there is a need to pay attention to inside-out activities of open innovation so that firms can reduce the ‘false negatives’, i.e. innovation projects not evaluated positively within the firm’s innovation process but which, when leaked out to the outside world, may turn out to be enormously valuable. Thus, there is a need to pay attention to the potential impacts of the innovation projects orchestrated by Alpha, which could have broader implications for other sectors and which could also in turn benefit Alpha and its value chain in the long run.

Tran *et al.* (2011), in asking what value innovation intermediaries generate in the fashion industry distinguished between ‘fast’ fashion and ‘slow’ fashion. In the

former, characterised by seasonal fashion apparel, the emphasis is on accelerating innovation to enhance product attributes in order to achieve competitive advantage. In the latter, more mundane fashion, where demand is more predictable, the driver for innovation shifts away from speed to finding innovation solutions that work. By a similar token we argue that, given how nuclear decommissioning as a megaproject can last for a long time (over 100 years in the UK), durability of technological innovations can sometimes trump speed of technological adoption.

CONCLUDING REMARKS

The open innovation paradigm has shifted the attention towards understanding the innovation process across a network of organisations. This has resulted in the proliferation of studies into the role of the innovation intermediary. While most scholarship has focussed on the private sector intermediary, we make a contribution here by adding to a growing line of inquiry into the role of the innovation intermediary in the public sector. By framing the searching of technological innovation as a project, we also situated this analysis by drawing on a unique case study of a public body innovation intermediary in a megaproject context in the UK nuclear decommissioning context. Our case analysis has highlighted three main contributions, as follows:

Multiplicity in the role of the public body intermediary: Scholars have recently argued for a more a nuanced understanding of the ways by which innovation is generated and diffused across a network of organisational actors (see e.g. Dahlander and Gann, 2010; Lopez-Vega et al., 2016). In a similar vein, there is also growing recognition of the variety of ways in which an intermediary operates (Bakici et al., 2013). While these various typologies expand our understanding of what ‘openness’ means and categorisations of the different kinds of intermediaries that (could) exist, we extend these understandings by identifying how Alpha can simultaneously play multiple intermediary functions depending on the forms of engagement across the value chain. In some cases, Alpha simply facilitates knowledge exchange between supply-side and demand-side actors, or funds research projects at a lower technology readiness level to produce foundational supply-side knowledge and capabilities, without the explicit intention of exploiting technological innovation. In other cases, Alpha brokers the relationship between supply chain actors and the Site License Companies to deploy technological breakthroughs that go beyond the proof-of-concept. Thus, we show that public body innovation intermediaries can often simultaneously play multiple roles in stimulating innovation. While we have only described this multiplicity here, future research can beneficially explore the tensions that these multiple roles can bring in managing the innovation process and the coping strategies that the intermediaries can adopt to mitigate against these tensions.

Demand-pull as opposed to supply-push: The emergence of the ‘open innovation’ concept coincides with increasing recognition of ideas such as user-centric design and democratising innovation. At its core, the focus shifts from a production (supply) logic to a needs-based (demand) logic (see e.g. von Hippel and von Krogh, 2015). Yet, in understanding the role of innovation intermediaries, there tended to be more focus on supply-side activities than on understanding demand (Edler and Yeow, 2016). In our case study research, we found that technological innovation tended to be exploited more effectively if demand-side stakeholders were involved early on in

the process of developing new technologies. Often, scholarship on the role of intermediaries shed light on how these intermediaries can drive innovation, with relative neglect on what technological innovation (should) matter for demand-side actors. Thus, there is a need to reframe the role of innovation intermediaries as a ‘what-not-how’ challenge, especially when innovation intermediaries go beyond brokering networks of information exchange to develop new products and technological processes.

Towards durable innovation: Much of the literature on innovation intermediaries seek to examine how intermediaries can speed up the uptake of technological innovation. Yet, associated with the ‘what-not-how’ challenge, we found that instances where technological innovations are short-lived, i.e. innovation is generated but not necessarily taken up by the end-user, simply because demand-side actors were not engaged early on in the technological development process. This is a particularly important point in the context of public body intermediaries. As Gascó (2017) observed, public body intermediaries are confronted especially by two key challenges: sustaining and scaling up innovations beyond the demonstration project or living laboratory. In our case study, we found that the failure to engage with demand-side actors early on in the development of new technologies not only potentially alienated the users of these technologies, but also led to the disenfranchisement of the producers of technological innovation since the suppliers of these technologies risked investing in the technological development without the potential of seeing a sound return for that investment. Thus, focus should shift away from accelerating innovation to considering the durability of innovation created by connecting supply and demand-side actors. This is arguably vital given the long gestation periods associated with nuclear decommissioning projects.

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OWNER COMMERCIAL CAPABILITIES IN CHINESE CONSTRUCTION PRACTICE

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ABSTRACT

The importance of owner-supplier interfaces on project delivery outcomes has been widely acknowledged in construction management research. Project owners rely on a host of organisations to supply the resources and capabilities necessary to deliver the projects that they invest in. To manage the owner-supplier interfaces, essential commercial skills, experience and knowledge are needed from both owner and supplier sides. Considering the fundamental role of project owners in project organising, we focus on the owner perspective and term such commercial skills and knowledge as owner commercial capabilities. The fundamental question here is what constitutes owner commercial capability and how they are applied in the construction industry. Thus, this research conceptualizes commercial capability and identifies underlying elements – activities and routines – that comprise owner commercial capability. Three sub-sets are identified from the literature: packaging, contracting, and relational capabilities. The applicability of these sub-sets is then tested against the experience of 25 project professionals in the Chinese construction industry. A qualitative research method is adopted with in-depth semi-structured interviews. The findings illustrate the practice of owner commercial capability in the construction industry and provide a preliminary understanding by elucidating potential problems that may occur regarding activities and routines in each commercial capability set. This research supports a conceptualization of commercial capabilities and is considered as a first step towards future studies into how commercial capabilities could be developed by project owners.

KEYWORDS

project owner, owner-supplier commercial interface, organisational capabilities, commercial capabilities

INTRODUCTION

In the project organising field, three principal organisations stand out: the temporary project or programme, the relatively permanent project owner and operator, and the project-based firm as supplier (Winch, 2014). Project owners often do not, or cannot, undertake entire projects on their own, so they typically procure a wide range of project-related resources and services from suppliers, forming owner-supplier commercial interfaces. If not dealt with appropriately, interface problems on construction projects may easily occur such as improper packaging strategies, a lack of alignment between work-breakdown structure and awarded contracts, insufficient

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coordination among suppliers, a mismatch between contracting strategies and project types, an absence of incentives for suppliers, and adversarial owner and supplier relationships (Weshah et al., 2013). Hence, the commercial relationship between owners and suppliers has great influence on successful project delivery.

The importance of owner-supplier commercial interfaces has been broadly recognized and commercial relationships have received significant scholarly attention in the construction management literature (e.g. Winch, 2010; Meng, 2012; Morris, 2013). However, comparatively little attention has been given to how the project owner, as a strategic actor in its own right, manages commercial interfaces with its suppliers in pursuit of improved effectiveness of projects (Winch, 2014; Winch and Leiringer, 2016). The project owner, acting as an investor, a purchaser of services for project delivery, and an operator of project assets, plays a fundamental role in determining the successful delivery of a project (e.g. Hui et al., 2008; Aritua et al., 2009). To procure resources and services from suppliers and manage the interfaces with them effectively, project owners need to possess a collective set of commercial skills, activities, processes, and routines. Anchored in the capability literature (e.g. Penrose, 1959; Wernerfelt, 1984; Teece et al., 1997), we term such commercial activities and routines as owner commercial capabilities (cf. Winch and Leiringer, 2016), which are essential and crucial for project owner organisation to achieve project delivery outcomes and eventually sustained growth.

The starting point of this paper is that commercial capabilities form the cornerstone for project owners to manage the interfaces with their suppliers. Research into owner commercial capabilities, however, is still in its infancy, and the skills and competences required by project owner organisations to manage the commercial interface with their suppliers for successful project initiation and implementation are not well understood (e.g. Winch and Leiringer, 2016). Therefore, this research attempts to contribute to current understandings of owner commercial capabilities by unpacking them and identifying the underlying activities and routines and exploring how they are applied in practice. To achieve this, the present study is informed by the following research question: what are commercial capabilities from the perspective of project owners in the construction practice? This research provides empirical support to form a preliminary understanding into how owner commercial capabilities are conceptualized in the project-based construction setting, what the underlying activities and routines that constitute commercial capabilities are, and how these activities or routines are utilized by project owners in project delivery.

The paper is organised as follows. First we provide the theoretical foundation for the term – owner commercial capability – by briefly introducing the capability literature, including organisational capabilities literature and the dynamic capability view. This is followed by an introduction of owner project capabilities in general and owner commercial capabilities in particular from the construction management literature with three identified dimensions: packaging, contracting, and relational capabilities. An initial description of underlying tasks and activities for each capability set is presented. We then outline the research method – an in-depth semi-structured interview - which is employed to provide empirical support for different commercial capabilities and elucidate the problems for project owners in initiating, implementing and developing these capabilities. We conclude with a discussion

around theoretical and practical contributions. Limitations and potential avenues for further research are also illustrated.

THEORETICAL FOUNDATIONS: THE CAPABILITY LITERATURE

Capability - the power or ability to do something - refers to having a generally reliable capacity to achieve outcomes as a result of intended actions (Dosi et al., 2000). Organisational capabilities, considered as firms' capacity to deploy and make use of human and material resources (Amit and Schoemaker, 1993), enable them to perform various tasks or activities within organisations (Dosi et al., 2000). Firm-specific capabilities are thus considered as primary determinants of a variance in firm performance (Wernerfelt, 1984; Dosi et al., 2000). The capability literature originates from the resource-based view of the firm (RBV), which explains how a firm's resources, both tangible and intangible, influences its sustained growth (e.g. Penrose, 1959; Wernerfelt, 1984; Barney, 1991). Research efforts have over time gradually focused more on the process of making use of resources, reflected in the term capability, and argued the importance of how valuable resources should be properly managed and leveraged (e.g. Prahalad and Hamel, 1990; Mahoney and Pandian, 1992; Barney, 2001).

An important stream of capability research is the dynamic capability view introduced by Teece et al. (1997) which, instead of only focusing on internal resources and capabilities within organisations, takes into account the dynamic and changing external environments in which firms operate. The concept of dynamic capability is originally referred to as firms' "*ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments*" (ibid.:516). Since then, the dynamic capability view, which emphasizes the importance of dynamic capabilities on firms' sustained competitive advantage when responding to changing situations, has received an increasing scholarly attention in the strategic management area (e.g. Eisenhardt and Martin, 2000; Helfat et al., 2007; Teece, 2007; Schilke et al., 2018). Several research streams have spawned from the dynamic capability literature, rooted in different identifiable theoretical foundations, such as evolutionary economics view (Nelson and Winter, 1982; Zollo and Winter, 2002), behavioural view (Eisenhardt and Martin, 2000), and knowledge-based view of the firm (e.g. Kogut and Zander, 1992).

This research follows the line of thinking on evolutionary economics and literature on organisational routines (e.g. Nelson and Winter, 1982; Zollo and Winter, 2002), which sees organisational capabilities as embedded and embodied in a combination of strategic processes, structures and routines. Routines are seen as the fundamental 'building blocks' of capabilities, the mechanisms by which they are used to execute and coordinate tasks and activities in organisations (e.g. Zollo and Winter, 2002; Helfat and Peteraf, 2003; Helfat et al., 2007; Dosi et al., 2008). A widely recognized definition in literature is that a routine is a "repetitive, recognizable pattern of interdependent actions, involving multiple actors" (Feldman and Pentland, 2003, p.96). Routines are contextually embedded processes (Parmigiani and Howard-Grenville, 2011) and they reflect the ways tasks or activities are completed or accomplished within an organisation. There are two distinct types of routines, operating routines which involves the implementation of existing procedures, and

search routines which seeks to generate desirable changes in the existing operating situations (Nelson and Winter, 1982; Zollo and Winter, 2002).

Based on the difference between operating routines and search routines, a distinction is also made between operational capabilities and dynamic capabilities (Zollo and Winter, 2002; Winter, 2003; Helfat and Winter, 2011). Operational capabilities, sometimes dubbed ordinary capabilities, zero level or zero order capabilities (Collis, 1994; Winter, 2003; Zahra et al., 2006), are based on operating routines. They enable organisations to perform activities on an on-going day-to-day basis so that organisations could make a living in the present. In contrast, dynamic capabilities are derived from search routines (Zollo and Winter, 2002). Dynamic capabilities are primarily about change and aimed to extend, re-configure, or modify how the organisation makes a living by altering operating routines and capabilities (Zollo and Winter, 2002; Winter, 2003) or the resource base of the organisation (Helfat et al., 2007).

The categorization of operational and dynamic capabilities has also been applied in the project-based organising setting. Previous research into innovation in complex product systems identifies project capabilities, which are referred to the knowledge, skills, and structures that required by project-based firms, as project suppliers, to deliver projects for project owners (Davies and Brady, 2000; Brady and Davies, 2004). Such project capabilities, allowing project-based firms to win projects and provide effectivity and efficiently materials and services to project owners, are more prone to be operational; while owner project capabilities, which are considered as abilities to extend, modify or improve the owner organisations' resource base through delivering projects, change the resource base in owner organisations and are, thus, more dynamic in nature (Winch and Leiringer, 2016). This corresponds to what Winter (2003) points out – that what constitutes a dynamic capability for a purchasing firm may be an operational for a supplying firm.

OWNER COMMERCIAL CAPABILITY

The concept of owner commercial capabilities has its root in the term owner project capabilities developed by Winch and Leiringer (2016) as they emphasize the contribution of the strong owner in overall project performance. Based on the dynamic capability view (Helfat et al., 2007) and initial research into project capabilities (Davies and Brady, 2000; Brady and Davies, 2004), owner project capabilities are put forward as the dynamic capabilities required by the owner organisation for acquisition of project assets in order to extend or improve its operational capabilities (Winch and Leiringer, 2016). Following this line of research and the three domains of project organising (Winch, 2014), we consider owner project capabilities as composed of three main capability sets: strategic capabilities which the owner itself needs to implement its investment projects; commercial capabilities needed to manage the interface between the owner and the project-based firms; and governance capabilities needed to manage the interface between the owner and the temporary organisation (Winch and Leiringer, 2016).

Project owners, in the position of procurers, play an indispensable role in commercial management in the project organising domain (e.g. Winch, 2014; Winch and Leiringer, 2016). To effectively manage the interfaces with suppliers in pursuit of

project delivery outcomes, project owners need commercial skills and knowledge to perform a bundle of activities and routines, such as developing contracting strategies, breaking down and packaging project scope, aligning packages with capable suppliers, selecting and motivating suppliers, and maintaining a good relationship with suppliers. Grounded in the capability literature, such activities and routines from the project owner perspective are dubbed owner commercial capabilities (Winch and Leiringer, 2016). The literature on owner commercial capabilities is, as mentioned above, not a developed one, but there are a few indications from the project management literature as to what commercial skills and activities might be needed for project owners both in the project development and execution stages. Following the work of Winch and Leiringer (2016), this research distinguishes between three sub-sets of capabilities: packaging, contracting and relational capabilities.

PACKAGING CAPABILITIES

Packaging capabilities refer to a project owner's ability to divide the project scope into market-friendly clusters of work and coordinate the interfaces between different packages (Winch and Leiringer, 2016). This includes activities such as finalizing the project scope, defining the work breakdown structure, identifying resource requirements and refining the sequencing of work. A package refers to activities grouped together for delivery and it dictates the type of contract required (Mead and Gruneberg, 2013). Packaging strategy is the first and critical step to develop an owner's contracting strategy (*ibid.*). Such strategy is related to the decision whether there will be a single contractor or whether work packages will be issued to several suppliers, ranging from a prime contractor to separate package contractors (Morris, 2013). The packaging decision is influenced by a number of factors, such as characteristics of the project, scale and nature of works, interdependencies between work packages, levels of competition among contractors, organisational and managerial complexities, the manner in which interfaces between packages are to be managed and controlled, matching contractor skills and capabilities, project risk allocations, in-house administrative resources and capabilities, and the degree of active control that the owner wishes to exert over the work (Morris, 2013).

After identifying the needs for different suppliers and packaging project scope, project owners need to manage the interfaces among different clusters of work packages. Packages establish the number of procurement transactions which need to be processed and the contractual relationships which project owners and their management team have to administrate and coordinate. This is related to the area of task coordination (Thompson, 1967). The interdependencies between processes create the need for coordination between tasks. Project owners need to make sure work packages interface with each other effectively to avoid overlaps, gaps, or contradictions among them (Morris, 2013). The greater the interdependence, the more resources such as rules, schedules, staff officials and efforts should be devoted to coordination mechanisms (Thompson, 1967; Sor, 2004). Coordination means integrating and linking together different parts to accomplish a set of tasks (Ven et al., 1976), in this case the project. Coordination could be achieved through three predominant modes, by: 1) programming through impersonal mode, such as the use of pre-established plans, schedules, formalized rules, policies or procedures, standardized information and communication systems, and coordination by feedback

or mutual adjustments through either 2) personal channels or 3) group/team meetings (Thompson, 1967; Ven et al., 1976).

CONTRACTING CAPABILITIES

Contracting capabilities are related to the project owner's abilities to identify, select, and motivate potential project suppliers (Winch and Leiringer, 2016). They are reflected in organisational routines and procedures to develop knowledge about the structure of supply market, procure services and products, undertake tendering/bidding, ensure the competitive tension through the procurement processes, select the most competent and efficient suppliers, decide pricing options (fixed price, cost reimbursable, or re-measure), select contract forms and prepare contract documentations, design appropriate incentives to motivate desirable behaviour from suppliers, negotiate with suppliers, do the final deal, and administrate contracts (Mead and Gruneberg, 2013; Morris, 2013). This capability set is associated with developing a contracting strategy, a strategy that governs the nature of the relationship which project owners wish to foster with their contractors or suppliers. This in turn determines the risks and responsibilities between the parties to contracts and the method by which suppliers are to be paid (Mead and Gruneberg, 2013).

Using contracts to regulate project suppliers' behaviour is a fundamental element in this capability set. The contract between transactional parties is a legal and formal way in control, coordination, and adaptation of inter-organisational relationships (e.g. Poppo and Zenger, 2002; Schepker et al., 2014). Contracts specify the terms of agreements, define the responsibilities, allocate project risks, determine payment terms, and provide the legal umbrella for a transactional relationship between contractual parties. Contracts describe what should be provided and under what conditions. According to the transaction cost economics, contracts safeguard against potential opportunism hazards of contracting parties and contractual governance is considered as an effective mechanism to control exchange hazards (Cao and Lumineau, 2015). Thus, contractual governance has been widely acknowledged as a crucial and formal mechanism in inter-organisational relationship management both in construction management literature and practice (e.g. Schepker et al., 2014; Cao and Lumineau, 2015).

RELATIONAL CAPABILITIES

Rigid application of contracts and over-dependence on contracts could negatively impact the flexibility of cooperation, which could lead to disputes and trust deterioration between contractual parties (Faems et al., 2008; Cao et al., 2013). However, contractual governance is not the only effective way to guarantee the transactions and avoid opportunism from buyers and suppliers. Relational governance mechanisms, based upon social processes, such as trust and social norms, which promote solidarity, flexibility, communication and information exchange, could safeguard informally against exchange hazards and facilitate the enforcement of obligations (e.g. Hartmann et al., 2010; Cao and Lumineau, 2015). Formal contracts set out the rights, responsibilities, and liabilities of the contractual parties, while informal relations complement contracts in maintaining the relationship between the parties. Thus, a third set of owner commercial capabilities – relational capabilities –

are put forward from the owner side, concerning the management of informal or trust-based inter-organisational relationships between contractual parties.

We consider the term relational capabilities as relational knowledge and experience reflected in collective activities and routines which facilitate the development and maintenance of trust-based inter-organisational relationships with suppliers (Capaldo, 2007; Pagano, 2009; Hartmann et al., 2010). They are manifested in trust (Das and Teng, 1998; Cao and Lumineau, 2015), communication (e.g. Claycomb and Frankwick, 2004; Cousins and Menguc, 2006) and coordination (Sivadas and Dwyer, 2000), occurring at different levels – individual, project and organisational. From the organisational level, relational capabilities comprise socially complex routines, organisational solutions, procedures and activities in promoting trust and communication with supplier organisations (Hartmann et al., 2010). They are reflected in the implementation of effective supplier management practices in order to align suppliers' activities to the strategic and performance objectives of project owners. From the project level, relational capabilities include relational skills and competences of project team members to facilitate communication and coordination between contractual teams. At the individual level, personal relations are important elements for communication between people from different project teams or organisations.

RESEARCH DESIGN

DATA COLLECTION

To further understand owner commercial capabilities and explore how they are applied in the construction practice, this research adopted a qualitative inductive approach. Primary empirical data were collected through semi-structured interviews with construction practitioners in China. Considering the difficulties to gain access to professionals from the project owner organisations, we employed a convenience sampling strategy to reach out to respondents. In total, 25 respondents were interviewed. Among them, 18 interviewees were conducted face-to-face at the participants' offices, while 7 were conducted remotely using on-line technologies. Each interview lasted between one and two hours. Among the interviews, 21 were tape recorded and transcribed to enhance data quality and reliability. Four participants did not allow audio recording. In these cases, notes were taken during the interviews. All interviews were conducted in Mandarin and the transcripts have been translated into English.

Among the 25 respondents, 21 are representatives of project owners from both the public and private sectors, while 4 are representing the contractor side. Among the 21 respondents from the project owner side, the majority of them (95%) are from project owner organisations that repeatedly initiate and deliver construction projects. In addition, 16 out of 21 respondents from the project owner side are within the public sector. Interviewees from the contractor side are included as these respondents provide additional insights regarding how project owners apply commercial capabilities in practice. All respondents are directly involved with managing commercial interfaces between contractual parties through working in the contract management, procurement, commercial, or project management departments of their respective organisations.

CODING PROCEDURES

The interview data were analysed using a qualitative data management tool – QSR Nvivo 8 – which allows us to structure the text units into trees of codes and sub-codes (Bazeley and Jackson, 2013). The coding followed both a bottom-up and top-down aspect. From a bottom-up perspective, we firstly analysed the transcripts and focused on identifying and coding the main activities in each capability sun-set. From a top-down perspective, we used the framework of owner commercial capabilities – packaging, contracting, and relational – to categorize the identified activities into each sub-set. The analyses were conducted as a dialogue between empirical data and theoretical pre-understanding of commercial relationship management. As agreed with interviewees, we reported the data in a manner that assures confidentiality in terms of specific persons, organisations, and practices.

EMPIRICAL FINDINGS

Based on coding of the interview data, we focus on the owner commercial capabilities by looking at the underlying main activities and routines involved, from which we could further understand how commercial capabilities are applied in the construction practice, as well as the potential challenges occurring when implementing these commercial activities. The three sub-sets of commercial capabilities (see Table 1) – packaging, contracting, and relational – will be discussed seriatim in the following sections.

Table 1: Three dimensions of owner commercial capabilities

Commercial capabilities	Packaging capabilities	Contracting capabilities	Relational capabilities
Key activities and routines	<ul style="list-style-type: none"> ▪ Package the project scope ▪ Coordinate interfaces among packages 	<ul style="list-style-type: none"> ▪ Select appropriate suppliers ▪ Design contract arrangements and payment structures ▪ Contract management 	<ul style="list-style-type: none"> ▪ Manage inter-organisational relationship (supplier management) ▪ Manage inter-personal relationship

OWNER PACKAGING CAPABILITIES

Packaging the Project Scope

There was fairly a unanimous agreement among the respondents regarding the need for project owners to have in-house capacity to finalize the project scope, divide the project into different packages, and understand the independence between different work packages. However, there was less agreement as to how the actual tasks were to be achieved. Some respondents claimed that routines of packaging projects were very common with fixed procedures in written documents. One respondent from an experienced housing developer stated that: *“Yes, we have routinized guidelines regarding dividing project scope into a series of small work packages, the process of which we call contract planning. The template for it is used every time and based on it we will then make procurement plans”*. Project owners who had routinized packaging activities seemed to have a more mature packaging capability. However,

some respondents, especially those working within the public sector, claimed that there were no formalized processes and that packaging followed the decisions from top managers: *“for the private developers or housing companies, they have accumulated a high level of experience and formed guidelines about how to slice the routine projects. All they have to do is to follow the book. But for us, a young and government-owned housing company, our executive manager is the boss and we follow his orders. We don’t have a very specific way to slice projects. Instead, we have a meeting, top managers and department managers, during which the decision will be made about whether we bid for two or three contractors”*. Though the routines of packaging were not well codified or written in this situation, owner organisations needed to possess in-house packaging capabilities for them to make decisions regarding the needs for different suppliers.

Coordinating Interfaces among Packages

The interfaces between packages define what project owners need to manage and procure, and it may require relatively intensive levels of coordination if there are a bundle of work packages. Normally, contracts are used to define the scope of work, clarify the interfaces, and explicate how the work is distributed. However, where contracts are incomplete and unable to foresee all circumstances, efforts into negotiation and communication among different parties are required by project owners to coordinate different parties during the project execution stage. Project owners could either depend on themselves by developing internal capabilities or rely on external parties for their abilities to coordinate interfaces in the project execution stage. According to the respondents, if project owners possessed adequate in-house administration and coordination skills, they could break up projects into smaller packages, which could help them maintain a greater overview and achieve greater control over the delivery of work. This was often the case for private housing developers: *“We intend to slice a housing project into hundreds of packages. Some are related to the design, while some are in the construction cluster. We also procure key materials ourselves from suppliers and keep a long term alliance with them”*. However, if project owners lacked enough coordination resources and administration skills, they were more likely to rely on the contractor side to coordinate the interfaces, commonly resulting in adopting larger packages. As one respondent from a young housing developer indicated: *“We don’t have enough people or experience. We just follow the traditional way to contract the project to two or three main contractors, which is easier for us to manage. As a result, we do not need to worry too much about the interfaces”*. The number of projects undertaken also played in for some owner organisations: *“We used to have small packages when there were not so many projects under implementation. In recent years, we have learnt from other companies to adopt larger packages since we don’t have enough in-house people to coordinate and there is no need to get into detail of all interfaces among different tasks. The contractor could do the work by themselves”*.

OWNER CONTRACTING CAPABILITIES

Select Appropriate Suppliers

After deciding contracting strategies, one important decision facing project owners is to evaluate potential suppliers and choosing appropriate ones. Most of the 21

respondents from the project owner side represented relatively permanent project owner organisations with continuing project delivery demands. They claimed that they have routinized procedures in house guiding them to select appropriate suppliers and that these routines were quite stable and clearly illustrated in the department manuals, in line with the procurement regulations. They would use a variety of tendering practice in different situations, such as open competitive bidding, limited competitive selected bidding, negotiated bidding, single source procurement, and request for quotation. In some cases, they relied on bidding agencies or consulting companies for services in procurement, especially those in the public sector. According to the respondents, the routines put in place to procure services and select suppliers were mainly determined by laws and government procurement regulations: *“The competitive tendering is often used. The common practice we have adopted is to select the supplier taking both price and their technical capabilities into considerations. But in fact, it is normally the lowest tender price. This is consistent with The Government Procurement Law of China, which we are forced to follow, though it is problematic in the construction practice”*. This was especially true for public sector clients. Private sector project owners would have more flexibility to choose the tendering practice and thus could more easily adopt new emerging contracting approaches, such as partnering and strategic alliances. Respondents from the private housing developers supported that they gradually developed long-term cooperation – strategic alliance – with suppliers such as consulting firms and material suppliers, which could enable them to buy services and materials with lower prices.

Design Contract Arrangements and Payment Structures

A suite of contractual arrangements is available for project owners ranging from lump sum (fixed prices) arrangements with transfer risk to suppliers to reimbursable arrangements where the project owner retains most risks. Some organisations which deliver repetitive projects develop their own contract templates which were aligned with the procurement regulations and some would just use the one proposed by local government. Normally, there were no written guidelines as to how they should come up with contract arrangements and select payment structures. What they did, according to most of the respondents, was to adopt the contract templates and may sometimes learn from previous projects: *“We have contract templates for different project work which are adapted from the local government. This is the case for almost every construction client. The special conditions of contracts are what matter. Sometimes we would add new items to it if we have encountered uncertainties or risks in the previous projects”*. In regards to the payment structures, most respondents claimed that they were getting used to adopt one certain payment option, especially with contractors: *“In most cases, unit price contract based on bill of quantities is used in our regular projects [the construction part]. We prefer to use this lump-sum type of contract, which makes it easy during engineering settlement. All we want is to better control the project cost”*. For cost management of contractors, in most cases project owners needed to rely on consulting firms for services. But they would keep some internal cost management related capabilities to try to benchmark and control consulting firms.

Contract Management

Contract management is a basic foundation of the relationship between owners and suppliers. The respondents gave different levels of emphasis to the role of contracts, some claimed that they would just put contracts in the desk drawer and forget about them during project implementation, whilst others claimed to actively use contracts as a means to control suppliers: *“Well, as a contract manager myself I value the role of the contract. But in the Chinese context, people are just not ready to realize the importance of contracts due to the legal environment. It is still about people in the project execution stage”*. Some respondents were adamant about how they recognize the importance role of contracts and that their organisations are paying increasing attention to contract administration. However, others maintained that though the role of the contract was well known in practice, contracts were not being seriously enforced in the Chinese construction industry. Inadequate emphasis and enforcement of contracts in the project execution stage was considered as a major problem: *“We are now actually paying more and more attention to contract design and the roles of contracts. But you know it is the project teams who implement contracts during execution of projects. And in China, a society full of ‘guanxi’ and social ties, a contract is just a guarantee in case something bad happens”*. Some respondents from the project management departments also supported this by stating: *“When we are at the construction site, what we care about is how to make work done within cost and schedule. You know, time is everything. If we use contracts to deal with all issues and conflicts, we are not getting anywhere”*. The practice of contract management seemed to be problematic in the Chinese construction industry.

OWNER RELATIONAL CAPABILITIES

Manage Inter-Organisational Relationship

The aim of managing and maintaining the inter-organisational relationship with suppliers, especially competent suppliers, is to secure resources for projects. For project sector owners, managing inter-organisational relationships is easier said than done. Some respondents, especially those in the public sector, went as far as stating that for them there is no need to maintain a long-term inter-organisational relationship as the contractor is always selected through open (competitive) bidding. While some others claimed that even though the importance of maintaining a long-term relationship was widely admitted, in practice, owners were unwilling to adopt new strategies or maintain active communications with supplier organisations, as these were regulated by procurement laws and therefore laden with political risks. This was especially true in the public sector, as one respondent illustrated: *“As a state-owned company, by rule and by book we kind of forbid inter-organisational interaction or communication. But you cannot forbid inter-personal communication, sometimes cronyism could still be possible”*. The public procurement laws set strict boundaries about how public sector clients should procure services and materials to reduce potential opportunism and corruption. This created a dilemma since maintaining communication with suppliers was beneficial, but such practice was risky from a political perspective. For the private sector owners, the situation was slightly different as illustrated by one respondent: *“Yes, we have a department manual regarding supplier management. Ways to promote interaction includes occasional meetings among managers, the annual conference (supplies annual conference), and*

socializing party among suppliers”. Private project owners seemed to have more flexibility in creating, managing, and maintaining inter-organisational relationship with supplier organisations. Thus, the procurement laws and regulations would have major impacts on how owner relational capabilities could fit in the owner organisations.

Manage Inter-Personal Relationship

Inter-personal relationships or personal ties were regarded as indispensable in the management of projects. The respondents held an agreement that inter-personal relationships were mainly maintained through ‘guanxi’ in the construction practice. At the organisational level, ‘guanxi’ or social ties between top managers or executives of companies were important elements not only during project implementation (e.g. in avoiding and mitigating conflict and dispute resolution) but also in securing future projects. This was more often the case for the contractors as one respondent from the contractor side emphasized: *“The construction market is the buyer’s market. The project owners are in the position to have strong power. As contractors, if we want to secure more projects, we are in the position to reach out to form good and stable relationships with project owners”*. At the project level, personal relations were also crucial elements to deal with project issues and complete on-going tasks. More interaction and communication occurred between project team members from contractual parties: *“During project implementation, we have regular meetings, informal meetings, as well as social activities to promote discussion and communication. This is very common”*. Such interaction activities were essential to quickly solve problems in project delivery: *“You know the Chinese society where guanxi is essential. We rely on the contractor to do the work, especially to accelerate progress and catch up with deadlines, where contracts do not work. We need to maintain a good relationship with them and trust them to do the work for us”*. For the interaction and communication between team members, some activities were routinized such as regular reporting meetings, but some were not. These commercial and relational activities in either way formed the foundations for trust-based relationship between people from different parties.

DISCUSSION

Owner commercial capability is a multi-dimensional construct comprising activities and routines involved in the management of commercial interfaces at different organisational, project, and individual levels. They are as such located in different departments and units, such as contract management, procurement, project management, and cost management. For project owners, investment projects are fundamentally about change in their organisations – either extending in scope operational capabilities or creating new ones to meet new challenges. In this way, owner project capability is considered as a type of dynamic capabilities (Winch and Leiringer, 2016). Owner commercial capabilities, as a sub-set of project capabilities, also fall into the dynamic capability cluster. However, the results from our interviews support the argument that the line between dynamic and operational capabilities is blurry (Helfat and Winter, 2011). In this context, owner commercial capabilities can serve both operational and dynamic purposes. For example, packaging capabilities, which indicate the routines to divide project scope into different packages, are more operationally oriented. Relational capabilities, on the other hand, are typically a first-

order dynamic capability (Donada et al., 2016), which could help owners secure the resources and capabilities from suppliers.

It is worth noting that our respondents represented a fairly broad range of organisations, some have in-house commercial skills and capacity while some others tend to rely on external consulting firms for capabilities. For instance, project owners purchase services from bidding agencies such as bidding document preparation, bidding procedures monitoring, etc. But internal capabilities are also needed to develop in house for project owners to benchmark and control the external consulting firms (Poulsen and Hansen, 2017). The literature on absorptive capacity (Cohen and Levinthal, 1990) indicates that it is important to have some initial knowledge sources and skills to ascertain and manage appropriate suppliers. Internal and external capabilities thus complement each other to form the basis of how project owners manage the commercial interfaces with suppliers. Thus, a critical decision for project owners is that they need to be aware of what internal capabilities shall be maintained. Another follow-up question is to consider how to choose from internally building capabilities and reliance on external suppliers for capabilities, which is actually the make-or-buy decision that has drawn a broad attention from the transactional cost view (e.g. Williamson, 2008).

Both contractual and relational mechanisms complement each other in the governance of relationships and are playing critical roles ensuring the inter-organisational relationships between owners and suppliers. This is in accordance with previous research (e.g. Cao and Lumineau, 2015; Benítez-Ávila et al., 2018). But it seems that in the Chinese construction industry, relational capabilities, relying on social ties, trust, guanxi, and personal relations, play an extremely remarkable role in ensuring that suppliers could deliver to what project owners expect. On the contrary, project owners, according to the interviewees, demonstrate an inadequate attention to the importance of contracts. This may be influenced by the legal environments in the Chinese context (Zhang et al., 2015). They only consider contracts as useful when unforeseen problems occur or severe conflicts happen. The role of contract governance can clearly be given more attention since it supports interaction between contractual parties and helps with the completion of projects. There is, therefore, room for project owners to consider both the roles of contractual and relational governance and develop combinative contracting and relational capabilities to address the commercial relationship with their suppliers.

According to the respondents from project owner organisations that deliver projects on a repeated basis, commercial processes and activities in project development and execution stages are fairly routinized, whether codified into written documents or not. Such project-based routines, reflecting project owners' commercial capabilities, form the cornerstone of effective commercial management and successful project delivery. However, routinization could also bring about rigidities within organisations. Some project owners tend to follow the traditional way of pricing mechanisms, contract forms, and tendering procedures and are reluctant to accept new strategies of procurement. In this sense, dynamic capabilities could be useful for them to alter and reconfigure operational routines and capabilities when necessary (e.g. Helfat et al., 2007; Davies and Brady, 2016). Project owners may thus

need to cultivate more flexible mind-sets to sense and judge situations and develop dynamic capabilities to respond to the emerging trends in the construction market.

Finally, it is observed that the government procurement laws and bidding regulations play pivotal roles in guiding project owners' decisions regarding whether and when to develop commercial capabilities. Changes in procurement laws and rules could trigger project owners to adjust their ways of performing and develop corresponding commercial capabilities. This situation is more obvious for public sector clients since public procurement is strictly regulated by governmental laws, notably the Law of Public Procurement (Zhang et al., 2015). The problem for project owners in possessing commercial capabilities is that public sector clients are acting very passively towards procurement laws and regulations and less motivated to respond to establishing new routines and capabilities, such as those related to new relational contracting strategies. In this case, project owners are suggested to develop essential dynamic capabilities to respond to changes and ensure effective project delivery in the long run (Winch and Leiringer, 2016; Adam and Lindahl, 2017).

CONCLUSION AND FUTURE RESEARCH

Project owners depend on an array of project capabilities to deliver the projects that they have initiated and shaped. This research presents some preliminary thoughts to augment knowledge of commercial capabilities – a distinct type of owner project capabilities, and effectiveness of managing commercial interface between project owners and suppliers. It outlines a sketch of what the term owner commercial capabilities might be by providing a conceptualization of it and unpacking its underlying elements – activities and routines – in capability sub-sets: packaging, contracting, and relational capabilities. We have identified some areas of research that are not normally in scope to the management of projects such as packaging, and also challenges for project owners when implementing commercial capabilities in the construction practice. The identified key activities and processes in each capability set represent possible objectives for routinization that project owners could enhance in pursuit for improved project delivery outcomes. The findings also provide insights into areas where organisations can usefully develop expertise and skills. A better understanding of routine-based commercial capabilities within the owner organisations is thus formed.

This research is a step further to the prior research work on project capabilities (Davies and Brady, 2000) and owner project capabilities (Winch and Leiringer, 2016) by expounding what commercial capabilities are. It seeks to contribute theoretically to the capability literature by introducing the capability view into commercial management in the project-based construction setting. By addressing what owner commercial capabilities are and how they are applied in the construction practice, the contribution sought is to add to the theoretical development of capability literature by illustrating the multi-dimensional and multi-level construct of capabilities. Commercial capabilities, as one type of organisational capabilities (Dosi et al., 2000), are reflected in the activities and routines within organisations, at different individual, project and organisational levels that allow project owners to make use of their resources and skills to manage interfaces with suppliers. They are indispensable and important activities in inter-organisational commercial relationship management for project success.

It follows that there are limitations which need to be addressed in assessing the contributions made. To start, the interview sample is limited. Most of the respondents are in the context of an experienced or continuing project owner organisations, which deliver repetitive projects and have regular requirement for construction work. However, different types of project owner organisations – continuing and one-off (Davies et al., 2016), may require different combinations of capability sets. For example, for a one-off project owner there is less need to keep in-house project capabilities. One further research agenda could be directed to take into account the contingency factors influencing different elements of commercial capabilities that are required in various contexts. This is research in progress and what has been presented here is based on a pilot study. In light of the understanding of owner commercial capabilities and how commercial capabilities are applied in construction practice, the next step, in this on-going PhD research, is to investigate how project owners develop or later commercial capabilities to respond to the changes in the construction industry, e.g. adopting a new procurement strategy.

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SUCCESS FACTORS FOR CROSS-FUNCTIONAL TEAMS IN THE CONSTRUCTION INDUSTRY: A LITERATURE REVIEW

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ABSTRACT

The use case for cross-functional teams (CFTs) as a means of improving project performance in the construction industry has increased over the last decade. These types of types of teams are a unique form of organization that can be leveraged in Design-Build (DB) and Integrated Project Delivery (IPD). Despite the need for better collaboration in the construction industry, there have been very few studies into how CFTs are formed and maintained over the life of a project. This study addresses this gap by conducting a systematic review of 51 selected peer-reviewed journal publications of CFTs across similar industries, who have a better understanding of these types of teams. For each type of CFT, we use literature to describe its purpose, typical membership and the factors that contribute to its success. From these studies, we identify five frequently cited success factors that have strong applicability to CFTs in the construction industry, including: clear team goals and shared vision, effective leadership, senior management support, human resources, and interpersonal relationships. The findings in this review are expected to provide researchers and practitioners with a set of factors that can aid in the creation of successful cross-functional teams in construction. These factors also provide a starting point to conduct further research on determining how each factor affects project performance in various types of construction projects.

KEYWORDS

Project delivery, organizational science, integration, performance, communication

INTRODUCTION

Cross-functional teams (CFTs) are used in different industries to attain innovative solutions to complex problems. They are created by combining people from different disciplines, cultural backgrounds, intellects, emotional intelligence, and problem-solving strategies (Parker, 2003). CFTs bring together an array of specialists who are jointly and simultaneously making design and production decisions. This concurrent, informed, consensus form of management has shown to produce reduced likelihood of rework, redundancy, and out of sequence activities (Love et al., 1998; Baiden et al., 2006). CFTs decentralize the vertical decision process model used in traditional organizations and utilize a horizontal decision process model that seeks out knowledge and information from a wide array of departments to speeds up the decision-making process and result in high-quality solutions (Bishop, 1999).

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A need for a decentralized system has long been established in the construction industry. For the majority of the 20th century, the Design-Bid-Build (DBB) delivery method has been widely used to complete projects in the industry. This method allows an owner to contract separately with a designer and a contractor who then operate independently using a traditional vertical process model (Ling et al., 2004). As buildings become more complex, the construction industry has become more specialized, segregating processes that were previously directed from inception to completion by one master builder (Yates and Battersby, 2003; Hale et al., 2009). The lack of collaboration in DBB establishes silos of expertise on a project, which often leads to high levels of fragmentation and high transaction costs. Over time, three alternative delivery methods were developed—Construction management at risk (CMR) in the 60s, Design-Build (DB) in the 90s, and Integrated Project Delivery (IPD) in the 00's (Yates and Battersby, 2003; Kent and Bercker-Gerber, 2010). These methods were made to improve the quality of relations between project participants and encourage feedback and consensus within the design and construction process. In a recent study, Franz et al. (2017) showed that the use of delivery methods with improved integration and strong team relationships led to greater cost savings, better schedule, improved quality and overall client satisfaction. As a form of organization, CFTs provide a structured approach to integration that may be leveraged within supporting delivery methods, such as DB or IPD.

Despite the importance of CFTs, creating and sustaining them can be difficult. About 75% of CFTs across various industries are dysfunctional; the major reason being the lack of a systematic approach to creating and sustaining them (Tabrizi, 2015). Without a strong understanding of how to manage these teams, they could bring more harm than good to a project, leading to confusion and conflict within the team. In the construction industry, there have been limited studies on the application of CFTs. Thus, the goal of this literature review is to examine previous studies on cross-functional teams across multiple research domains, such as new product development, industrial engineering, business and finance, and healthcare, to identify success factors that could be translated to CFTs in the construction industry. The identification of these key success factors will inform future work in formulating and testing hypotheses linking them to construction project success.

METHODOLOGY

To gain an understanding of the factors that contribute to the success of CFTs, we performed a systematic literature review of publications related to their performance. A systematic literature review is a useful way to gain insight into a subject matter and appreciate the existing body of knowledge about a topic (Siddaway, 2014). This methodology used four main phases to screen for and identify relevant publications: (1) systematic search, (2) targeted search, (3) literature classification, and (4) primary publication selection. After compiling a list of primary publications, we perform a cross-comparison of CFTs across the industries in which they are used. To do this, each industry will be studied to understand their goals and objectives, challenges faced, disciplines making up the CFT, and the success criteria required for their formation and functionality. In doing this, we will draw similarities between each industry and the construction industry.

SYSTEMATIC SEARCH

The first step in the systematic search involved identifying databases that would produce a wide range of publications focusing on CFTs. *EBSCO Host*, *Engineering Village*, and *Web of Science* were chosen, as they are regarded as top databases for science- and management-related research. The second step involved filtering out papers and publications to improve the quality of selected works. Only peer-reviewed journals were included, as they have been highly scrutinized by peers for errors, and deeply analyzed by experts in various fields. The search itself was run using a string of keywords to find matches in the title, abstract or keyword sections of publications in the databases. The keywords chosen were “cross functional team,” “success,” “performance” and “factor.” Using the Boolean logic strings shown in Table 1, these keywords were arranged and used to search each database. We made no restriction on the publication date during this search. Across all databases, a total of 287 peer-reviewed journal publications were selected and exported to the EndNote X8 document manager. After removing duplicate articles, the total number of unique publications resulting from the search was reduced to 186.

Table 1: Boolean search strings used in systematic search

Database	Search terms	Results
EBSCO Host	[“Cross Functional Team”] AND [Success OR Performance OR Factor]	91
Engineering Village	[“Cross Functional Team”] AND [Success OR Performance OR Factor]	121
Web of Science	[“Cross Functional Team”] AND [Success OR Performance OR Factor]	75

TARGETED SEARCH

Due to the limited number of CFT-related publications from the construction industry, a more targeted search was undertaken of three additional databases. The first database chosen was *Google Scholar* for having a wide array of published and unpublished works from various research domains. The second was the *American Society for Civil Engineers* (ASCE) database for its focus on just engineering and construction-specific journals, and the third was the *Engineering Project Organization Society* database for its focus on organizational science in the industry. Upon manually searching these databases for studies that evaluate CFTs in the construction industry, five additional articles were selected, bringing the total publication count to 191.

LITERATURE CLASSIFICATION

After identifying all relevant publications, we then classified the articles based on the types of CFTs that they studied. These types of CFTs, their use and the numbers of publications in each classification are summarized in Table 2. Publications that did not specify the specific CFT being studied were classified as “General” teams. This classification had the most publications with sixty-one (61) studies, while the construction management category had the fewest with just nine (9) publications.

Table 2: Publication classification by type of CFT studied

Team Type	Use	No. of Papers
New product development (NPD)	Research and design new products	41
Industrial and manufacturing engineering (IE)	Improve production process or systems	52
Business and financial (BF)	Improve business operations	13
Construction management (CM)	Manage construction projects	9
Healthcare (HC) provider	Provide integrated patient services	15
General	Not specified	61

PRIMARY PUBLICATION SELECTION

Not all publications within each CFT classification focused solely on determining success factors; some simply considered the effect of CFTs on projects outcomes, rather than the factors that contribute to a successful CFT. A review of the abstracts of all 191 publications was conducted, followed by an in-depth text review, to select only those publications dealing directly with success factors. This process reduced the total number of publications from 191 to a final count of fifty-one (51). A summary of the results of the publication identification process in our systematic literature review are shown in Figure 1.

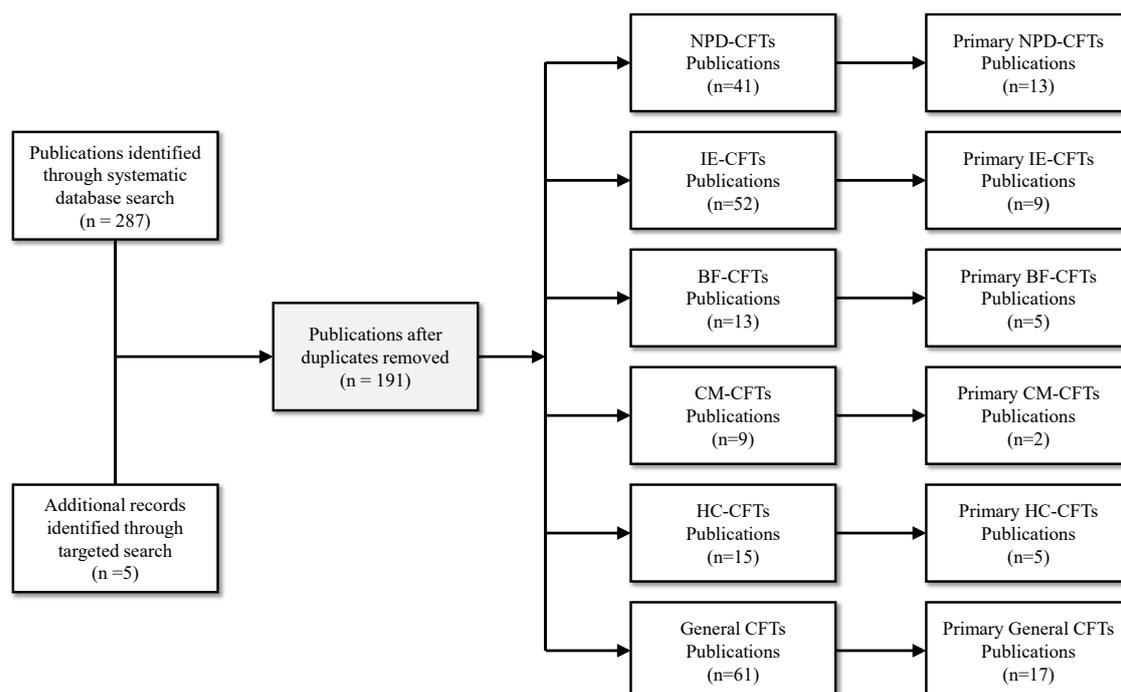


Figure 1: Summary of literature search results

RESULTS AND DISCUSSION

TRENDS IN PUBLICATIONS

Interest in CFTs has slowly increased over time. Figure 2 shows the distribution of the 191 publications that we initially identified in the literature search. The figure indicates interest in CFTs beginning around 1991 with just three papers, with the highest publication count occurring in 2015 with twelve papers. Although there are some

notable years with a drop off in CFT-related publications, there has been a slight upward trend as more industries learn to apply CFTs. This literature reviewed the use of CFTs across five different industries—new product development, industrial and engineering management, business and financial, construction management, and health care—to determine the success factors for teams in each of these fields. The following sections describe the purpose and characteristics of each type of CFT, as well as the success factors found in their primary publications.

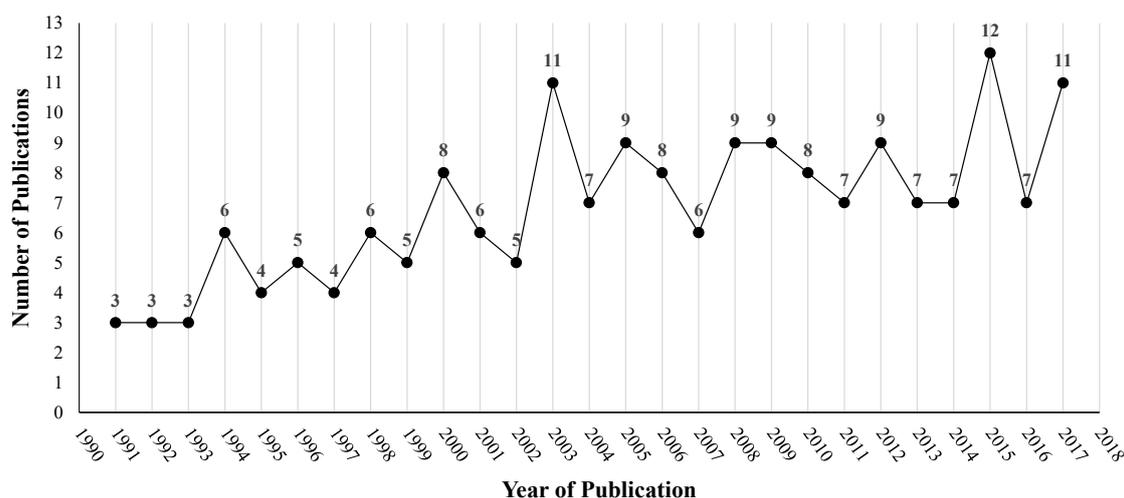


Figure 2: Number of publications focused on CFTs success criteria

NEW PRODUCT DEVELOPMENT CFTs

New product development (NPD) is the process of bringing new products to the marketplace. The objective of NPD is to produce innovative products that can cultivate, maintain, and increase a company's market share by satisfying consumer's needs (Kahn et al., 2012). The NPD process often consists of four basic stages: (1) opportunity identification, (2) development, (3) testing, and (4) launch (Kahn, 2012). The first stage, opportunity identification, involves the creation of an innovative idea for a product that either builds upon already existing products or helps in creating a revolutionary new one. This involves brainstorming research sessions with consumers, engineers, designers, and marketers to understand what product is needed by customers and how it can benefit the company. The second stage, involves the development of the product. Several prototypes are designed, manufactured and modified during this stage to maximize the product's functionality and reduce production cost. The third stage is the testing stage. This involves the testing and analysis of a beta product with a small group of consumers and allows the NPD team to confirm if the product design is viable and ready to be sent to a manufacturer for mass production. The final stage is the launch stage which involves the introduction of the product to the market. Teams involved in this stage span between manufacturing and industrial engineers, finance and R&D, and marketing research and sales (Pitta, Franzak, and Katsani, 1996; Kahn, 2012; Kahn et al., 2012).

Due to the competitiveness and fast-paced nature of the NPD industry, cross-functional teams are vital to a company's success. NPD research shows that there are two types of CFTs, operating and innovative (Barczak and Wilemon, 1989). Operating teams exist within the organization and are concerned with maintaining competitive

positions in an existing business (Bart, 1988a; Bart, 1988b). These teams recognize the need to keep up with customer needs and their competitors; therefore, these teams focus on providing updates to existing products and services. Operational NPD-CFTs consist of disciplines ranging from designers, R&D, and engineers, to market researchers, and sales agents. These CFTs are intra-organizational as they compose of disciplines that operate within the same organizations. Mutual decision making is vital to meet the team's objectives and CFTs are used to avoid problems caused by miscommunication under high-pressure situations (Barczaka and Wilemon, 2003). Innovative teams, on the other hand, explore new grounds. They focus on developing new ideas and business for the firm; and are excluded from everyday activity of the firm (Bart, 1988a; Bart, 1988b; Burgelman, 1980; Pitta, Franzak, and Katsani, 1996). Using generative learning, they challenge firms to rethink assumptions made about its customers, competitors, and strategy (Slater and Narver, 1995; Barczaka and Wilemon, 2003). Like operating teams, innovative teams are cross-functional and span a variety of disciplines. These teams, however, are *inter*-organizational. They consist of experts from different fields and industries brought together for a limited time to develop and bring an innovative product to consumers (Pitta et al., 1996). Operating and innovative CFTs are essential to the NPD industry. Upon review of fifteen (15) primary publications, we identified five factors commonly cited in the success of these teams:

- *Clear goal setting*: Nine (9) papers concluded that establishing a clear goal for NPD-CFTs was essential for their success. Clear goals were seen to provide two benefits for these teams. First, they provided team members with a common frame of reference. Second, superordinate goals helped to structure tasks and constrain team efforts within boundaries, thereby reducing confusion and improving the division of labor amongst teams, and in turn, promote cooperation and increase productivity (Conklin, 1996; Hirunyawipada et al., 2010; Kim and Kang, 2008; Melton and Hartline, 2015; McDonough and Edward, 2000).
- *Effective leadership*: Eight (8) papers reported that an effective leader was needed for NPD-CFT success. An effective leader was described as a good communicator, climate setter, and planner, who uses a participatory style of leadership to manipulate situations and surroundings to achieve desired behaviors and set goals (Conklin, 1996; Raunaiar et al., 2008; Barczaka and Wilemon, 2003; McDonough and Edward, 2000).
- *Human resources*: Six (6) papers focused on acquiring individuals with the right technical and interpersonal skills for a job. A study conducted by McDonough (1993), showed that using more highly educated teams in operational CFTs resulted in faster development while having team members with no ties to the NPD organization in innovative teams resulted in faster development. During the organization of innovative teams, studies suggested that care should be taken to ensure the recruited members are technically and emotionally balanced (McDonough and Edward, 2000; Bamber et al., 2003; Barczaka and Wilemon, 2003; Hirunyawipada et al., 2010).
- *Interpersonal cohesion*: Six (6) papers also mentioned the importance of creating interpersonal cohesion to combat the functional and personal differences within NPD-CFTs. Developing and maintaining trust amongst

members of CFTs was seen as important to reducing stress and increasing cooperation given the complexity and uncertainty inherent in the NPD process (Mat and Jantan, 2008; Hirunyawipada et al., 2010; Ghobadi and D'Ambra, 2013; Bamber et al., 2003).

- *Senior management support:* Lastly, five (5) papers identified senior management support as essential to the success of both types of NPD-CFTs. This support took a variety of forms, including demonstrating commitment, championing teams during stressful periods, and allocating funds for tools and services needed by these CFTs (Kim and Kang, 2008; Raunaiar et al., 2008; McDonough and Edward, 2000; Barczaka and Wilemon, 2003).

NPD has many similarities to the design and construction process. NPD-CFTs design products that address consumer needs or improve on an existing product. The value to consumers is central to the design as it must achieve the required function at a reasonable cost. This is very similar to the objective of design teams in the construction industry. Design teams develop building designs for their clients that maximize functionality, ideally within their client's budget. Likewise, to achieve the maximum functionality of new product design, NPD teams work with consumers to design and determine criteria for a new product. Using these set criteria, a prototype is developed and refines through testing before it is finalized and mass produced. These steps allow the NPD teams to maximize value by reducing cost and impressing functionality (Kahn, 2012). The development of design documents in the construction industry follows similar steps. In collaboration, architects and their clients work together to set programmatic criteria for projects. The architect then produces a building prototype design that is refined and tested using tools, such as building information modeling (BIM), value engineering, energy modeling, and life cycle costing (Gray and Hughes, 2007).

The main difference between NPD and construction management CFTs is in the process of making. NPD-CFTs typically plan for mass production, where their prototype can be replicated an unlimited number of times with close precision. CM-CFTs, on the other hand, plan to produce a one-off product, where due to differences in the site and local building codes, can never be completely reproduced. Despite this difference, the success factors used to form and manage CFTs in the NPD industry have a strong relevance to CFTs in the construction industry.

INDUSTRIAL AND MANUFACTURING ENGINEERING CFTS

Industrial engineering (IE) is a branch of engineering that involves the optimization of complex processes, systems, and organizations. Industrial engineers aim at reducing production costs, increasing efficiency, improving the quality of products and services, and ensuring worker's health and safety, while protecting the environment and complying with government regulations (Salvendy, 2001; Kalpakjian and Schmid, 2014). Industrial engineers work across several industries and some of the tasks they perform include: streamlining operating rooms in hospitals to improve efficiency; working with logistics, shipping, and distribution facilities to improve delivery time; or at an assembly line to improve safety and increase efficiency (Davenport and Short, 1990; Garner, 2012; Boysen et al., 2007).

One of the most common industries that industrial engineers work in is the manufacturing industry. In this industry, industrial engineers coordinate with different teams throughout the manufacturing process. IEs work with (1) NPD teams to refine products and determine the manufacturability of proposed designs, (2) CAD teams to develop and simulate manufacturing processes and protocols to increase production efficiency, (3) procurement teams and material suppliers to ensure an uninterrupted flow of raw materials during production, (4) robotics and mechanical engineering teams to implement robot into the manufacturing process, and (5) quality and safety engineering team to ensure the new product meets the desired performance, safety, and government standards (Cooper and Ellram, 1993; Kalpakjian and Schmid, 2014). Due to the vast array of disciplines involved in the manufacturing process, industrial engineers utilize the breadth of knowledge contained in cross-functional teams to coordinate with other functional teams throughout the manufacturing process.

IE-CFTs are typically intra-organizational teams that coordinate with external, specialized or cross-functional teams such as NPD-CFTs, material suppliers, mechanical engineers, or sales teams to ensure that planning, implementation, and execution of the manufacturing process are done efficiently. They could also be a temporary inter-organizational CFT brought together to plan and implement a new manufacturing process (Pinto et al., 1993). Upon the review nine (9) primary publications, six factors, many similar to the factors identified for NPD-CFTs, were consistently cited as necessary for the success of IE-CFTs:

- *Clear goal setting*: Six (6) papers cited clear goal setting as an important factor for the success of both intra- and inter-organizational IE-CFTs. In temporary intra-organization CFTs, having a clear goal helped to align each member of the team strategically. In inter-organizational CFTs, external members often focus on the profitability of their home organization rather than the goal of the new team; thus, goal setting was found to shift their perspective to that of a unified internal goal (Bestow et al., 1998; Gupta and Wilemon, 1998; Piercy et al., 2013; De Oliveira et al., 2016).
- *Human resources*: Five (5) papers discussed the skills and expertise of the individual members that make up an IE-CFT. Due to the number of disciplines involved in the manufacturing process, teams in IE literature relied heavily on the expertise of functional members within the cross-functional group to improve the efficiency of the existing system. Having functional members who are both intelligent and emotionally balanced, provided a reliable source of knowledge and information for industrial engineers during the manufacturing process (Gregg, 2005; Meschnig and Kaufmann, 2015; Kaufman and Wagner, 2017; Malhotra et al., 2017).
- *Senior management support*: Four (4) papers reported the need for senior managerial support, specifically in ensuring that senior managers buy into the idea of cross-functional interaction, as well as being willing to work with other departmental heads to create programs that encourage these CFTs, provide quality team members, and allocate funding to acquire the necessary work tools and technology for the team (Gupta and Wilemon, 1998; Bestow et al., 1998; Piercy et al., 2013).

- *Interpersonal cohesion*: Four (4) papers recognized the importance of interpersonal cohesion, especially in inter-organizational IE-CFTs where each member's home organization are subjected to different levels of risk. These papers suggested that organizational individualism must be forgone, and interpersonal relationships created to improve team cohesion (Gupta and Wilemon, 1998; De Oliveira et al., 2016; Kaufman and Wagner, 2017).
- *Team proximity*: Four (4) paper also identified the importance of physical proximity to build trust, cooperation and improve communication. IE-CFTs often consist of individuals from organizations located around the world. Internal CFTs that worked in the same building or on the same floor were more successful. Similarly, external CFTs that encouraged individuals to relocate to the project site were associated with more positive outcomes (Gupta and Wilemon, 1998; Piercy et al., 2013; De Oliveira et al., 2016). Virtual spaces were also used to reduce team distance, but they were not as effective as a reduction in physical proximity (Dani et al., 2006).

Similar to NPD, IE-CFTs share many characteristics with construction management teams. IE teams utilize engineering and management skills to optimize processes and systems. Manufacturing and delivering a high-quality product to the market on time and within manufacturing budget is essential to their success. This objective is very similar to general contractors in the construction industry. The goal of every construction team is to deliver a high-quality project that is both on time and within budget. IEs often achieve this objective by planning, managing, and simulating the manufacturing process with cross-functional teams (Cooper and Ellram, 1993; Kalpakjian and Schmid, 2014).

IE-CFTs consist of a manufacturing engineer who acts as the project manager; material suppliers who ensure materials are available on time and within budget; CAD designers to help simulate and streamline the manufacturing process; and quality and safety engineers to ensure factory workers are safe and the products being manufactured meet design specifications. These cross-functional teams also work with NPD teams in the product design phase to provide design input concerning feasibility and manufacturability of the product (Kalpakjian and Schmid, 2014). The composition of these teams is similar to those in the construction industry. Construction teams often consist of a project manager; material suppliers who supply materials when needed; lead designers to help coordinate designs from different disciplines; quality and safety engineers to ensure quality standards; and a variety of trades who construct the product (Gray and Hughes, 2007). The similarities between these industries suggest that the success factors for forming and using CFTs in the industrial engineering industry would likely be similar for CFTs in the construction industry.

BUSINESS AND FINANCIAL CFTs

The business and financial industry uses technology and societal trends to manage money. Organizations in this industry aim to increase revenue, profit margins, retrench in times of hardship, and earn a return on their investments (Johnson, 2001; Saunders and Thomas, 1997). This sector consists of three general services: accounting services, which provide instruction in developing and utilizing general accounting systems; banking and related services, which focuses on the fundamentals of lending and

banking regulations; and business financial management, which helps develop skills in investment analysis and guidance (Johnson, 2001; Zhu, Kraemer, and Dedrick, 2004). These services are often undergoing shifts from traditional to non-traditional technologies and markets in response to ongoing deregulation of the industry (Storey and Easingwood, 1996; Storey and Easingwood, 1999). Due to this shift, the need for innovation is vital for organizations to stay competitive.

Utilizing the dual-core conceptualization of innovation in this industry, two types of innovations occur—technical and administrative. Technical innovation refers to innovation in the design and delivery of products and services, as well as marketing and office operations. An example of this type of innovation is the use of online banking to improve customer satisfaction and banking experiences (Bantel and Jackson, 1989; Lassar et al., 2005). Administrative innovation refers to innovations related to general management issues, such as staffing and employee survey, strategic planning, compensation systems, and training programs. An example of this type of innovation is the use of CFTs to forecast trends in the economy and create solutions to react accordingly (Bantel and Jackson, 1989; Zhu et al., 2004). These CFTs are typically intra-organizational teams that consist of department heads, strategic planners, operations officers, and human resources officers. These teams work together to make decisions that affect the profitability of the organization. Risks are associated with these decisions; therefore, having a team that views the problem from various angles is imperative to taking calculated risks (Broadbent and Weill, 1993; Alam, 2003). Upon review of five (5) primary publications, the following success factors were found to be frequently cited:

- *Effective leadership*: All five (5) papers on CFTs in the business and financial industry emphasized visionary leadership, capable of anticipating upcoming trends (Cooper, 1994; Cantrell and Benton, 2007; Ainamo, 2007).
- *Senior management support*: Three (3) papers described the importance of senior management and their role in establishing a climate that encouraged easy collaboration between departments and allowed for “out of the box” thinking (Cooper, 1994; Cantrell and Benton, 2007).
- *Effective communication*: Three (3) papers also identified communication as a success factor, specifically in the manner in which teams included debates about developed ideas and stimulated collaborations across departments. (Mishra et al., 1998; Cantrell and Benton, 2007; Ferdousi, 2012)

Teams within the business and financial industry have less in common with construction teams than NPD or IE. By bringing together various high-level functional department leaders, teams in the business and financial industry plan observe trends in the market and make adjustments to the entire organization to either profit from a positive trend or cut back on operational costs when needed (Alam, 2003). The only similarity with the construction industry is that construction projects are first and foremost capital investments that are affected by variations and fluctuations in the market. An increase in the price of steel causes a rise in material cost estimates of all construction projects. Some success factors from the business and financial industry may be applicable to construction management CFTs, specifically those that are tasked with forecasting or responding to market trends.

HEALTH CARE CFTs

The health care provider industry consists of organizations that maintain, improve or re-establish the health of patients. Often, achieving this aim requires the coordination of multiple service providers and the industry has recently begun to use cross-functional teams. CFTs in this sector consist of medical professionals (e.g., doctors, surgeons, nurses, and paramedics) and non-medical staff (e.g., IT, office administrators, and financial advisors) working together to maximize the service being rendered to the public (McCullough, 2010; Reiling, 2006). Upon review of five (5) primary publications, the following factors were determined to be related to the success of CFTs:

- *Functional diversity*: All five (5) papers cited having a wide array of specialized medical professionals as crucial to providing timely and accurate diagnoses and treatment plans to patients (Legare, 2001; Alexander et al., 2005; Kono and Antonucci, 2006; Bitter et al., 2015).
- *Coordination*: Four (4) papers referenced the need for coordination, such that CFTs could be assembled quickly during an emergency and enabled to complete their work efficiently (Legare, 2001; Alexander et al., 2005; Bitter et al., 2015).
- *Team size*: Three (3) papers concluded that the number of members in the CFT influenced its success. While the optimal team size varied by task, the number of members was recommended to be small enough for quick assembly and decision-making, but large enough to capture the needed expertise (Legare, 2001; Kono and Antonucci, 2006).
- *Effective leadership*: The same three (3) papers also described the importance of an effective leader as one who quickly defined team goals, evaluated proposed solutions and implemented the right one accordingly (Legare, 2001; Kono and Antonucci, 2006).

Due to the time--sensitive environment in which professionals in this field work, the breadth of knowledge present in CFTs is vital to improving the quality of diagnosis, treatment, and services provided to patients (Cashman et al., 2004). The construction industry has some similarity to healthcare providers, in that design and construction firms often render services under tight schedules and high-intensity conditions that require a diverse team to provide innovative solutions to a problem. However, the scale of the work is drastically different between industries. For a healthcare CFT, their project may be a single patient, compared to a large-scale infrastructure project that construction teams must manage and deliver. Thus, there is a low similarity between healthcare CFTs and those that would be found in the construction industry.

GENERAL CFTs

Many publications studied success factors of cross-functional teams, without referencing a specific type of team or industry in which they operate. Most of these publications focused on either one or a grouping of multiple factors to study how they could be developed to improve an existing CFT. Upon reviewing seventeen (17) primary publications, the following factors were commonly cited:

- *Clear goal setting*: Six (6) papers discussed the building of a shared vision among a CFT, which is unique and sometimes at odds with external parent organizations (Webber, 2002; Chan et al., 2003; Gregg, 2005; Denison et al., 2017).
- *Effective leadership*: Five (5) papers highlighted the role of an effective leader, specifically identifying the participatory form of leadership and the ability to quickly manage conflict and stress when they arise in the team (Webber, 2002; Ehrhardt et al., 2014; Denison et al., 2017).
- *Conflict management*: Four (4) papers mentioned conflict management skills or procedures as necessary for success. During the early stages of CFT formation, resistance and inter-team conflict are common. To guide the team through this phase of development, systems of managing conflict were found in more successful teams. (Gregg, 2005; Ehrhardt et al., 2014; Denison et al., 2017)
- *Functional diversity*: Four (4) papers also recognized the need for the right balance of individuals from different disciplines. Too little diversity led to suboptimal solutions, whereas too much diversity led to more conflict (Webber, 2002; Randel and Jaussi, 2003; Tekleab et al., 2016).

CONCLUSIONS

Over the last decade, research interest in the creation, management, and use of CFTs to achieve organizational objectives and improve productivity across several industries has increased. However, to date, there have been limited study on these teams in the construction industry. Therefore, this paper reviewed and analyzed publications in peer-reviewed journals with regards to factors critical to the success of CFTs across industries similar to the construction industry. *EBSCO Host*, *Engineering Village*, and *Web of Science* databases were searched using a keyword string to identify 191 papers, which were then reduced to fifty-one (51) papers using abstract and in text review to select relevant papers. Five types of CFTs were represented in the selected literature. These CFTs are new product development (NPD), industrial engineering and management (IE), business and financial, healthcare provider, construction management, and general CFTs. Based on the number of publications, it was determined that the NPD industry had a better understanding of the functionality of CFTs, while construction industry had the least.

The analysis of publication in these various industries showed that each industry focused on many similar success factors. Industries that contained inter-organizational CFTs, such as NPD and IE, considered clear goal setting to be the most important factor to CFT success, as it helps to align functional members to strategically work towards a common goal. Intra-organisational CFTs from industries such as healthcare providers, with already aligned goals tended to focus more on team diversity, as having a broad knowledge base was crucial to delivering timely patient services. Upon cross-tabulation of the most common success factors across all types of CFTs, the top five success factors were: (1) clear team goals and shared vision, (2) effective leadership, (3) senior management support, (4) human resources, and (5) interpersonal relationships. Table 3 shows the complete list of other important factors and the types of teams for which they were considered necessary for success. We conclude that these five factors and the other listed in Table 3 have strong applications for CFTs in the construction industry.

Table 3: Factors for successful CFTs

Success Factors	No. of Publications	Type of Team
Team goals and shared vision	23	NPD, IE, BF, HC, G
Effective leadership	18	NPD, BF, G
Senior management support	12	NPD, IE, BF
Human resources	11	NPD, IE
Interpersonal cohesion	10	NPD, IE
Functional diversity	9	HC, G
Team composition	6	BF, HC
Conflict management	4	G
Physical proximity	4	IE
Effective communication	3	BF
Team size	3	HC

NPD = New product development, IE = Industrial and manufacturing engineering, BF = Business and financial, HC = Healthcare providers, G = General

Although the research objectives were achieved, some limitations of this study are worth mentioning. One limitation is in the use of databases that focused on technical industries such as NPD, IE, and construction. To get a better understanding of CFTs in non-technical fields such as healthcare providers and the business and financial industry, an additional targeted search towards journals in those research domains is recommended. Another limitation comes from relying solely on peer-review journals, as this may have introduced a publication bias by not reviewing unpublished works. Despite these limitations, the findings in this review are expected to provide researchers and practitioners in the construction field with a set of success factors to consider when forming and managing cross-functional teams.

As a result of the developed list of factors, this paper will be useful for researchers to conduct further empirical studies on cross-functional teams within the industry. First, there is a need to define the meaning of “success” for construction CTFs, with an emphasis on measurable outcomes that are common across project types. In other words, the factors that were identified in this literature review should result in more successful CFTs, but what does that success look like and how can a CFT maintain that success throughout the project? Second, there is need to understand how the success of the team translates to the performance of the project. Having a highly effective CFT is desirable in theory, but their efforts must ultimately have a measurable impact on commonly cited project outcomes (e.g., cost growth, delivery speed and facility quality) to gain broader acceptance in the industry. Can the team be successful, but have a poor performing project, and vice versa? Understanding the magnitude of this impact would help practitioners to determine when and how to implement CFTs, as well as encourage academics to conduct more research into the subject matter.

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FACTOR AND ACTOR NETWORKS: ALIGNMENT OF COLLECTIVE ACTION GROUPS FOR WATER SUSTAINABILITY IN ETHIOPIA

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FACTOR AND ACTOR NETWORKS: ALIGNMENT OF COLLECTIVE ACTION GROUPS FOR WATER SUSTAINABILITY IN ETHIOPIA

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ABSTRACT

As the international water, sanitation, and hygiene (WASH) sector moves towards approaches that strengthen the wider political, social, technical, institutional, and environmental sub-systems that keep WASH infrastructure functioning, there is a growing need to understand the organizations, governments, and people that manage and rely on these sub-systems. As no single actor has the ability to manage all elements of these complex systems on their own, many approaches are turning to principles of “collective action” that aim to enable efficient, collaborative, stakeholder-driven action. One of the key steps in a “collective action” approach is converging or aligning the diverse agendas, mindsets, and priorities of the actors in the collaborative partnerships toward a single common goal or shared vision. As perspectives are diverse, dynamic, and potentially contradicting, there is a need to elucidate these perspectives and understand how to design collaborative partnerships so they operate effectively. We partner with the Sustainable WASH Systems Learning Partnership to explore how to assess alignment of priorities by analyzing network relationships and prioritized actions of actors engaged in a collaborative partnership. We conducted semi-structured interviews with all partners (n = 22) engaged in a collective action group in a single district in Ethiopia, then qualitatively analyzed each actor’s priority and assigned these as actor attributes in a network analysis. We then analyzed the network and the actors that prioritized similar actions based upon sub-group densities and external-internal indices. This work contributes to theory by exploring perspectives and alignment within a network; it potentially aids practice by showing the extent of alignment of actors within the network toward a common goal.

KEYWORDS

Collaboration, water governance, sustainable systems, network analysis, organizational communication

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INTRODUCTION

Sustaining water supply and sanitation services in low-income and developing contexts is a pressing challenge. Against daunting failure rates following decades of efforts to build infrastructure, sustaining long-term service functionality is increasingly recognized as a complex problem that cannot be solved using traditional problem-solving methods (Meadows 2008; Zhang et al. 2016). Instead, studies show that sustaining water services requires a healthy system of interconnected financial, political, institutional, economic and social sub-systems that can support the proper use, maintenance, and monitoring of infrastructure (Carter and Ross 2016; Loorbach 2010; Welle et al. 2015; Westley et al. 2011). These sub-systems are managed and relied on by a diverse range of actors (people, government offices, and organizations), and often no single actor has the knowledge, resources, or authority to fully comprehend and manage the system. Progress towards sustainable services thus requires innovative approaches that not only identify which factors to target, but also how to align actors toward common, joint actions to sustain services. Involving a diverse web-like network of actors with unique priorities, values, and perspectives introduces another level of complexity to this already-complex problem (Berg 2016; Ogada et al. 2017; Ricart et al. 2018). Thus, the upcoming movement of systems-approaches (Liddle and Fenner 2017) and network-approaches for sustaining water, sanitation, and hygiene (WASH) services must also consider the tradeoffs of strengthening collaboration while navigating diverse perspectives across sectors, organizations, and administrative levels.

Guided by principles of collective action, collaborative partnerships bring together relevant actors and generate joint action (Kania et al. 2011; Ostrom 2000). The process for establishing these partnerships starts with learning about the problem and their relationships with the other actors involved (Gray 2000; Kania et al. 2011), discussing potential solutions (Hardy et al. 1998), agreeing on a solution, and then collectively taking action. Doing these activities with a diverse range of relevant actors allows the complex problem to be negotiated based upon differing experiences and expertise. However, convening diverse perspectives, assumptions, interpretations of the problem, beliefs, and priorities poses a challenge of reaching consensus and alignment on a single vision and action (Gray 1989, 2000). Organizations and government offices with different roles may be constrained by external structures or preconceived notions that limit their willingness to collaborate (Ostrom 2000). Understanding these differences is a core goal of typical “collective action” work, which aims to bring a group of important actors together to establish a common agenda, problem definition, and solution to a complex social problem (Kania et al. 2011). Through this lens, we narrow the focus of this study to alignment, specifically, we analyze how actors (organizations and government offices) align, or do not align, regarding the actions they prioritize to strengthen their local WASH system.

Achieving the “right” amount of alignment of priorities is a primary and well-documented challenge of collaborative work (Bruns 2013; Gray 2000; Hardy et al. 2005; Koschmann 2016). Collaborative partnerships consist of people and organizations that are connected in various ways (communicating, sharing information, sharing resources, joint planning, etc.) to achieve a common, “aligned” goal. However, context-specific and dynamic relationships between actors are unique to each partnership, and it is difficult to implement a standard process to get all actors “on the same page” and align their priorities. While many scholars acknowledge the need for

alignment (Murphy et al. 2015) and the presence and challenges of misalignment (Gray 1989; Ulibarri and Scott 2017), the need for concrete methodologies for explicitly assessing the extent to which a group aligns has escaped scholar's attention. One stream of academic work has established techniques for "stakeholder analysis" which can evaluate how collaborative partnerships are structured and function (Reed et al. 2009). However, while techniques for stakeholder analysis are increasingly used, no feasible methods exist for understanding where misalignment occurs and how alignment emerges (Reed et al. 2009; Starkl et al. 2013).

As the international WASH sector moves away from infrastructure-only approaches and towards systems- and network- strengthening, there is an increasing need for context-specific tools to visualize, assess, and measure alignment within collaborative partnerships. Without a way to measure and evaluate alignment, they may not be able to build an evidence base of how their approaches lead to positive outcomes and report on performance (Emerson and Nabatchi 2015). Without a method to adequately visualize and quantitatively assess alignment, actors establishing collaborative partnerships are often unable to understand the nuanced differences in partner priorities and how these differences may be associated with an actor's position in the network or role. These limitations affect their ability to determine how to strengthen a network and may reduce their ability to attract and hold funding from large donors.

Filling this gap in the WASH sector requires adopting perspectives and frameworks from outside the discipline. To build an understanding of alignment, this work draws from both network theory and communication theory to employ network analysis techniques while also prioritizing context-specific negotiation of perspectives. Recent work has found that the alignment of missions and strategies is more valuable than alignment of values (Murphy et al. 2015), thus we focus our study on the alignment specifically of actions that the actors prioritize. By "alignment" we mean the extent to which actors' prioritized actions converge toward a common, collective goal or action to strengthen their local system, including understanding how smaller groups emerge within the greater network of actors.

In this paper, we first establish a point of departure by reviewing relevant academic and practical directions in the WASH sector, network literature, and communication literature. Our intent is to provide the rationale for why alignment should be measured in collective action approaches, why network and communication perspectives provide an important lens, and how this methodology can be applied. As demonstrated by empirical and theoretical works in communication, we propose that complete alignment of priorities is not ideal; rather a collaborative network must balance a shared group vision with individual interpretations and ideas. Our approach for a methodology recognizes that the structure of the collaborative network influences how it functions, and we use a combination of network analysis and semi-structured interviews to visualize, assess, and measure alignment and sub-groupings of alignment within the network. By overlaying the priorities of actors and combining it with network structure, our preliminary results display the network of "factors and actors", or *(f)actors*, combined to determine the extent of misalignment and alignment amongst the network. This new approach provides a process for WASH practitioners to understand how actor priorities align in a collaborative partnership while also contributing to communication and network theories and applications. We conclude this paper by presenting the direction of this research, including known limitations and foreseen next steps.

POINT OF DEPARTURE

Here we briefly review the topic of stakeholder collaboration in the WASH sector to set up the need for understanding the processes and structures that occur in collaborative networks. Establishing a premise of past work on processes in communication literature and on structures in network literature, in the following section we develop a point of departure and objectives for this study.

COMMUNICATION

The communication field has provided a well-established lens to understand and observe alignment in collaborative partnerships. Seminal work by Hardy et al. (2005) defines *collaboration* as “a cooperative, interorganizational relationship in which participants rely on neither market nor hierarchical mechanisms of control”. The goal of a collaboration is to “create a richer, more comprehensive appreciation of the problem among the stakeholders than any one of them could construct alone” (Gray 1989). Interorganizational collaborations are rife with complexities and tensions, particularly in international contexts, and thus must be carefully planned to be successful (Gray 1989; Heenan and Perlmutter 1979; Innes and Booher 1999; Koschmann 2016). The inclusion of diverse organizations and governments, each with their own vision, values, priorities, and resources, leads to “staggering” challenges that “require a radically different approach to organizing and managing” (Gray 1989). Some challenges include selecting who is included and excluded (i.e., boundaries) as members in the collaborative partnership, coordinating laterally without a hierarchical authority, achieving consensus on a shared vision, ambiguous authority and leadership towards that vision, dual roles of individuals representing organizations, and unclear measures of effectiveness (Crona and Bodin 2006; Koschmann 2016; Lewis 2006).

In addition to other challenges, achieving consensus on a shared vision is requires trade-offs. Within the field of communication, the concept of alignment is investigated within areas of consensus-building through discussions and negotiation, establishing shared visions and directions for the group, and group versus individual constructions of the problem and solutions. These investigations show that complete alignment is not necessarily desirable: identical “aligned” perspectives minimize creativity and innovation needed to solve complex problems, as demonstrated by the idea of “group think” (Hardy et al. 2005; Innes and Booher 1999; Lawrence et al. 1999). Instead, establishing common priorities and agendas requires trade-offs, such as balancing involvement of diverse perspectives with time and capacity requirements (Ulibarri and Scott 2017).

However, there is a gap between the groundwork laid by these researchers and those studying a specific area of collaborative work called “collective action”. Established by Olson in *The Logic of Collective Action* in 1965, collective action work explores the processes through which self-interested individuals in a group can work together to achieve a common goal, as long as they all benefit from this goal. Empirical investigations have taken this further to study the role of collective action in managing common-pool resources and public service goals (Lynn et al. 2018; Ostrom 2000). As it has developed, collective action work has claimed it is “distinctly different” from typical collaborations, in that it “involve a centralized infrastructure, a dedicated staff, and a structured process that leads to common agenda, shared measurement, continuous communication, and mutually reinforcing activities among all participants” (Kania et

al. 2011 p. 38). Despite this claim as an outlier, collective action work is based on many of the same ideologies as collaborations and thus face the same complexities, challenges, and tensions described in other work.

From this extensive work from communication researchers studying interorganizational collaboration and collective action, we have a firm understanding of the challenges associated with developing alignment and the tradeoffs that limit the desirability of complete alignment. Yet, neither stream of research provides concrete methodologies for measuring and assessing alignment and how it changes over the course of collective action work. Needing an analysis that provides quantitative rigor while acknowledging context-specific, qualitative meaning, we turn to network analysis techniques.

NETWORK ANALYSIS

To better understand best practices for the formation, processes, and structures of collaborative partnerships, practitioners and academics can use stakeholder analyses to assess actors and reveal the nature of the web-like “network” of their interactions (Reed et al. 2009). When forming a collaborative partnership, understanding the structure of existing relationships is useful to design appropriate actions to strengthen them. One such analysis, network analysis, is increasingly applied to these types of complex systems.

An extensive review by Provan et al. (2007 p. 482) defined a network as “a group of three or more organizations connected in ways that facilitate achievement of a common goal”. Network research evaluates the presence or absence of relationships between actors in a network and evaluates how the network structure facilitates achievement of goals (Barley and Weickum 2017). The method employed for collecting data for network analysis allows researchers to build a network based on specific types of relationships for a pre-determined outcome. For example, we can see organizations as tied to each other via *information sharing related to water sustainability*, and then answer questions such as *who needs to strengthen information sharing with whom to ensure proper maintenance of water and sanitation infrastructure?* Once an outcome of interest is determined, the type of relationship, analysis metrics, the level of analysis (individual actor or whole network), and boundary of actors can be selected for that outcome.

Metrics such as centrality can help determine who spans boundaries and who is particularly well-connected with the rest of the network (Doerfel and Taylor 2004; Koschmann and Wanberg 2016). For our example in WASH, this assessment would be valuable to visualize a bridge-like connection that a temporary organization might serve between actors. From this, the collaborative partnership could identify which actors would need to be connected if that bridging actor leaves, to ensure that information sharing remains active. In addition, subgrouping algorithms can determine clusters and silos (Provan et al. 2007), which for our example, could reveal fragmented and isolated actors with unique local knowledge that leads to duplication of efforts.

As a single group of actors may have distinct types of relationships with many actors, the type of relationship selected for the network analysis determines network structure. For example, information-sharing relationships may look entirely different than the resource-sharing relationships in the same network. Relationships (e.g., ties or links) often used include quantitative and qualitative relationships. Quantitative

relationships could include the amount of resources shared, frequency of communication (Walker and Stohl 2012), information (Poleacovschi and Javernick-Will 2016), knowledge (Wanberg et al. 2015), and referrals to clients (Cooper and Shumate 2012; Koschmann and Wanberg 2016). Qualitative relationships could include trust and perception of drawbacks to collaboration (Provan et al. 2003) and provision of social support (Provan and Kenis 2007). These qualitative metrics can then be converted to quantitative measures using Likert scales for analysis. Once quantified, metrics can be based at a zoomed-in level looking at actors themselves or a zoomed-out level looking at the entire network of actors. Yet, as many researchers investigate network structures, there is also a need to investigate how the networks function as a result of that structure (Provan et al. 2007; Provan and Kenis 2007).

Network analysis has shifted from a technique used by empirical researchers (Provan et al. 2007) to a tool for practitioners to inform action in collaborations (Bodin et al. 2017; Starkl et al. 2013). These analyses allow decision makers to see what gaps exist in the current network structure and to inform decisions about how it might be strengthened. In other words, network analysis enables an abstraction of reality based on data collection methods, analytic assumptions, and user interpretation that can be used to sway decision makers.

While current network analysis techniques can be used to evaluate these context-specific strengths and gaps in network structure, they do not allow visualization of perspectives and priorities of the actors existing in a network. Current technique also does not allow for in-depth analysis into the processes through which true collaboration occurs, such as how diverse priorities are navigated and negotiated toward a set of aligned priorities. Thus, existing tools and approaches in network analysis are incapable alone in explicitly informing decision makers on how to enhance alignment of collaborative partnerships for WASH governance.

COMMUNICATION AND NETWORKS IN THE WASH SECTOR

Collaborative partnerships are encouraged by donor agencies as they are assumed to be a viable solution for addressing complex problems that are otherwise unsolvable by a single entity (Huxham et al. 2000; Huxham and Vangen 2000; Koschmann et al. 2011). As a result of an increasing awareness of WASH system complexity, the WASH sector has seen an emergence of partnerships, coalitions, networks, collective action groups, and collective impact groups that seek to jointly solve these complex problems (Bisung et al. 2014; Boschet and Rambonilaza 2018; Dickin et al. 2017; Harrington 2017; Lienert et al. 2013).

As the WASH development sector shifts away from pure “community management”, the paradigm is moving toward providing more long-term external support by external partners to increase sustainability (Hutchings et al. 2015; Schweitzer and Mihelcic 2012). Often, these approaches focus on strengthening the wider system needed to sustain services over a long period of time (Moriarty et al. 2013; Schweitzer and Mihelcic 2012; Verhagen et al. 2008). This type of approach integrates diverse, and inherently complex, ranges of organizational values, beliefs, and priorities and therefore requires partnerships of a collaborative nature.

The first area of relevant work in the WASH sector is multi-criteria decision aids. In water projects, decisions are often based on multiple criteria, which can be weighted differently according to who weights the criteria. In the case of disagreement, Stark et

al. (2013) explored consensus-finding for weights in multi-criteria decision aids, though they did not investigate collaborative partnerships specifically. For cases where stakeholders held conflicting preferences, they used social network analysis to determine clusters of actors that agreed. This study advised that if actors were misaligned, then top-down decision making should ensue. In collaborative partnerships, there is often no hierarchical form of control (Hardy et al. 2005) and thus while the study took an important step at using network analysis to understand alignment, the top-down advice provided by Stark et al. (2013) does not apply to collaborative arrangements. Furthermore, the study used information about extent of alignment to determine the type of decision make, rather than use the information to inform the establishment of a common vision.

A noteworthy first effort at assessing alignment in the WASH field was the work done by Walters and Javernick-Will (2015) on rural water services in Nicaragua. Using stakeholder theory and project management literature, they assessed how four stakeholders valued an array of factors to provide insight into their associated actions and therefore potential alignment. However, their study did not evaluate how these actors interacted with one another and worked together as part of a larger structure network of actors. Other studies have looked at the network structure, but do not consider the priorities and perspectives of the actors in the network. Notably are work by Walters and McNicholl. Walters (2016) applied social network analysis to inform exit strategies for NGOs in Nicaragua based on communication relationships between the NGOs and governments. Related work by McNicholl investigated ties of skills and information between governments and relevant stakeholders using social network analysis to characterize and identify potential gaps in relationships (McNicholl 2017; McNicholl et al. 2017). While these studies have laid important groundwork in the WASH field using network analysis, they do not consider the perspectives of actors within that structure. Values and interests of actors in collaborative water governance are two of the most important elements tied to infrastructure performance as they provide “the basis for prioritizing water sector outcomes and determining the incentives that promote the achievement of shared objectives” (Berg 2016 p. 13). Here, Berg identifies the importance of balancing diverse interests and priorities between actor groups and calls for application of stakeholder analysis and public participation to better understand these differences, though to date, no studies have undertaken this endeavor. We answer these two gaps by rooting our network analysis in collaborative work and looking at the perspectives and priorities of the actors within that structure.

One notable study has employed both stakeholder analysis and network analysis separately to assess a collaborative governance. Ogada et e. (2017) used stakeholder analysis to qualitatively compare perceptions, finding that actors with higher interest in the sector had higher perceived influence. In addition, they used social network analysis to quantitatively compare centrality of actors and assess who was most influential. Recognizing that a network of “like-minded stakeholders can also limit diversity of knowledge”, they also used an external-internal index to quantify homophily, the extent to which actors with similar characteristics related to each other (such as those with the same function, sector, and type of resource used). Findings of low homophily reinforced the idea that for water governance, actors were required to reach outside of normal groups to solve complex problems. While these findings are a notable next step in rigorously documenting misalignment within networks through

qualitative stakeholder analysis and the quantitative network analysis, Ogada et al. did not integrate both analyses in combination to further investigate how different interests and perceived influence was distributed across the network structure. In this case, this limited the study's ability to explore how fragmentation affected the ability of the partnership to sufficiently align these interests toward a common goal.

In sum, a growing movement is emerging in the WASH sector around not just what systems are needed to support infrastructure, but which actors are necessary to support each local system. Rigorous stakeholder analysis is required to understand these actors and their relationships to each other, but application of these tools is limited in their application and relevance to context-specific situations. Yet, even though this management approach is considered “emerging” in the WASH and water governance sectors, it is not a new approach to management and is relatively well-studied in other contexts (Browning et al. 1995; Lubell et al. 2002). As the WASH sector begins implementing more collective action approaches, organizations cannot ignore the challenges and tradeoffs present, less they risk unplanned and unsuccessful consequences inherent to collaborative work.

STUDY OBJECTIVES

WASH practitioners seek to employ collective action without proper tools for analyzing alignment of priorities toward a collective goal. Previous studies have documented the value of diversity of perspectives without providing guidance for how to overcome challenges introduced by the added diversity of values and priorities. In light of the gaps related to collective action in WASH, our research seeks to build upon and improve knowledge and practice in the WASH sector through the application of communication and network theory. Specifically, we are interested in applying these theoretical paradigms to better understand ways that the priorities of network actors align, both between individuals and in relation to the whole network. In doing so, we respond to calls for more combination of stakeholder analysis techniques indicated by Reed et al. (2009) and the need for quantitative and qualitative methods for understanding network function and evolution indicated by Provan et al. (2007) and (Hardy et al. 2003).

Specifically, through the exploratory research in this paper we start to assess alignment of priorities of actors in a collaborative partnership using network analysis technique and qualitative analysis of semi-structured interviews.

RESEARCH CONTEXT

The Sustainable WASH Systems Learning Partnership (SWS) aims to improve the sustainability of future WASH programs and catalyze national and international uptake of successful approaches to strengthen wider WASH systems. Funded by the United States Agency for International Development (USAID), SWS seeks to better understand collective action initiatives in Ethiopia, Uganda, Kenya, and Cambodia. The SWS partnership provides a unique opportunity to understand how a collective action group is initiated, developed, evolved, and either succeeds or fails. Our study uses data from one collective action initiative in Ethiopia.

Ethiopia is listed as one of the high priority areas in the US Global Water Strategy of 2017 due to low coverage of water services, rapidly growing modern economy, and worsening drought conditions. The Strategy emphasizes the challenging political

environment, with “limited private sector engagement, policy constraints, and the lack of data for decision-making limit the sustainability of current service provision” (“U.S. Government Global Water Strategy” 2017). To overcome these challenges at a district level, SWS establishes collective action platforms called Learning Alliances to engage all key actors and then support action toward a common goal (Verhagen et al. 2008).

SWS partners with districts where key stakeholders show interest in supporting and strengthening the broader system necessary to sustain water hardware. The selected district in Ethiopia has some actors that share these interests, but there is no clear priority and direction for how to support and strengthen their system. The Learning Alliance includes about 20 actors (organizations and government offices) that were selected through consultation with the district’s government water office. The selection process resulted in roughly 40% district “*woreda*” government offices, 40% zonal government departments, and 20% NGOs. In Ethiopia, the hierarchical structure of government flows from the national level to regional, then zonal, then district “*woreda*”, then community “*kebele*” level. In November 2017, SWS facilitated the first convening of the Learning Alliance, where they presented results from a variety of planning tools that assess the wider system, including network analysis, to help decision makers better understand and plan for the complexities of the factors. Informed by planning tool results, members met in March 2018 to start to collectively plan actions for sustaining WASH services. This research builds on existing system-analysis tool techniques and generates additional insights that can be used to (1) better understand the ways that diverse actors come together to jointly address shared priorities and (2) track and evaluate the process of alignment of these priorities over time.

METHODS

This research proposed to evaluate actor priorities in combination with the network structure. Below we detail the methods for data collection and analysis used to accomplish this.

DATA COLLECTION

The data for this work was collected in twenty-two interviews conducted with each organization in the Learning Alliance during the summer of 2017. Interviews were approximately an hour long, with the longest taking two and a half hours. Interviews collected data on each actor’s perceptions of challenges, solutions, and prioritized actions.

Priority Action

Semi-structured interviews lasting 15-25 minutes asked representatives a series of questions about *challenges and solutions to sustaining water services* as well as *which solution is the most important*. Interviews were conducted in the national language, Amharic, and conducted by two experienced enumerators hired and trained by the authors in June 2017. During training, we proposed interview questions and discussed what we intended each question to mean once translated, then received feedback as to the question appropriateness, and finally had each enumerator translate the questions to Amharic then re-translate them back to English to ensure questions conveyed the intended meaning.

Network Structure

Following interviews, the remaining time was spent collecting network data about each actor's relationships with other actors in the network. Organization representatives were first asked which other organizations in the network they interact with. For each named organization, they were then asked to identify how often their organization received or sent information, solved problems with, and/or actively implemented with a given organization. Relationships were specified to be outside of formal structures. For example, if an organization is required to send formal reports to a district finance office, these reports were not counted as sharing information. This was done to target informal relationships outside of normal hierarchies.

DATA ANALYSIS

The data analysis for this work occurred in two phases, described in the following sections. The first phase analyzed the results of the twenty-two interviews, including analyzing priorities using qualitative analysis and network structure using network analysis. The second phase combined the two data types to build a network that overlays actor priorities with their relationships to visualize, assess, and measure how priorities differ amongst the network.

Qualitative Analysis of Priorities

For the first round of analysis, we summarized all themes that interviewees discussed by assigning each incident to a theme or “code”. To draw theoretical insights from the respondents' perspectives themselves and to minimize bias from our outsider status, we employed grounded theory techniques (Strauss and Corbin 1990). To do this, we qualitatively coded the translated, transcribed interviews using inductive, emergent coding to start to show themes based on their forcefulness, recurrence, and repetition (Owen 1984). To organize the interviews and emergent codes, we used QSR NVivo software (QSR n.d.). As groupings emerged organically from the interviews, it was important to ensure the author's coding was unbiased. Validity of the coding was checked using an intercoder reliability NVivo feature that compared the author's coding with a second researcher who was given the same data (0.57, where kappa values > 0.4 are considered acceptable agreement (Opdyke et al. 2015; Saldaña 2009)). Then, using the emergent list of codes, we conducted a second round of coding to analyze answers to which solution do you think is the most important. Through this, we identified a single priority for each actor.

Building Collaborative Network Structure

The first round of analysis consisted of typical network analysis techniques and software packages UCINET and NodeXL, which tied actors together through relationship data for information sharing, coordination, and problem solving. This standard analysis was analyzed as a part of the USAID Sustainable WASH Systems Learning Partnership, and it revealed the structure of each relational network. This analysis, though not completed by the authors, provided a skeleton for the authors to add qualitative data from interview coding. For each actor, we imported the prioritized factor that emerged from the open coding process into NodeXL. We then assigned the priority as an attribute for the organization, alongside other characteristics such as organization function, type, and sector of focus.

PRELIMINARY FINDINGS

Issues of alignment emerged from interviews, which are presented below to set the context and need of alignment in the selected district Learning Alliance. Following this, we present preliminary findings of the combined actor and prioritized factor analysis.

ISSUES OF ALIGNMENT FROM INTERVIEWS

Often mentioned was the issue related to organizations having separate values and organizational structures, as well as lack of a shared mission or goal. Euphemisms such as organizations “running on one leg”, “running separately”, and “running independently” to reach their own visions were mentioned by half the interviewees. This is associated with having separate values or goals and being constrained by differing missions and organization mechanisms such as funding. Some actors saw this as just a part of working together, while others saw it as a serious barrier that would inhibit any successful collaboration. No actors discussed how the differences in goals, born out of different experiences and perspectives, might lead to better outcomes for the complex problems they seek to solve.

An NGO expressed how all external organizations that work in the area have different donors, and thus “also have different kinds of priority areas and reporting systems.” In contrast, they mentioned that organizational structures and goals can hinder efforts such as establishing a Learning Alliance, in that “even if a coordination office is available, as the missions of these institutions vary, the coordination office will be a symbol.” However, the NGO still saw that despite issues that may undermine coordination, a platform for learning would still enhance ongoing work, as “still it will add values to share knowledge and experiences.”

This was the only actor that discussed how their own organizational structure would limit their ability to collaborate on some tasks. In the WASH sector, key actors are often non-governmental organizations, domestic or international, that are often constrained by their parent organization’s structure and culture. If some actors don’t recognize constraints such as incentives and reporting structures, group discussions around alignment can be exacerbated.

COMBINED FACTOR-ACTOR ANALYSIS, OR (F)ACTOR ANALYSIS

Over thirty factors emerged from the coded interviews as influential for providing sustained WASH services in the district. Following the second round of coding where we assigned a single priority to each actor, only five priority factors were identified as the most important by the group of 22 actors: Budget, Community Awareness, Coordination, Water Resources, and Site Selection. Table 1 provides the definitions for these factors along with the number of actors that prioritized them.

Table 1. Prioritized factors

Factor	Definition	# of actors prioritizing
Budget	Finances available through budget allocated by the government, contributed by the community, or funded through external sources.	7
Community Participation and Awareness	Participation by the community in aspects of service construction and provision, including community awareness on proper use of the scheme.	7
Coordination	Coordination of woreda offices, zone offices, kebele administrators, and the community, with a common plan. Coordination on planning activities, monitoring water schemes, training, sharing resources (technical, material, and financial resources), and sharing information.	4
Water Resources	Quantity of water available, including groundwater, reservoirs, rivers, and rainwater. Includes conducting hydrogeological assessments for groundwater.	3
Site Selection	The selection of where schemes will be constructed, including geographical differences in water resources. Includes the unfair selection of scheme locations.	1

To undertake preliminary analysis to demonstrate this methodology, we selected a single relationship from LINC’s analysis. We chose the relationship of “coordination” to analyze how actors that coordinated planning and activities may prioritize similar factors. Specifically, in a survey given to each actor in the network, respondents were asked: *With whom did your organization directly coordinate planning or activities in the past six months? This includes planning your own activities with significant input and communication with one another, as well as planning joint activities.*

In network analysis, each actor is identified by a single dot (from here on called a node), where node size denotes the actor centrality. Nodes are connected by a line (from here on called an edge) if they coordinated plans or activities together. The strength of the edge can be determined based qualitative scoring by the respondent, quantitative values such as amount of resources or information flowing, or on reciprocity such as if both actors reported a relationship. Here, we used reciprocity as strength, denoted by a darker line. Relative placement of the nodes uses the Harel-Koren fast multiscale algorithm to minimize edge intersection and improve network clarity (Harel and Koren 2002; Kim and Hastak 2018). The factor that each actor prioritized is noted by the color of the actor node, creating a visual representation of what we term a *(f)actor network* (Figure 1).

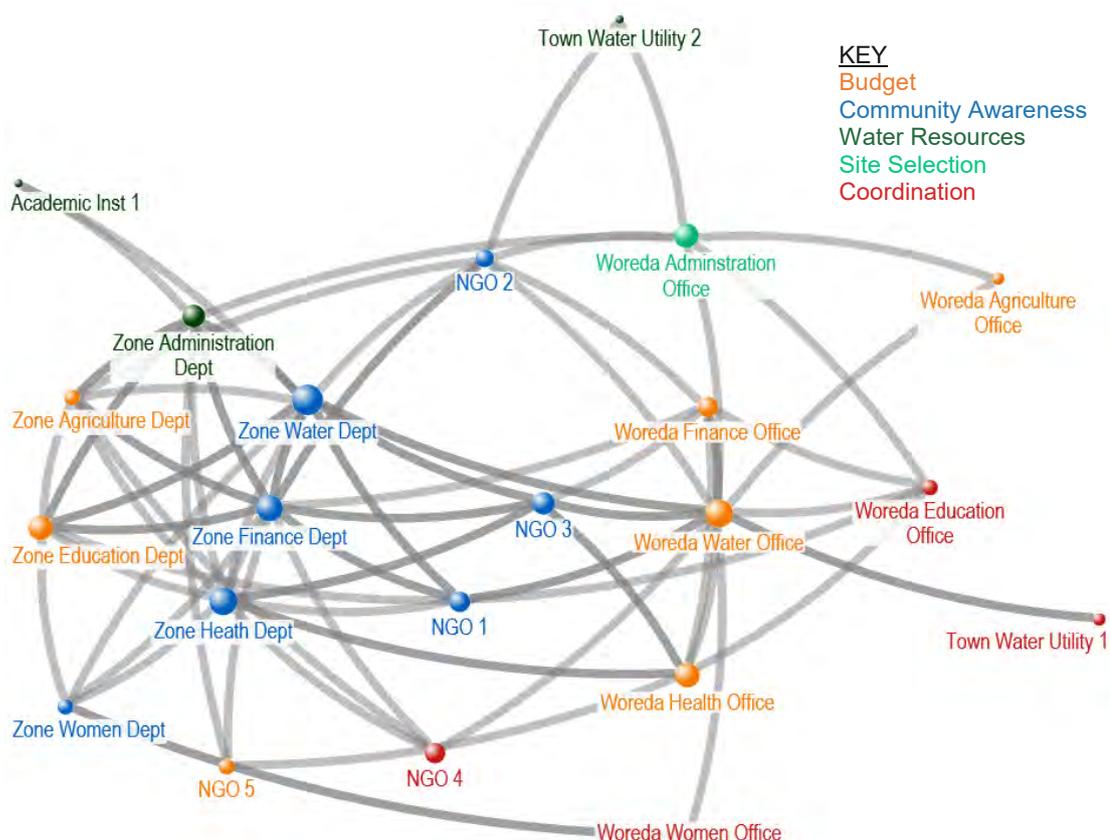


Figure 1. Network demonstrating coordination relationships between actors in a single district in Ethiopia, with node color designating prioritized factor, termed a *(f)actor network*.

By visualizing prioritized factors alongside network analysis results through the *(f)actor network*, we note trends regarding coordination and community awareness.

First, the four actors that prioritize coordination (red in Figure 1) are those that coordinate the least with others, and none of them coordinate with each other. This is supported by the interviews. One of the four organizations stressed that coordination is the reason for project failure:

“the major solution is coordination among stakeholders... At the first place there is weak coordination among WASH stakeholders that is why ongoing water projects are not completed yet... WASH plans and activities should be discussed together; one office cannot be effective. There should be a common plan, including capacity building...this might include sending their quarter year report to water office and participating in annual and other meetings.”
- Woreda Women’s Office

In contrast, the interviews revealed that while all actors discussed coordination as a factor that has prevented or could enable sustained services, some of the more well-connected actors did not see it as a problem.

“At a woreda level we have no coordination problem. Particularly the WASH program supports water, health and education sectors. These sectors use their budget according to the plan without violating the finance regulations. If their plans are not feasible, our office evaluates and reject their budget proposal. Thus, our coordination with these sector offices is good.”

- Woreda Finance Office

If the actors expected to take the lead on collaborative efforts fail to see it as a pressing issue, they may feel less motivation to initiate actions such as establishing Learning Alliances and incorporating other actors at the outskirts of the network. This is similar to findings in a study of fishermen networks by Crona and Bodin (2006), where “without the appropriate incentives and knowledge, favorably positioned actors will not exploit their positions to initiate collective action” (p. 18).

Besides this easily-visualized trend, it is also apparent that there are groups of nodes that coordinate with each other (e.g. have a coordination tie) and share priorities (e.g. are the same color). For example, the group of zone offices and NGOs that prioritize *community awareness* appears to be well-connected and close to one another. Furthermore, no woreda offices belong to that group. In this context, responsibility for working on community awareness lies at the woreda government level:

“There is a community mobilization unit at woreda level. This unit is responsible to support WASH committees and water user associations. However, in practice they are not supporting the community related to operation and management of water schemes. Thus, I recommend that this community mobilization unit should have a plan to support the community on operation and management of water schemes. This unit should also collaborate with non-governmental organizations in building the capacity of the community to ensure sustainable water service in the area.” – NGO 1

NGO 1 points out the actors with the responsibility to work on community awareness, the woreda government, does not coordinate activities with NGOs. Looking at the (f)actor network map, the woreda government does have ties to the three NGOs that prioritize community awareness, but there appears to be a disconnect of who works with whom to improve community awareness. Looking at the priorities of the woreda government actors, budget, coordination, and site selection are more important than community awareness and thus may limit their interactions with the NGOs that do prioritize community awareness. By visually considering interview responses with network data, we can better understand where misalignment occurs, which can be the first step toward negotiating a shared plan forward.

While visual cues are useful for facilitating discussion and noticing initial trends, to develop a nuanced understanding and characterization of alignment for this complicated network, we employ social network metrics from the analysis software. We are still exploring the metrics that best characterize nuanced differences and their implications on alignment. We seek to expand upon known relationships of “who works with whom” to better understand “who shares priorities with whom” (identified

through ties and priorities). For example, we seek to not only demonstrate who works together on activities – but who works together as a means to the same end.

Considering that some actors may be better positioned to work towards some priorities, we investigate alignment as the right people converging on the same priorities, we currently envision using two complimentary types of network metrics to evaluate alignment: (1) density within the groups partitioned by priority and (2) external-internal indices of varying levels. Density within each group can help us better understand how often those with the same priorities work together on the same issue, revealing levels of alignment towards a common goal. The optimal amount of density here is context-specific: as density increases, at what point does it reach an ability to achieve collective action and at what point is a high density of ties indicative of “group think”, or homophily?

The External-Internal (E-I) index represents an idea of “birds of a feather flock together”, testing the frequency of which those with a certain priority have ties to those that also share that priority. The E-I index metric compares the number of External connections (different priorities) to the number of Internal connections (same priority) relative to the total number of possible connections. These can be calculated for the entire network, each group that shares priorities, and for individuals. Table 2 presents our preliminary analysis of the network, with potential insights, using the two aforementioned metric types.

Table 2. Proposed metrics for measuring alignment of priorities within a network, between groups that share priorities, and between individuals. Outlines what the metrics tell us, outputs, and potential insights.

Proposed metric	Tells us	Output	Potential Insights
Density (group that shares priorities)	The percent of ties present within one group	Budget: 0.17 C. Awareness: 0.5 Coordination: 0.0 Water Res: 0.17 Site Selection: N/A	- Half of the actors that prioritize community awareness are jointly coordinating activities. - None of the actors that prioritize coordination are coordinating activities
E-I Index (whole network)		Raw: 0.354 Max possible: 1.0 Min Possible: -0.57 (Max and Min given density & group size) Scaled to between Max/min: 0.176	There is a tendency toward external connections; actors in the network coordinate with those that do not share their priorities.
E-I Index (group that shares priorities)	Ratio of ties outside a group to ties inside the group Ranges from: -1 (all internal) to 1 (all external)	Budget: 0.44 C. Awareness: 0.02 Coordination: 1 Water Res: 0.67 Site Selection: 1 [Values for each, some examples:] Woreda Ag Office: 0 W. Water Office: 0.5 W. Women Office: 1 Z. Water Dept: -0.09 Z. Women Dept: -0.2	- Actors that prioritize coordination and site selection only coordinate with those that prioritize different actions. - E-I indices would be negative if actors in groups work more with actors that share priorities. However, no groups had negative indices. - Two actors (Z. Water Dept and Women Dept) have negative E-I indices, meaning that they work more with those that share their priorities than those that do not. - Six of the 22 actors had scores of 1, where they only work with actors that do not share their priorities.
E-I Index (individual)			

Comparing group-level metrics provides insights into how each group works with each other. However, group-level metrics do not assess who exists in each group. Thus, it could be useful to compare the E-I index with other attributes, such as organization type or sector of focus, with other metrics, such as average centrality of group members. These comparisons could start to answer questions such as *to what extent do NGOs share priorities with zone offices and woreda offices?* and, if central actors are those that typically drive group action, *which priorities do the central actors prioritize?*, or if there is concern of isolation, *do well-connected actors tend to be more endogenous (relate to more internal actors, EI index less than 0) or exogenous (relate to more external actors, EI index greater than 0)?* Findings from the E-I index indicate that only a few actors exhibit slight homophily, and overall the groups and whole network are more exogenous than endogenous. This reinforces the findings of Ogada et al. (2017) and contradicts expectations of collective action principles where complete alignment is desired.

CONCLUSIONS AND FUTURE RESEARCH

As the Learning Alliance develops, members will collectively decide which actions the alliance should undertake; however, generating consensus requires overcoming these differences in priorities. The extent of alignment required to efficiently achieve “collective action” is context specific and not well documented. Through the analysis of the actor network and each actor’s prioritized factors, a *(f)actor network*, we inferred how the relationships between actors and their relative priorities influence the ability for the right actors to work together collectively. Our study presented here presents a preliminary method to uncover key areas of alignment or misalignment that the Learning Alliance should leverage or address, considering interaction between organization types, subgroups of actors that worked together, as well as their position in the collaborative network. More broadly, this work demonstrates how analyzing network structure alongside interview data reveals important areas of alignment. These can facilitate discussions that lead to more effective action in collaborative partnerships.

As a part of an ongoing project, we aim to expand and adapt this research in four ways. First, we will expand this methodology to more cases to allow for cross-case comparison. Cross-case comparison will point to useful metrics to compare alignment between different stakeholder groups.

Second, we will re-assess alignment in the same cases over time to allow for longitudinal analysis. This intends to show how particular collective action interventions such as establishing knowledge-sharing platforms and backbone organizations change aspects of alignment, if the changes are what organizations expected, and how long these changes can take.

Third, we will evaluate which network analysis metrics can be used to demonstrate changes in alignment over time to measure and report alignment evolution in collective action work. Metrics will be used to quantify the key differences observed in cross-case comparison and the longitudinal assessment.

Fourth, we will validate the results with the local actors themselves. This will involve presenting the results and then conducting interviews and focus group discussions to better understand the extent to which the visualization, assessment, and measurement aspects of the factor-actor network agree with what is experienced by

those within the network. Future applications would aim to engage local actors in the analysis and interpretation of findings.

With these next steps, we intend to build an evidence base about how collective action approaches create alignment. Conjointly, we plan to provide a validated methodology for how stakeholder analysis can be used to improve understanding of the extent to which actors in networks share priorities toward a common goal, and how this might influence WASH service delivery outcomes. This work builds evidence toward a broader research question of *how alignment of actors in a collaborative WASH network be measured and assessed using network analysis*.

LIMITATIONS

There are well-established methodologies for determining priorities, such as the Analytical Hierarchy Process (AHP) and others. We recognize that in establishing a more rigorous understanding of priorities requires a more systematic approach. Furthermore, our analysis assumes that the perspectives of the actors (organizations and government offices) can be represented by the perspective of the individual person that was interviewed. We aim to continue investigating which methodology is best for determining priority actions of the actors and invite the reader to provide additional insights by contacting the authors.

This work focused on priorities, but we recognize that misalignment could manifest in other ways. We plan to restructure interview questions and coding to consider where other areas with differing perspectives could prove problematic; such as definition of collaboration, definition of sustainability, perceived effectiveness of collaborative efforts, and information used to make decisions.

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BUILDING INFORMATION MODELLING, DATA- AND STAKEHOLDER- MANAGEMENT FRAMEWORK FOR MATERIAL PASSPORTS

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BUILDING INFORMATION MODELLING, DATA- AND STAKEHOLDER- MANAGEMENT FRAMEWORK FOR MATERIAL PASSPORTS

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ABSTRACT

European Architecture, Engineering and Construction industry (AEC) consumes a significant rate of materials like steel, aluminum, copper and plastics, thus creating a large reservoir on secondary raw materials in buildings. One of the main strategies of the European Union is to maximize recycling rates in order to minimize environmental impacts and the energy consumption caused by extraction of primary materials. To enable circularity, and in consequence high recycling rates, information about the existing stock is necessary.

The early design stages play a crucial role in the waste reduction, the reusability of the building elements as well as in the increase of the recycling potential. As planners and architects are major decision makers regarding the design, materials, construction and assembly method, they bear large responsibility defining the resources efficiency over the life cycle. In order to optimize the recycling potential and material composition of buildings, new design-centric tools and methods are required as well as tools, which enable a compilation of data repositories on the material composition of buildings.

The potential of an automated generation and data management for a Material Passport (MP) was tested through linking BIM to the Material Inventory and Analysis Tool, thus allowing the assessment of embedded materials in buildings. Further on, the MP acts as a crucial instrument for material manufacturers, construction companies, engineers and architects, recycling and waste companies and policy-makers. Thereby the successful implementation of the MP in the AEC industry requires close collaboration of a broad spectrum of stakeholders, in order to achieve standardization and regulatory frameworks.

The results show that the semi-automated compilation of a MP is possible, even though there exist several obstacles. In this work, we also show the role of the stakeholders in generating a MP through a data and stakeholder framework.

KEYWORDS

Material Passports, Recycling, Building Information Modelling, Data and Stakeholder Management, Resources Efficiency.

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INTRODUCTION

According to the United Nations Environment Programme (UNEP), the world population will grow from 7 billion persons today to 9 billion people in 2050 (UNEP, 2011). Consequently, the consumption of raw materials will also grow. The construction industry is the world's largest consumer of resources and responsible for 25-40% of global carbon emissions (WEF, 2016). Only 20-30% of Construction and Demolition Waste is recovered, whereby many of the discarded materials have the potential to be recovered for different purposes. These purposes can be fertilizer additive, gravel and road-building materials. If the industry focused on reusing and recycling of materials, it could improve the resource efficiency significantly (WEF report, 2016). The increasing of recycling rates and reusability of building elements and materials in construction is part of a larger concept of circular economy. Circular Economy aims to maintain the value of products, materials and resources in the economy as long as possible in order to reach a low carbon and resource efficient economy (European Commission, 2015).

In order to enable the increasing of recycling rates it is necessary to have detailed knowledge about the materials incorporated in buildings. Recycling is amongst others depending on constructive criteria as for example accessibility and separability of building elements and materials. As constructive criteria is defined in early design stages, it is necessary for architects and planners, to have tools, which enable the evaluation of the recycling potential. However, there is lack of tools, which allow an assessment in early design stages. In order to fill this lack, we propose a Material Passport (MP). The MP is a tool, which provides knowledge on the material composition of buildings. It also gives qualitative and quantitative information about the embedded materials, their recycling potentials and environmental impacts.

In this paper we will present the ongoing research within the funded research project "BIMaterial: Process-Design for a BIM-based Material Passport"⁴, as presented in "BIM-based Material Passports as tool for enhancement of circular economy in AEC industry", at the EPOC 2017 (Kovacic et al., 2017). The focus of the previous work was on the proof of concept for the compilation of a BIM-based Material Passport (MP), demonstrating that a semi-automated generation of MP is possible. In this paper we describe the improved and updated proof of concept in the chapter "BIM Framework for Material Passports".

Extending the previous work, this paper will focus on challenges in data and stakeholder management for implementing the MP into the whole life cycle of a building. Therefore we propose a Data and Stakeholder Management Framework for Material Passports. The main contribution of the current paper starts with chapter "Challenges in Data Management".

This paper is structured as follows: First, we start with the literature review, introducing the main topics related to the Material Passport concept, which are Circular Economy, Urban Mining, BIM and Institutional theory. Secondly, we

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proceed with the BIM Framework for the compilation of a MP and introduce the main challenges in data and stakeholder management. Then we show the proposal for a data and stakeholder management framework for the compilation of a MP. Finally, we conclude with an overview of the main challenges and a discussion of the meaning of a MP as a tool for enhancement of circular economy.

LITERATURE REVIEW

URBAN MINING AND CIRCULAR ECONOMY

Circular Economy (CE) is considered as the solution to wasteful industrial and production processes of current world enterprise; through minimization of steadily increasing consumption of material resources, waste generation and environmental pollution. The concept of CE is not new, as it has its roots in the 1970ies. Through industrial revolution, mass production of goods was enabled by new manufacturing methods. Due to mass production, products were available in large amounts and at low cost. This consequently led to huge solid waste generation and landfill. Apart from that, the strong world population growth expanded the demand for resources, wherefore first solutions to minimize raw materials consumptions were illustrated by Meadows et al. (Lieder and Rashid 2016, Meadows et al., 1972). CE is based on moving away from linear economic models, such as unlimited extraction of raw materials and production, consumption and disposal of goods and products, towards circular economic models, where resources and energy consumption is reduced through reuse of existing resources within the economic sphere (European Environment Agency, 2016).

Waste and resource management is getting an important issue for the society. The main reasons therefore are the concern about increasing global consumption of non-renewable resources, progressive shortages of primary raw materials, reduction of space available for final disposal of wastes, the need for quantity and volume reduction of wastes generated, as well as for control of environmental contamination caused by emissions from waste treatment, etc. (Mining, 2015).

The term Circular Economy has been defined in different ways so far. In eco-industrial developments, CE is described as “realization of closed loop material flow in the whole economic system” (Geng and Doberstein, 2008). In relation to the 3R principles (reduction, reuse and recycling), the main aim of CE is the circular flow of materials and the use of raw materials and energy through multiple phases (Yuan et al., 2006). For the European Union (EU), the main objective of CE is to maintain the value of products, materials and resources in the economy as long as possible to reach a low carbon and resource efficient economy. The EU developed an action plan for CE, demonstrating that the main strategy is to maximize the recycling rates in order to minimize the environmental impacts and energy consumption caused by extraction of primary material (European Commission, 2015).

Urban Mining is one main strategy within Circular Economy, among some other such as landfill mining and waste minimizing. Urban mining is a new approach towards recycling, which promotes the systematic reuse of anthropogenic materials from urban areas. A huge amount of materials is incorporated within buildings and

infrastructures, representing a huge stock. This stock shows large resource potential that can eventually become available at the end of the lifetime. In contrast to usual recycling, urban mining includes, apart from mining of waste, also the exploration and observation of materials in buildings and infrastructure (Klinglmar and Fellner, 2010). As the extracting and processing of materials is related to economic aspects, public policy plays an important role in driving recycling practices through regulations (Mining, 2015). To enable urban mining, information about materials and substances is required (Brunner, 2011), which represents the main challenge, as several studies show. One of these studies was conducted by Kohler and Hassler (2002), who analysed the material flows in the German building stocks through coupling statistical data and analysis of building elements and materials (top-down and bottom-up). Another study was performed by Lichtensteiger and Baccini (2008) in Switzerland. By using the so-called ARK method, buildings were categorized according to their age and typology. A similar method was used by the “Christian Doppler Lab for Anthropogenic Resources” (CDL, 2017) at TU Wien, where building and infrastructures were analyzed in terms of recyclability (Kleemann et al. 2016). Markova and Rechberger (2011) proposed a concept for the generation of a Material Passport based on three use cases. Thereby they used the top-down and bottom-up approach. In the top-down approach, the building is divided in functional elements in the first step, and in the second, in the lowest level, which is the specific material in a building element. Whereby on the contrary, in the bottom-up approach, the materials of each element in the building were scaled up to the building level.

The urban mining concept and Material Passport are closely related to the concept of circular economy, as general striving to reduce the resources consumption and move away from the make – consume – dispose model towards more sustainable production and consumption models through keeping goods and products as long as possible in the economic cycle (Prins et al. 2015). Currently, many projects make Circular Economy and resource efficiency a subject of discussion, as for example the EU-funded project BAMB (Buildings as Material Banks). BAMB is a Horizon 2020 project with 15 partners from 8 European countries, aiming an implementation of CE in the AEC (Architecture, Engineering and Construction) industry. One of their concepts to implement CE in the AEC industry is the Material Passport. Material Passports in BAMB are sets of data, which describe defined characteristics of materials in products that give them value for recovery and reuse.

Urban Mining and Circular Economy are accepted as essential concepts to improve recycling rates and minimize waste. However, information about the existing stock is necessary, to enable circularity. Generating knowledge about materials embedded in buildings manually, is a time-consuming process. Through the MP concept, we aim to provide information about material composition of buildings and their recycling rates. A manually created MP is time-consuming and error-prone, wherefore we propose a BIM (Building Information Modelling) -based Material Passport.

BUILDING INFORMATION MODELLING (BIM) FOR MATERIAL PASSPORTS

Building Information Modelling (BIM), as one of the most promising developments in the AEC (Architecture, Engineering and Construction), has large potentials

regarding process-automation and data management. By international standards, BIM is defined as “shared digital representation of physical and functional characteristics of any built object...” (ISO Standard 2010). A BIM is modelled with object-oriented software and contains parametric objects, which represent building components (Volk et al. 2014). Since a BIM-Model consists of information about the geometry, spatial relationships, quantities and properties of building elements, cost estimates and material inventories, it contains relevant data, which is required for the design, fabrication and construction activities. (Bazjanac, 2006, Eastman et al., 2008 and Azhar et al. 2011). Reisinger et al. (2014) developed and compared a building-material-data sheet, which is created without BIM, with a BIM-based material information system. The results of the comparison show, that the BIM-based system has more potential.

As a BIM contains information rich building elements, and further coupled information, it is suitable to serve as a knowledge-basis for MPs and accordingly for a Life Cycle Assessment (LCA). Apart from being a knowledge-basis, BIM also shows potential for an automated creation of a MP. Even though BIM consist of large potentials to optimize and document the material consumption of a building, there exists no methodology to compile an automated MP with BIM so far.

INSTITUTIONAL THEORY

Institutional theory considers processes by which normative and behavioural systems maintain stability or undergo changes over time (Scott, 2005). The three elements or the so-called “three-pillars” of institutional theory are regulative elements, normative elements and cultural cognitive elements, which contribute to the construction, maintenance and change of institutions. Regulative elements are the rule-setting activities, which constitute and strengthen arenas of control and create a system of control. Normative elements consist of values and norms, which present a prescriptive and obligatory dimension into social life. The cultural-cognitive pillar describes the cultural elements, e.g. shared beliefs within community and their relation to cognitive elements such as thinking, feeling and acting (Scott 2012, 2014). The regulative, normative and cultural-cognitive elements seldom occur isolated and can be found in construction project organizations (Henisz et al. 2015). In our research, we show how the three pillars of institutional theory can influence the implementation of the Material Passport, as MPs are part of a larger socio-economic system, where public policy and social interests are interconnected with intra- and interfirm organisations and their interests.

BIM FRAMEWORK FOR MATERIAL PASSPORTS

In the previous paper, we have presented the first version of the BIM-Modelling framework. In the current work, we describe the final BIM-Modelling framework.

The Material Passport plays multiple roles along the life cycle of a building as shown in Figure 1. allowing not only generation of building passport, but moreover the complete Life Cycle Assessment (LCA) of the ecological footprint of the building construction. As the MP and LCA require similar data and same methodology, we integrated the LCA into the MP. In the conceptual design stage, the MP serves as a

rough analyses and optimization tool. In early design-stages changes can be conducted easily and at low cost, therefore the MP is an important decision support tool. In this stage, variant studies can be carried out e.g. enabling a comparison of a timber versus concrete variant, in order to choose the one with less waste creation and lower environmental impact. In the preliminary design stage, the MP enables variations of in the layers of building elements. For example, an insulation layer, which leads to huge waste masses, can be replaced by an alternative insulation with a better recycling potential. Further, the thicknesses of layers can be changed. In the tendering stage, the MP acts as a documentation tool, where the material composition of the BIM-Model -as designed by the planners- is documented. In the documentation stage, the building is already erected. In this stage, the MP provides information for recycling, serves as an inventory of the realized building and as a basis for an urban material cadaster. In this work we present the MP in the early design stages.

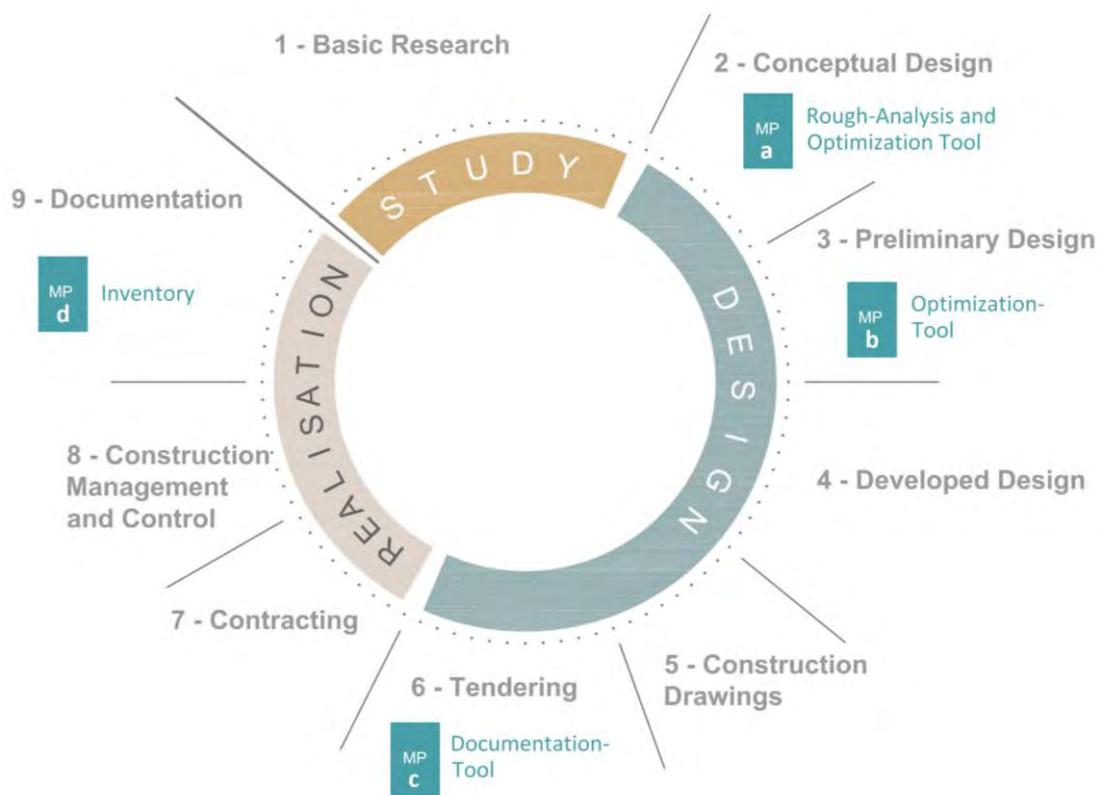


Figure 1: The Material Passport along the life cycle of a building

The process for generating a MP and related LCA is based on coupling various digital tools, as shown in Figure 2. BIM-Software (Graphisoft Archicad and Autodesk Revit) is used for modelling, whereby a modelling guide serves as assistance. We created the modelling guide based on the Austrian Norm A 6241 2:2015 (ÖNORM). The guide provides information on the appropriate modelling methodology for the relevant design stage. For enabling the semi-automated process of compiling a MP, we also offer a template-file, which consists of pre-defined building elements and materials. These pre-defined elements are multi-layered walls and slabs, provided by the eco-

inventory “baubook” (baubook). Before the model is exported to the Material Inventory and Analysis Tool (BuildingOne), it has to be tested by the Control Tool (Solibri Model Checker). The control tool makes a general BIM-check and verifies, if the pre-defined elements and materials were used. After verification, information out of the model is exported to the Material Inventory and Analyses tool, which offers a bidirectional connection with the BIM model. Through this bi-directional connection, changes in the model e.g. the height of a wall, can be adopted easily. Apart from that, the Material Inventory and Analysis Tools allows the parametrization of layers/materials, whereby information can be linked to each layer/material. Since parametrization of layers/materials is not possible in BIM at present, the Material and Inventory Tool plays a crucial role in the generation of a MP. Further, we gather data on recyclability potential and eco-indicators, pre-defined building elements and data from the BIM-Model in the Material Inventory and Analysis Tool. The final MP-document is also generated that Tool.

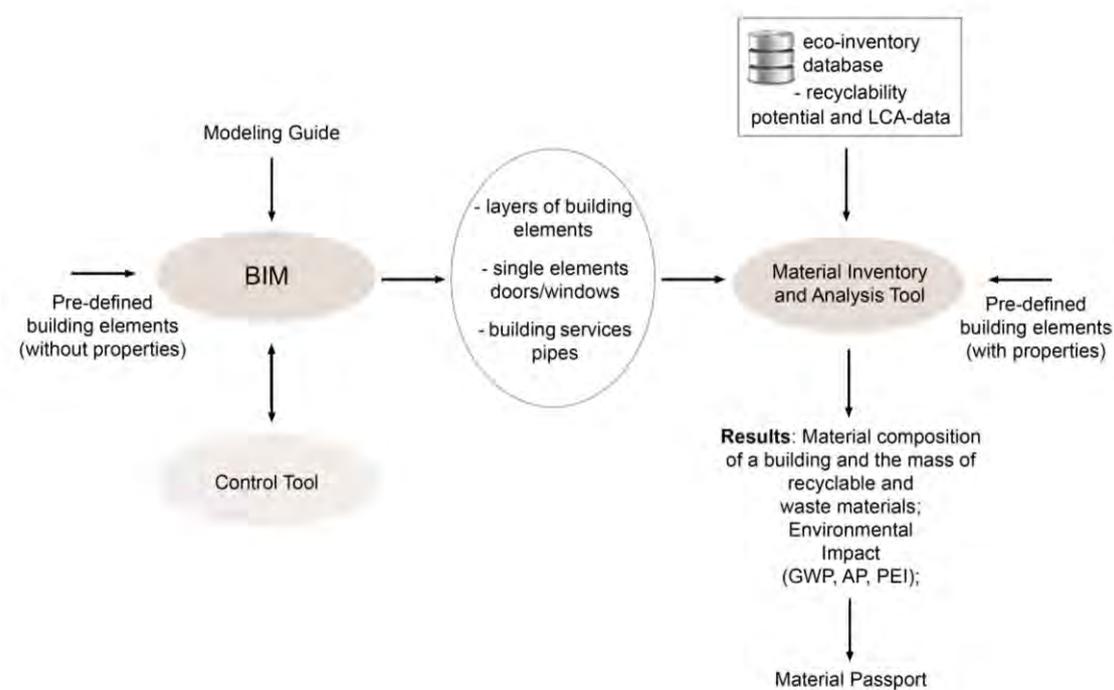


Figure 2: BIM Framework for Material Passports

CHALLENGES IN DATA MANAGEMENT

For compiling the MP numerous databases are required. These databases provide data for the composition of construction elements, their recycling potential and eco-indicators (Figure 3). Through application of the BIM Framework for Material Passports on Use Cases, we could identify main challenges in data management. The main challenge in data management is the inconsistent naming of the products and elements in various databases. In addition, the units, in which data is provided, vary from database to database. Consequently, the utilization of various databases lead to inconsistencies, which cause incoherent and non-comparable results. In order to avoid

inconsistencies, it would be necessary to compare and match the data from various databases. However, matching of incoherent data is a very time-consuming process, which requires a collaboration of all eco-data (eco-inventories) and building element providers as well as manufacturers, in order to supply harmonized data.

In general, within the planning process and workflow for the generation of both MP and LCA the needed data can be identified as:

- Eco-inventories – listing eco indicators of specific products or materials
- Catalogues of the building and construction elements, where the composition of building elements according to standard or state of the art is listed
- Product Declarations – data provided by product manufacturers – EPD (environmental product declarations)

To harmonize the data, a collaboration of the various eco-data and building elements providers as well as manufacturers is necessary, which could be enhanced by regulations and the public policy making.

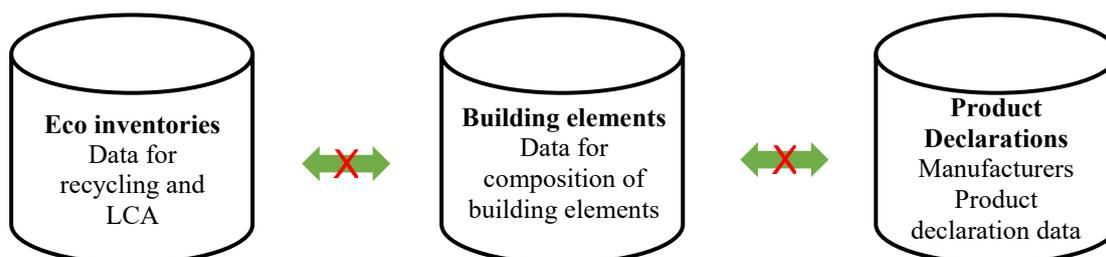


Figure 3: Inconsistencies in the various databases for MP and LCA

CHALLENGES IN STAKEHOLDER MANAGEMENT

As the MP is used as a design optimization tool, as well as documentation on material composition of a building, thus supporting urban mining and CE strategies on the macro-economic scale, it addresses the stakeholders of several domains:

- The planning process stakeholders (architects, BIM Manager, MP Consultants building owner)
- Public Policy Stakeholders – institutions regulating the resources efficiency and CE, environmental agencies etc.
- Industry – product manufacturers (EPDs), product database providers (eco-inventories)

As designers and planners decide about the design, construction, materials and assembly method, they bear large responsibility. In early design stages, many changes can be conducted in order to optimize the recycling potential or environmental impact

of buildings. Therefore the Material Passport acts as an important decision and optimization tool. Since for creating a Material Passport BIM is used, there is need for knowledge in BIM application and consequently for BIM Managers. Through using the BIM Framework for Material Passports on use cases and expert-interviews (demolition companies, material industry, planners and construction firms) we could identify challenges in the creation of a MP. The main obstacle is lack of knowledge in BIM-application. BIM as emerging tool has large potential to serve as a knowledge basis for a Material Passport, as all elements and materials exist in the BIM-Model (Azhar et al. (2011)). As described in section “BIM Framework for Material Passports”, the generation of a MP requires a specific BIM-Modelling methodology. Planners and designer do not have knowledge about this specific modelling methodology, wherefore they need to be trained by BIM Managers. BIM Managers usually exist in construction companies that use BIM. The main role of the BIM Manager is to manage the implementation and or maintenance of the BIM – process (Barison and Santos, 2010). For generating a MP, there is also need for specific Know-How in data-management and databases, materials and constructions as well as their recycling potential and environmental influence. This knowledge is usually not possessed neither by designers nor by BIM Managers. Therefore there we propose a new stakeholder, which is the MP Consultant.

As mentioned above, material manufacturers and eco-inventories both provide information about recycling and LCA. In our research, we found out that the main obstacle is the incoherent nomenclature of data. In addition, the units in which indicators as for example Global Warming Potential (GWP) are provided, are not equal. Therefore collaboration and consolidation of product and material databases as well as EPDs is necessary.

Public Policy as a stakeholder is important for the implementation of the MP, as Public Policy can enhance the use of MPs through incentives and/or regulations. To enable optimized recycling processes and integration of CE solutions, Public Policy has to be in strong collaboration with Recycling & Waste and CE Organizations. Together with Recycling & Waste and CE Organizations they can define regulations to improve recycling rates of buildings as well as to implement the MP in the construction sector. The European Commission claims an increase of recycling and other material recovery of materials to a minimum of 70% by weight by 2020 (European Union, 2011). Similar regulations could be introduced by Public Policy as for example use of materials that have a minimum recycling rate of 80%. The agenda of Recycling & Waste and CE Organizations has to be in close relationship with the eco-inventories and manufacturers in order to provide information about recycling potential of specific materials.

DATA AND STAKEHOLDER MANAGEMENT FRAMEWORK

Through expert-interviews (demolition companies, material industry, planners and construction firms) and application of the BIM Framework for Material Passports on use cases, we identified a lack of collaboration and information transfer between various stakeholders. In order to improve the recycling potential and environmental

impacts through the generation of a MP and accordingly LCA, it is necessary to increase the cooperation between the stakeholders. Therefore we developed a data management framework (Figure 4), which shows the optimized collaboration and data exchange between the stakeholders. The initial step for creating the framework was basic research, in order to capture stakeholder interests and challenges in stakeholder management. As a further step, we conducted expert-interviews and applied the BIM Framework for Material Passports on use cases, whereby we could identify the main challenges in data and stakeholder management.

The developed framework is based on the three pillars of institutional theory by Scott, which are the regulative, normative and cultural-cognitive elements. We identified 3 domains in the Data and Stakeholder Management Framework. These domains are the planning domain, the industry domain and the institutional domain.

The regulative pillar is in our case the institutional domain. The institutional domain should integrate EU-regulations, which for example define the recycling rate for new buildings. The European Commission claims an increase of recycling and other material recovery of materials to a minimum of 70% by weight by 2020 (European Union, 2011). The normative elements in the MP concept are the norms, as for example the Austrian Norm ÖNORM A 6241 2:2015 (ÖNORM), which describes the modelling method as well as the Modelling Guide, which is based on the ÖNORM. These norms also have to be integrated into the institutional domain. The third pillar in the institutional theory are the cultural-cognitive elements, which are not covered by our proposed framework. The cultural-cognitive pillar would include the behavior of society as for example the acceptance of new concepts as well as the changing attitudes towards waste management and consumption of non-renewable resources. Terms, such as Urban Mining, Circular Economy, recycling and waste minimization, should be more frequently used by politicians and industrialists, in order to raise awareness of the society to these topics. Figure 4 also displays the stakeholder domains and inter- and intrafirm relationships of the system.

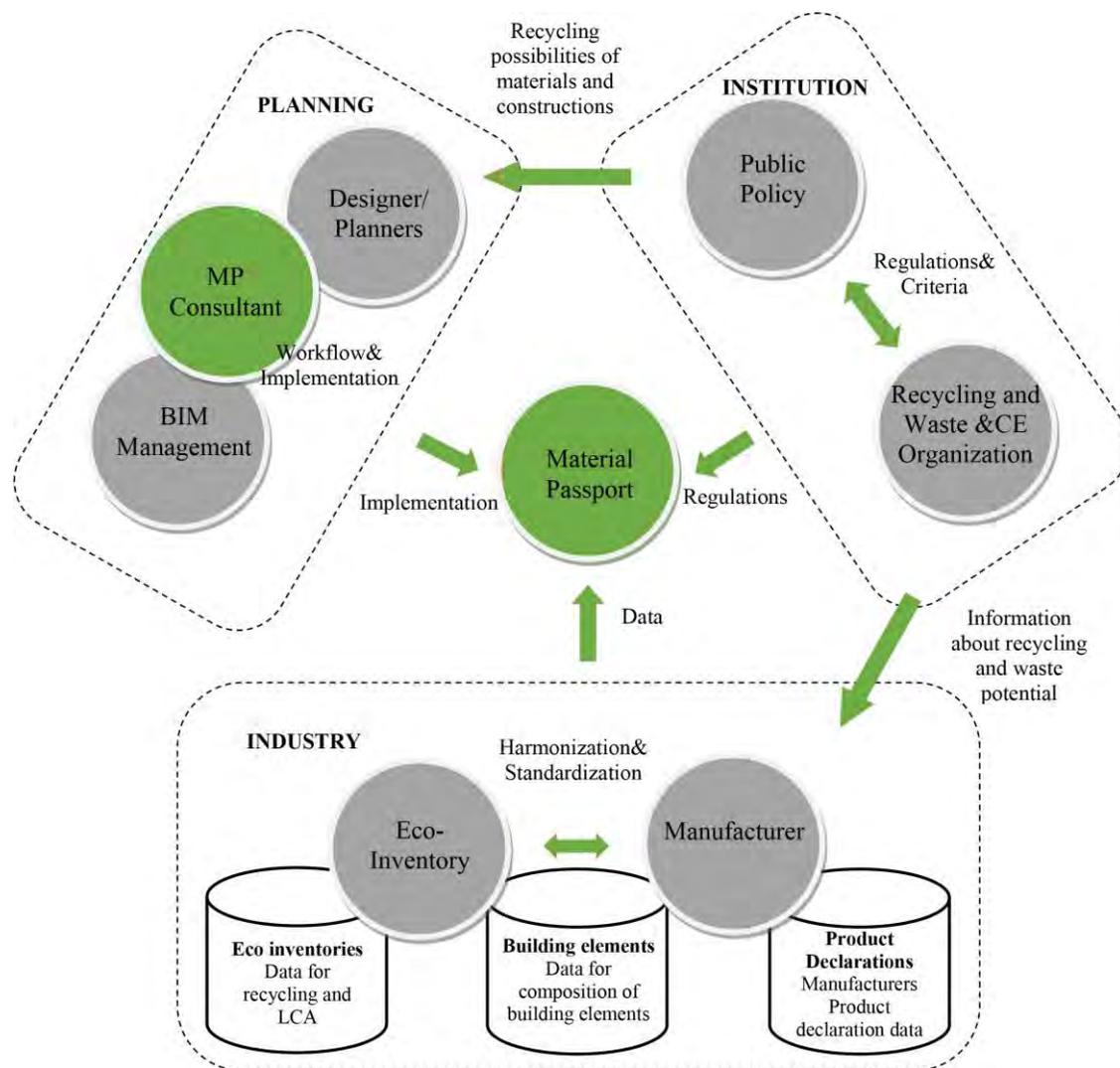


Figure 4: Data and Stakeholder Management Framework

As mentioned above, the planning domain consists of 3 stakeholders, which are the BIM Manager, the designers and planners and one new stakeholder, which is the MP consultant. The planning domain has an intrafirm relationship, since in general all stakeholders work in one firm.

According to Barison and Santos (2010), a BIM Manager is responsible for managing the implementation and or maintaining the BIM – process. Through use of the BIM Framework for Material Passports, we figured out, that for applying the BIM Framework for Material Passports, the responsibilities of BIM Managers have to be increased. We propose that the BIM Manager implements the modelling methodology into the firm, as well as controls the workflow for compiling a MP, as shown in Figure 2. Further, we suggest that the BIM Manager is in charge of the application of the Control Tool and the Material Inventory and Analysis Tool and in addition integrates the Modelling Guide and pre-defined elements into the daily use in firms.

The designer and planners are those who use BIM and model the buildings as required for the MP. Thereby they apply the Modelling Guide, use the pre-defined elements and control the BIM-Model. In general, they are responsible for generating a MP-appropriate BIM-Model.

For making the BIM Framework for Material Passports applicable in practice, we propose a new stakeholder, which is in charge of compiling the MP. As the MP is a tool, which requires a semi-automated process, the MP consultant is indispensable. At present, MP consultants do not exist in construction firms. The MP consultant is in charge of integrating recycling and LCA-data into the BIM-process, wherefore they use the Material Inventory and Analysis Tool. The MP Consultants link the pre-defined elements without properties from BIM to the pre-defined elements with properties in the Material Inventory and Analyses Tool. Thereby they are also creating variants and proposing the best variant in terms of recyclability and environmental impact (LCA). In order to be able to evaluate variants and accordingly building elements, the MP Consultant also needs knowledge about materials, constructions and their recycling potential as well as environmental impacts. The final task of a MP Consultant is the generation of the MP.

Apart from individual knowledge of the stakeholders, there is also need for a strong collaboration between the stakeholders in order to make the implementation of the MP possible.

We analyzed the relations within the institutional domain in Austria and identified a mix of intra- and interfirm relations, as the Recycling & Waste and CE Organizations are often also part of Public Policy. A strong collaboration is required, as the Recycling & Waste and CE Organizations is in charge of the optimized supply chain including the enhancement of recycling and decrease of waste. The Recycling & Waste and CE Organizations have knowledge about current recycling methods and rates for materials and constructions. Together with Public Policy, Recycling & Waste and CE Organizations can define regulations to improve recycling rates of buildings as well as to implement the MP in the construction sector.

The industry domain consists of manufacturers and eco-inventories, which all provide data for recycling, LCA and building elements. As mentioned above, a standardization and harmonization is necessary, wherefore a strong collaboration between these stakeholders is vital. The MP could serve as a milestone for creation of a joint platform, which provides structured data.

In this work, we figured out, that apart from the lacking collaboration within the domains, there is also need to increase the exchange of knowledge between the domains. A close collaboration is necessary on the one hand between the institutional and planning domain and on the other hand between the institutional and industry domain. As the institutional domain has knowledge about recycling possibilities of materials and construction, the planning domain should integrate that knowledge into their domain. Further, the industrial domain could profit from information about recycling and waste potential from the institutional domain and compare this information with their data.

For a successful implementation of the MP a strong collaboration between and within the domains is necessary, whereby the planning domain is responsible for the implementation in BIM, the institutional domain for regulations and the industrial domain for providing data.

CONCLUSIONS

In this paper, we presented the results within the research project BIMaterial-Process Design for a BIM-based Material Passport.

As introduced in the previous paper, the semi-automated creation of a MP is confronted with many challenges. One of these is the varying designation in databases, which leads to difficulties in data management. Another challenge faced during this research is the limits of BIM-Tools, as the parametrization of materials is not possible in BIM. Through the development of a workflow, we identified a need for introduction of new consultants/experts in the planning process and for increased training of existing stakeholders, in order to be able to implement the MP.

Urban Mining and Circular Economy are accepted as essential concepts to improve recycling rates and minimize waste. To enable circularity, and in consequence high recycling rates, information about the existing stock is necessary. Therefore the BIM-based Material Passport serves as a crucial tool, as it consists of the material composition as well as the recycling potential and environmental impact (LCA) of buildings. Apart from that, the MP is a multifunctional instrument and a central data repository along a building's life-cycle. In the early design stages, it acts as a design-optimization tool, allowing to conduct variant studies in order to select the best variant in terms of recyclability and environmental impacts. In the tendering phase, it serves as a documentation tool and in the documentation phase as an inventory as well as basis for a material cadaster. The information on material composition of buildings is usually distributed within the whole life-cycle of a building starting at the planning stage and finishing with the "as-built" building. Currently, such a data collector does not exist. Therefore the MP is novelty, as it serves as a central data repository, which collects all information about the material embedded in buildings throughout the life-cycle and provides this information for all participants of the planning process, which are the planners, building owner, demolition companies etc.

The current paper presents a BIM Framework, as well as a Data- and Stakeholder-Management Framework for compiling a Material Passport.

The BIM Framework describes the process for generating a MP and related LCA, which is based on coupling various digital tools. Thereby we used BIM-Tools, a control tool and a Material Inventory and Analysis Tool. BIM is used for modelling the building, wherefore a Modelling Guide serves as a basis, which provides general information about stage-oriented modelling as well as detailed information about the use of pre-defined elements. In this research, we figured out, that the main obstacle in compiling a BIM-based MP is the parametrization of layers/materials, which is not possible in BIM. Further, as in early design stages the detailed material composition

is not available, wherefore pre-defined elements are necessary, which leads to restrictions for architects.

In our research we also developed a Data- and Stakeholder- Management Framework for the generation of a MP, whereby we could identify 3 domains, which are the planning, institutional and industrial domain. We found out that there is lack of collaboration within the domains and therefore between the stakeholders, as well as between the domains. In the planning domain, there is need for a new consultant, which is the MP Consultant, who is in charge of integrating recycling and LCA-data into the BIM-process. Further, there is need for strong collaboration between the MP Consultant, the designers and the BIM Managers, in order to implement the MP in construction firms. In the industrial domain, there is lack of harmonization and standardization, as the provided data is incoherent at present. A strong collaboration is also necessary within the institutional domain, in order to define regulations for the use of MPs.

Apart from technical and regulative obstacles, it is also necessary to convince the society to accept new concepts. Urban Mining, Circular Economy, recycling and waste minimization, should be more present in media and used by politicians and industrialists, in order to raise awareness of the society to these topics.

The MP presented in this paper acts as decision-support tool for planners for the optimization of resource efficiency in early design stages. In this paper we showed the function of the MP in early design stages. However, the new construction rate across Europe is around 2%. The Urban Mining strategy, which consists of identifying and finally recycling of materials incorporated in buildings, would significantly reduce the consumption of primary resources. New methods for capturing the existing stocks is necessary in order to make use of the secondary materials. Laser- and Radarscan Technologies, which capture the geometry and materials of existing buildings, could support the development of a secondary raw materials cadastre. Through data obtained from Laser- and Radarscan an “as- built BIM” (Tang et al., 2010) could be generated, which could serve as a basis for a materials cadastre.

Widespread use of Building Information Modelling and Material Passports should promote information sharing about different resources and their life cycles, re-use of materials, productive processes, including improved engineering, procurement and supply chain management. Thereby, numerous stakeholders and institutions are the part of the process, linking industry, designers, users and public policy. We conclude that the compilation of BIM supported MPs requires increased stakeholder management and consolidation of standards among industry, planners and public policy in order to enhance the use of MP as tool for circular economy and consequently for minimizing waste and increasing recycling.

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LEGITIMIZATION OF THE INCLUSION OF CULTURAL PRACTICES OF DISPLACED PERSONS IN THE PLANNING OF WATER AND SANITATION SERVICES IN ACCOMMODATIONS

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LEGITIMIZATION OF THE INCLUSION OF CULTURAL PRACTICES OF DISPLACED PERSONS IN THE PLANNING OF WATER AND SANITATION SERVICES IN ACCOMMODATIONS

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ABSTRACT

During periods of high and rapid influxes of displaced persons, hosting communities may face challenges in accommodating incoming populations due to factors such as lack of front-end planning or cultural differences between the displaced and hosting community. With the short response timeframe and the consideration of transient vs resettled displaced populations in the hosting communities, decisions must be made regarding the inclusion of cultural practices differing from local norms. Human-infrastructure interactions associated with water and sanitation are diverse, such as differing water use trends, types of toilets, dietary habits, etc. This study seeks to assess the institutional response to internationally displaced persons through exploring how stakeholders (de)legitimized decisions pertaining to the inclusion of cultural practices in the planning of water and sanitation for displaced persons both at the system scale and building scale. This study is enabled by 28 semi-structured interviews of individuals involved in the accommodation of displaced persons in Germany conducted during the summer of 2016 during the peak of the population displacement. Qualitative analysis of the interview content was performed to identify the types of: (1) decisions made by stakeholders regarding the provision of water and sanitation services in response to the influx of population, (2) legitimacy used to (de)legitimize those decisions, and (3) information used to assess displaced persons' cultural practices. The results indicate that the institutional response was (largely) reactive rather than proactive. Stakeholders perceived providing education for proper use of German accommodations as morally constructed (moral legitimacy), while physical alterations to the built environment before and after displaced persons' arrival were primarily culturally constructed (cultural-cognitive legitimacy) and driven by benefits to organizations responsible for providing accommodations to displaced persons (influence legitimacy). This study demonstrates that decision-makers may

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underestimate their power when making decisions about the built environment provided to displaced persons.

KEYWORDS

Refugees, legitimacy, culture, water, sanitation, institutions, displaced persons

INTRODUCTION

The provision of accommodation for asylum seekers and refugees can pose challenges for governments and other associated organizations due to unanticipated needs. Displaced persons may have differing practices associated with the built environment from those of the hosting community that may lead to differing needs for services provided. For instance, water and sanitation needs (of interest to this study) may vary between displaced persons and the hosting community due to practices, such as the types of toilets used (e.g. sitting versus squatting), cooking habits (e.g. use of grease poured down the drain), and daily water usage trends driven by daily routines (Hacker et al., 2016). Decision makers can either try to repress needs associated with different cultural practices (e.g. using signs informing about the local use of facilities), or adapt to cultural or personal needs (e.g. renovations of existing accommodations; Faure et al., 2016). Anderson (2016) highlighted this phenomena, in the context of displacement and accommodations, stating that governments and organizations are “imposing shelter[s]” to large displaced populations, while those populations are “carrying shelter[s] with themselves”. Anderson (2016) explained that governments, by deciding the types of accommodations provided to displaced persons, do not account for displaced persons’ individual identities. Differences in practices and needs between hosting communities and displaced persons thus poses a dilemma for urban planners and other decision makers in choosing between imposing a norm on displaced persons or adapting local norms to better align with those displaced. This challenge is exacerbated during periods of high influxes of displaced persons as organizations responsible for providing housing need to plan and design accommodations under extreme time constraints. Those periods of emergency are regarded by some scholars and media as *opportunities* to improve the body of knowledge regarding construction techniques and designs suitable for people from different backgrounds (e.g. Dare, 2016; Mallonee, 2014), focusing on adapting local norms to meet varying needs.

Instability in the Middle East has triggered, since 2015, the largest displacement of persons seeking asylum since the Second World War (UNHCR, 2016). In 2015, the European Union received over 1.2 million asylum applications, of which over a third registered in Germany (Eurostat, 2016; UNHCR, 2016). This sudden and high population influx placed stress on the urban housing system and critical services. Cultural practice amongst displaced persons and the German people presented additional challenges. This study seeks to assess the project of providing water and sanitation services for displaced persons arising from the Refugee Crisis in 2015 and in the first half of 2016 in four German cities. This includes: (1) the design of water and sanitation facilities (e.g. showers, toilets) inside accommodations, (2) the provision

of water and sanitation services at the building scale (e.g., the education about the use of facilities), and (3) the planning of water and sanitation at the system scale—i.e. the infrastructure connection to accommodations. Stakeholders in this study include government agencies, architects, utilities, nonprofits, and other associated companies. Accommodations in this paper include both centralized (emergency or longer-term) accommodations and private apartments for displaced persons. Qualitative analysis of interviews conducted is used to explore the process of making decisions pertaining to the provision of water and sanitation services when planning the construction and renovation of accommodations and any necessary system-wide infrastructure modifications (physical, operational, or managerial), both before and after the arrival of displaced persons. Answers sought include: Which source of information was used by stakeholders to make and (de)legitimize decisions pertaining to cultural practices and expectations when planning water and sanitation for displaced persons? What specific decisions were made and how were they (de)legitimized by stakeholders in the hosting communities?

The assessment of the decision-making process pertaining to the accommodation of displaced persons performed explores the way institutional power is used during sudden and high influxes of individuals with diverse cultural backgrounds. This understanding of institutional power provides insight into how stakeholders view displaced persons' identities and whether they believe that those identities should be homogenized—e.g. “Germanized” or marginalized—when settling in the hosting community. Furthermore, how individuals constitutive of institutions of power perceive their own power when making choices pertaining to the design of accommodations for displaced persons is explored. In summary, this paper assesses how institutions evolve, by analyzing how decision-makers legitimize choices they make about the provision of water and sanitation to displaced persons in accommodations during periods of emergency.

POINT OF DEPARTURE

The power of place

In this paper, we define place as the built environment used by individuals, its meaning to them, and how they experience or use it (Cresswell, 2004). This definition, although one of many used to describe places, is relevant as it focuses on interactions between persons and the built environment provided to them. For example, assessing a communal room in a centralized accommodation for displaced persons as a “place” would correspond to the study of the: (1) room's physical characteristics (e.g. Are there windows and chairs? Is the room equipped for children?); (2) the intended purpose of this room (e.g. Is it called a “TV-room” by the centralized accommodation managers?); and (3) the meaning of this room for displaced persons (e.g., Is it interchangeably a “TV-room” and a “prayer room” for them?). Existing literature discussed below pertaining to places, as defined in this paper, highlights their influences on the identity of individuals experiencing them, and how the making of place is deeply related to power. We define power as the ability to influence the behavior of others (Clegg, 2006).

History demonstrates that organizations can use strategies (i.e. they can make decisions about places) to obtain and maintain power (De Certeau, 1984). One way of doing so is to restrict locations where selected individuals can or cannot travel to or live in. The

apartheid in South Africa after 1948 is an example of a travel restriction based on race set by populations to maintain power (Klotz, 1995). In the United States, the use of restrictive covenants between 1900 and 1950 that led to racial residential segregation is another example of states exercising on a whole racial group (e.g. Gotham, 2000; Tretter, 2012). Those two examples are extreme in a way that access to a built environment was directly restricted for some specific groups of individuals. Large organizations (e.g. state or local governments) can also use places more subtly or even unintentionally to obtain and maintain power. For instance, naming the built environment (e.g. streets, schools) has an effect on the way individuals will experience, and attribute meaning to, this environment. Replacing street names by numbers was a way for totalitarian states to prevent groups of people from associating popular myths to those streets (De Certeau, 1984). Naming can shape, or even prevent, the production of history and memory associated to the built environment (De Certeau, 1984; Cresswell, 2004). De Certeau (1984, p.104) points out that “proper names carve out pockets of hidden and familiar meanings”. Those examples show how governments and global institutions can exercise their power through places, but power can also be non-centered and held by social groups. For instance, “the gated communities in the inner city [...] can be understood as the middle classes flexing their economic capabilities to protect their lifestyles and differentiate themselves from the urban ‘mass’” (Allen, 2011, p.18). In summary, decisions made by organizations or institutions about places exercise power on individuals using those places.

In opposition to strategies used by organizations, individuals can use *tactics*— methods used by individuals to create their own way of life in the built environment provided to them by institutions of power (e.g. urban planners) — and affirm their identities and differences (De Certeau, 1984). Individuals can add decorations to the built environment to make it more familiar and use facilities differently from their original purpose (e.g. parts of a restaurant for religious purposes; Sen, 2013). Thus, through those tactics, individuals can shape cities by making places. For example, communities can associate a meaning to a public square by gathering there weekly. Individual tactics can then result in a fight for power between different communities (e.g. the inhabitants of a village and Latino newcomers; Duncan and Duncan, 2004), or between communities and organizations of power. We thus kept in mind that the built environment and its meanings are crucial, for displaced persons to claim their identity and for organizations to obtain or maintain power.

Institutional power through places

Power is not always centered and a top-down process. Power, as highlighted by Foucault (1980), also operates through knowledge. Power can be constructing the norm, or the taken-for-granted (Clegg, 2006). Exercising power is securing “particular forms of conduct or, more pointedly, through which people fashion their own sense of self” (Allen, 2011). Constructing the norm for an institution shapes decisions made by organizations constitutive of this institution “[a]s a specialized subsystem of larger societal structures, organizations are under normative pressure to ensure that their goals are congruent with wider societal values” (Scott, 2013, p.184). The production of places—e.g. the provision of the built environment or the attribution of a meaning to it—plays a crucial role in the construction of institutional norms (Allen, 2011). One can, through spatial relationships, define what (or who) is “out-of-place” or abnormal,

and what is “in place” or normal. For example, displaced persons can be associated with mobility in a country that “values roots, place and order over mobility and fluidity”, and thus, those displaced persons can be viewed as disruptive or out-of-place (Cresswell, 2004, p.122).

Places can be used to marginalize or homogenize groups of individuals. An example of this is the notion of “aboriginality” in Australia that was partially constructed by essentializing places frequented by Aborigines (e.g. by creating negatively racialized neighborhoods; Anderson, 1994; by mapping; Jacobs, 1993). Jackson and Penrose (1993, p.207) argued that there is a strong relationship between places and the making of nations by homogenizing identities. “The space that a country occupies becomes a context for legitimizing and enforcing dominant ideas about ‘race’ and about the relationship between ‘race’ and nation.” They additionally highlighted the need for more studies about the legitimization of both hegemonic power and the forms of resistance to it.

One can view nations as institutions sharing beliefs and norms. This study seeks to assess the way such an institution, Germany, responded to a sudden international population influx. Namely, this study may help identify whether (and how) institutions try to modify—e.g. by “Germanizing” or marginalizing— displaced persons’ identities through places, and whether (and how) they adapt to such influxes by constructing a new norm.

The water and sanitation services challenge

Interactions with the water and sanitation services within the household vary worldwide. For instance, an individual’s water consumption habit can be related to their cultural background or access to water; individuals in areas lacking water may be more likely to conserve water through means such as showering or cooking. Cooking and dishwashing habits differ, as well as what individuals place in the drain—e.g. grease poured in the drain versus disposed of in the trash. Similarly, sanitation habits are diverse across populations. These interactions with the sanitation system differ by individual, dependent on factors such as beliefs and religion. For example, select religions follow specific cleansing rituals. Furthermore, the types of facilities, defined in this study as a single infrastructure component, such as, showers, toilets, and sinks, differ across cultures. The diverse types of toilet facilities and use are striking examples— squat or sit-down toilets (used by about two thirds of people around the world in 2016; WASH e-paper, 2015), water-based or dry flushing system, and bidet or toilet paper (WASH e-paper, 2015), to name a few. Internationally displaced persons, when arriving in Germany, may have diverse cultural practices and expectations about water and sanitation services. Accommodations provided by the German government follow, for the most part, German norms (e.g. sit-down toilets), which may differ from displaced persons’ cultural practices and expectations. During the investigation for this study, the German government did not provide any guidelines about the types of water and sanitation facilities and services that should be provided in accommodations (e.g., should there be both sit-down and squatting toilets?). Additionally, seven out of the 16 German states did not provide minimum requirements for the design of accommodations in terms of water and sanitation facilities. The states that did only provided guidelines for the number of users per facility provided and a few basic design criteria (ProAsyl, 2014). For example, a state’s requirements for water and sanitation

services within an accommodation were the following (translated from a report provided by a state agency interviewed in July 2016):

- Sanitary facilities, such as toilets and showers, are to be protected from visibility.
- If the housing facility does not provide individual sanitary facilities for each room, communal sanitary facilities must be provided. These must be in close proximity to the living quarters as well as separated by gender and lockable. There must be at least:
 - a. One sink per five (maximum 7) inhabitants,
 - b. One shower per ten (maximum 15) inhabitants,
 - c. One toilet per ten female inhabitants, and
 - d. One toilet and one urinal per 15 male inhabitants.
- Sinks with cold and hot water with the possibility of being switched off [in communal kitchens].

This lack of guidelines can be challenging for decision makers as they have to make choices about water and sanitation for displaced persons based on their own perception of the situation rather than concrete guidelines. To help decision-makers with this challenge, a German nonprofit recommended interventions in “awareness-raising and education on hygiene; adapting and converting existing facilities; [and/or] building new accommodation and sanitary facilities” (WASH e-paper, 2015). Additionally, due to the potential differences in water use habits between German people and displaced persons, utilities can have difficulties anticipating the water and sanitation demands at accommodations for displaced persons, and thus planning modifications of the systems serving those accommodations. With this in mind, due to the multiplicity of related habits and beliefs, there can be subject to major discrepancies between displaced persons’ and the hosting country’s expectations. Studying the decision-making pertaining to water and sanitation facilities for displaced persons can thus be an indicator of the institutional response to such diverse cultural practices and needs.

MOTIVATION

Existing research about the way institutions use—willingly or not—places to exercise power, or about the way individuals use places to express their identities, is primarily focused in literature on cities as a whole (e.g. De Certeau, 1984, Jackson and Penrose, 1993, Anderson, 1994), or the workplace (e.g., De Vaujany, 2013, Kornberger and Clegg, 2014). This differs from that explored in this study, which assesses an individual’s home and household behaviors (e.g. cooking, sleeping, and showering). This may be due to the fact that for most housing is not provided by governmental agencies, but rented or owned by individuals themselves. Thus, places where individuals live are private, and there is no power confrontation between large institutions and individuals. For instance, in his study of the interactions between cooking habits and cities’ places, De Certeau (1998, p.145) assesses housing as a “private territory that must be protected from indiscreet glances”. The applicability of

this study differs in that the housing situations assessed are provided by the government, and are not private, allowing organizations of power control in the design of facilities and their use by displaced persons. This study is an opportunity to assess institutional responses to migration through the built environment within the home—i.e. the accommodation—rather than at the city scale. Understanding these institutional responses may help decision-makers within institutions responsible for accommodating displaced persons realize the power they have through various choices. This study location presented a unique opportunity as it was conducted during periods at which institutions' equilibrium was suddenly and unexpectedly stressed by the international displacements. During this period of stress, individual stakeholders had to make “satisficing rather than optimized decisions” (Forester, 1989, p.55) due to the emergency situation. During this process, decision-makers legitimize their choice in terms of accommodations using their own perspective on the situation. Those perspectives are partly based on norms constructed by institutions in which individuals evolve, such as, in this study Germany or organizations employing decision-makers. In this study, interviewed stakeholders, who have the power of making decisions concerning water and sanitation design and service types for displaced persons, are shaping the evolution of institutions they are part of through the power of place, by constructing the new norm, as discussed above.

Existing research related to emergency housing primarily focuses on refugee camps and natural disaster-related displacements. First, camps of internally and internationally displaced persons are studied in developing countries with a focus on physical and mental health of those residing (e.g. the effects of inefficient water and sanitation services; Guthmann et al. 2006), with only limited assessment of the built environment. Additionally, camps in developing countries were studied to understand their social and cultural complexity (e.g., Agier 2002; Ramadan 2013); however, camps in developing countries are as large as cities, while the accommodations assessed in this study are single buildings dispersed in existing cities. Other research topics include natural disaster-related internal displacements in developed countries, which typically pairs emergency responses with sustainable recoveries (e.g. Lizarralde, Johnson, and Davidson, 2009). The approach of pairing emergency response and recovery differs from the situation in Europe as the studied emergency response (in Germany) is geographically distinct from the recovery, located in the countries of origin of displaced persons. Presently, there is a gap in knowledge regarding housing for internationally displaced persons in developed countries and the impact of this rapid population influx with limited front end planning on emergency housing accommodations. Specifically, existing knowledge about considerations of cultural practices during the planning of construction and renovation work in accommodations for displaced persons is limited. This study aims to contribute to filling this gap in knowledge by providing an understanding of the planning of water and sanitation services for displaced persons during periods of high influx.

RESEARCH METHODS

Fifty-nine (59) ethnographic semi-structured interviews with stakeholders involved in the provision of housing for displaced persons were performed in four major German cities during the summer of 2016. Accommodations discussed were both long- (more than 6 months) and short-term (less than six months) accommodations, and were both

centralized accommodations and private apartments. This data collection process was chosen to “provide complex textual descriptions of how people experience a given research issue” by collecting personal histories, perspectives, and experience (Mack, 2005). Spradley (1979)’s guidelines were followed to conduct interviews, and topics covered include: the position and daily responsibilities of the interviewee; challenges related to water and sanitation services that they encountered; and their position regarding decisions made during the emergency process. Two investigators prepared and conducted most interviews, enhancing “the creative potential of the study [and] the convergence of observations from [them] enhances confidence in the findings” (Eisenhardt, 1989). The two investigators have two different cultural backgrounds (i.e. French and American), further enhancing this creative potential.

Interviewees were selected using criteria for good informant selection for ethnographic interviews (Spradley, 1979). They were contacted using a snowball sampling method to locate knowledgeable but hardly accessible individuals (Biernacki, 1981). Interviewees selected were all involved in the accommodation of displaced persons during the Refugee Crisis in Germany at the end of 2015 and beginning of 2016. Out of the 59 interviews, 28 were selected for the study presented in this paper based on if interviewees discussed decisions including cultural practices (or not) in the provision of water and sanitation services. The 28 interviewees had diverse responsibilities and were part of diverse organizations (see Table 1). Fourteen (14) interviewees were working in City A, eight in City B, two in City C, and four in City D. Such a diversity in interviewees was intended to get a holistic understanding of the institutional response to the influx of displaced persons and ensures that results did not reflect a single community’s norms. When needed, a German interpreter was present to help with cultural and language barriers.

Table 1. Interview summary

Responsibility	Organization				
	Architecture company	Other company	Nonprofit	Government agency	Utility
Displaced persons accommodation management			6		
Design of accommodations for displaced persons	4				
Construction and renovation work		2	1 (also included as accommodation manager)		
Advising role and urban planning		2	1	4	
Design of water and wastewater systems					9

Interviews were recorded (with permission), translated to English as needed, and transcribed. Interview content was coded for excerpts legitimizing or delegitimizing decisions and actions made by stakeholders to provide water and sanitation facilities and services to displaced persons. In this study, excerpts coded for delegitimization are

parts of the interview content that either legitimize decisions to not provide services and facilities, or that withhold legitimacy to decisions made to provide services and facilities. Interviews were coded to capture their “primary content and essence” (Saldaña, 2015, p.4) using Dedoose, a cross platform software for qualitative data analysis (SCRC, 2016). Codes for this analysis were defined using a coding dictionary (Singleton and Straits, 1993) iteratively developed by the research team and verified through inter-coder reliability checks to ensure replicability of the analysis (LeBreton and Senter, 2008). Codes corresponding to the legitimacy types used were developed using definitions provided by Suchman (1995) as a point of departure.

According to Suchman (1995), “[l]egitimacy is a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions.” There are three primary forms of legitimacy and nine subtypes of legitimacy (Suchman 1995).

(1) Pragmatic legitimacy relies on an assessment of the possible benefits brought by the legitimized organization to interviewees or a broader group of persons. Pragmatic legitimacy can rest on direct interactions between organizations and their audience, but also on “broader political, economic or social interdependencies” (Suchman, 1995). Subtypes of include (Suchman 1995):

- Exchange legitimacy, which is a “support for an organizational policy based on that policy’s expected value to a particular set of constituents.” For this study, this “particular set of constituents” was defined as interviewees themselves or persons in direct contact with them (e.g. their coworker).
- Influence legitimacy, that represents a support for an organization because informants “see it as being responsive to their largest interest” (e.g. to the interviewee’s city’s interest).
- Dispositional legitimacy, used when interviewees “react as though organizations were individuals,” and legitimize organizations’ actions by attributing dispositional characteristics (e.g. organizations are passionate, altruistic).

(2) Moral legitimacy that assesses benefits of an action to societal welfare to determine whether this action is the “right thing to do” (i.e. what will benefit to the societal welfare) based on a socially constructed value system. Subtypes include (Suchman, 1995):

- Consequential legitimacy, judging organizations based on their accomplishments.
- Procedural legitimacy, judging organizations based on the techniques and procedures they use.
- Structural legitimacy, judging organizations based on their structural characteristics. For example, interviewees can legitimize an organization’s actions because this organization has experience.
- Personal legitimacy that “rests on the charisma of individual organizations leaders.”

(3) Cognitive legitimacy, which considers “what is understandable” rather than “what is desirable” and is based on taken-for-granted cultural and personal accounts (Suchman, 1995). Subtypes include (Suchman, 1995):

- Comprehensibility, corresponding to interviewees using their daily experiences and larger beliefs systems to legitimize a decision or action by understanding it.
- Taken-for-grantedness that interviewees use to automatically legitimize actions when an alternative is unthinkable for them.

For example, a centralized accommodation manager was legitimizing his decision to close down a single-toilet room to create punitive consequences for residents’ misuse of the facility. Some residents were squatting on toilets designed for sitting because they used squatting toilets in their countries of origin. In describing his decision, he said, “that’s not the nicest way, but apparently it worked, so [we still closed it]”. This excerpt was coded to pragmatic legitimacy since the interviewee was focusing on the perceived positive effect of the action of closing down the toilet on the entire centralized accommodation. Namely, this excerpt was coded to exchange legitimacy because the action benefits the centralized accommodation managers, whose work was made easier.

A secondary analysis was performed after the legitimacy coding. Excerpts legitimizing or delegitimizing the inclusion of cultural practices in the project of providing water and sanitation services to displaced persons were selected for further analysis and separated from the main coded dataset. Those selected excerpts were then topically coded to identify the types of information used by interviewees to assess the situation, and the decisions (de)legitimized.

Additional data used for a more holistic understanding of the interviews’ context include: (1) pictures and notes taken during visits to eight centralized accommodations for displaced persons; (2) publically available reports provided by nonprofits; and (3) publically available guidelines set by local government agencies about the provision of services in accommodations for displaced persons.

Limitations to this study include the possible subjectivity of the qualitative analysis performed by the research team. Although a coding dictionary was developed and investigators were from different cultural backgrounds, the analysis performed might be biased by some taken-for-granted accounts that researchers share and did not identify while developing the coding dictionary. For instance, some of those possible taken-for-granted accounts could be related to the fact that the investigators in the field were two women from developed countries. Limitations also include the fact that the institutional response studied here might depend on factors that were not accounted for in this study. An example of this might be the political circumstances in which interviews were conducted might have affected interviewee’s perspectives, such as the upcoming state elections or select incidents related to displaced persons drawing media attention at the end of 2015 (e.g. the Cologne incident, Die Zeit, 2016). Finally, the results of this study may not be applicable to all developed countries, as institutional responses greatly depend on the cultural aspects of the countries (Hofstede, 1984).

RESULTS

GENERAL RESULTS

Two hundred and fifty-five (255) excerpts coded for legitimacy are included in this discussion. Table 2 provides a summary of the excerpts coded for this study. Projects at the system scale correspond to the planning of modifications in the city's water and wastewater systems to serve accommodations for displaced persons. Those modifications include the addition of connections to accommodations and the resizing of existing pipes to meet the demand. Projects at the building scale correspond to: (1) the design, building and renovations of accommodations for displaced persons; and (2) the provision of services related to water and sanitation inside accommodations. These specific projects at the building scale span: the design of communal areas for showers and toilets; the replacement or addition of toilets, showers, and sinks in bathrooms and kitchens; education for proper use of toilets; and the provision of bottled water.

Table 2. Summary of excerpts coded for this study

Project	Number of excerpts (interviewees) legitimizing the...	Number of excerpts (interviewees) delegitimizing the...
Inclusion of cultural practices in the planning of water and sanitation at the system scale	11 (3)	13 (5)
Inclusion of cultural practices in the planning of water and sanitation at the building scale	43 (14)	15 (12)
Provision of water and sanitation services at the system scale without reference to the (de)legitimization of cultural practices	36 (9)	18 (7)
Provision of water and sanitation services at the building scale without reference to the (de)legitimization of cultural practices	140 (18)	36 (8)

Figure 1 shows the legitimacy subtypes used by interviewees to (de)legitimize the project of including cultural practices in the provision of water and sanitation to displaced persons. Figure 2 shows the legitimacy subtypes used by interviewees to (de)legitimize the project of providing water and sanitation services to displaced persons *without* referencing specific cultural practices.

The results (see Figure 1) indicate that interviewees legitimized decisions about the inclusion and consideration of cultural practices in the context of water and sanitation services differently dependent on scale, primarily using comprehensibility for systems, and the use of influence legitimacy for water and sanitation at the building level. Notably, the ratio of delegitimizing to legitimizing excerpts is more than twice as high for the inclusion of cultural practices (58%) than for the general project of providing water and sanitation to displaced persons (27%).

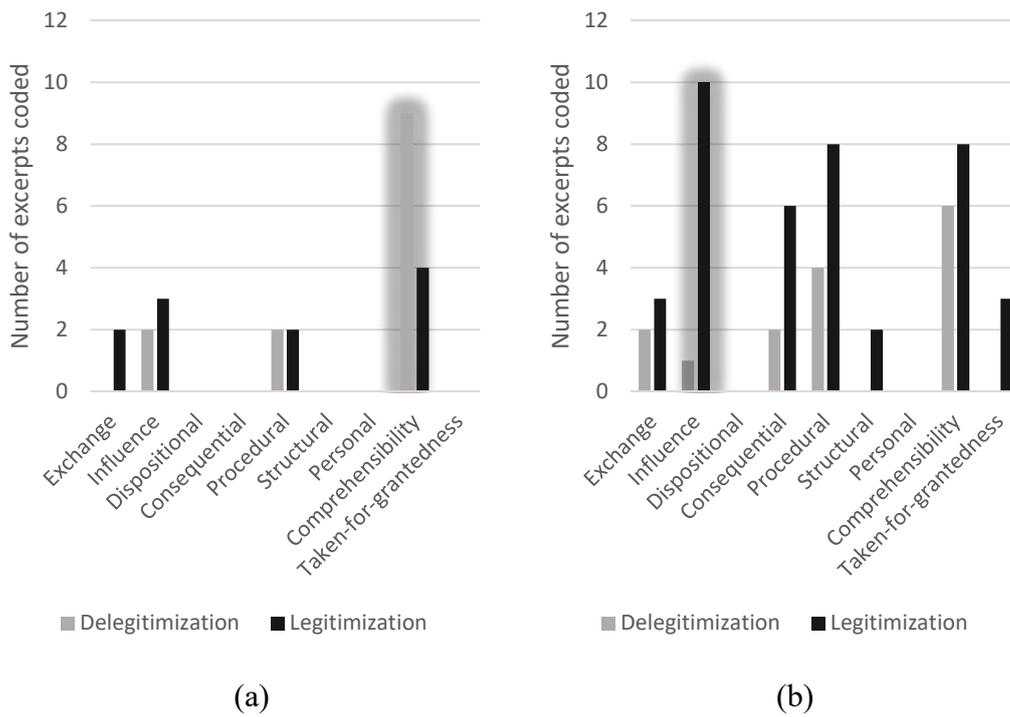


Figure 1. Frequency of legitimacy subtypes used to (de)legitimize the project of including cultural practices in the provision of water and sanitation at: (a) the system scale, and (b) the building scale

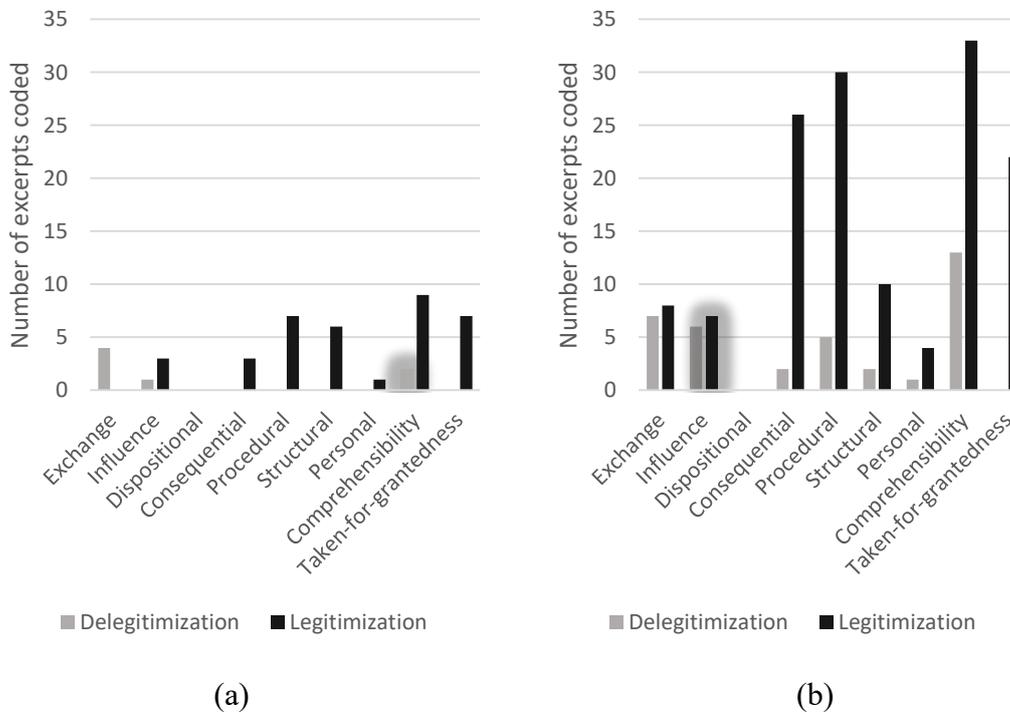


Figure 2. Frequency of legitimacy subtypes used to (de)legitimize (*without* mentioning cultural practices) the project of providing water and sanitation at: (a) the system scale, and (b) the building scale

TYPES OF INFORMATION USED TO ASSESS CULTURAL PRACTICES AND DECISIONS MADE

A secondary analysis was used to evaluate the types of information used by interviewees to assess displaced persons' cultural practices and needs to make various types of decisions pertaining to water and sanitation (Table 3). During the analysis, it became apparent that the types of information used by interviewees is related to the type of organization employing the interviewee. This may be related to the fact that a majority of nonprofit interviewees were in direct contact with displaced persons, working inside accommodations as social workers. For example, nonprofits primarily used direct observations of damaged showers and toilets to decide whether they should use educational signs in centralized accommodations.

Table 3. Organization and information type used to (de)legitimize the inclusion of cultural practices in the planning of water and sanitation services at the building and system scale

Organization type \ Information used to assess cultural practices	Utilities	Nonprofits	Government Agencies	Architecture agencies	Private companies	Public/private companies
Assumptions (total)	20	7	5	14	8	1
Assumption about habits, tastes and capabilities	14	5	5	0	2	1
Indirect observations of practices in housing	6	2	0	14	0	0
Previous experience with other groups from foreign countries	0	0	0	0	6	0
Direct observations (total)	4	22	3	2	0	3
Direct displaced persons testimonies/complaints	0	9	0	2	0	0
Direct observations of practices in housing	2	13	3	0	0	3
Plumbing issues in or around accommodations	2	0	0	0	0	0
Refusal to assume anything	12	0	0	3	1	0
Other (e.g. language differences, "feeling")	1	2	0	0	0	0

Decisions that were (de)legitimized by interviewees underwent a secondary analysis and were topically coded (Table 4). Notably, decisions related to water and wastewater systems were primarily the responsibility of the utilities, and architects interviewed did not discuss education method of facilities use. Interviewees with diverse backgrounds legitimized other decisions.

SHORT- VERSUS LONG-TERM PROJECTS

Thirteen (13) out of the 28 interviewees selected in this study specifically described the work that they were performing for the accommodation of displaced persons as *long-term*. This is to say, when asked "Do you think that the accommodation you are working for be used long- or short-term?", they answered "long-term". For example, architects working on the design of apartments for refugees who were granted asylum defined their work as long-term as it was anticipated that corresponding with the legal status, these individuals would remain in Germany for several years. Similarly, seven

interviewees described their work on accommodations as short-term, and six interviewees described their work applicable to either period, meaning that it could possibly be short- or long-term (e.g. their projects could be used for six months or for several years). Finally, two interviewees acknowledged that they did not know whether their work would be used for short- or long-term. The ratios of delegitimizing over legitimizing excerpts are 0.73 for long-term work, 0.25 for short-term work, and 0.57 for both. Those ratios indicate that the inclusion of cultural practices was primarily legitimized for short-term projects. Table A.1. (found in the Appendix) provides a summary of decisions that intentionally included cultural practices when planning of water and sanitation services at the system and building scale, and the corresponding information and legitimacy types associated with the decisions. Conversely, Table A.2. provides a summary of the decisions that intentionally excluded cultural practices.

Table 4. Decision types (de)legitimized by interviewees

Decision type	Number of excerpts (<i>excerpts can be coded for more than one decision type</i>)
Include cultural practices in the planning of water and sanitation facilities and services (total)	48
Adapt systems to cultural practices	8
<i>Adapt the design of accommodations: improve privacy in facilities to respond to displaced persons' needs or complaints</i>	5
<i>Adapt the design of accommodations: separate men-women facilities</i>	4
<i>Adapt the design of accommodations: provide resistant sinks, showers and toilets</i>	5
Provide education for proper use of water and sanitation facilities (e.g. putting signs)	21
Provide other services in accommodations (e.g. providing bottled water to replace the hose in toilets)	3
Other (e.g. provide adequate facilities in general)	5
Exclude cultural practices in the planning of water and sanitation facilities and services (total)	28
Purposely not adapt the systems and perform calculations using German standards	13
<i>Purposely not adapt the design of accommodations—improve privacy in facilities to fit the German habits</i>	3
<i>Purposely not adapt the design of accommodations— set timers to control water use</i>	2
Provide sit-down toilets to match local norms	5
Not provide education for proper use of water and sanitation facilities	3

DISCUSSION

THE CHARACTERISTICS OF A REACTIVE RESPONSE

It is important to remember that the decisions presented above regarding the inclusion (or exclusion) of cultural practices of displaced persons in the project of providing water and sanitation in accommodations for displaced persons represent a primarily *reactive* response to the high and sudden influx of displaced persons in Germany. This reactive response was largely intentionally a wait and see attitude to avoid incorrect

assumptions or modifications that were not necessarily. Of the 76 excerpts coded as (de)legitimizing the inclusion of cultural practices in the planning process, 28 were coded for decisions to *exclude* cultural practices in the planning process (Table 4). Additionally, half of the excerpts coded as legitimizing the inclusion of cultural practices in the planning process correspond to a willingness to teach displaced persons to use facilities provided to them that align with local norms, or provide other services in accommodations (e.g. provided bottled water or toilet paper). Interviewees thus primarily legitimized the provision of accommodations that did not take cultural practices of displaced persons into account *before* arrival, and to reactively adapt water and sanitation services and facilities—at both the building and system scales—upon arrival. Due to the reactive nature of incorporating cultural practices, upon conducting fieldwork in accommodations, their adaptation by the residing population was apparent. For instance, multiple educational (Figure 3) and ephemeral (e.g. written by hand on a sheet of paper) signs posted near water and sanitation facilities may be found. Direct observations of the accommodation modifications by displaced persons was used as a primary source of information (see table 3) to assess possible issues and differing needs related to cultural practices that were not met. A social worker in a collective accommodation said: *“I knew [we should put signs] because I worked in a different shelter before. In the beginning we could see [...] footprints on the toilets because they were using [the toilets differently], [...]. But they don’t tell us.”* Figure 4 provides another example of adaptations that occurred within the centralized accommodations when displaced persons’ cultural practices misaligned with those of the local facilities. Empty water bottles were frequently found in the bathroom after use for cleansing, as opposed to using toilet paper.

As shown in Figures 1 and 2, the stark difference between trends in legitimacy types used in this context —rapid influx of population with limited front-end planning— for the planning process that *excludes* considerations of cultural practices and the planning process that *includes* considerations of cultural practices shows that: (1) comprehensibility is primarily used to delegitimize the inclusion of cultural practices and practices in the planning of water and sanitation at the system scale; and (2) influence legitimacy was primarily used to legitimize the inclusion of cultural practices and practices in the planning of water and sanitation at the building scale. The use of comprehensibility to delegitimize the inclusion of cultural practices in the planning at the system scale was addressed by four utility engineers that stated that they depended on previous experience. As they had not accommodated displaced persons before, they preferred to use existing, familiar methods that assumed water consumption trends did not differ significantly from that of locals. As stated by an interviewee from a utility: *“Cultural aspects... well... we wouldn’t really have the experience, because say there are a lot of people from one area that live suddenly, I mean, we always choose the numbers we have from experience as basis for our calculation, the way we know it.”* This response to the influx of displaced persons studied is willingly reactive, as shown in Table 3 where a majority of excerpts corresponding to a refusal to make assumptions were from utility interviews.

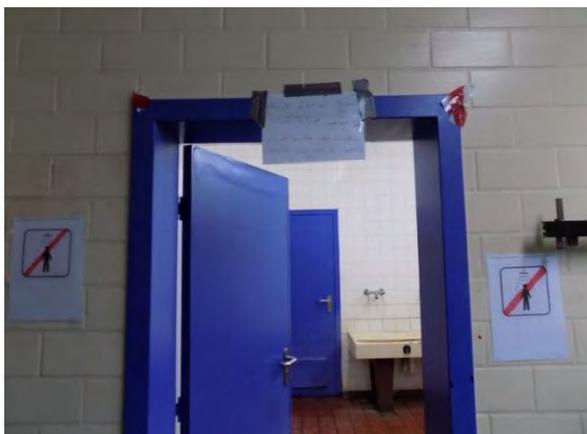


Figure 3. Entrance of a lavatory room with signs posted by a centralized accommodation manager after noticing that select displaced persons were using sinks as showers



Figure 4. Empty water bottles that were previously used for cleansing

The use of influence legitimacy for the inclusion of cultural practices in accommodations were primarily from eight interviewees—accommodation managers and employees of construction companies—who legitimized the adaptation of centralized accommodations based on observed human-infrastructure interactions that differed from the intended, local use (e.g. providing more robust toilets and sinks). Interviewees anticipated that this adaptation of centralized accommodations would benefit the organizations responsible for managing and providing accommodations by preventing them to spend money and efforts. For example, an interviewee indicated “[displaced persons] handled the facilities a lot rougher than we expected. And that makes it expensive, of course. If you have to install safety valves like in a prison, then maybe it makes more sense installing showers and toilets in the rooms.” Thus, the institutional response to the influx of displaced persons with diverse cultural practices was mostly reactive. Select organizations (namely, utilities) purposely adopted this reactive response while other organizations adopted it unwillingly.

Finally, the types of information used by interviewees to assess cultural practices further supports the reactive nature of cultural inclusion that differs from the local norm (Table 3). Interviewees tended to use the information directly available to them without seeking additional sources. Nonprofit interviewees primarily worked in direct contact with displaced persons, and thus a majority of information used were direct observations. Other interviewees who were not working in direct contact with displaced persons, primarily made assumptions based on existing knowledge (e.g. through word-of-mouth). Moreover, using Tables 5 and 6, no trends were identified between the type of information used and the intended time frame of the projects (short- vs. long- term). This indicates that a reactive response was mostly adopted by interviewees independently from the frame of the project. This reactive response is understandable for short-term projects given the emergency situation: stakeholders had to make “satisficing” rather than optimized decisions (Forester, 1989), mainly to prevent displaced persons from being homeless (as indicated by seven interviewees). However,

the reactive response for long-term projects indicates that decision-makers might not perceive the influence of the *places* they provide to displaced persons on their identity.

SHORT- VERSUS LONG-TERM PROJECTS

The ratios of delegitimizing over legitimizing excerpts provided in the results section indicate that the inclusion of cultural practices in the planning of water and sanitation services and facilities was mostly legitimized by interviewees describing their work as short-term. This inclusion of cultural practices was slightly legitimized by interviewees describing their work as possibly either short or long-term, while it was highly delegitimized by interviewees describing their work as long-term. Decisions made to include cultural practices in the planning of accommodations were legitimized more frequently for the short-term accommodation of displaced persons than for long-term accommodation. This observation ties to the interviewees' perceptions of integration. Eleven (11) interviewees discussing long-term projects delegitimized the inclusion of cultural practices due to the belief that adhering to local cultural norms was beneficial for the "integration" of displaced persons that were anticipated to remain in Germany.

The education of displaced persons for proper use of facilities was legitimized differently from design practices (Tables A.1. and A.2. in the Appendix). The education of displaced persons was mainly legitimized with several subtypes of moral legitimacy—indicating that it's "the right thing to do"—for projects described as long- and possibly either long- or short-term, while education was legitimized with influence and cognitive legitimacy for projects described as short-term. This indicates that interviewees viewed the education of displaced persons for proper use of facilities as beneficial in the short-term for reasons such as solving possible issues related to misuse of facilities, but as the "right thing to do" in the long-term to help displaced persons integrate with German culture. For instance, an interviewee stated: *"if refugees were guided with care and taught how to use the flats and how everything works, then I would see no problems for the future."* This is further supported that the exclusion of cultural practices in the design of facilities for long-term projects was entirely legitimized using moral legitimacy. As stated by two interviewees: providing designs following the *"high [...] German housing standards"* would help displaced persons integrate; and *"I personally think that if we offer apartments like we traditionally do in Germany; you have one, two, three bedrooms, you have a bathroom, you have a kitchen, this has an effect on integration because it makes the people feel how we live in central Europe."*

Contrary to the education of displaced persons discussed in the previous section, the adaptation of designs to cultural practices was primarily legitimized with cognitive and influence legitimacy for long- and possibly either short- or long- term projects, while it was mainly legitimized with consequential legitimacy for short-term projects. Four interviewees involved in such projects stated that adaptations *"made sense"* based on their understanding of the situation, and that those adaptations were needed for a smooth management of the accommodations. Additionally, three interviewees responsible for designing emergency accommodations focused on the needs of displaced persons for their well-being. For example, an interviewee designing an inflatable dome used as a temporary centralized accommodation stated that *"[i]t should*

play a role, what kind of people are coming, [...], what do they need?” The choice of the type of toilets installed in accommodations is an extreme example since sit-down toilets, as opposed to squatting toilets or mixed use toilets, were chosen by all the six interviewees who were responsible for this choice. This decision was legitimized using exchange, influence, or cognitive legitimacy, indicating lack of moral consideration when choosing sit-down toilets. This decision was supported by: (1) the anticipated benefits of this decision on institutions responsible for the provision of accommodation to displaced persons (e.g. the German government, interviewees themselves); and (2) stating that an alternative (e.g. squatting toilets) is “unthinkable”. An interviewee was asked whether a nonprofit discussed the type of toilets chosen. He replied: “[n]o, no, no, no, no, no. This was not a discussion because there is no time for that. There is a situation that is totally chaotic, and we need to solve this situation with the available means..”

THE USE OF THE POWER OF PLACE

As seen in the two previous discussion sections, the integration of displaced persons was a key component of the decision-making process pertaining to the provision of water and sanitation services described by interviewees. When asked about decisions made related to displaced persons’ cultural practices when designing water and sanitation-related built environment in accommodations, a majority (17 out of 28) of interviewees linked those decisions to the integration of displaced persons in Germany. This result indicates that interviewees perceived the power that *places* – accommodations and how displaced persons use them – have on individuals using them. Interviewees primarily perceived that providing “German” (or “European”) toilets, showers, and other water and sanitation related built environment components, and helping displaced persons learn how to use them “the German way” would change displaced persons’ identity to fit the characteristics of German identities.

However, the results presented in the previous section reveal that interviewees perceive the power of the components of *places* (i.e. the built environment itself and its use) differently. For long-term projects, the interviewees’ decision regarding education of displaced persons and other social services related to water and sanitation was more morally rooted; that is to say, it was based on an assessment of what is “the right thing to do.” However, when concerning physical alterations to the centralized accommodations to incorporate cultural practices, interviewees focused on what “makes sense” and is beneficial to organizations responsible for providing accommodations. Stakeholders interviewed seem to perceive their power on displaced persons when deciding about education about how to use the built environment provided, but not their power when deciding about the built environment itself. Thus, interviewees perceived the power of the components of *place* on individual’s identities differently; they perceive the power of the way individuals use the built environment more than the power of the built environment itself.

Overall, interviewees perceived the influence of places on displaced persons’ identities, but interview content also indicates that interviewees were not anticipating German cultural practices to evolve with the arrival of displaced persons. The German cultural practices primarily discussed in interviews include: (1) sitting toilets, referred to as

“normal toilets”, “German toilets”, or “European toilets” by interviewees; (2) a willingness to conserve water (e.g. by reducing the shower time), even in areas with abundance of water; and (3) the provision of high water quality to the population. Water and sanitation-related German cultural practices were primarily described by interviewees as static and not evolving in the near future. Thirteen (13) interviewees described those cultural practices as static, while only four interviewees perceived those practices as evolving. For example, an interviewee described German willingness to save water by stating: *“that’s the philosophy in Germany, that water should be saved and so we save, no matter what it costs”*. The results thus show that displaced persons were expected to adopt German water and sanitation-related cultural practices without making those German cultural practices evolve.

CONCLUSION

Rapid migration is a worldwide phenomenon that increased in the last years (UNHCR, 2016) due to more frequent natural disasters and political instabilities. During periods of high and rapid influx of internationally displaced persons, the hosting country can face multiple challenges (e.g. lack of available housing) while trying to accommodate the incoming populations. One of those challenges are decisions pertaining to the inclusion of cultural practices. Displaced persons may have unanticipated (or anticipated) needs related to differing cultural norms. Decision makers can choose to either repress or accommodate such needs through the services provided. This case study was a unique opportunity to capture the institutional response to sudden and unexpected population dynamics. For this study, a specific focus on water and sanitation was chosen because associated cultural practices worldwide are diverse.

Fifty-nine (59) semi-structured interviews of individuals involved in the accommodation of displaced persons in Germany were conducted. Twenty-eight (28) of those interviews were relevant to this study based on the criteria that they include a discussion about water and sanitation cultural practices. The selected interviews underwent qualitative analysis to identify the types of: (1) decisions made by stakeholders regarding the provision of water and sanitation services; (2) legitimacy used to legitimize those decisions; and (3) information used to assess displaced persons’ cultural practices.

The results of this study indicate that the institutional response to the Refugee Crisis and described in this paper are representative of a reactive rather than proactive response. On the one hand, some interviewees willingly adopted a reactive response for various reasons, including: (1) a willingness to help displaced persons integrate in cities and assimilate the German culture, and (2) a refusal to make assumptions when lacking knowledge. Additionally, the results of this study indicate that interviewees perceived that the displaced persons’ cultural practices should be included in the planning of the design of short-term accommodations (using influence and cognitive legitimacy), but not in the design of long-term accommodations (using moral legitimacy). The main alternative chosen by interviewees to reduce issues related to cultural practices, mostly legitimized with moral legitimacy, was the education of

displaced persons. On the long-term, they view this alternative as helping displaced persons assimilate to the German culture.

Overall, this paper highlights the fact that the thought process of stakeholders concerning the education of displaced persons is morally constructed (moral legitimacy), while the thought process concerning the provision of built environments is more benefit driven (pragmatic legitimacy) and culturally constructed (cultural-cognitive legitimacy). This difference in thought process highlights the fact that, although decision-makers perceived the power of place on displaced persons' identities, they might focus mainly on the way displaced persons use the built environment rather than on the built environment itself. In a way, their decisions can modify displaced persons' identities and be part of claiming and maintaining hegemonic power. Most interviewees legitimized some of their decisions by highlighting that this is "*how [they] do it in Germany*". This study thus highlights a need for more research and awareness raising in countries hosting a high number of internationally displaced persons about the effects of design choices in accommodations on displaced persons' identities.

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APPENDIX: SUPPLEMENTARY LEGITIMACY TABLES

Table A.1. Inclusion of cultural practices and practices

I	Type of decision made	Work described as long-term					Work described as short-term				Work described as possibly short- or long-term			
		Adapt the design of accommodations	<i>Adapted design example: robust toilets</i>	Adapt systems to cultural practices	Education for proper use of facilities	Other services provided in accommodations	Adapt the design of accommodations	<i>Adapted design example: robust toilets</i>	Education for proper use of facilities	Other services in accommodations	Adapt the design of accommodations	<i>Adapted design example: robust toilets</i>	Adapt systems to cultural practices	Education for proper use of facilities
	Total number of excerpts (unique respondents)	5 (2)	2 (1)	4 (3)	7 (4)	1 (1)	8 (3)	2 (1)	4 (2)	2 (1)	3 (2)	1 (1)	4 (2)	7 (1)
Information type	Assumptions (total)	4	2	2	6		7	2	2		1		3	7
	Assumption about habits, tastes and knowledge	2		1	4		1		1		1		3	1
	Indirect observations of practices in housing	2	2	1	2		6	2	1					
	Previous experience with other groups from foreign countries													6
	Direct observations (total)	1		1	4		1		2	3	2	1	1	
	Direct Displaced persons testimonies/complaints	1								2				
	Direct observations of practices in housing				3		1		2	1	2	1	1	
	Plumbing issues in or around accommodations			1	1									
	Refusal to assume anything			1										
Legitimacy subtypes	Pragmatic legitimacy (total)	1	1	2	1		3		2		1		1	2
	Exchange legitimacy			1	1									
	Influence legitimacy	1	1	1			3	2	2		1		1	2
	Dispositional legitimacy													
	Moral legitimacy (total)	1			5		4			2			1	4
	Consequential legitimacy	1			1		4			1				1
	Procedural legitimacy				3					1			1	2
	Structural legitimacy				1									1
	Personal legitimacy													
	Cognitive legitimacy (total)	3	1	2	1	1	1		2		2	1	2	1
	Comprehensibility	1	1	2	1		1		2		1		2	1
	Taken-for-grantedness	2				1					1	1		

Table A.2. Exclusion of cultural practices and practices

	Work described as long-term		Work described as short-term				Work described as possibly short- or long-term				
	Type of decision made	Not adapt the design of accommodations	Not adapt systems to cultural practices	Not adapt the design of accommodations	<i>Non-adapted design example: sit-down toilets</i>	Not provide education for proper use services	Other services in accommodations	Not Adapt the design of accommodations	<i>Non-adapted design example: sit-down toilets</i>	Not adapt systems to cultural practices	Not provide education for proper use of facilities
Total number of excerpts (unique respondents)	4 (3)	7 (5)	1 (1)	1 (1)	1 (1)	1 (1)	5 (2)	4 (2)	3 (2)	2 (1)	
Information type	Assumptions (total)	1					1	3	2	2	2
	Assumption about habits, tastes and capabilities	1					1	2	2		1
	Indirect observations of practices in housing							1		2	1
	Previous experience with other groups from foreign countries										
	Direct observations (total)		2			1		2	2		
	Direct Displaced persons testimonies/complaints					1					
	Direct observations of practices in housing		2					2	2		
	Plumbing issues in or around accommodations										
	Refusal to assume anything	3	7							1	
Legitimacy subtypes	Pragmatic legitimacy (total)		1			1		2	2	1	
	Exchange legitimacy		1			1		2	2		
	Influence legitimacy									1	
	Dispositional legitimacy										
	Moral legitimacy (total)	3						1		2	1
	Consequential legitimacy	2									
	Procedural legitimacy	1						1		2	1
	Structural legitimacy										
	Personal legitimacy										
	Cognitive legitimacy (total)	1	6	1	1		1	2	2		1
	Comprehensibility	1	6	1	1		1	2	2		1
Taken-for-grantedness											

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AFFORDABILITY AND SUSTAINABILITY: THE CONTEXT OF TECHNOLOGY

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ABSTRACT

Affordability and sustainability are key issues in the built environment. At times they are viewed as complimentary and at other times they are seen as mutually exclusive. This paper presents an initial examination of affordability in the single family housing market. Specifically, this research takes a macro perspective on means and methods as it relates to the affordable realization of the structure. This is part of a larger research project that is geared towards developing a more formal understanding of affordability and sustainability as well as their interaction.

INTRODUCTION

The twin goals of affordability and sustainability are central issues in the discussion of the future of the built environment. These goals are often framed as a tradeoff especially when it comes to discussion of housing. It is necessary to understand the relationship between these goals which at times are symbiotic and at other times mutually exclusive. These are not abstract issues.

According to HUD (2017) “Families who pay more than 30 percent of their income for housing are considered cost burdened and may have difficulty affording necessities such as food, clothing, transportation and medical care. An estimated 12 million renter and homeowner households now pay more than 50 percent of their annual incomes for housing.” According to the World Bank “the struggle to obtain adequate and affordable housing could affect at least 1.6 billion people globally”. (Kacyira, 2016)

According to the EPA (2009), “The average household spends at least \$2,000 a year on energy bills — over half of which goes to heating and cooling. Out of the total energy consumption in an average household, 50% goes to space heating, 27% to run appliances, 19% to heat water and 4% goes to air conditioning.... Buildings in the United States contribute 38.9 percent of the nation’s total carbon dioxide emissions, including 20.8 percent from the residential sector...”

The dynamic relationship between these two concepts is in part definitional. Affordability is often defined in terms of intrinsic and temporal characteristics. The intrinsic characteristics refer to the essential characteristics of the structure. These include building materials, location, size and amenities. These intrinsic characteristics are a major determinant of the cost of the structure. The second major determinant is the process by which the intrinsic characteristics are realized. Together they determine the cost basis of the structure. The temporal characteristics refer to the lifecycle costs of the

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structure. These are the future costs of maintenance and energy consumption associated with the structure. These costs are a function of the investments made at the time of the realization of the structure. The lifecycle costs then are the discounted future savings less the initial investment made to achieve those savings. Note that these investments, which occur at the same time as the realization of the structure, are conceived of as separate and in addition to the cost basis.

Sustainability has a focus that goes beyond that which is associated with the structure and the users of the structure. The Brundtland Commission (1987) defines sustainability as “meeting the needs of the present generation without compromising the ability of future generations to meet their own needs”. This macro definition includes but moves beyond the micro concerns associated with affordability. Below (Figure 1) are two models (Willard, 2010) of sustainability that inform this research.



Figure 1: Sustainability Models

In both models economic concerns interact with environmental and societal concerns. Within these economic concerns some of the issues addressed in affordability are embedded. While the benefits are at a more abstract level, sustainability costs can be calculated in the same manner as affordability. The sustainability costs are the discounted future benefits to the environment, society and the economy less the initial investment made to achieve those benefits.

Given this discussion we have three outflows associated with a structure: the intrinsic cost basis, the affordability investment and the sustainability investment. We also have three inflows: The intrinsic benefits of the structure, the lifecycle benefits, and the sustainability benefits. In order to begin to understand these constructs a conceptual model has been developed to understand the relationship between the investment constructs. The outcomes of the model are shown in the Figure 2 below.

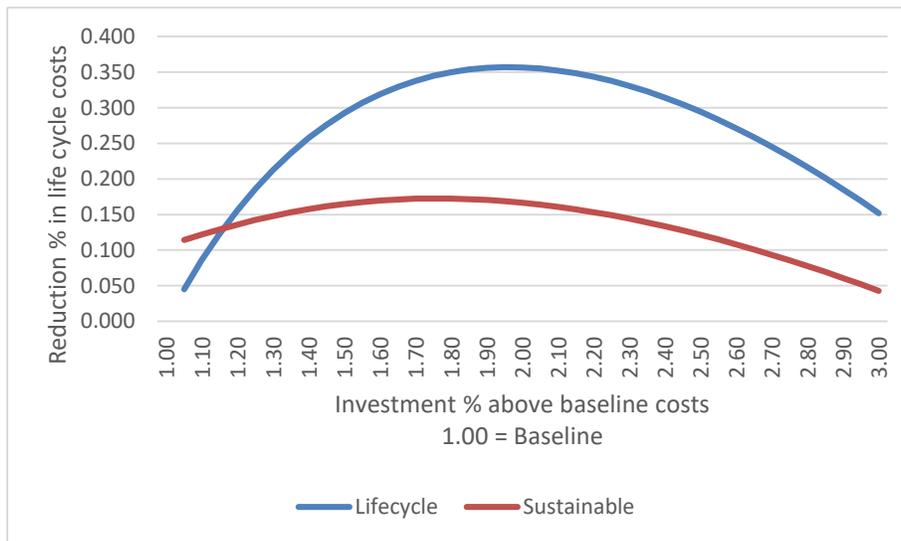


Figure 2: Investment vs Benefit

This model is an initial effort to begin to quantify the factors that would influence the return on investment. The model builds on our current understanding and makes the following assumptions:

- The lifecycle costs reflect 75% of the Total Cost of Ownership.
- The initial return on lifecycle investment is \$2 in reduced lifecycle costs for every dollar invested.
- However, there are diminishing returns of the form $1/X^n$ (X = the incremental investment; n = inflator/deflator value appropriate for lifecycle investment)
- Sustainability benefits are 3.125 times the energy savings and energy savings reflect 50% of the lifecycle savings.
- However, there are diminishing returns of the form $1/X^n$ (X = the incremental investment; n = inflator/deflator value appropriate for sustainability investment.)

While this model is only a starting point, two important characteristics of the outcomes should be noted. The benefits associated with both lifecycle and sustainability have differing optimum points. For lifecycle costs the maximum benefit occurs at an investment of 1.9 times the base investment resulting in a decrease in lifecycle costs of 36%. For sustainability costs the maximum benefit occurs at an investment of 1.55 times the base investment resulting in a decrease in sustainable costs of 17%. With the optimum costs and benefits differing, developing and validating a model that can identify the actual optimum investment will be a major focus of this research.

THE FOCUS

The discussion above describes the foundation for a large project. This particular research will focus on the realization of the structure. Specifically, the focus of the research will be on the intrinsic cost and efforts to ‘industrialize’ the production process

through different approaches to the means and methods. It is widely recognized that the construction process encompasses a significant amount of inefficiency and waste (Puddicombe, 1996). The major factors associated with the situation can broadly be described as failures in the management of the project process and failures to develop and adopt new technologies. In this research the focus will be on developing a macro view of the technology involved in realizing the built environment. Technology is broadly defined as ‘how the work is accomplished’. At this stage the technology is defined in terms of Built Vs Manufactured structures. These are very broad categories and in order to begin to understand these technologies it is necessary to understand the broader economic context in which they operate and the impact of these technologies on intrinsic affordability. This is an area that has received scant attention. Piazzesi and Schneider (2016) in a major work for the National Bureau of Economic Research on macroeconomics and housing define construction simply as a standardized production function that produces an intermediate good that is defined by quality.

BRIEF LITERATURE REVIEW

Housing affordability is a pressing issue that effects individuals as well as the economy and the environment (Mulliner and Maliene, 2011). Affordability has traditionally been considered in relationship to income. A price for the structure that falls between 2.9 and 3.5 times gross household income (depending on the structure of the household) has been suggested (CLG, 2006). Others, recognizing that housing is typically financed as well as rented, measure affordability in terms of rents in the 25 to 35 percent of gross income (Mulliner and Maliene, 2011). While these metrics are clearly measurable they do not consider the nature of the housing. More expansive definitions include a concern for the standards of the housing as well as the other costs associated with other necessities of life (Chaplin et al. 1994). A last ingredient in the equation is location where researchers have suggested that the interaction between location and housing provides a truer measure of affordability (CTOD & CNT 2006).

In the previous scenarios the costs associated with the housing assume that the process by which the housing is realized is a given. That is the cost of the same structure will vary based upon economic and location factors. This ignores the opportunity to affect the affordability quotient by changing the process cost. If the cost of the structure can be driven down, all else being equal, the affordability of the housing will increase. Gann (1996) examined industrialized housing projects in comparison to Japanese car production. He notes that in Japan 25% of the new housing stock was produced by off-site building processes. However, this use of technology has not resulted in greater affordability. In fact most of Japanese industrialized housing producers identify their customers as upper income and focus on high price/high quality. (Aitchison, M., 2014) An acknowledged benefit is the reduced time to complete the projects. Stick built homes averaged 120 days, panelized homes 90 days, and modular homes 40 days to be realized. This emphasis on time is echoed by the Modular Building Institute (MBI) where faster not less expensive is argued as the primary benefit of off-site construction. One of the few areas that has demonstrated the potential for reducing the costs associated with the structure is the manufactured housing industry.

Genz (2001) argued that we need to rethink the stigma associated with manufactured homes. Thirty percent of unsubsidized low cost housing are manufactured homes. Their cost per square foot is one-half the cost of a built structure. This would suggest that there is significant potential involved in exploring the dynamics of these manufactured systems. Lastly it has been suggested that 30-40 % of the cost of built environment projects are attributable to waste and inefficiency. Improving these processes by the application of targeted techniques provide significant opportunity for cost reduction (Puddicombe, 1996; 2013)

RESEARCH

The Built and Manufactured single family housing markets are large and volatile. In 2006 a combined 1,771,000 units were brought to market in comparison to 2016 where only 831,000 units introduced. The Built sector is defined by thousands of small businesses. The Manufactured sector is dominated by large corporate entities. The nature of product (shelter) makes it fundamental concern for most individuals. In addition, it is the largest investment that most individuals will make. The characteristics of the industry suggested that an overall macro perspective was a baseline requirement. In order to achieve this, we examined the Built sector and its two subcomponents onsite and offsite production as well as the Manufactured sector. The result is a high level description of these technologies and their impact on affordability. The research was primarily conducted with US government data. Unless otherwise specified all data was drawn from the U.S. Department of Commerce, U.S. Department of Housing and Urban Development Office of Policy Development and Research & U.S. Department of Commerce Economics and Statistics Administration U.S. Census Bureau.

THE BUILT SECTOR

The Built Sector of the single family residential construction industry is a volatile but important part of the US economy. Its contribution to GDP has ranged from 4.5% during the period 2000-2007 to 2% during the 2008-2012 period (Abt Associates, 2012). It has increased to approximately 3.5% in 2016 (Logan, D, 2017). The volatility in GDP contribution has not been correlated with the cost of housing. In this section cost is the cost to construct the structure it does not include land or other factors that would be included in the final price paid by the consumer. This allows the discussion to focus on the process of realizing the structure. As can be seen in Table 1 and Figure 3 there has been a steady increase in the square foot cost (except for 4 years) in the period 1992-2016. The upward trend in unit cost has not been accompanied by an increase in volume of units produced as can also be seen in Table 1 and Figure 4 the industry has gone from a high of 1,654,000 in 2006 to a low of 447,000 in 2011

Year	Median	% Change	Average	% Change	Units	% Change
1992	53.33		56.16		964	
1993	56.74	6%	59.22	5%	1039	8%
1994	59.09	4%	62.46	5%	1160	12%
1995	61.5	4%	64.85	4%	1066	-8%
1996	63.92	4%	66.28	2%	1129	6%
1997	66.11	3%	69.18	4%	1116	-1%
1998	69.18	5%	73.02	6%	1160	4%
1999	68.99	0%	72.36	-1%	1270	9%
2000	70.78	3%	75.57	4%	1242	-2%
2001	74.97	6%	79.9	6%	1256	1%
2002	74.79	0%	78.3	-2%	1325	5%
2003	76.28	2%	82.16	5%	1386	5%
2004	81.41	7%	88.84	8%	1532	11%
2005	88.11	8%	95.25	7%	1636	7%
2006	90.24	2%	98.44	3%	1654	1%
2007	91.76	2%	101.59	3%	1218	-26%
2008	92.52	1%	103.89	2%	819	-33%
2009	86.02	-7%	93.69	-10%	520	-37%
2010	85.86	0%	93.01	-1%	496	-5%
2011	87.12	1%	96.04	3%	447	-10%
2012	88.38	1%	97.9	2%	483	8%
2013	93.46	6%	103.56	6%	569	18%
2014	96.32	3%	107.39	4%	620	9%
2015	99.73	4%	112.01	4%	648	5%
2016	101.72	2%	113.9	2%	738	14%

Table 1 SQFT Cost and Volume

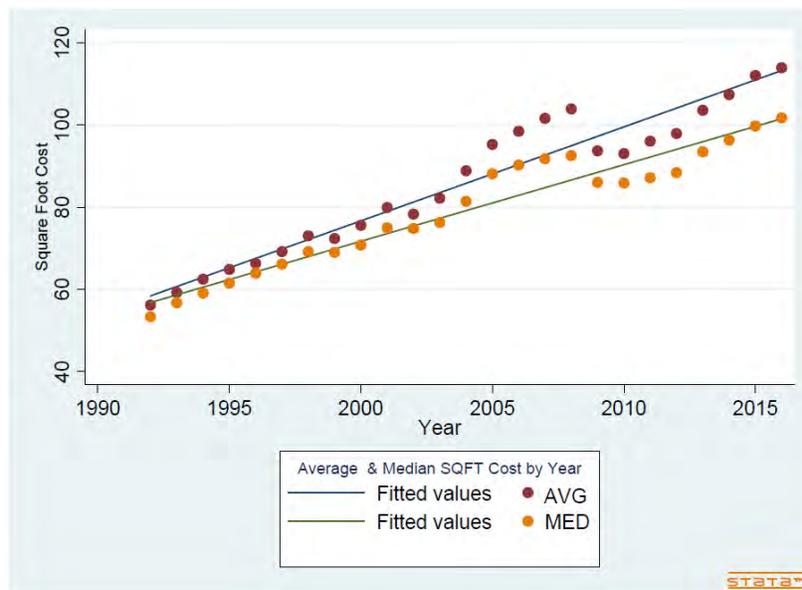


Figure 3 Average and Median Cost over Time

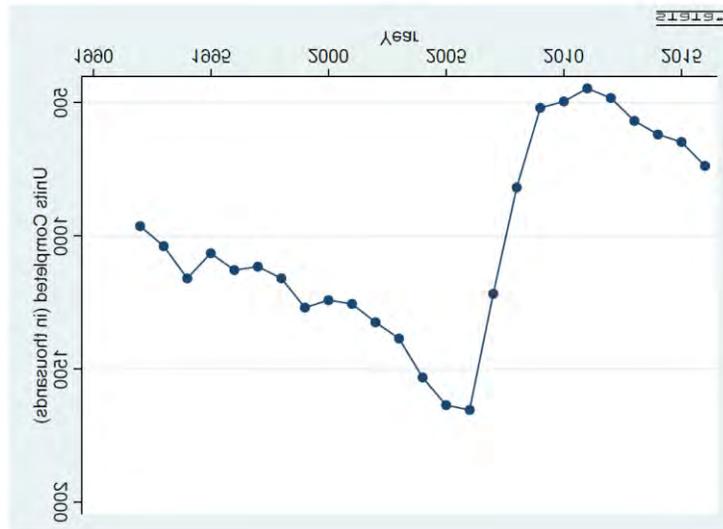


Figure 4 Volume over Time

In many industries decreases in volume of this magnitude would be accompanied by decrease in price as actors tried to cover their fixed costs. However, the structure of the industry has mitigated against this. Most home builders are small businesses. The single family residential market is largely defined by self- employed independent contractors who make up 81% of the homebuilders and specialty trades. Even when firms with employees are considered two thirds of homebuilders generate less than a million dollars in revenue. (Siniavskaia, N. ,2015)

Professional Builder conducts a yearly ranking of builders in the housing industry. These firms represents homebuilders not the specialty trades. Even with this distinction the fragmentation of the industry is evident in Figure 5 below. The top 75 firms account for 25% of the units produce. Of these only the top 20 firms have revenues over one billion dollars. The next 175 firms produce 5% of the units with units produced and revenues varying widely. The remaining 810,000 units are produced by small builders.

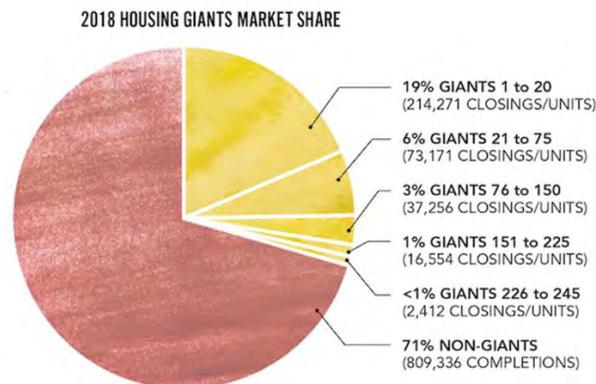


Figure 5 Builder / Units (Professional Builder)

This structure combined with low barriers to exit, due to an emphasis on variable costs, results in little to no correlation between volume and costs. This can be clearly seen in figure 6 below. In order to further validate the lack of a connection between volume and cost a simple analysis was run regressing units against the average cost from Table 1. The regression output as seen in Table 2 is not significantly significant.

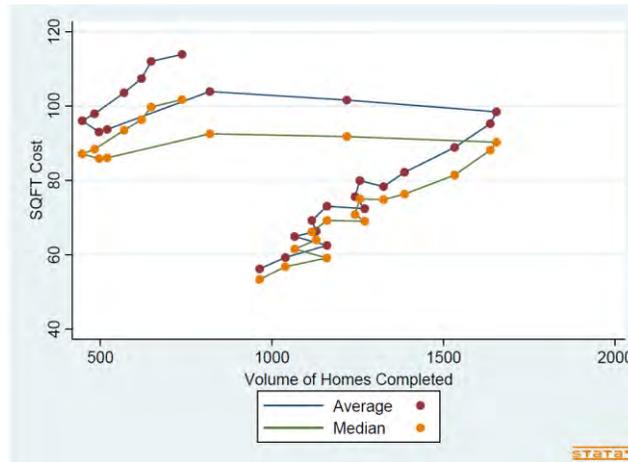


Figure 6 Volume and Cost

Source	SS	df	MS	F(1, 23)	=	3.88
Model	1044.30184	1	1044.30184	Prob > F	=	0.0611
Residual	6193.07102	23	269.263957	R-squared	=	0.1443
Total	7237.37286	24	301.557203	Adj R-squared	=	0.1071
				Root MSE	=	16.409

aus	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
totalcon	-.0177727	.0090246	-1.97	0.061	-.0364416 .0008962
_cons	103.922	9.770295	10.64	0.000	83.71061 124.1334

Table 2 Volume and Unit Cost

This brief overview suggests that addressing affordability in the single family home industry presents unique challenges. The structure of the industry mitigates against market forces causing actors to reevaluate their production processes to reduce cost. In fact, as can be seen, even during times of significant economic retrenchment the square foot cost of the product continued to increase.

ONSITE

The dominant method for delivering Built residential units remains traditional stick built onsite construction. As can be seen in Table 3 below onsite construction has increased from 94% to 97%. As a result, the costs that were described in the previous section primarily reflect the costs associated with onsite construction.

Year	Total	Site		Modular		Other	
1992	964	903	94%	33	3%	28	3%
1993	1039	978	94%	32	3%	29	3%
1994	1160	1093	94%	38	3%	30	3%
1995	1066	1001	94%	35	3%	29	3%
1996	1129	1059	94%	37	3%	32	3%
1997	1116	1046	94%	40	4%	30	3%
1998	1160	1082	93%	44	4%	34	3%
1999	1270	1197	94%	40	3%	34	3%
2000	1242	1163	94%	40	3%	39	3%
2001	1256	1184	94%	42	3%	30	2%
2002	1325	1246	94%	46	3%	33	2%
2003	1386	1313	95%	41	3%	33	2%
2004	1532	1454	95%	42	3%	36	2%
2005	1636	1565	96%	44	3%	26	2%
2006	1654	1579	95%	40	2%	35	2%
2007	1218	1166	96%	31	3%	22	2%
2008	819	779	95%	23	3%	17	2%
2009	520	497	96%	11	2%	12	2%
2010	496	473	95%	12	2%	12	2%
2011	447	427	96%	10	2%	10	2%
2012	483	465	96%	8	2%	9	2%
2013	569	548	96%	11	2%	10	2%
2014	620	601	97%	10	2%	8	1%
2015	648	628	97%	11	2%	10	2%
2016	738	713	97%	15	2%	11	1%

Table 3 Absolute and Relative Volumes

Understanding the particulars of onsite construction then becomes a key to understanding the cost drivers of housing. Unfortunately, as described previously, the diverse structure of this segment makes generalization difficult. In addition, there are distinct differences across the country (Table 4). In 2016 the average square foot contract cost across the US was \$113.90 in the South was \$96.35, in the Midwest it was \$117.98, in the Northeast it was \$152.92 and in the West it was \$159.77. Despite the wide variance in square foot cost the average square feet showed much less variance: in the South it was 2,769, in the Midwest it was 2,576, in the Northeast it was 2,872 and in the West it was 2,685.

Year	Northeast		Midwest		South		West	
1999	78.23	2520	71.33	2166	66.96	2312	85.98	2209
2000	79.44	2656	74.9	2226	68.77	2328	94.75	2273
2001	82.51	2694	76.14	2251	74.78	2352	102.76	2309
2002	87.41	2734	77.18	2255	71.38	2368	94.52	2374
2003	92.19	2671	83.29	2311	73.44	2389	97.84	2387
2004	95.5	2796	90.17	2353	79.73	2470	107.72	2394
2005	110.16	2894	89.11	2398	83.01	2519	123.43	2506
2006	111.81	2842	89.72	2388	89.27	2574	123.58	2535
2007	121.32	2905	94.97	2406	89.17	2605	131.7	2564
2008	120.94	2900	96.43	2372	91.8	2588	137.47	2537
2009	112.95	2728	95.7	2270	80.97	2546	133.07	2430
2010	114.43	2777	89.8	2283	83.16	2607	122.26	2368
2011	120.59	2707	92.98	2346	83.97	2665	128.2	2448
2012	123.44	2793	93.17	2488	88.77	2763	132.96	2510
2013	130.77	2831	97.87	2619	93.06	2820	131.54	2606
2014	154.87	2884	99.68	2606	94.04	2858	146.72	2700
2015	142.94	3020	108.08	2623	102.88	2852	145.58	2690
2016	152.92	2872	117.98	2576	96.35	2769	159.77	2685

Table 4 Regional Differences

While cost has continued to increase the relative proportion of the cost attributable to different parts of the building process has remained relatively stable. The National Association of Home Builder (NAHB), the largest homebuilder association in the US, conducts a biannual survey on the costs associated with the construction of single family homes (Ford, 2017). While they have data from 1998 they changed their data collection method in 2013. As can be seen in Table 5 there has been very little variation in the percentage attributable to each work structure. This suggest that despite rising square foot costs there has been little change in the construction processes.

	2013	2015	2017	Average
Site & Permits	6.80%	5.60%	6.70%	6.4%
Foundations	9.5%	11.6%	10.8%	10.6%
Framing	19.1%	17.8%	17.3%	18.1%
EXT Finish	14.3%	15.1%	14.0%	14.5%
MEP	15.1%	14.7%	15.0%	14.9%
Int Finish	29.3%	29.6%	28.6%	29.2%
Misc	6.60%	6.80%	7.10%	6.8%

Table 5 Relative Cost

In Table 6 you can see a breakdown of the other costs associated with the realization of housing. The construction costs shown above are reflected in item 2. There are two points that should be commented on from Table 6. First, despite the continuous rise in the square foot cost of a project the impact of that cost on the overall price of the house has varied randomly over time. The impact has varied from 48% to 62% and it does not follow the linear trend we have previously observed. Secondly, the construction process is only one variable in the affordability equation. There are other significant issues that need to be addressed in addition to the cost of construction.

Sale Price Breakdown	1998	2002	2004	2007	2009	2011	2013	2015	2017
1. Finished Lot Cost	24%	24%	26%	25%	20%	22%	19%	18%	22%
2. Total Construction Cost	55%	51%	52%	48%	59%	59%	62%	62%	56%
3. Financing Cost	2%	2%	2%	2%	2%	2%	1%	1%	2%
4. Overhead and General Expenses	6%	6%	6%	7%	5%	5%	4%	6%	5%
5. Marketing Cost	1%	2%	2%	3%	1%	2%	1%	1%	1%
6. Sales Commission	3%	4%	3%	4%	3%	3%	4%	3%	4%
7. Profit	9%	12%	10%	11%	9%	7%	9%	9%	11%

Table 6 Relative Construction and Other Costs (Ford, 2017)

MODULAR AND OTHER

While the use of onsite construction is dominant across the US there are significant variations across geographic areas. (In examining Table 7 the missing values in the West result from either an issue with response rate or a volume of less than 0.5%.) In the chart Other refers to the use of panelized or precut units while Modular refers to boxes. It can be seen that the Northeast, and the Midwest adopted modular and other techniques at a much higher rate than the South or the West.

During the analysis of the overall Built industry no evidence of cost savings was seen with Modular or Other building techniques. This stands in contrast to the Modular Home Builders Association (2016) which claims that reductions in waste and labor savings can result in savings in the area of 5%. The variation that was observed in techniques across geographic areas allowed for a further examination of this relationship. Models regressing the square foot cost in different geographic areas (Table 4) were regressed against the percentage of the work that was completed with Modular and Other techniques. The significant results are displayed in Table 8 below. There were no significant relationships observed with the data from the Northeast. Significant relationships between Modular (MWM) and cost (MW) were observed in the data from the Midwest. Significant relationships Between Other (SO) and cost (S) were observed in the data from the South. The west was not tested due to the number of missing elements.

The incontinuity across regions requires that these results be taken with caution. However, they do suggest that further examination of the potential cost savings that can result from non-onsite methods are warranted.

	Northeast			Midwest			South			West		
	Modular	Other	Total	Modular	Other	Total	Modular	Other	Total	Modular	Other	Total
1992	10	4	14	6	3	9	2	3	5			0
1993	9	4	13	6	3	9	2	3	5			0
1994	9	4	13	7	3	10	2	3	5	1	1	2
1995	9	5	14	7	3	10	2	3	5			0
1996	9	6	15	7	3	10	2	3	5	1		1
1997	9	3	12	7	4	11	2	3	5	1	1	2
1998	8	3	11	7	3	10	3	3	6	1	2	3
1999	7	3	10	7	3	10	2	3	5	1	1	2
2000	9	4	13	6	4	10	2	3	5	1	2	3
2001	10	4	14	6	3	9	2	3	5	1		1
2002	10	4	14	6	3	9	3	3	6	1		1
2003	11	4	15	4	3	7	2	3	5	1		1
2004	11	6	17	4	2	6	2	3	5			0
2005	11	4	15	4	2	6	2	2	4		1	1
2006	9	4	13	5	4	9	2	2	4	1	1	2
2007	8	5	13	5	3	8	1	2	3	1	1	2
2008	10	3	13	4	4	8	2	2	4	1	1	2
2009	6	2	8	4	3	7	2	2	4		1	1
2010	7	3	10	4	3	7	2	3	5	1	1	2
2011	7	2	9	3	2	5	1	3	4	1	1	2
2012	5	2	7	3	1	4	1	2	3		1	1
2013	7	3	10	4	2	6	1	2	3		1	1
2014	8	3	11	2	2	4	1	1	2		1	1
2015	6	6	12	4	2	6	1	1	2	1	1	2
2016	7	4	11	3	1	4	2	1	3		1	1

Table 7 Relative Volume of Offsite Construction

Source	SS	df	MS	Number of obs	=	25
Model	2706.68233	1	2706.68233	F(1, 23)	=	43.61
Residual	1427.62229	23	62.0705344	Prob > F	=	0.0000
				R-squared	=	0.6547
				Adj R-squared	=	0.6397
Total	4134.30462	24	172.262693	Root MSE	=	7.8785

MW	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
MW	-710.3847	107.5766	-6.60	0.000	-932.9238	-487.8456
_cons	115.8087	5.493691	21.08	0.000	104.4441	127.1733

Source	SS	df	MS	Number of obs	=	25
Model	3364.17516	1	3364.17516	F(1, 23)	=	122.14
Residual	633.504773	23	27.5436858	Prob > F	=	0.0000
				R-squared	=	0.8415
				Adj R-squared	=	0.8346
Total	3997.67994	24	166.569997	Root MSE	=	5.2482

S	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
SO	-1580.363	142.9975	-11.05	0.000	-1876.176	-1284.55
_cons	109.2541	3.726143	29.32	0.000	101.546	116.9622

Table 8 Regression Results

THE MANUFACTURED SECTOR

The manufactured home industry represents a significant and often denigrated sector of the housing market. According to the Manufactured Housing Institute (2018) approximately 22 million people with a median income \$30,000 live in manufactured homes. Manufactured homes currently cost on average 54% of the cost of a built home.

The structure of the manufactured home industry differs dramatically from the structure of the single family built industry. Where the Built industry is defined by small operators the Manufactured industry is more traditional in nature and is concentrated in the hands of a number of Corporations. The reason for this difference are the barriers to entry that result from the needs to have manufacturing plants. In Figure 7 below the distribution of plants across the continental US is shown. While every state does not manufacturer homes every state does consume them.

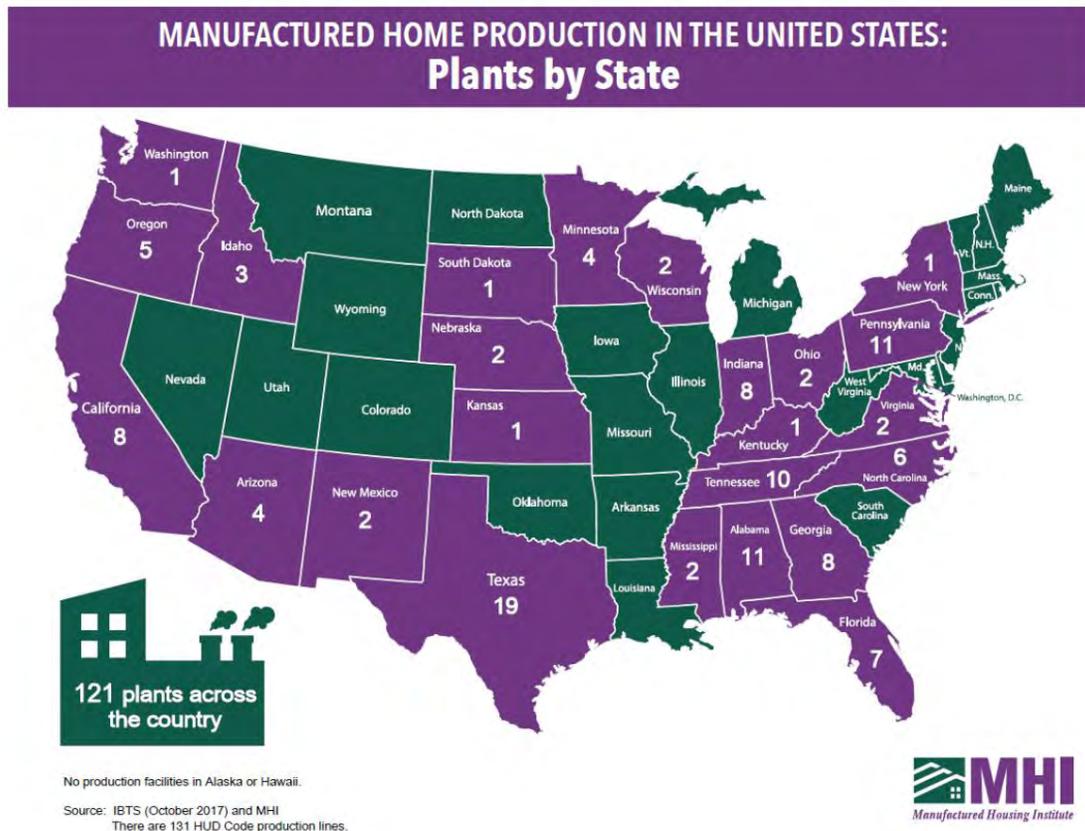


Figure 7 Distribution of Manufacturing Plants

The industry has experienced significant change and consolidation. As can be seen in Tables 9 and 10. From 1995 to 2016 Manufactured units decreased from 340,000 and 24% of all single family housing units to 93,000 units and 11% of all single family units. In Figure 8 the percentage change from year to year for both the Manufactured and

the Built sector are graphically displayed. As can be seen both segments have experience significant volatility. The built segment went from a high of 1,654,000 in 2006 to a low of 447,000 units in 2011 representing a decrease of 73%. The Manufacturing sector went from a high of 348,000 in 1999 to a low of 50,000 units in 2009 representing a decrease of 86%. This was accompanied by a decrease in the number of Manufacturing firms from 100 in 1990 to 45 firms in 2012. The number of plants also decreased from 250 to 123. The decrease in the number of firms, plants, and units sold suggest significant retrenchment in the Manufactured sector. Dun and Bradstreet estimates that 60% of the revenues in the sector currently accrue to the top eight companies.

Year	Manuf Units	% Change in Vol	Built Units	% Change in Vol	Manuf % of All Units	Year	Firms	Plants
1995	340	0%	1066	0%	24%	1990	100	250
1996	363	7%	1129	6%	24%	1991	85	216
1997	354	-2%	1116	-1%	24%	1992	98	227
1998	373	5%	1160	4%	24%	1993	93	244
1999	348	-7%	1270	9%	22%	1994	98	269
2000	250	-28%	1242	-2%	17%	1995	92	285
2001	193	-23%	1256	1%	13%	1996	98	313
2002	169	-12%	1325	5%	11%	1997	89	323
2003	131	-22%	1386	5%	9%	1998	89	330
2004	131	0%	1532	11%	8%	1999	71	323
2005	147	12%	1636	7%	8%	2000	70	280
2006	117	-20%	1654	1%	7%	2001	69	263
2007	96	-18%	1218	-26%	7%	2002	66	235
2008	82	-15%	819	-33%	9%	2003	62	206
2009	50	-39%	520	-37%	9%	2004	66	210
2010	50	0%	496	-5%	9%	2005	67	217
2011	52	4%	447	-10%	10%	2006	67	205
2012	55	6%	483	8%	10%	2007	65	196
2013	60	9%	569	18%	10%	2008	61	170
2014	64	7%	620	9%	9%	2009	61	156
2015	81	27%	648	5%	11%	2010	51	131
2016	93	15%	738	14%	11%	2011	45	122
						2012	45	123

Table 9 and 10 Manufacture Volume and Firms

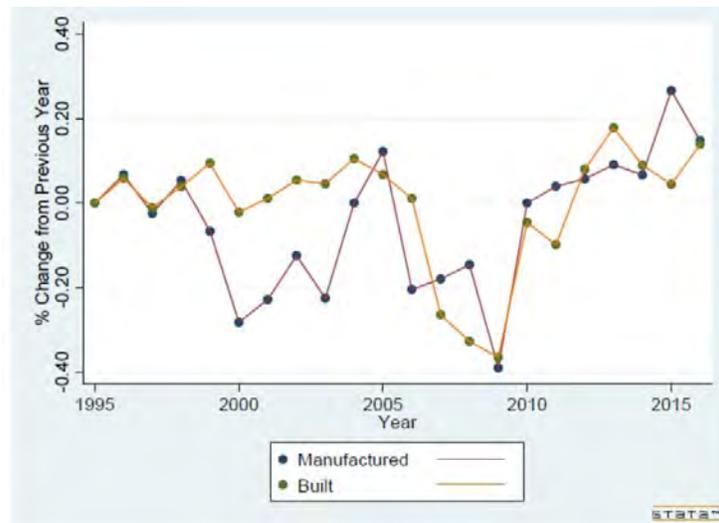


Figure 8 Manufactured v Built

As a result of the format of the available data the following analysis substitutes price for cost. In addition to the nature of the data the structures of the industry would make comparative cost analysis difficult. The Manufactured sector has high fixed costs which would not be evident in per unit cost. As discussed previously the Built sector consists primarily of variable costs. As a result, price while not a perfect parallel for understanding the segments presents a more unbiased comparison. In addition, the values have been modified to reflect that land is not included in the either price.

The differences in the structure of the Built and the Manufactured sectors would suggest that we should observe differences in the cost/ pricing structures of the two segments. This is not the case. Table 11 below shows the Price data for both Manufactured and Built homes. As can be seen there again appear to be a trend of price escalation associated with the passage of time.

Year	Manuf Price	% Change in Cost	Built Price	% Change in Cost	Price Difference	% Price Difference
1995	25.96	0%	62.45	0%	36.49	58%
1996	26.86	3%	64.38	3%	37.52	58%
1997	28.03	4%	66.81	4%	38.78	58%
1998	28.59	2%	67.83	2%	39.24	58%
1999	29.56	3%	67.70	0%	38.14	56%
2000	30.83	4%	70.43	4%	39.60	56%
2001	31.65	3%	71.93	2%	40.28	56%
2002	32.26	2%	75.68	5%	43.42	57%
2003	33.89	5%	79.21	5%	45.32	57%
2004	35.82	6%	85.13	7%	49.31	58%
2005	39.25	10%	90.63	6%	51.38	57%
2006	40.06	2%	91.99	2%	51.93	56%
2007	40.88	2%	92.51	1%	51.64	56%
2008	41.34	1%	88.31	-5%	46.97	53%
2009	41.24	0%	83.89	-5%	42.65	51%
2010	41.32	0%	84.07	0%	42.75	51%
2011	41.30	0%	83.38	-1%	42.08	50%
2012	42.02	2%	86.30	4%	44.28	51%
2013	43.54	4%	93.70	9%	50.16	54%
2014	45.41	4%	97.10	4%	51.69	53%
2015	47.55	5%	100.65	4%	53.10	53%
2016	48.82	3%	107.18	6%	58.36	54%

Table 11 Price Manufacture Vs Built

In addition to the escalation that resulted from time I also examined the impact of volume on price. Decreased volume resulted in consolidation in the industry. I hypothesized that it should also impact the price structure. In the following Table 12 the results from a simple regression of Price (SQFTMS) against Time (Year) and Volume (UNITSM) is shown. As can be seen in the first full model there is high significance and explanatory power however there is a high VIF indicating multicollinearity between Volume and Time. I therefore ran two separate regressions and we find that Time as the sole dependent variable loses very little power in comparison to the first model. In the model examining volume we lose some power but it is still highly significant. In Figure 9 a graphic of the relationship between Volume and Price is shown. In Figure 10 a graphic of the relationship between Time and Price for both the Manufactured and the Built sector is shown.

Source	SS	df	MS	Number of obs	=	22
Model	991.654518	2	495.827259	F(2, 19)	=	287.46
Residual	32.7723519	19	1.72486062	Prob > F	=	0.0000
				R-squared	=	0.9680
				Adj R-squared	=	0.9646
Total	1024.42687	21	48.7822319	Root MSE	=	1.3133

SQFTMS	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
Year	.9910621	.0974647	10.17	0.000	.7870661 1.195058
UNITSM	-.0041184	.0053704	-0.77	0.453	-.0153587 .0071219
_cons	-1949.803	196.2494	-9.94	0.000	-2360.557 -1539.048

Variable	VIF	1/VIF
UNITSM	4.88	0.205055
Year	4.88	0.205055
Mean VIF	4.88	

Source	SS	df	MS	Number of obs	=	22
Model	990.640135	1	990.640135	F(1, 20)	=	586.41
Residual	33.786735	20	1.68933675	Prob > F	=	0.0000
				R-squared	=	0.9670
				Adj R-squared	=	0.9654
Total	1024.42687	21	48.7822319	Root MSE	=	1.2997

SQFTMS	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
Year	1.057703	.0436781	24.22	0.000	.9665919 1.148814
_cons	-2084.125	87.59689	-23.79	0.000	-2266.848 -1901.401

Source	SS	df	MS	Number of obs	=	22
Model	813.309557	1	813.309557	F(1, 20)	=	77.05
Residual	211.117313	20	10.5558656	Prob > F	=	0.0000
				R-squared	=	0.7939
				Adj R-squared	=	0.7836
Total	1024.42687	21	48.7822319	Root MSE	=	3.249

SQFTMS	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
UNITSM	-.0528068	.006016	-8.78	0.000	-.065356 -.0402576
_cons	45.73729	1.203492	38.00	0.000	43.22685 48.24773

Table 11 Regression Analysis

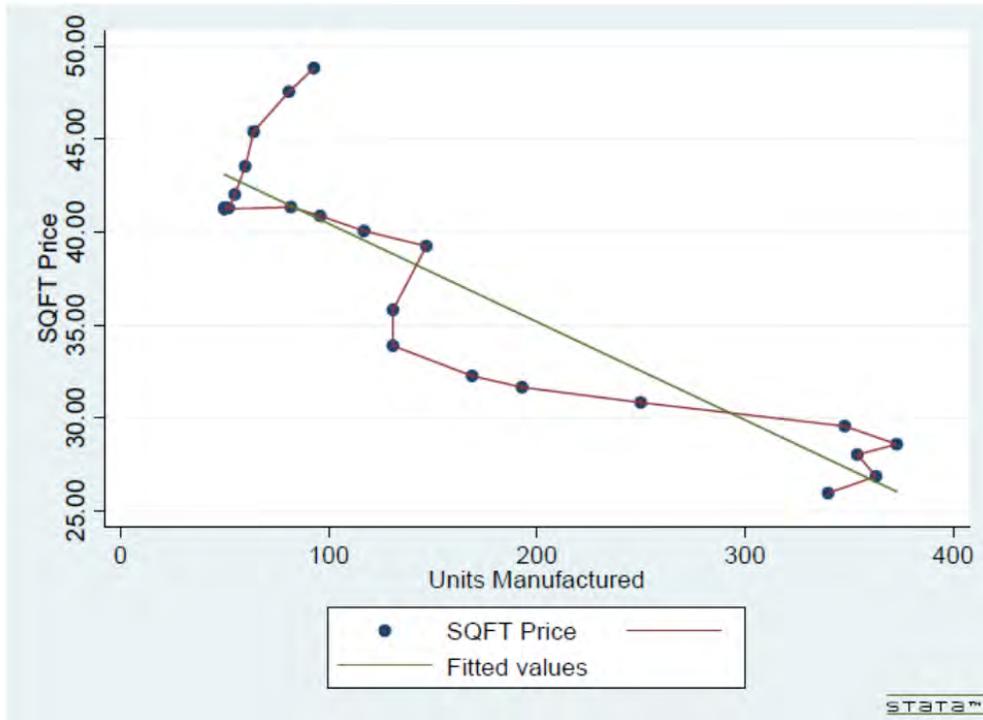


Figure 9 Volume and Price

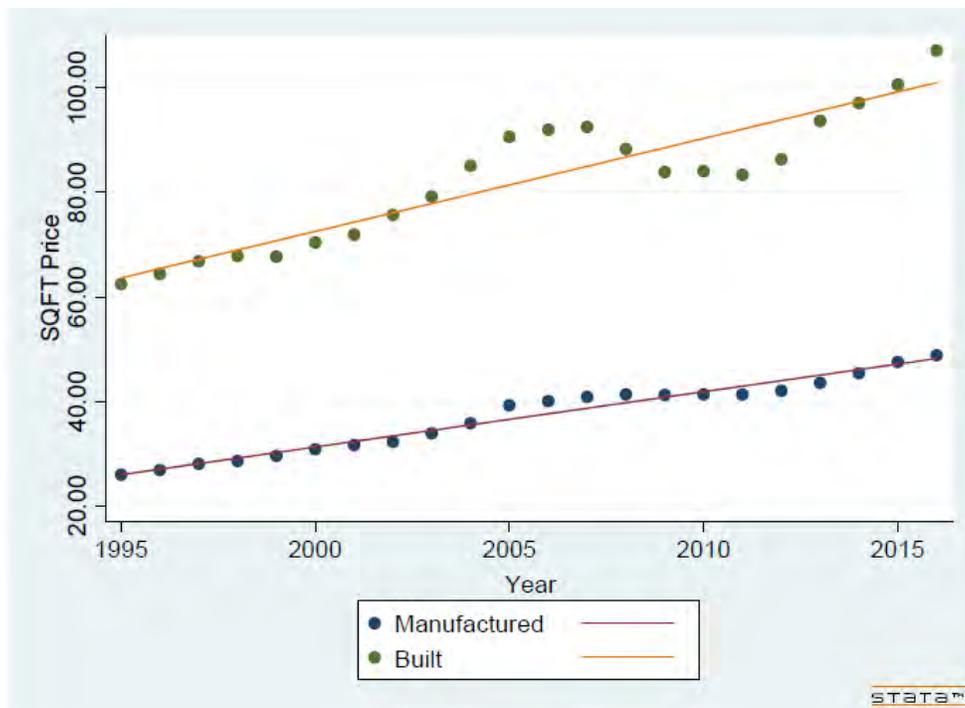


Figure 10 Price over Time

DISCUSSION AND CONCLUSION

The analysis presented above show that there are multiple factors (see Figure 6) that affect the affordability of single family residences. It is clear that the production process employed in the Manufactured sector results in a much more affordable structure.

However, it is still to be determined if the nature of the Manufactured product or public perception of the product can be changed sufficiently to increase the segments market share. Although their share has risen to 11% from a low of 7% it is still far below the high of 24%. This low market share is especially interesting given the fact that home affordability is decreasing dramatically.

Figure 10 also raises an interesting question. Although the Manufactured sector is consistently over 50% more affordable than the built sector it has escalated its prices at the same rate as the Built sector. Given the radical differences in production processes does this indicate that there is an underlying cost driver that is effecting both segments? Another alternative is that the Manufactured sector, given its smaller market share, is pricing in relationship to the larger Built segment. Understanding the drivers of this phenomenon would be critical to understanding cost structures.

In terms of the built sector the disconnect between demand and price is striking. With the exception of 2009 (-10%), 1999 (-1%), 2002(-2%) and 2010 (-1%) the square foot cost has consistently increased. It appears that the structure of the industry with the dominance of small actors and low barriers to exit could explain this. However, there are larger firms involved in the segment and exploring their cost structure could provide insight. Implementing technological efficiencies may be unrealistic to the small business segment of the sector

The weak association between cost and offsite construction is also interesting. The industry seems to emphasize schedule reduction over cost reduction as a selling point. It would seem reasonable that many of the efficiencies associated with the Manufactured sector could be transferable to the offsite sector. However, it does not appear that this has occurred. A better understanding the offsite sector better is important. Are they manufacturing operations or are they stick built in an offsite environment?

The questions raised here form a foundation and give some direction for future research into understanding affordability. The development of propositions and the testing of hypothesis developed from the propositions is the next step.

A last caveat is important. It would seem reasonable, and our analysis suggests, that housing responds to the particular geographic environment in which it is realized. Therefore, it is important to recognize that this analysis is strictly focused on the US market and while there may be some generalizable findings no claim can be made to that effect.

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CONTRADICTIONS IN PROJECT BASED LEARNING: A QUALITATIVE STUDY OF THREE CITY DEVELOPMENT PROJECTS

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CONTRADICTIONS IN PROJECT BASED LEARNING: A QUALITATIVE STUDY OF THREE CITY DEVELOPMENT PROJECTS

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ABSTRACT

In complex product system industries such as construction, innovation and explorative intra-project learning are critical aspects for developing and delivering complex and customized products. Some research has, however, demonstrated that it is difficult to utilize learning from development projects in the permanent organisation. Hence, the project learning paradox explains that the unique and discontinuous character of project-based activities creates intra-firm boundaries that hinder the transfer and use of valuable knowledge gained within particular projects.

In this paper we aim to gain further understanding of the obstacles in project based learning in a public client organisation by illustrating the impact of the learning paradox on daily practices in complex urban area development projects. This paper is based on the data from three qualitative case studies at a large Municipality in the western part of the Netherlands. We present results of a set of 15 semi-structured interviews with different actors representing the project organisation and the permanent organisation. Each interview was individually analysed on the basis of an analytical framework based on layers of knowledge governance and were then further analysed within the project team.

The results indicate six contradictions; three contradiction in the learning structure of project organisation and permanent organisation, and three contradictions in transferring and capturing knowledge by project organisation and permanent organisation. This contributes to unravelling the complex phenomenon of organisational processes of knowledge governance in PBO's since the temporary versus permanent dichotomy appears to problematic in its pervasiveness.

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KEYWORDS

Construction client, organisational learning, project based learning, urban area development

INTRODUCTION

Projects represent decentralized environments and can be understood as specific forms of temporary organisations. They are seen to provide unique opportunities for innovation because they allow for exploration (Bygballe & Ingemansson, 2014; Davies & Hobday, 2005; Kenny, 2003). As Grabher (2002) explains, temporary organisations comprise project or event specific entities; they are constituted either to deliver some specific temporally defined project or to deal with some event or occurrence, after which they cease to be. Organisational structures developed around projects are often used as tools for accomplishing change in other organisations, which in most cases are their parent organisation (Johansson, Löfström, & Ohlsson, 2007). In relation to this, organisational learning, in terms of both explorative learning within projects and exploitative learning across projects, is recognized to contribute to the competitive position and of strategic importance (Eriksson & Leiringer, 2015; Van Donk & Riezebos, 2005).

Recently, project management scholars have developed a growing interest in project based learning. Project-based learning is about encompassing both the creation and acquisition of knowledge within projects (Ayas & Zeniuk, 2001) and the subsequent transfer of such knowledge to other parts of the organisation, including other projects (Bakker, Cambré, Korlaar, & Raab, 2011; DeFillippi & Arthur, 1998; Scarbrough et al., 2004). Organisational learning in Project Based Organisations (PBO's) specifically refers to the process of making newly created project-level knowledge available to the organisation as a whole by sharing, transferring, retaining, and using it (Bartsch, Ebers, & Maurer, 2013; Prencipe & Tell, 2001). Hence, while projects are recognized for their advantage in learning and innovation, the transfer of the ephemeral innovation to the permanent practice faces substantial challenges (Bartsch et al., 2013; Prado & Sapsed, 2016).

The knowledge-based view on PBO's assumes that the project and organisational levels should interact to ensure the accumulation of knowledge. This gets expressed in knowledge governance, which is about achieving long-term and successful interaction between the project level and the organisational level (Lundin et al., 2015). However, in PBO's effective knowledge sharing remains a challenge, as the unique and temporary nature of projects and programs does not support knowledge transfer 'from, between and within' projects (Almeida & Soares, 2014; Lindner & Wald, 2011). So on the one hand, through their transience and inter-disciplinary nature, project ventures are likely to be very suitable for creating knowledge in the context of its application (Hobday, 2000). On the other hand, however, the temporary nature of projects by the same token seems to inhibit the sedimentation of knowledge, because when the project dissolves and respondents move on, the created knowledge is likely to disperse (Bakker et al., 2011; Grabher, 2004).

Exploring how organisations can attend to organisational tensions that become paradoxical when opposing each other is part of paradox studies (Smith & Lewis, 2011; Stoltzfus et al., 2011). Bakker et al. (2011) discusses the ‘project learning paradox’: the autonomy of projects offers opportunities for creating new and innovative knowledge, but disseminating this knowledge is difficult exactly because of this autonomy. The relation between temporary project organisations and more enduring forms of organizing is an interesting phenomenon in this respect (Bakker, DeFillippi, Schwab, & Sydow, 2016; Burke & Morley, 2016). Some research has demonstrated that it is difficult to utilize learning from temporary development projects in the permanent organisation (Pemsel & Wiewiora, 2013; Swan, Scarbrough, & Newell, 2010), and that implementation is often ceremonial (Johansson et al., 2007). Others have discussed the differentiating characteristics separating the ‘temporary’ from ‘ordinary’ organisations (Lundin & Hallgren, 2014; Lundin & Soderholm, 1995; R.A. Lundin & Steinhórnsson, 2003). Hence, the unique and discontinuous character of project-based activities creates intra-firm boundaries that hinder the transfer and use of valuable knowledge gained within particular projects by subsequent projects and or the project-based organisation as a whole (Bartsch et al., 2013; Prencipe & Tell, 2001).

This research contributes to the project based learning literature that focuses on the relation between the project organisation and the permanent organisation in knowledge governance (Davies & Brady, 2016; Prencipe & Tell, 2001; Scarbrough et al., 2004). The aim of this study is to gain further understanding of the obstacles in project based learning in complex urban area development projects. The central research question in this paper is: “In what way is the permanent organisation able to learn from knowledge gained within temporary projects organisations?”. We look into the temporary versus permanent dichotomy and explore the (temporary) notion of organisational learning processes by looking into the lack of integration between exploitation practices in projects and exploration practices by (permanent) parent organisations (Grabher, 2002; Lundin & Hallgren, 2014; Lundin & Soderholm, 1995; van Marrewijk, Ybema, Smits, Clegg, & Pitsis, 2016; Winch, 2013).

To answer our question and identify the potential of being a ‘learning organization’, the learning capacity of the engineering department of a large Dutch Municipality is studied using an interview series. Our study includes three complex urban area development projects in which new ways of collaboration were applied. It illustrates the impact of the learning paradox on daily practices in complex urban area development projects of public client organisations. We elaborate on six identified contradictions; three contradiction in the learning structure of project organisation and permanent organisation and three contradictions in transferring and capturing knowledge by project organisation and the permanent organisation. In addition, the paper also shows some early practices of mechanisms to bridge the gap between the project organisation and the permanent organisation.

The paper proceeds as follows. The theoretical background discusses themes of organisational learning in PBO’s, considering the practice of transferring of knowledge from projects to the permanent organization. We then explain the qualitative research approach to studying the knowledge governance practices of

three city development megaprojects in a large Dutch municipality followed by a discussion and conclusion.

ORGANISATIONAL LEARNING IN PBO'S: TRANSFERRING KNOWLEDGE FROM PROJECT TO PERMANENT

Learning in PBO's (or organisational departments with project-based characteristics) takes place at different levels; individual, group (project team) and organisational levels (Bakker et al., 2011). The focus of project-based learning is to encompass both the creation and acquisition of knowledge within projects (Ayas & Zeniuk, 2001) and the subsequent transfer of such knowledge to other parts of the organisation, including other projects (Bakker et al., 2011; DeFillippi & Arthur, 1998; Scarbrough et al., 2004). Project Based Organizations (or specific project-based organisational departments within an organisation) operate mainly at the project level (which includes project management, project control, learning in projects) and the organisational level, including strategy, top management, cross-project coordination, and learning across projects (Hobday, 2000; Sydow, Lindkvist, & DeFillippi, 2004).

The extent to which these levels are developed but also integrated with each other can lead to desired learning outcomes. The knowledge governance approach (Foss, 2007) aims to transcend these different levels by looking into the micro-foundations of knowledge in order to see how knowledge can be institutionalized in organisations. This knowledge-based view on PBO's assumes that the project and organisational levels should interact to ensure the accumulation of knowledge and focuses on finding mechanisms that will affect individuals and their interactions (i.e., at the micro level) to achieve both aggregate pre-set outcomes and collective knowledge-based goals (Foss, 2007).

THE PROJECT LEARNING PARADOX: PBO'S INTRA FIRM BOUNDARIES IN TRANSFERRING KNOWLEDGE

In general, the construction of a project organisation in order to achieve product or process innovation by a process of detachment forming an independent organisational unit, is seen as a way to make an innovative project manageable (Johansson et al., 2007). The results of projects are generally expected to be implemented in a permanent organisation. This precondition establishes some kind of relationship during the projects' life cycle and it also creates opportunities for implementing results from a project in the permanent organisation (Kenny, 2003). This implementation phase is described as institutionalized termination and includes a component called bridging (Johansson et al., 2007). Bridging occurs when experiences from the temporary organisation's lifetime are transferred to other temporary or permanent organisations. This implies a relationship that influences in both directions, or embeddedness, going beyond project management (Blomquist & Packendorff, 1998; Johansson et al., 2007). It is about balancing between competing and often incompatible institutional demand of the more permanent parent organisation and situational requirements of a developing project (Stoltzfus, Stohl, & Seibold, 2011). A focus on long-term organisational learning, which might be

beneficial for the portfolio as a whole, will likely be sacrificed for short-term problem-solving in troubled projects (Eriksson & Leiringer, 2015).

Literature suggests that projects present what might be called a “learning paradox”. Through their transience and inter-disciplinary nature, project ventures are likely to be very suitable for creating knowledge in the context of its application (Gann & Salter, 2000; Grabher, 2004; Hobday, 2000; Scarbrough et al., 2004). The temporary nature of projects by the same token seems to, however, inhibit the sedimentation of knowledge because the created knowledge is likely to disperse when the project dissolves and respondents move on (Bakker et al., 2011). It appears that PBO’s face substantial obstacles in capturing knowledge and in the re-cycling of project-based learning that stem from the relatively self-contained, idiosyncratic and finite nature of project tasks (Almeida & Soares, 2014; René M Bakker et al., 2011; Bartsch et al., 2013; Bresnen, Edelman, Newell, Scarbrough, & Swan, 2003).

Research has shown that the unique and discontinuous character of project-based activities create intra-firm boundaries that hinder the transfer and use of valuable knowledge gained within particular projects by subsequent projects and/or the project-based organisation as a whole (Bartsch et al., 2013; Gann & Salter, 2000; Prencipe & Tell, 2001). From a knowledge governance perspective, organisational structures and mechanisms play an important role in influencing and shaping learning processes that involve the creation, sharing and integration of knowledge across organisational levels (Eriksson & Leiringer, 2015; Nicolai J Foss, Kenneth Husted, & Snežina Michailova, 2010; Gooderham, Minbaeva, & Pedersen, 2011). The project management office (PMO) is one such organisational structure. The PMO could provide a strategic link that represents the interests of the project managers at strategic level (Eriksson & Leiringer, 2015; Hill, 2004).

Following from this project learning paradox, one of the crucial challenges for project managers concerns the successful transfer of knowledge created in a project to the wider organisational context in which it is embedded (Bakker et al., 2011; Schindler & Eppler, 2003). This is ‘problematized’ by the perspective of the permanent organisation being referred to as project owners (Bakker et al., 2011; Turner & Müller, 2004). A high level of absorptive capacity of the project owner is a necessary condition for successful project knowledge transfer, which implies that the responsibility for knowledge transfer seems to in the first place lie with the project permanent parent organisation, not with the project manager (Bakker et al., 2011)

EXPLOITATION VS. EXPLORATION IN ORGANISATIONAL LEARNING: LACK OF INTEGRATING PRACTICES

Organisational learning in PBO’s specifically refers to the process of making “newly created project-level knowledge available to the organisation as a whole by sharing, transferring, retaining, and using it” (Bartsch et al., 2013). Other definitions of organisational learning focus on learning of ‘organisational members’, the acceptance of their knowledge and applicability in organisational activities, implying changes in these activities (Berends, Boersma, & Weggeman, 2003). For Simon (1991), organisational learning always starts with individual learning, and this poses challenges in terms of how individual knowledge is transferred or to other organisational members or how it sediments into the organisational memory. Looking

into organisational learning it is therefore important to not only focus on how ‘learning’ is officially organized in order to stimulate the transference of knowledge (e.g. training programs, official evaluations), but to also take into account the way that project managers or respondents engage in informally organized ways of learning (discussions/reflections ‘on the job’, how new project managers become a member of the practicing community, how best practices are communicated, etc.).

Literature on knowledge governance describes three mechanisms of knowledge sharing activities: formal, relational and informal mechanisms, taking place at different levels; individual, group (e.g. project team) and organisational (Bakker et al, 2011). Learning takes place through both implicit individual knowledge building within tasks and practices, as well as the more reflective moments within teams and organisational efforts to adequately capture or implement this acquired knowledge. In this context Zollo and Winter (2002) distinguish three learning processes: 1) experience accumulation - learning by doing which leads to local experts, 2) knowledge articulation – learning by reflecting, think and confront, leading to awareness and understanding – and 3) knowledge codification – learning by (re) writing, implementation and replication, translated into manuals and procedures on project management processes.

Organisational learning is about balancing exploitation and exploration where exploration concerns the development of new skills and competences and exploitation concerns relying on ‘old certainties’ and developing or improving already existing skills and competences (March, 1991). March (1991) proposes that exploitation and exploration are two fundamentally different learning activities between which firms divide their attention and resources. Whereas exploitation is associated with activities such as “refinement, efficiency, selection, and implementation”, exploration refers to notions such as “search, variation, experimentation, and discovery” (March, 1991). Exploitation and exploration may therefore require fundamentally different organisational structures, strategies, and context (March, 1991). In PBO’s there often is a lack of integrating mechanisms between the explorative development projects and the exploitative business. Therefore the structural separation of exploration and exploitation at SBU and project portfolio levels does not enhance exploitation of explorative knowledge and technologies (Eriksson, 2013). The PBO has an internal diffusion problem, often leaking the benefits of innovation and new knowledge, which flow more easily through communities of practice that extend beyond rather than within firm boundaries (Brown & Duguid, 2001; Prado & Sapsed, 2016). PBOs face a recurring tension between the always-immediate demands of the project and the opportunities for learning and disseminating best practices and innovations (Prado & Sapsed, 2016; Sydow et al., 2004). March (1991) therefore argues that successful firms are ambidextrous contributed to a general shift in organisational research from trade-off to paradoxical thinking, as explicated in the work of for example Eisenhardt & Martin (2000), Gavetti & Levinthal (2000) and Smith & Lewis (2011).

METHODS

This research is based on the data from three qualitative case studies at a large Municipality in the western part of the Netherlands with the overall aim of studying on the municipality as a ‘learning organisation’ (Örtenblad, 2002). The underlying idea of the studied organisation in testing out innovative collaborative contract forms in urban area development projects was to initiate a cultural change within the municipal organisation by adopting a new role and a new working method. The studied municipality is aware that this ambition does not just arise and requires learning. In the past few years, this large public client, actively worked on the application of new forms of cooperation to gain experience. Specifically, in recent years, the municipality has applied new ways of cooperating with the market in a number of very large, complex area development processes, expecting that this method would yield added value to the municipality.

Three of these projects are used as case studies for this paper, studying the learning capacity of the organisation, specifically department of Area Development. This department has project-based characteristics, as the Project Management Office (PMO) composes project teams for each project ‘hiring’ different professions from various departments/groups within the organisation as a whole. The case projects proceed each other in time, allowing to build on experiences in former projects. Project 1 and Project 2 are both initiated as large scale public-private partnerships and both tendered out using a competitive dialogue. Both projects had, next to project goals/ambitions, goals ambitions regarding building knowledge/learning. Project 3 was even more ambitious in using the expertise of the market in a well advanced public private collaboration in which many of the learning objectives were placed with the market parts

A series of qualitative semi-structured interviews has been conducted. In addition evaluation reports are studied. We take on a knowledge-based view on PBO’s, focusing on how the project- and organisational levels, besides inherently in a tense relationship, should interact to ensure the accumulation of knowledge (Pensel, Müller, & Söderlund, 2016). Due to the multi-faceted characteristic of the concept of project-based learning in PBO’s there is a need to reach a certain layering in the interviews. Hence, studying the learning capacity of a municipality in the context of urban projects, we analyse both the individual, the project team, the departments and the (permanent-)organisation itself. In addition to this the municipality may have different roles in the urban development process. In line with this from analytical reports of urban development projects there are indications that various stakeholders, at various institutional levels or in different permanent organisations, are benefit from different types of organisation. Therefore a group of interviewees was chosen to represent a cross-section of the organisation.

We interviewed employees both from the permanent organisation (line organisation) as well as those primarily working for one or more of the three cases in the project organisation. For each of the three projects (Project 1, Project 2, Project 3, the ascending numbers correspond to the sequence of execution), we spoke with the internal commissioner, the project manager, and the members of the project team

which were engaged with either market and contracting, legal affairs or involved in drawing up the program of requirements (PofR). This led to a series of 15 interviews (respondent A to O, see table 1), of which some of the interviewees had multiple roles (e.g. respondent A who was involved in both the project environment as the permanent organisation), and some were involved in multiple projects (like respondent M, N). The interviews varied from one hour to one and a half hour and were combined with several related internal documents relating to knowledge governance and learning practices. The interviews were all recorded and transcribed verbatim to ensure reliability.

Table 1: Overview of respondents

Function	Permanent organization	Role in project	Project 1	Project 2	Project 3
Head of Commissioning	A	Internal commissioner	A	A	E
Head PMO	B	Project manager	F + G	H	I
(Head) of Exploitation	C	Market & Contracting	J	J	K
Organisational advisor / HR	D	Legal Affairs	L + M	L + M	M
		Space & Living (PofR)	N	N	O

The multilevel approach is also reflected in the analytical framework which is used as an underlying structure to develop a topic list by means of which the three projects could be discussed in relation to learning. This analytical framework was based on the theoretical understanding of knowledge governance. We distinguished three levels of measurement; 1) awareness, 2) active steering, and 3) structures and systems, each containing themes that represent elements of the theory discussed, see table 2.

Table 2: Analytical framework project based learning

Level of measurement	Themes		
Awareness	Use of own network; Informally collecting knowledge	Awareness of existing knowledge and experience	Interest in learning
Active Steering	Organisation of knowledge sharing; learning pathways / learning activities during projects	‘Right’ knowledge – ‘Right’ moment – ‘Right’ place	Stimulating knowledge sharing; atmosphere / culture team, mind set and trust
Structures & Systems	Influence of organisational structure	Organisational culture	Tools

Each interview was individually analysed by the first two authors on the basis of an analytical framework, and then further analysed within the project team. These results

were completed both from the perspective of inter-project learning and organisational learning. Next, all tables with results were combined in a summarizing table, only stating the findings that were named, or indirectly commented on, by at least half of the interviewees. This way, not only topics that one agrees on are included, both also aspects where consensus is missing are included. Only existing programmes and other aspects named only ones that could be checked on their existence are also included, however with a notion that they were mentioned by less interviews. Six key ‘opposing forces’ traversing all three layers of analysis (awareness, active steering and structures and systems) emerged from our data; three following from contradictions in the learning structure of the project organisation and the permanent organisation (living apart together, the transparency dilemma and complementarity of learning objectives), and three contradictions in transferring and capturing knowledge by the project organisation and the permanent organisation (incoherent parallel systems of learning, discontinuity on attention to learning and vulnerability of securing knowledge). These provide the structure in presenting the findings.

CONTRADICTIONS IN THE LEARNING STRUCTURE

LIVING APART TOGETHER

In the projects we have studied, our respondents generally seemed to be aware of the fact that as a project you have to distance yourself from the permanent organisation in certain ways. The dissociation from the relatively political and bureaucratic permanent organizations appeared to lead to a confidential and safe environment that encourages learning within the project and positive results. The dissociation can either be a physical separation between permanent and project, or a more symbolic distance. However, our data suggest that these different ways of seclusion are strongly related. For example, in one of the projects, the physical dissociation was quite literal as the project team started to work in another building. Many respondents experienced this as positive, emphasizing that it allowed them to work more decisively

“Put it on the table, discuss it with one another, make sure you have an open atmosphere, so that everything is discussed well and that you know of one another: yes, that point has been discussed, but we agree, so this is the decision and this is how we will proceed. That is very important.” (respondent O: Space & Living, project 3).

Several respondents reflect on this aspect in the context of the municipality's political and bureaucratic work environment. The distance ensures that there is more freedom and space to operate outside the municipality's 'regulatory' system. This makes that project team members do not have to ensure support from the separate departments over and over again (with every decision) and encourages project team members to challenge each other and search for creative solutions for complex problems.

The physical distance between project and line has also created a more symbolic distance between the different employees and departments. An illustration of the symbolic distance found in one of the cases is the 'secrecy/mystery' that was built around the project.

“That distance works very well inwards. Specifically in the tender, because it was very exciting, there were a lot of discussions, but there was also a real bond. Outwards, this works exactly the other way around, we were seen as a closed stronghold. And that had two reasons: we were in a tender, so everything was confidential, it really should not be revealed. We were in our own space, which contributed a lot to that team formation and the collective feeling, but that really created a distance with outside.” (respondent F: project manager, project 1)

The project team members felt that the respective departments did not fully appreciate the knowledge that was acquired within the project. The context of complex urban area development projects appear to ask for more creative solutions 'out of the box' to meet the ambitious objectives. According to our respondents this has however resulted in a certain 'jealousy' from the staff in the permanent organization, because they interpreted the project as a group of people who have been 'freewheeling'. This feeling may have been reinforced by the general idea that 'the best people in the municipality' have been chosen to do this project. Although not every respondent clearly indicates that this 'paradox of distance' impedes the daily course of events, it does have repercussions on the learning ability of the organisation.

Looking from the perspective of inter-project learning we especially see a connection between two of the case projects. Much of the earlier executed tender of Project 1 is 'projected' on the subsequent tender of Project 2. For example, there was a well-functioning 'soundboard' (steering committee of former project team members), influencing inter-project learning in an advantageous way. Current project team members were able to ask questions whenever they felt they needed it, and because these project team members became project team members of other projects as well, information was implicitly transferred to other projects.

This also gets expressed in the occupation of the project team. From experiences in Project 1 it was understood that the group dynamics with a strong team spirit and a high commitment of all team members was of great importance in innovative confidential tender procedures. Project team members depend on each other and have to exchange knowledge and experience. By working very closely together, people became aware of the knowledge that is present and one works (forced in a certain way) on building the right group dynamics to stimulate knowledge sharing. It is precisely this awareness of the available knowledge that offers benefits for current project and future projects. However, the involvement of team members of the former project in the subsequent project created a 'divided' group dynamics because the project team of the former project was already known as a 'special' group in the permanent organisations, the different permanent organisations from which each project team is composed. Combining created a harmful hierarchy between experienced and inexperienced project team members, with a negative effect on learning/knowledge exchange. Certain tasks were taken over by 'flown in' experienced team members instead of giving the inexperienced ones the chance to gain experience.

“And the learning moments, or the transfer of knowledge, mainly involved the same crew. Largely the same crew. Also the external parties, the office that supported it

was the same office that had supported us earlier.” (respondent F: project manager, project 1)

To sum up, the dissociation of project, and thereby its project team members, either physically or symbolic, creates a dynamic and a strong culture that is thought to be positive from the project goal. This, however, appears to hinder learning between the project and the permanent organisation.

THE TRANSPARENCY DILEMMA

The experience of ‘distance’ between project and permanent is enhanced by the confrontation with confidentiality in carrying out projects. On a daily basis the project team is confronted with the political tension around certain unique urban area development projects. Legal obligations from the public domain lead to confidentiality in projects that hinders exchange and embedding of knowledge within the organisation. Many respondents indicate that they experience the political responsibilities in their client organisation quite heavily. This has its effect on transparency, as this responsibility often create a ‘seeming’ openness. Especially in the initial stages of complex projects, particularly in the tender process, project team members are faced with a high level of confidentiality. This obstructs the learning capacity, and it affects the possibility and way of learning from and between projects and the possibility to (and term of) 'embedding' lessons in the permanent organisation. The respondents revealed that the political pressure creates a reaction of ‘cramps’, a defensive culture is created. In this respect respondents often mention an abundance of control mechanisms arising at different levels of the organisation. The organisation is explained as an organisation that wants to control everything, to rethink everything three times.

In addition, several respondents mention the conservative nature of public officials, contributing to a certain fear of innovation that does not stimulate learning new things. It is explained that the desired course of action in innovation, openness and discussion, is counteracted by confidentiality that is necessary to function in a politically sensitive environment. It is explained that this transparency dilemma hampers the 'normal' course of events whereby exchange between project team and departments (permanent organisation) is possible when certain questions arise during innovative projects. Where, with new innovative ways of working the desire is to communicate/ and discuss options and their consequences.

“For new things - that's the way I look at it at least - you want to have conversations, you want soundboards, you want your ideas to be tested by market parties, by stakeholders, but that cannot be done, at least not in important phases of the tender.” (respondent H: project manager, project 2)

Many respondents also emphasize that the increasing collaborative way of working is changing learning: you do not have to know certain things yourself, you have to find the right people.

“For example, let's have look at how my children currently function. My son is trying to set up a company. And then I see how that works, he just goes searching on the

internet or in his network and he involves people and so he builds up the knowledge that he needs at that moment.” (Respondent B: Head PMO, permanent organisation)

However, some respondents mention that this ‘looking for information outside’, outside the ‘project bubble’, is problematized by confidentiality, and may therefore counteracts learning.

“So that conversation, with someone who is not in that project organisation, cannot take place, and that kind of conversations prove, at least in my practice, to have added value. So I missed that.” (respondent H: project manager, project 2)

What is often also mentioned by respondents is the use of more experienced project team members for a politically charged project. Next to choosing these experienced people because they are trusted in their ability to deal with the pressure on these politically charged projects, respondents notice the additional advantage of immediate presence of a lot of knowledge and experience in the project team. In a way this steers the right knowledge and experience on the ‘right place’ at the ‘right time’.

“To the nature of the assignment. What is the complexity, both in a political sense as well as in a substantive sense. (...) So you immediately look for the heavier categories. Someone with experience in similar projects.” (respondent E: internal client, project 3)

So although it can be concluded that political responsibility ‘paralyzes’ complicating various ‘routes’ of knowledge exchange, learning from these confidential projects is not impossible. Experience is always gained and the knowledge exchange within the project team intensifies. This leads to a greater awareness of the knowledge and experience that various disciplines (i.e. departments) bring along.

COMPLEMENTARITY OF LEARNING OBJECTIVES

When discussing organisational learning it is important that lessons from projects eventually are structurally found back in the organisation. This starts with embedding the experiences and knowledge that individual project team members take back to their department, belonging to the permanent organisation. Respondents mention that many development opportunities are offered; both in the professional field - e.g. course development consultations and peer audits-, as well as in the areas of personal growth, - e.g. talent development, mentoring program and training. Respondents also indicate that individual preferences are leading. Hence, there is generally no correspondence between the required knowledge in the department and individual learning objectives of employees of the department. The learning objectives of the organisation, spread over the different departments, thus do not find their way down, and coordination with respect to complementarity within the department is absent in many departments.

“In principle you have a conversation cycle which is actually your assessment cycle and functioning cycle. Of course you can mention that, your supervisor can do it or you can do it yourself, what your learning goals are and in what way you want to meet them.” (respondent J: Market & Contracting, project 1 and 2)

With regard to the translation of the personal development into concern interests, the compartmentalization in the organisation seems to have a paralyzing effect on the individual development that is separate from the professional aspect. Respondents indicate many initiatives of bottom-up learning, and emphasize that learning from each other and with each other is considered important in different situations. However, some respondents also admit that bottom-up reflecting and analysing is only initiated at times when this is considered important by the concerned project team members. This evaluation is not always done.

In the context of organisational learning evaluation cycles are also important. Interesting is that the respondents belonging to the permanent organisation acknowledge the inappropriate use of evaluations. It is explained that evaluations are used as a way of defending. Respondents representing the project organisation often discuss the inefficient use of evaluations. The emphasis here is on the lack of 'depth', partly because evaluations are carried out by external parties, and therefore do not produce lessons that can be used well in projects. For this reason it is often decided to have its own evaluation. However, both by respondents representing the permanent organisation and at the project organisation it is also recognized that no time is taken to learn. There seems to be a short-term orientation. For the permanent organization, this stems from the short term of political administrative attention. For the project organisation, the result-oriented culture contributes to taking no time for learning, especially not in between the successive phases of the project.

"The project is already finished for this organisation. I think the ground breaking was 3 weeks ago, but the political and administrative focus is already gone. (.....) The attention is therefore already entirely gone from the project, so you do not put the best people on it anymore, they are already looking for something new. "
(respondent A: head of commissioning, permanent organisations + internal client, project 1 and 2)

The aforementioned aspects all have a link with the way in which the organisation is organized; 'Concern Municipality' seems to oppose the learning capacity. Thinking from clusters, departments and projects leads to good coordination towards higher levels. This appears to be related to the line of responsibility in the project organisation (project-based), information goes from person to person, from project to project, from department to department, from departmental consultation to MT. This flow runs in one direction (reciprocity is lacking) and with this it is difficult to learn as an organisation. Reflecting on these bottom-up initiatives, they seem to go beyond working according to structures and systems. With regard to learning this proactive attitude is desirable - the own initiative, the marking of a situation from which it is useful to draw lessons or the sharing of the lessons learned to different places and levels of the organisation where the lessons are considered important. But what we also see is that project leaders do not always provide feedback, they choose to work on their own and account is only taken of what falls within the mandate. When it is actually necessary to step outside the mandate, no question is asked to the internal client which can lead to 'escalation'. However, because individuals 'grow' within the

organisation and start working on an increasingly higher level of abstraction, experiences with this situation will ultimately unconsciously find their way within the higher layers of the organisation. Hence, we can conclude that although there is no active or conscious management of complementarity in project and concern goals, information finds its way - in a limited way - into different parts of the organisation.

Table 3 presents an overview of the contradictions as found in the learning structure of the Municipality based on the three urban area development projects that are included in our study. Both the physical and symbolic distance, the transparency dilemma and the misalignment between learning objectives contribute to the structural gap between the project organisation and the permanent organisation in the context of project based learning.

Table 3: Summary of three contradictions in the learning structure of ‘project’ and ‘permanent’ organisation

Contradictions in the learning structure of ‘project’ and ‘permanent’ organisation	
Living apart together	The dissociation from the political/bureaucratic leads to a confidential and safe environment that encourages learning within the project and results in successful projects. The distance this creates however hinders learning between project and permanent-organisation (bilateral).
The transparency dilemma	The political tension around certain unique urban area development projects and legal obligations from the public domain leads to confidentiality in projects that hinders exchange and embedding of knowledge within the organisation.
Complementarity of learning objectives	There are many opportunities within the organisation to develop on an individual level, supported by the organisation. The learning objectives of the organisation, however, don’t find their way down and alignment in terms of complementarity within the department remains omitted at many departments.

CONTRADICTIONS IN TRANSFERRING AND CAPTURING KNOWLEDGE

INCOHERENT PARALLEL SYSTEMS OF LEARNING

We experienced that respondents hold different ‘visions’ regarding learning. Therefore different systems of learning have arisen, originating from the permanent organisation or the project organisation, more or less connected to each other. Yet, respondents seem to agree on the importance of certain systems and protocols with regard to learning or knowledge assurance. Respondents know about different existing information sharing tools (for example IntraNet, standards in which evaluation and reflection cycles are embedded, separate evaluation cycles) and know where to find them. The importance is mainly seen in the possibility to structure learning within and between projects (so that the wheel does not have to be reinvented every time) and enabling the acquired knowledge to be safeguarded (so that knowledge does not 'linger' with individuals. but also find more embedding in the

broader organisation). However, the analysis also showed that a certain tension exists between wanting to outline frameworks and norms that also require a certain flexibility to meet the specific contextual details of a complex project. This does not necessarily mean that existing systems and protocols are insufficient, but that the existing tools alone do not cover the total spectrum of learning within complex projects. When respondents representing project team members talk about learning and knowledge transfer, they emphasize that in addition to the already existing systems, a more informal system must exist that does justice to the 'network qualities' of these types of projects. For example respondents often mention sharing knowledge with the - proverbial or literal - coffee machine or elevator.

“And of course you also regularly talk to other project managers. And sometimes that happens in a more organized form, but often also informally at the coffee machine.” (respondent I: project manager, project 3)

“Well, a lot is already happening in the corridors, or at the lift, because you have to wait a long time for the elevator in this building.” (respondent O: Space & Living, project 3)

These kind of more informal moments of knowledge sharing are explained to be flexible in the sense that they are not, as the existing tools do, bound to a stringent location or time; it is the more 'spontaneous' encounters in which employees can keep each other up to date on each other's daily routine. It offers openings to retrieve or bring knowledge in a freer way, e.g. through network meetings, critical conversations, sounding board groups, etc. Many respondents see these ways of learning as a valuable addition to (or perhaps even more valuable than) the already existing systems that structure learning and knowledge sharing:

“It is most beneficial if you have experienced it from the inside. You have been part of such a dynamic or of those discussions with market parties. That is something you do not lose anymore. In addition, I did my very best to give lectures about such a tender process, about that performance orientation. But if you hear that, and you go to a lunch lecture, it is still different than if you were part of such a team. And that's what I find complicated. ” (respondent F: project manager, project 1)

There are indications from data that the different systems of learning stand in the way of each other and that they are not connected in good synergy. In this respect we identified the distinction between on the one hand the slow, incremental learning belonging to the permanent organisation and, on the other hand, the more dynamic project learning that is focused on the - sometimes sudden - changes within complex projects.

“The crux of this kind of complex projects is: acting quickly. You do not do that in your formal project meeting. You do that as soon as you get out of the meeting. You just think quickly: 'we have to do that too', or 'oh, we still have to sit together for about an hour tomorrow' (...) It's all about thinking about conscious deliberations,

and what you need to fight for now, if you want to deviate from the standard." (respondent N: Space & Living, project 1 and 2)

This image is reinforced, as the respondents often appeared to consider learning through systems and protocols as a form of control. Several times the proverbial 'tick a box' is suggested to suggest that learning has degenerated into something purely instrumental. Respondents emphasize that learning and knowledge transfer has an important creative component that can not only be captured in the 'tick off boxes'. As one of the project managers reflects, when we talk about incitement to learning.

"I want to make project members very aware of what they want to learn and how they think they should learn. I want to enable and empowering and not be opinionated (...) I see that as a challenge: how can I make those people as enthusiastic as possible and stimulate someone as much as possible, so that that he or she capitalizes his learning potential with his own convictions, expertise and skills" (respondent G: project manager, project 1)

What especially seems to be difficult is the management from the permanent organization on integral, flexible, sustainable projects crossing the boundaries of the organization. Where the lines represent different disciplines, the projects work throughout the whole organisation organised in a matrix.

"We are a line organisation, but the municipal assignment is often matrix, flexible or sustainable. And that is not how we are organized." (respondent L; legal affairs, project 1 and 2)

Facilitating project team members through the line also means that different interests come together. Project team members deal with both overall organizational goals (from the department) and project goals (translation of the political mandate represented by the project manager). In principle, the departments puts project team members in service of the project. Project goals and organizational targets must not collide. However, discussing the knowledge transfer between line and project it seems that departments in the line do not appreciate the practical project lessons, do not know how to embed them in the department. The context sensitivity of gained knowledge and experience is pointed at as hard to capture, and capturing this knowledge and experience does also not correspond with the dynamic environment of projects, the 'truth' changes during the project.

This may also have to do with the difference in 'structure' of learning. The permanent organisation focuses on organized learning moments to create a certain form of measurability. However, this structure is not considered appropriate within the project organisation; there the focus is more on 'learning on the job'. Where the permanent uses tools to create more uniformity in projects, the project organisation requires more flexibility because of the changing and often unique projects. In the absence of suitable top-down systems for the projects, different learning initiatives develop bottom-up from the projects. These initiatives seem to coexist in parallel and are

insufficiently connected. This raises the question whether the right form of facilitation has been found, when in addition a large amount of personal initiatives is organized.

DISCONTINUITY IN ATTENTION TO LEARNING

Although there are different systems of learning and the importance of the different systems is acknowledged, there is not always enough attention for learning. There seems to be a discontinuity in attention to learning in different phases of complex urban development processes. The development of a large urban area takes a long time and goes through a wide range of different phases before a project is actually completed. Respondents acknowledge that the idea exists that the start phases of the project (development, tendering, signing of contracts) are more important than the phases that follow. This phenomenon is explained to be understandable in a way, because the project is still vulnerable in the initial phase and there is a risk that the parties will withdraw and the project will be terminated early. However, in the context of learning, this has a number of consequences, which mainly focus on the continuity in the expertise and competences of project staff involved. As respondents mentioned, ambitious and progressive politically sensitive project, with complex new forms of cooperation, are often started with experienced people in order to get the project off the ground in a solid and successful way. What in this case is labelled as 'right' has to do with someone's experience and expertise. The selection of the 'right' project staff for a particular project generally takes place through the Project Management Office (PMO), and in a way that most closely resembles the principle of supply and demand: clients reach out to the PMO and ask about the people who could be suitable for this project.

"You mainly look at what they have done before and how they have done it. And we have very intensive contact with all people. I sum up a top five by heart. And then after that come the substantiation and so on, but so, I can think of those like that. And when I ask my colleagues they will come up with about the same list. You just know that. " (Respondent B: Head PMO, permanent organisation)

However, the selection of employees also takes place in a different way, based on an already existing 'network' of people who know each other (for example from earlier projects). This informal selection takes place both to check the quality of the employees but also because this would go faster than if the usual route were to be followed. This selection takes place outside the formal line under pressure of 'heavyweights' in the function of project manager.

"Partly it is decided, and in the crucial position I simply look for people within the organisation, because I know, of course, who I should have. (...) I just approach them personally: do you feel like it? Yes, look, this organisation is not that big either, so I know most people. (...) And then I do not go to the department manager initially, but I use my confidant in that department to see who would be suitable for that. " (respondent N, Space & Living project 1 and 2)

In this context the respondents express that this informal selection happens because you may not get the best or right people for your project via the line manager, because he or she is mainly concerned with looking at who has time to be placed on a

project. The changes within project teams could however be explained from the perspective of phasing. When discussing the three area development projects within the Urban Development Cluster, it becomes clear that the long-term character of these projects means in practice that different phases are followed within which different types of knowledge and experience are desired. A number of explanatory practical situations emerge in the interviews. For example, the transition from the start-up phases to the execution of regular work processes is often mentioned in the follow-up phases, and the respondents of this study are of the opinion that this relates to the 'type' of people that is needed for these different phases. The start-up phase is characterized by the fact that everything has yet to be figured out and where much experience and integral thinking capacity is required. In the follow-up phases, there is a need for a different level of education, and accumulated experience is more focused on subject-specific and substantive knowledge.

"... and you enter a phase now, where you actually have to make more use of the regular work processes (...) Because it is completely devised, there are models and the models have to be completed and guided further" (Respondent M: legal affairs, project 1,2 and 3)

As already mentioned above, a project receives a certain importance label before the project has already started. However, this importance seems to be reduced once the first phases of a project have been successfully completed. It is mentioned that often after the tender, and when the contracts have been signed, these projects seem of less important from a political point of view, while in reality it sometimes takes ten to twenty years before a project is actually completed. One of the respondents characterizes this as *'the treadmill of next project, next project, next project'* (Respondent B: Head PMO, permanent organisation). After the tendering of a project, a different kind of expertise of employees is expected and the 'heavyweights' or already been 'taken away' for another eye-catching project. The moment people leave a project or are removed from the project can be a pitfall. There thus seems to be not enough continuity of knowledge and thereby knowledge sharing throughout the different phases of the construction cycle of complex urban area development projects.

"The conscience of a project is very often in the minds of people. You cannot transfer that to a file. The contract between the municipality and a market party for the project is something like 7000 pages and that does not even contain anything. That's in the minds of the people who work there" (respondent A, head of commissioning, permanent organisation + project manager, project 1 and 2).

VULNERABILITY OF SECURING KNOWLEDGE

Looking at the changes in project teams resulting from in time changing 'importance' (or attention to) of projects another concern comes up; it brings along a vulnerability in knowledge assurance, especially of process knowledge. The need for other types of knowledge and experience in the different phases of the area development project (from complex and initiate method to standardization and work with regular work processes) is expressed in (often consciously directed) changes in the project team. Dealing with the pure, profession-specific execution of individual processes within

the project, this does not cause any problems, because after all, the right knowledge and experience are being delivered at the right time in the right place. However, with the change of project team members, in addition to subject-specific knowledge and experience, process knowledge (e.g. insight into (in) formal agreements and e-mail exchanges) is also lost. In line with this also the networks that have been built up with people working in the project area and their colleagues, especially contextual, knowledge, disappear. Whereas any lack of subject-specific knowledge can be taken care of by the use of other people and or training, ensuring process knowledge is a different story. As emphasized by the respondents, this type of knowledge is largely in people, in relationships that have been built up, and in not public information such as email exchanges and the like.

The awareness of this vulnerability inherent in this project-oriented organisation is present at different levels of the department. At various levels initiatives arise aiming to deal with this vulnerability. For example, many respondents mention looking for a natural moment of change. It is considered important that a certain phase in the project can be closed properly.

"Then it is important to look for a natural moment. It's not that you switch between people in a negotiation process, because then another party tries to put things on the table again, which we thought we had settled." (respondent E: internal client, project 3)

In order to be able to guarantee continuity, it is extra important to think about how knowledge gained can be safeguarded during these transitional moments so that this knowledge and expertise remains 'within' the project. An abrupt change in occupation of the project team is experienced as negative by most of our respondents, and it is often suggested that it is important to think about how the overlap of project staff should take place. This means that a new project employee for a certain period of time 'walks along' with the departing employee so that relevant knowledge and details of complex projects of this kind can be shared. It is indicated by respondents that this is already happening, but not consistently or sufficiently, especially for the reasons given above that a new project is seen as more important than managing an already existing project in its executing phases. This overlap has the additional advantage that there is time for the successor to find his or her place in the team and build trust that is necessary for effective knowledge exchange.

"You try to ensure as quickly as possible that the department in question will propose a new person to you and, if possible, a good transfer takes place. (... ..) But we always try to have an overlap in which the new project manager can be prepared for the job." (respondent E: internal client, project 3)

One is also aware of this vulnerability when external forces are hired. In this discussion respondent make a distinction between various reasons for hiring external forces and in relation to this the importance of learning. Firstly, the hiring for a 'second opinion' where the goal is not necessarily to acquire knowledge. Secondly, the hiring to solve underemployment where the knowledge and experience is already

present within the organisation. And thirdly, the hiring of knowledge that is not present within the organisation and therefore could be learned. For this last reason of external hiring, an attempt is made to let ‘hired knowledge’ land within the organisation, often by linking the externally hired person to an internal employee, working side by side on the assignment. However, respondents were also aware that this takes time so a trade-off is made; when the knowledge is incidental (used once in a very specific project) it is not considered profitable to put these hours into it, and therefore no, steering on, active learning takes place.

Although it definitely possible to learn in this context, the dynamics and time pressure do lead to a different process of learning which require specific initiatives. For example, a ‘soundboard’ group was initiated at Project 1. This ‘soundboard’ group consisted of departing project team members and is intended to consult process information during the follow-up phases of the long-term area development project, by presenting and testing different situations and / or difficulties in people with previous experience in the relevant project. In addition to regular meetings, the current project team members can individually approach the members of the sounding board group.

"We have now also set up a soundboard group for the project. A lot of experienced people from the project have started doing other things. But in order to maintain that historical knowledge for that new organisation, there is a soundboard for the project and there are some veterans in there. There, the new organisation simply has the space to ask questions, involve them, ask them for advice, and so on. " (Respondent J: market & contracting, project 1 and 2)

In line with this, at a higher organisational level, and at the same time also at a higher scale level, the studied organisation has taken steps to become more area-oriented. By deploying project leaders for a defined area, and creating a larger pool of project staff for this area - which in turn can be deployed in groups on projects in the area - knowledge of actors in the area can be built upon and maintained. In addition, it offers time and space to build true confidential relationships - both within the project teams and with the stakeholders from the area - that are necessary for effective exchange. Thus, while a changes in the team for long-term urban area development projects problematize knowledge sharing and capturing, especially process knowledge sharing and capturing, there is a great awareness of this vulnerable situation and several initiatives arise to deal with this phenomenon.

"And that people also have common knowledge of the area. That they then not only know that specific project, but also what's going on outside. And that you sometimes also have to deal with the area people, the area organisation, that you just know them as well. " (Respondent I: project manager, project 3).

Table 4 presents an overview of the contradictions that relate to transferring and capturing knowledge between the project environment and the permanent organization. We found that parallel systems of learning are often not coherent, a

certain discontinuity exists in the attention towards learning and a specific initiative need to be taken to secure the transference of knowledge due to its vulnerability.

Table 4: Summary of three contradictions in transferring and capturing knowledge by ‘project’ and ‘permanent’

Contradictions in transferring and capturing knowledge by ‘project’ and ‘permanent’	
Incoherent parallel systems of learning	Within the organisation there is a level of awareness of the value of systems (protocols) aiming to steer on learning activities. And much is done, developed and organized around learning from projects. In the absence of adequate top-down systems for projects, different initiatives are developed bottom-up from projects. These initiatives however seem to exist next to each other (parallel) and are not sufficiently aligned.
Discontinuity in attention to learning	There seems to be not enough continuity on learning activities throughout the construction cycle of complex urban area development projects. In the initial phase(s) (i.a. contracting phase), projects receive a lot of attention and (a lot of) lessons are drawn therefrom. However, the monitoring learning during the continuation phases (implementation, management) is often limited.
Vulnerability of securing knowledge	One is, at different levels of the municipal organisation, aware of a certain vulnerability in securing process-knowledge in dealing with changes in the team for long-term urban area development projects, both in relational terms and in terms of (in) formal agreements. At various levels initiatives arise aiming to deal with this vulnerability.

DISCUSSION AND CONCLUSION

The aim of this study is to gain further insight in project based learning by asking the **FOLLOWING** question; “In what way is the permanent organisation able to learn from knowledge gained within temporary projects organisations?”. **WE FOCUSED ON THE ENGINEERING DEPARTMENT OF A LARGE DUTCH MUNICIPAL ORGANISATION AND STUDIED THREE COMPLEX URBAN AREA DEVELOPMENT PROJECTS.** Overall, we saw that project-based learning is difficult. Without a dedicated learning strategy, an accompanying structure to support the implementation of this strategy and an organisational culture that explicates learning, the character of a project oriented organisation can hinder learning processes. Within projects the effects of learning may be beneficial (e.g. involving outside expertise, disseminating knowledge informally, developing innovative ideas). However, this strong internal focus may negatively affect learning between different projects or between the project environment and the permanent organisation. The findings show six contradictions between the project organisation and the permanent organisation representing several barriers in project based learning. So despite the fact that prior research indicates that alignment between project and permanent organisation is necessary in learning, our findings embody opposing forces that make project based learning somewhat paradoxical (Fairhurst et al., 2016; Stoltzfus et al., 2011).

We studied the impact of the learning paradox on daily practices of public client organisations. This contributes to the academic project management debate on project

based learning in two distinct ways. First, it contributes to the knowledge governance perspective on constructing detached project organisations to achieve innovation and better organizational performance. The three contradictions related to the differences in learning structures between the client organisations and the permanent organisation - 1) 'living apart together', 2) the transparency dilemma and 3) the complementarity of learning objectives - reflect organisational structures and mechanisms that play an important role in influencing and shaping learning processes across organisational levels (Eriksson & Leiringer, 2015; Nicolai J Foss et al., 2010; Gooderham et al., 2011). Second, it contributes to the interpretation of organisational learning and its different definitions. The three contradictions related to the differences ways of learning, knowledge sharing and capturing - 1) incoherent parallel systems of learning, 2) discontinuity in attention to learning at the different stages of complex projects, and 3) vulnerability of securing knowledge, illustrate the difficulty in making bottom-up creation of project level knowledge available to the organisation with its top-down learning structures (Bartsch et al., 2013). This shows the difficulty of balancing exploration and exploitation (March, 1991); where in the initial phases complex projects receive a lot of attention and lessons are drawn, in the continuation phase project team members rely on existing skills and competences. It also clarifies the problematizing of acceptance of knowledge of organisational members (Berends et al., 2003) due to the differences in type of knowledge gained in project organisations, process knowledge, and the knowledge on which different departments of the permanent organisation are build, the subject-specific knowledge.

To practitioners the findings of this study could to better prepare for temporary collaboration in complex infrastructure projects. By looking into the knowledge governance practices, we gained understanding about the practical challenges that project managers and the project management office face in bridging the gap between inter-project learning and organisational learning. The project manager is expected to be the linking pin between different departments and the internal client, as they carry out the mandate within the project team. Therefore project managers are in the 'right' position to 'serve as a bridge' between inter-project learning and organisational learning, facilitating the solutions to the six identified paradoxical dualities. However, what seems to be difficult is the management from the permanent line organization towards integral, flexible, and sustainable projects. Where the organizational lines represent different disciplines, the projects are organized throughout the organisation in matrix. In order to support the project manager, it could be interesting to look at the an 'equivalent' person in the permanent organisation who also has responsibility for learning. The appointment of a knowledge manager at organizational management level and structural evaluation should focus on all phases of the project preparation up to and including implementation. This is in line with the idea of project sponsorship (Sense, 2013). Agreements on learning goals, bridging the relation between temporary project environments and permanent parent organisations, and a long term learning philosophy are needed for organisations to learn from their projects and become a learning organisation. This involves reflection upon the context and situatedness of temporary work in order to align mutual expectations and to stimulate learning between the project and permanent organisation. Without these, project employees may fall back on isolation and establish innovative work practices out of sight of the

permanent organisation. Future studies could focus on the long-term effects of project based learning, as also expressed by Pettigrew (1990). Our study confirms the problematic nature of the temporary versus permanent dichotomy and its pervasiveness, which needs to be further explored in order to adhere to the temporary notion of organizing learning processes (Lundin and Hallgren, 2014).

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HORIZON 2020 TRANSCENDED: THE REDESIGN OF THE AEC ORGANIZATION

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HORIZON 2020 TRANSCENDED: THE REDESIGN OF THE AEC ORGANIZATION

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ABSTRACT

Has building really changed organically, structurally and/or process-wise in North America over the last generation? What happened since the 1990s on the AEC scene? In 1995, Katsanis and Davidson launched a series of five articles entitled “*Horizon 2020*” (H2020) on how the construction industry would evolve over the next 25 years. This was followed by a wave of forecasting articles and public reports appearing in the US, UK, Europe and Australia. Spread over six years, the H2020 series covered critical issues such as “*Building procurement and industry fragmentation - a North American scenario*” (1996), “*Design-Build*” (1998), “*Network organizations in the AEC Industry*” (1999) and “*Professional trends for the professional practice firm and for the building contractor*” (2001). This research examines what really happened, whether the forecasts made between 1995 and 2001 were on target and if not, what really took place in building procurement. Two financial crises (2000 and 2008) heightened market risk tension and accelerated the industry split into two major segments and risk configuration: the integrated large and multinational (LME) firms moving toward servitization and full fiduciary real asset management, while small to medium size enterprises (SME) remaining stewards of local construction with greater specialization and wider HR and resource supply chain responsibilities. The findings are based on a thorough review of forecasting literature in building procurement, a series of semi-structured interviews and a risk survey of industry practitioners. All illustrations are from the authors, except for the adapted graphics of Edwards, 1998 and of WEF, 2016.

KEYWORDS: AEC, Construction engineering, Decision making, Fiduciary duty, Environment, Finance, Forecast, Human resources, Infrastructure, Innovation, Integration, Market, PPP, Real asset management, Regulation, Risk, Servitization, Stewardship, Technology.

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“As a group, civil engineers typically do not spend enough time thinking about the future. I often asked local members a simple question, ‘What is the biggest challenge that civil engineers will face in the year 2008?’ Normally, there was silence and a room filled with bewildered faces... As a group, civil engineers spend too much time on our immediate work... We do not set aside creative time to look over the horizon.

Now is a good time to change that habit.”

– **Daniel S. Turner**, (1998) former ASCE chairman

“Since 1998 we could have had a revolution and what we've achieved so far is a bit of improvement.”

– **Sir John Egan** (author of *Rethinking Construction*, 1998), foreword to the Wolstenholme Report, United Kingdom, 2009

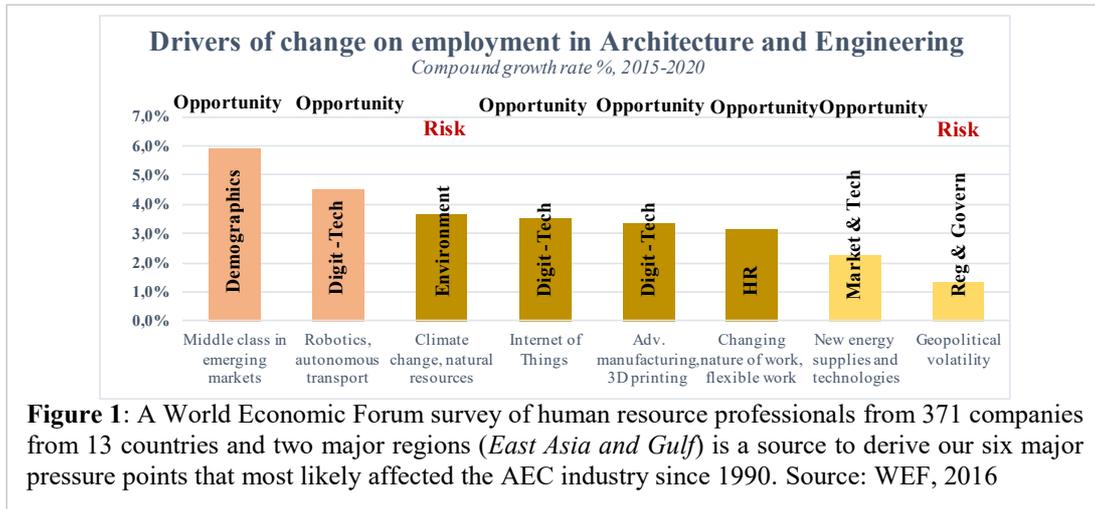
Introduction

Christian Koch attributed the lack of engineers' creativity to the «*Tyranny of projects*», the result of continuous working pressures from structural, organizational, professional and individual sources (Koch, 2004). Jeffrey Russel (Stouffer et al. 2004) concluded similarly by wondering why the “*perception persists that engineers are uncreative, or worse, do not need to tap into creativity when most engineering projects demand creative or innovative approaches in the design of equipment, systems, and facilities?*” Five years later, Gordon Culp (2009) reaffirmed the introverted character of engineers (Culp, 2009), which Holly M. Johnson and Amarjit Singh (1998) had outlined over a decade before. The ASCE Structural Engineering Institute later reaffirmed this finding by underlining that such self-direction – which supports creativity (Rice, 2006) – is one of the soft skills that should be developed by future structural engineers (Damci et al. 2017).

Radical changes were facing engineering management and projects over that same period. The growing productivity and constraining issues facing civil engineering gave way to a wide range of research papers on the future, vision and challenges of the industry since the Great Financial Crisis of 2008 (ASCE, 2006; Boston Consulting Group (BCG), 2016; GFC- Ibbs, 2003; Bin Ibrahim et al., 2010; Peterson, 2006; Russell, 2013; Toor & Ofori, 2008; Zawawi, 2016). This leads us to question: if creativity did not stem from within or amongst the engineers' community, where did the real pressure points come from to explain the challenges and some of the innovation that has transformed the industry?

Based on extant literature over the last fifty years, we found reciprocal forces that influenced and continue to influence and reshape engineering firms around the world. Those forces are driving the infrastructure and urban development (IU) industry with an annual turnover of nearly \$10 trillion and 6% of the world's Gross Domestic Product (WEF, 2018). But even there, “a case can be made for the sector accounting for almost 20% of GDP rather than the 6-7% GDP ... [representing] construction output alone” according to Wolstenholme (2009), if the “built environment sector covers the planning, design, manufacture and assembly/construction and commissioning of built facilities [and] their subsequent operation, maintenance, refurbishment, deconstruction and re-use”. Construction 2020 from Australia estimates “that the actual contribution of the construction cluster was roughly double the standard figure, accounting for 14% of GDP” (CRCCI, 2004)

Design professionals are expected to expand at 2.71% over the period, the second fastest growth after computer and mathematical jobs, compared to management (0.97%) and finance (0.70%) (WEF, 2016), while the demand for civil engineers in the US is projected to grow 11% from 2016 to 2026 (US BLS, 2018).



With such trends as a reference point and the dynamics of the system described, we endeavor to explain and better understand the evolution of the organizational transformation and the paths that such changes are likely to open, by attempting to provide answers to the following questions:

1. How have engineering companies really changed in the last generation?
2. What were the driving forces of this transformation?
3. What future trajectories are possible for the creation of a viable model for AEC firms?

To answer these three questions, we have:

1. Set the starting or benchmark point by referring to the context of the AEC industry from the 1990 to the early 2000 both in terms of the economy and industry growth. By doing so, we set the benchmark against which future changes might have occurred after 2010 on three fronts: the organizational firm, its managerial structure and its procurement process.
2. Described the vision of the AEC, civil engineering and infrastructure scenery 20 to 25 years hence, according to the research literature assumptions and projections made between 1990 and 2005;
3. Identified major catalytic sources through a dual approach: a) A micro qualitative review of leading papers on various changes in the AEC/civil

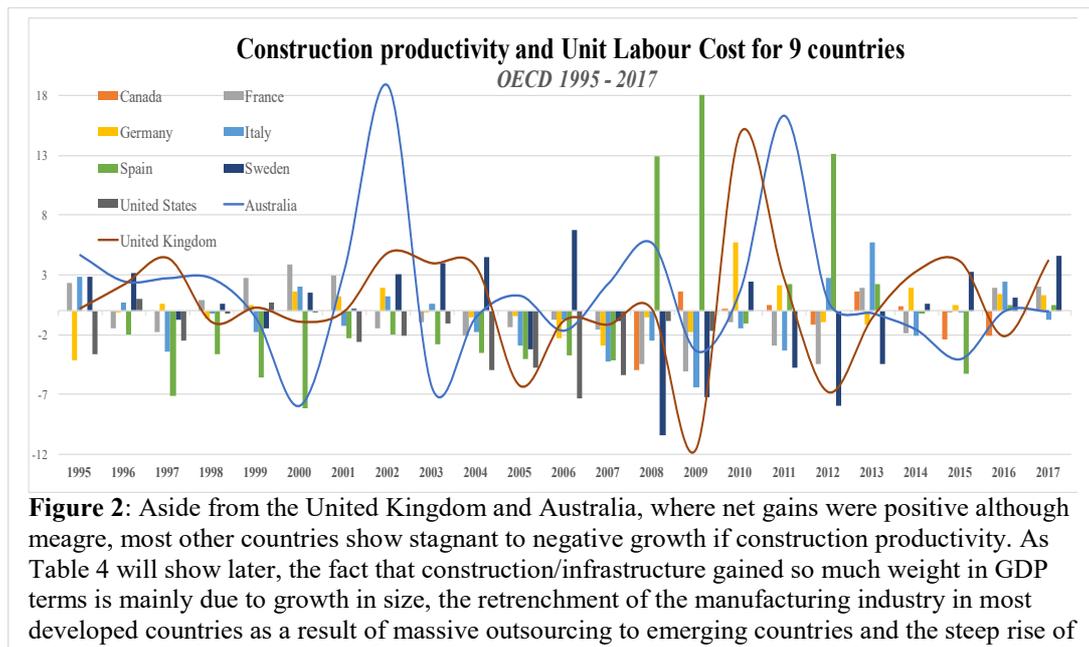
engineering/construction landscape from 2005 to 2016; b) a high level quantitative review on how key-word driven research trends emerged over the 1966-2015 period on ‘Risk’, ‘Finance’ and ‘Market Risk’.

4. Circumscribed the most critical areas of change for the period between 1990-2005 for research assumptions and emerging changes post 2010. This stems both from the review of literature and a dozen semi-structured interviews with executives of engineering firms from Montreal and Calgary.
5. Verified the asymmetries between major research assumptions and key-word evolution over time and the actual industry trends now shaping the AEC industry in 2015, by referring to research on productivity.
6. Carried a survey on risk perception amongst infrastructure professionals attending the 2017 10th Global infrastructure leadership forum staged in Montreal.

Our findings reveal that major changes occurred on three fronts. First, construction engineering is becoming a soft industry, leaving the hard building work to a world of ongoing small to medium-size firms (*SME*) and craftsmen teams increasingly specialized in the mobilization and management local project procurement. Second, the split of the industry between soft horizontal (*SH*) straight-through project servicing and hard vertical (*HV*) work has helped to mature how risk is being managed (*Wolstenholme, 2010 ; Robinson et al. 2016*). Third, new means of decision-making have emerged among large to multinational firms in selecting and managing their projects thanks to a wide range of new technology and intelligence systems.

All in all, AEC firms may have altered their organic form and processes, but little evidence reveals structural changes, as productivity figures don’t seem to have improved significantly since the 1990s around the world, with perhaps the exceptions of the UK, Australia and developing countries (*OECD, 2018; Wolstenholme, 2010*).

The major causes of those three changes are six major pressure points acting as catalysts: technology, finance, environment, market, regulators and human resources with a direct effect on the dynamics of the AEC system and the way risks are being managed and decisions made.



The research begins with a review of literature (*'white' for academic and 'grey' for professional*) covering those topics with the following approach:

Outlining the most recent transformation of the industry prior to the new millennium of 2000;

- Focusing on the market and economic scenery over the period of 1990 through 2017 that propelled the AEC
- Looking at studies projecting future outcomes of the industry
- Concentrating on more specific and micro-oriented research, with a strong emphasis on post 2010 articles, on the various issues and pressure points, which have long characterized the industry or sprung since the late 1990s.

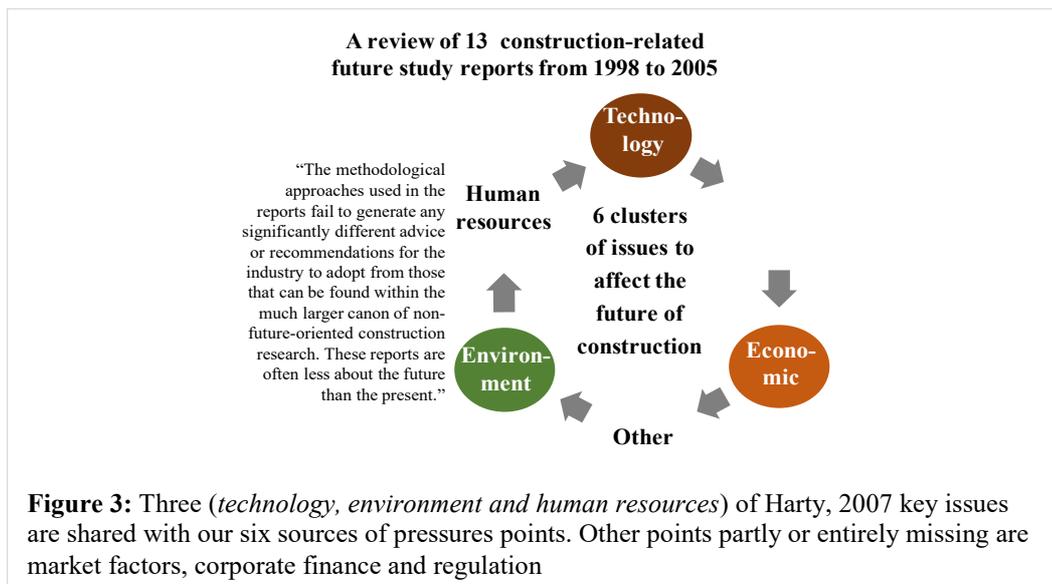
The second section outlines the market and economic scenery over the period of 1990 through 2017. The third illustrates the waves of changes that triggered major transformations by concentrating on more specific and micro-oriented research, with a strong emphasis on post-2010 articles describing each of these pressure points in more details. The fourth section outlines a risk perception survey conducted in March 2017 among 90 attendees of a Global Infrastructure Leadership Forum.

The fifth section outlines the search for the emerging AEC model through new shapes of risk management and decision-making. The last section concludes by discussing key weaknesses of this research and opening new vistas for future investigation.

I- LITERATURE REVIEW, RESEARCH DATA AND METHODOLOGY*

The literature review was divided in three parts:

Leaving aside the Katsanis and Davidson’s H2020 series, the first task was to search for papers that included in their titles the words ‘Future’, ‘Vision’ and ‘Horizon’ in order to capture a wide spectrum of expectations about the AEC industry up to 2020 for a total of 16 papers, including Harty 2007 who reviewed 13 papers (*of which 8 are from the UK*) between 1998 and 2005 and covered a range of issues liable to affect construction in the future. Harty (2007) extracted six major themes: technological, environmental, human, economic, governance and other (*essentially wild cards and major shocks*). Oddly enough, he mentions risk only twice: once to suggest that standardized components could reduce risk and a second time to underline the hazard of integrated supply chains and AEC functions (*AEC*). Such integration does not account for the “conflicting interests and expectations of construction firms and practitioners, and the risks of introducing dependency and exposing core competencies that interorganizational collaboration can produce”. “In reality, Harty adds, integrating supply chains, especially in a consistent way and across a number of



separate projects, is a hugely difficult challenge requiring a significant change in both the practices of the whole sector, and the assumptions and expectations of its constituents (*c.f. Dainty et al. , 2001*).”

1. There is not a single mention of finance and no direct reference to decision-making, either in terms of corporate strategy or concern.

Ten years later, Harty (2017) expanded on construction management research by making only three references to risk and none to finance. Other papers using

* Methodological notes are available in the Apendix.

‘Future’, ‘Vision’ or ‘Horizon’ in their titles rarely refer to risk or finance, as the Table 1 shows:

Table 1: Omission of risk and finance in the future/vision/horizon articles on the AEC		
Research articles	Times used the word of ‘Risk’	Times used the word of ‘Finance’
1. Pennoni, 1992	1	0
2. Katsanis, 1995	3	1
3. Bon, 1997	0	0
4. Katsanis, 1996	2	0
5. Katsanis, 1998	3	0
6. Bourdeau, 1999	3	2
7. Katsanis, 1999	0	0
8. Voros, 2012	1	1
9. Katsanis, 2001	1	1
10. CRCCI, 2004	14	2
11. Chan et al., 2005	3	0
12. Soetanto et al., 2006 (reviews 13 reports from 1998 through 2005)	0	0
13. Harty, 2007 (reviews 12 other articles and reports out of 13)	2	0
14. Davidson, 2009	2	0
15. Borg & Lindt, 2010	14	2
16. Harty, 2017	3	0

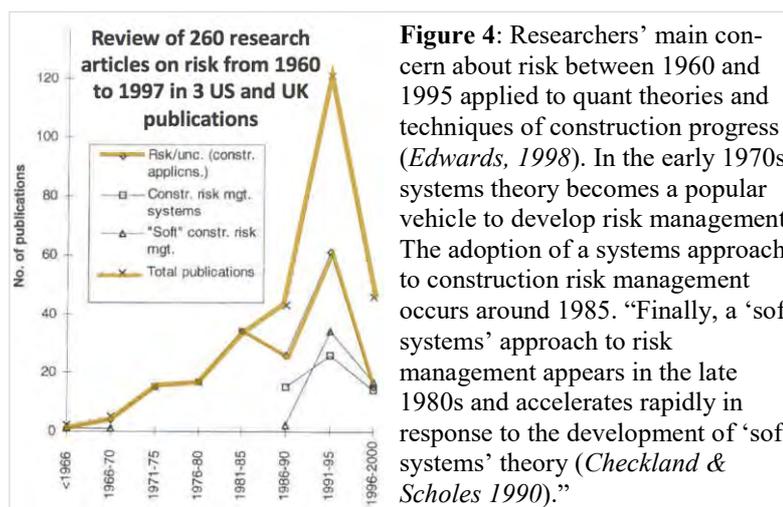
Some exceptions are Lindt and Borg (2010) and CRCCI (2004), though they do not directly reference risk management or market risk for an AEC firm, aside from saying that greater risk should generate greater profit or that risk should be equally shared among project stakeholders. On the other hand, Chan et al. (2005) are the only ones to mention risk management three times by referring to three different reports on the future of construction^{IV}.

This “Future”-oriented literature review shows that AEC organizations, and especially those that rose to the level of nationals and multinationals have grown more complex and diversified with greater changes occurring internally than externally. The changes are as follow:

- a) A swift rise of risk management awareness, beyond technical and logistic factors, took shape on the eve of the new millennium. However, the review of literature about the future of AEC between 1990 and 2010 reveals that risk management is virtually absent from most articles, despite the birth of ‘soft systems’ in the late 1980s (Edwards, 1998).

^{IV} The three reports are: “*The future of the design and construction industry (projection to 2015)*” from the Civil Engineering Research Foundation – CERF, 2000; “*Vision 2020*” from the Construction Industry Institute-CII of the University of Texas, 1999; “*The professionals’ choice – the future of the built environment professionals*” from the Commission for Architecture and the Built Environment-CABE, 2003.

- b) The new role of finance was omitted from the whole future AEC scenery, not only in terms of performance, but as a key engine on the eve of the most formidable consolidation drive in the history of the AEC industry.
- c) An increasingly service-driven industry as opposed to a product one, with all the means required to ensure the appropriate transition. That is where most of the change of culture is happening.



The second task what to verify how the literature evolved over the issues of risk and finance from 1966 through 2017, as shown in table 2. This was done by using two sets of key words: variable ones, such as construction, civil engineering (*CE*) and infrastructure (*infra*), and independent ones, such as 'Risk' and 'Finance' as follows:

Table 2: Applying keywords to 'Risk' and 'Finance' through Google Scholar and ACE library

Combinations linked to the independent keyword of 'Risk'	Combinations linked to the independent keyword of 'Finance'
Construction	Construction
Infrastructure	Infrastructure
Civil engineering (CE)	Civil engineering (CE)
CE and construction	CE and construction

The search covers the period spanning over 50 years with periodizations (*or divisions*) of 5 years apart (*pursuing the model of Edwards, 1998*). In order to avoid various biases of knowledge bases (*KB*), as further explained in the discussion section, two universes were used: Google Scholar (*GS*), the world's largest knowledge base, and the American Society of Civil Engineers' (*ASCE*) Library. The main advantage of such combination is to rely on a much larger generic *KB* (*through GS*) to verify if the trends it reveals are confirmed in the more focused world (*ranging from 12 times up to nearly 200 times*) of *ASCE* as Table 3 shows. The second reason is that the *ASCE* *KB* contains a relatively higher rate of contribution from practitioners. This data analysis approach

enabled us to identify trends in awareness (*measured by size*) and awakening (*illustrated by breakout jumps*), verify dispersion rate of ideas between generalists (*Google Scholar*) and specialists (*ASCE*) and capture the variance of research between the three variable key words according to their breakout years. The awareness or size effect is aimed at measuring the academic reflection of the industry's main concerns

Table 3: Gaps and Trends between Knowledge bases of Google Scholar and ASCE

Comparing the size of two knowledge database on the keyword combination of 'Risk'				
Dependent key-word □	Construction	Infrastructure	Civil Engineering (CE)	CE & Construction
Total Google Scholar (GS) in '000	4622,4	1916,17	616,37	274,03
Total ASCE in units	23747	11450	20096	15373
Multiple = (GS*1000)/ASCE:	194,65	167,35	30,67	17,83
Comparing the size of two knowledge database on the keyword combination of 'Finance'				
Total Google Scholar (GS) in '000	1968,9	1100,9	301,52	144,54
Total ASCE in units	17017	7860	13570	11621
Multiple = (GS*1000)/ASCE:	115,70	140,06	22,22	12,44
<i>Data were tabulated from Google Scholar and ASCE Library on May 2nd 2018</i>				
Comparing the size of two knowledge database on the keyword combination of 'Market Risk'				
Dependent key-word □	Construction	Construction & Infrastructure	Civil Engineering (CE)	CE & Construction
Total Google Scholar (GS) in '000	1882,66	340,47	195,486	132,43
Total ASCE in units	4971	2370	73	64
Multiple = (GS*1000)/ASCE:	378,73	143,66	2677,89	2069,22

Comparing the size of research posted respectively by the two knowledge databases (*KB*) reveals wide gaps between the three independent keywords of 'Risk', 'Finance' and 'Market Risk'. The Google Scholar (GS) KB size ranges between 70 (*under 'Finance'*), 105 (*under 'Risk'*) and up to 341 times larger (*under 'Market Risk'*) that of the ASCE Library. Two reasons may explain such differences. GS is far more generic and covers a much wider sphere of risks than the ASCE KB. On the other hand, most practitioners contributing to ASCE are presumably much closer to CE operations and management than to financial operations and especially market risk considerations.

while the awakening effect (*from a breakout year*), illustrated by a steeper curve, tends to express the retroactivity of research to industry practices thanks to more applied research based on empirical results.

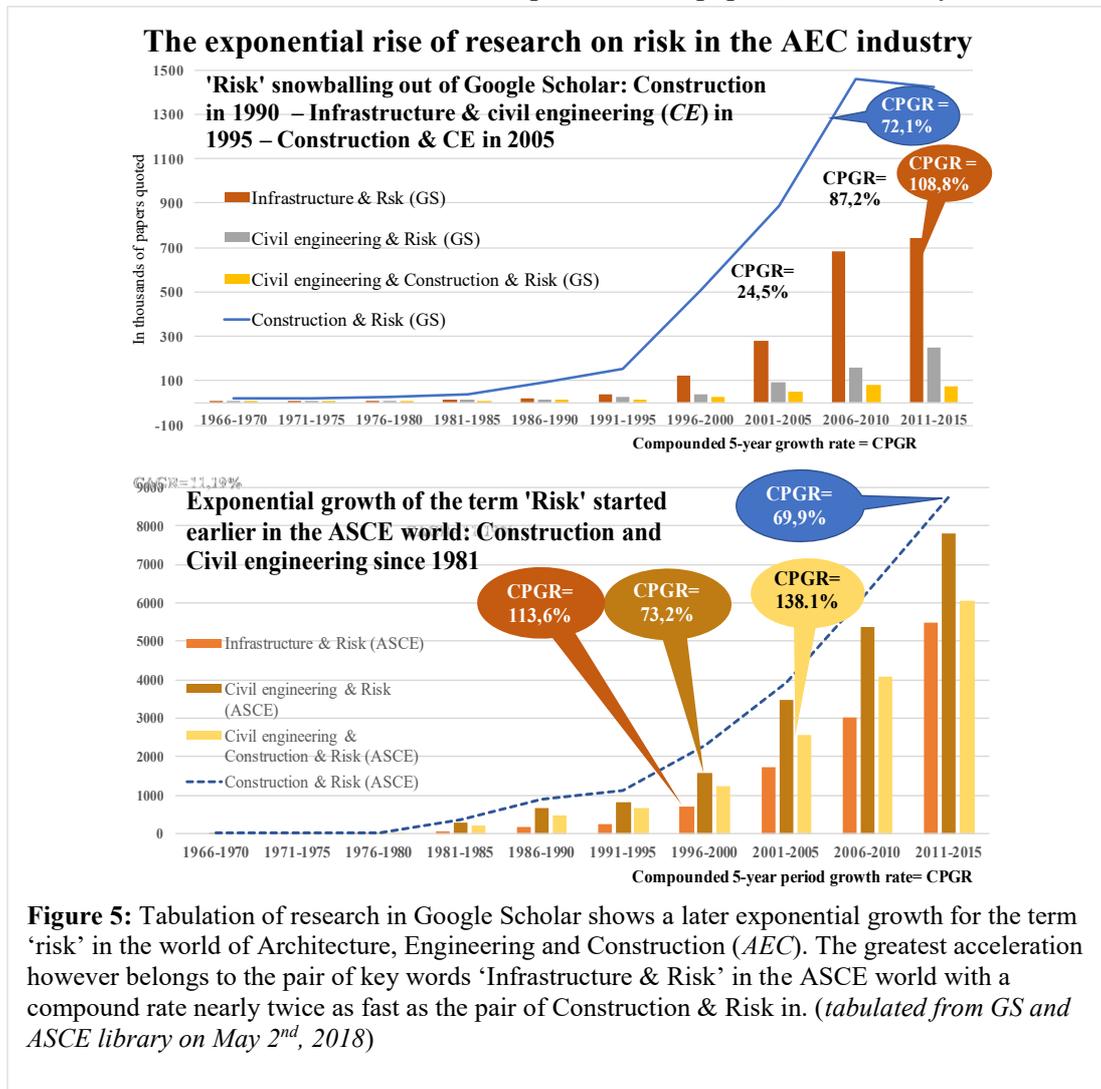
From this search, four major differences appear.

- The ASCE KB appears as a trendsetter by introducing research involving the keywords of Risk and Finance in 1981-1985, 5 to 20 years before the GS KB. However, the GS KB was much quicker to recognized the keyword of "Market Risk", a critical factor in the major industry consolidation that occurred during 1990s through to 2015.
- The steepness (or *CAGR slope*) of the awakening curve is also much higher under the ASCE KB, with the exception of two combinations with 'Finance': Construction and CE. The compounded average growth rate (*CAGR*) aims to measure the real build-up or take-off of research in each KB. The CAGR is calculated to cover a period starting only with a growth disruption or break-out growth in number of articles of around 100% or more from one year to another (*see appendices for further description*), instead of with the beginning of column series in 1966. The CAGR measures the strength and persistence of the influence it may have retroactively on the industry.

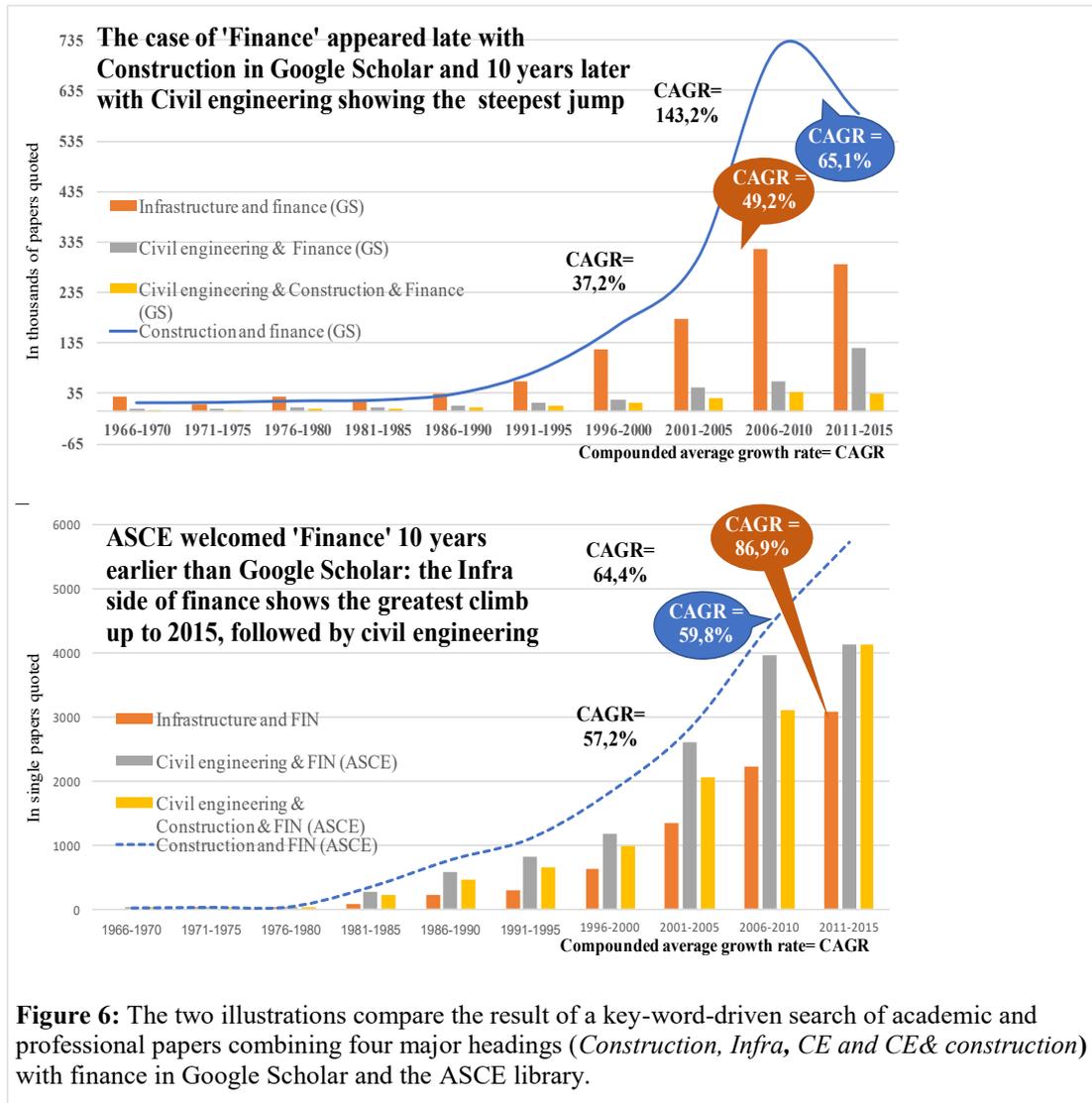
- Third, the dispersion between keyword variables, measured by comparing the standard deviation of volume of research under each combination, is four times greater under the GS KB than under that of ASCE ($\approx 100\%$ versus $\approx 25\%$), except for ‘Market Risk’ where the dispersion rate is only slightly higher (140% vs 121%). This is a reflection of the higher noise level of GS.

If those jumps were not taken into account to estimate the CAGR, the growth rate tabulation would be too linear and would hide the real break-out/takeoff events. Because of the high specialty of ASCE KB, there is little if any variance in the disruptive growth year. By variance, we mean here the variation of break-out years between different pairs. For instance, all four keyword combinations share the same break-out ($1981-1985$) for both ‘Risk’ and ‘Finance’, with the sole exception of the CE-Construction-Risk combination emerging 5 years earlier.

As a significant research key-word, ‘risk’ appeared fairly late in the AEC industry literature. Sampling Google Scholar (=GS), ‘risk’ only takes off in pair with construction after 1986 in academic and professional papers, followed by cascades of



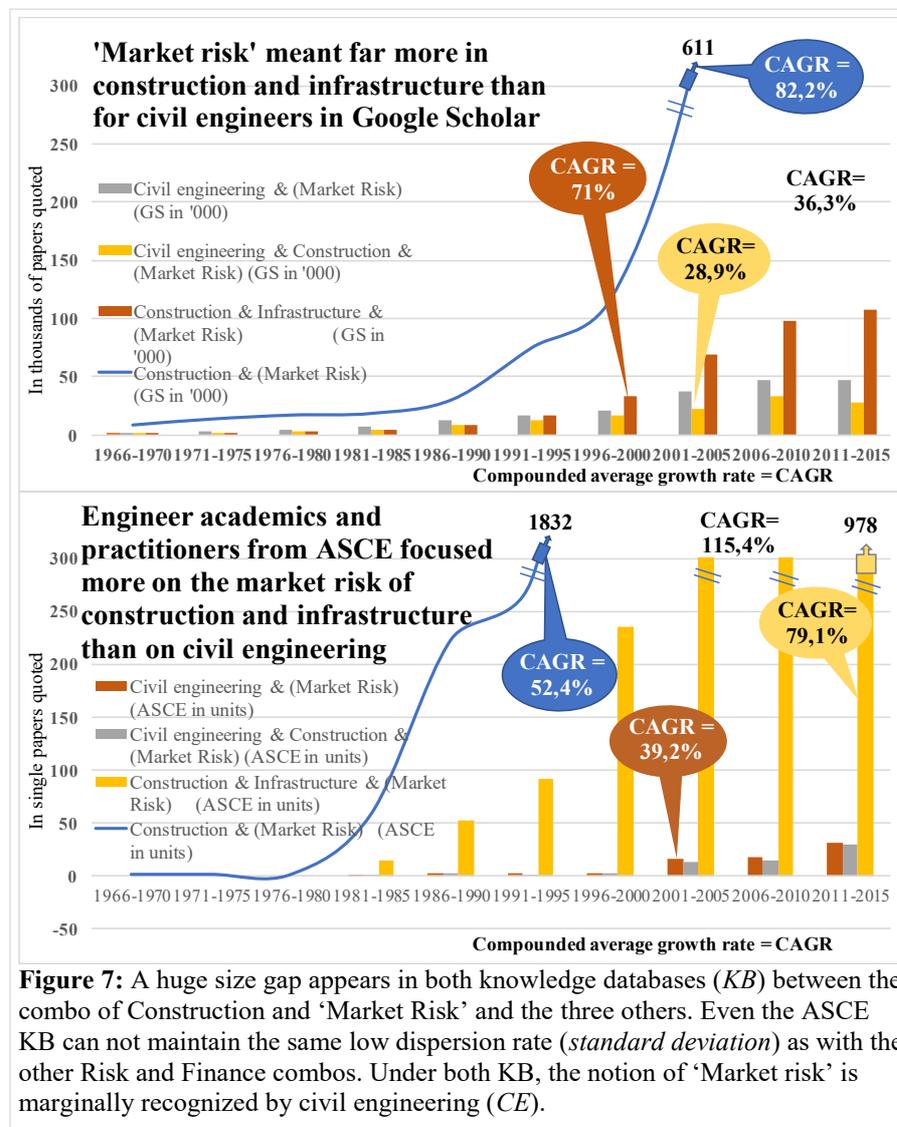
5 years for infrastructure (1991-1995), civil engineering (CE) (1996-2000) and CE & Construction (2001-05), as the applications of risk expand. Yet, research grows the quickest in ‘Infrastructure’ (‘infra’), followed by CE. This corresponds with the emerging logic of ‘risk sharing’ between stakeholders stemming from the birth of the PPP/PFI. ‘Risk’ emerged about 5 years earlier in the much smaller world of the American Society of Civil Engineers (ASCE), with 100 times less references. More focused than Google Scholar because of a relatively higher contribution from practitioners, the momentum between all four headings with risk (*construction,*



infrastructure, CE and the three together) moves far more in tandem with much steeper awakening in infra (CAGR nearly double the construction pair) than for Google. Yet, unlike the Google Scholar census where it comes last in both awareness (*general recognition and knowledge*) and awakening (*discernment and realization*), the trio of CE-Construction- Risk topples the pair of Infra-Risk in volume and records the fastest catch-up of all for combinations due to its earlier start.

Although construction still generates the largest literature around 'finance', the pair of CE-Finance appears as a very late starter (*post 2001*) under the KB of GS but records a sharp awakening ($CAGR=143,2\%$) over the last ten years of the series. This corresponds clearly with the real take-off of the PPP/PFI in Australia, Europe and Canada in the mid-1990s. By contrast, it is the pair of Infra-Finance that topples the other in terms of research growth under the ASCE KB.

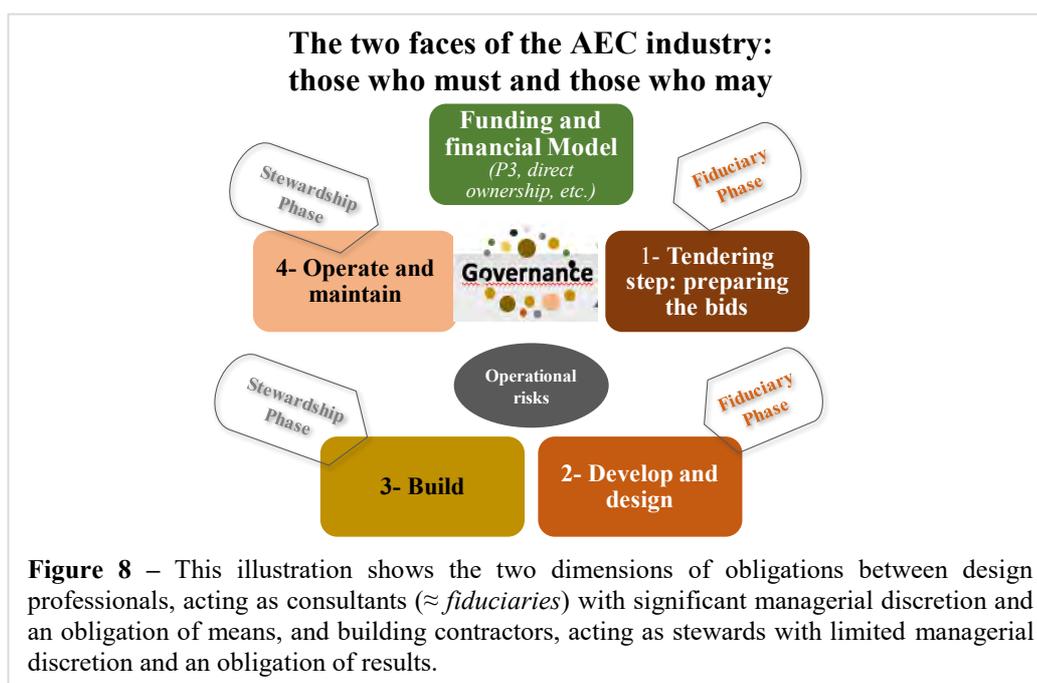
Not surprisingly, the keyword of 'Market Risk' appears strongest with the quickest research awakening under the GS KB, although Google shows a much higher variance between the four combinations with the trio of Construction-Infra-MR breaking out first in the late 1970s, followed by CE and, 10 years later, by Construction and the trio of CE-Construction-MR. This time, Google appears to be the trend-setter, with the ASCE trailing behind in the late 1980s through the early 2000s for the trio CE-Construction-MR and the combo of CE-MR.



2. The third task was to identify emerging new practices that might connect or spring from the six major sources of pressure points. Such a search was driven by various keywords liable to define, expand the use of, explore the opportunities or reveal the constraints that might trigger various applications or derivatives of pressure points. Over 124 papers were found that could elaborate on the various dimensions of strictly exogenous factors. A particular focus was put on the search for papers after 2010. The first reason was to distance those researches from the Future articles on AEC to avoid wide overlaps. The second was to detect two major behavioral derivatives of those pressure points: the decision-making process and the risk management, two endogenous components of the change process of AEC firms.

In light of the H2020 series and the review of literature, here is how each of these six reciprocal forces pressured the industry for a change that is only now emerging:

- a) Mergers and acquisitions, as well as various alliance forms (*Sparkling et al., 2017; Sznewais, 2017; Livingston, 2010; McIntyre, 2018; Morris, 2015; Shen, 2017; Sanderson, 2017*) are accelerating to meet growing competition (*Bhattacharya et al. 2009; Kreitl, 2002; Kenney, 2008; Shuster, 2011*).
- b) Emerging Public-Private partnership and privatization of infrastructures (*Liu, 2016; Lam, 2015; Hall, 2010; Jayasuriya, 2016; Hueskes, 2017; Marty, 2013*) have triggered a major catch-up effect on Grand Public Interest Projects (*GPIP*) by governments around the world.
- c) The rise of new finance (*Saha et al., 2018; Diaz, 2017; Zawawi, 2014; Gray, 2015; Gemson, 2015; Esty, 2004; Smyth, 2017; Whitfield 2016; Whitfield 2017*) has altered the way capital is allocated to the industry and the Modigliani & Miller (1958) view that corporate finance decisions (*between debt and equity*) do not affect firm value.



- d) Rising pressure for improved environmental concern and sustainability (*Olanipekun, 2117; Rao et al. 2015; Hojem, 2011; Koch, 2013; Siew, 2016; Rodriguez-Nikl, 2015; Martinez, 2015; Kajander, 2016, Zavadskas et al., 2016; Yeheyis, 2013*) are combined to introduce brand new practices and risk controls over various procurement stages.
- e) The extension of Design-Built to Finance, Operate and Maintain (*FDBOM*) (*Braun Deshaies, 2012 ; Mogalli, 2016; Berns, 2009; Siew, 2116*) and the integration of fiduciary and credit risks (*Kong et al., 2008; Camilleri & Clarke, 2011; Castro, 2011; Edwards, 2012; Erger, 2012; Gurney, 2014, Kapliński, 2008; Schwarz, 2007*) have expanded the capacity and competitiveness of engineering & construction firms globally, while raising the bar of litigations and transactional cost.
- f) The impact of technology and digitization (*Agarwal, 2016; Bansal, 2012; Bilal et al., 2016; de Laubier, 2018; Rao, 2015;*) against growing constraints of skilled labor gaps and a shortage of engineers (*Fiori, 2003; Green, 2009; Unesco, 2012; Ellis, 2017*) has flattened the classic hierarchy of many organizations;
- g) The regulatory burden continued to grow by imposing new constraints on the industry's behavior (*Abdallah, 2007, Anslow, 2015, Bastianelli III, 2008; Zhong, 2012; Beach, 2015; Schwartz, 2017; Matsuura, 2017, Umeokafor, 2014, EU, 2015, Marques, 2017, Diaz, 2017, Ryan 2012, Nea, 2005, Tao, 2014, Testa, 2011*).

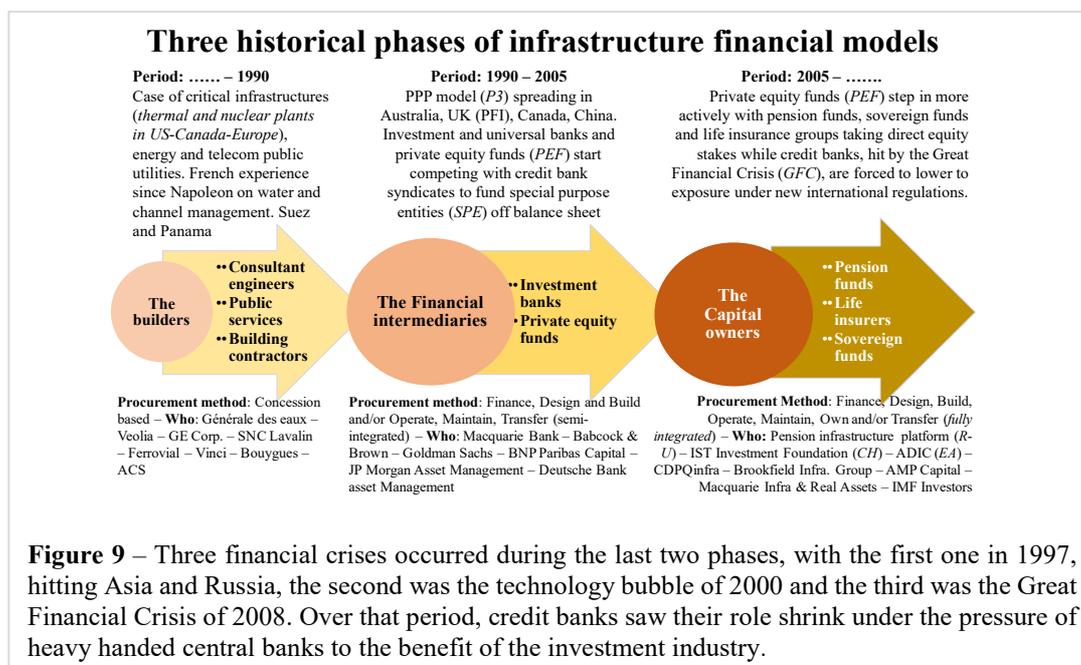
II-PUTTING THINGS INTO CONTEXT

A series of articles under the general rubric “*Horizon 2020*” undertook to forecast the future of directions on the building industry in North America in the 1990’s. The focus of these articles were several key areas such as procurements practices, the diffusion of technological developments, the changing organizational structures as well as influences exerted on these themes from the broader socioeconomic environment. The connecting thread amongst these articles was a systems dynamics approach that examined the interdependencies of these areas based of critical paradigms that prevailed at that time.

In this paper (*with the benefit of hindsight*), the influence that these paradigms on the trajectory of various elements that have shaped the AEC industry over the last twenty years is examined. The AEC industry is viewed as a complex dynamic system subject to prevailing forces that are likely to shape how AEC organizations evolve and transform over the next twenty years.

In this process, the reciprocal influences that technology, various stakeholders, society and government exert on one another and how these influences shape the reorganization of firms, projects, inter-relationships and contractual arrangements (*including offshoring*), business models and practices are considered. The emphasis is placed on the firm’s operations and the role they play on the procurement of engineering groups to infrastructure projects.

Two major cycles marked the growth of the AEC industry over 50 years through to 2017 and shaped significantly its business model under historically high financial and economic pressure, both upwards in the late 1990s and mid 2000s, and downwards, following 2000 and after the Great Financial Crisis (GFC) of 2008



Stagflation and contraction: From 1964 through 1995, when leading forecast studies started in the construction industry, the growth was purely illusory. At the end of 1995 according to the US Census, the annual value of construction put in place and seasonally adjusted reached \$568 billion or roughly 7-times the value recorded when the first US census was held in 1964. However, such spectacular growth had been puffed up by years of double digit inflation in the late 60s and 70s. As a result, once converted into constant dollars, this explosive growth uncovered serious stagflation. Growth proved to be 5 times slower than what appeared in balance sheets, while return on investment narrowed significantly. The profit squeeze *in the early 90s* gave way to various business processes of reengineerings (or BPR) (*redesign of core business processes to achieve radical improvements in productivity, cycle times and quality*) such as Total Quality Management-TQM through the emergence of ISO 9000, partnering and value engineering (*to ensure that required functions are performed at the lowest possible overall cost*). Contractual arrangements (*cases of Jacobs Engineering, Bechtel Group, Fluor Corporation and Washington Group International*) were also reviewed intensely to improve value for shareholders and counter increasing market risks of complex projects and stiffer competition. Economies of scope and scale were gained with the launch of the 5th largest merger and acquisition wave (*cases of SNC-Lavalin, AECOM, Stantec, WSP, Jacobs Engineering, KBR*), while de-consolidation of conglomerate approaches (*case of Fluor Corp.*) was undertaken to improve business focus and net margins. The contracting revenue of the top 250

international contractors reached US\$1430.8 billion in 2014, of which more than one third was derived from overseas.

Share of value added	Germany	France	Japan	Sweden	United States
Manufacturing in 2015	4,94	5,53	5,56	6,26	4,19
Construction. In 2015	23,06	11,53	20,90	15,45	12,27
Professional, scientific, support services -PSSSn 2015	12,91	10,996	7,271	11,197	11,846
Manufacturing (1980-2015)	-22,4%	-53,3%	-25,9%	-36,9%	-48,2%
Construction. (1980-2015)	-33,2%	-28,2%	-40,9%	-2,2%	-17,8%
Construction+25% of PSSS -1995-2015	-20,3%	2,6%	-25,0%	20,6%	1,4%
Share of employment	Germany	France	Japan	Sweden	United States
Construction	-24%	-34,8%	-23,2%	-9,1%	8,6%
Manufacturing	-7,2%	-52,4%	-33,0%	-0,60	-0,50

Table 4: The declining share of value added and of employment in both manufacturing and construction since 1980 across five different types of economic models (*Anglo-saxon, Rhineland, Scandinavian, Latin and Nippon*) is probably the strongest symptom of the des-industrialization phenomenon of developed economies. Yet, when design services are added to statistics, as they account for about 25% of the Professional, scientific and support services of national accounts (PSSS), the fall of construction dwindles and even reverses in France, Sweden and in the USA. The rise of engineering and architectural services has not only slowed the value erosion of construction, in addition to diversifying market risk but contributes to its modernization, as we shall see in part three. This will have a catalytic effect to stimulate servitization (=facilities or real asset management) explains the attraction of institutional money.

Acceleration and global expansion: As overall inflation trickled down (*except for building materials under the pressure of soaring emerging markets*), building activities accelerated. From 1996 onwards and despite the TMT crash of 2001 and the Great Recession of 2008, annual value of US construction put in place and seasonally adjusted more than doubled to exceed \$1.2 trillion on the eve of 2017. The same phenomenon occurred in Canada (*8-fold growth over 1964-1995 in current dollars*) with, however, a much higher rate of acceleration through 2016 (*3.2 times in current CDA dollars vs 2 times in current US dollars*) to reach \$86 billion, as a result of the world commodities' boom in energy, mining and forestry.

Profitability recovered thanks to unprecedented industry consolidation and stronger management controls by financial players such hedge funds and private equity firms, both liaising with their major funders: pension funds that were desperate to improve their return on capital, in light of historically low interest rates, to meet their annuity obligations. The new millennium marked a spell in public listings of construction and engineering firms such as Chicago Bridge, KBR, AECOM, WSP (*the latter through a back-door listing in London*), with a majority of shareholders (*over 80%*) coming from the institutional fields (*fund managers, pension funds and mutual funds*).

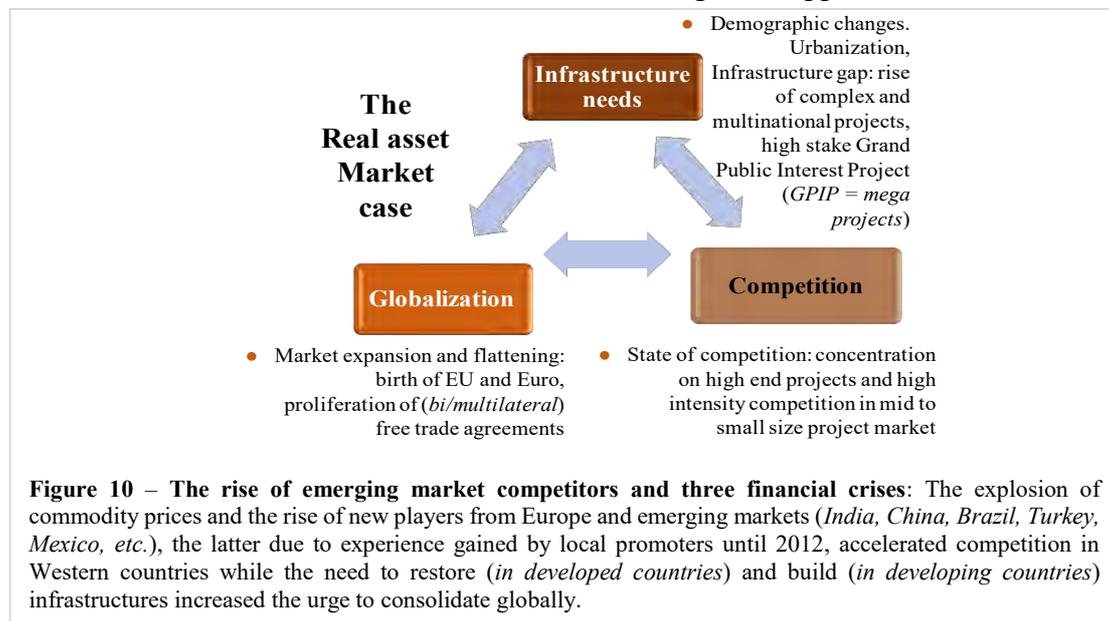
This tremendous push from finance and the snowballing growth of P3 projects around the world opened the door to increasing AEC integration with the emergence of service-led construction, which extended the Design-Build approach to Maintenance and Operate.

The original forecast of innovation through new IT facilities (*the World Wide Web only appeared in the mid-1990s*) underestimated the trend that paved the way to lean construction, building information modeling (*BIM*), Big data management and virtual design and construction (*VDC*).

III- WAVES OF CHANGE

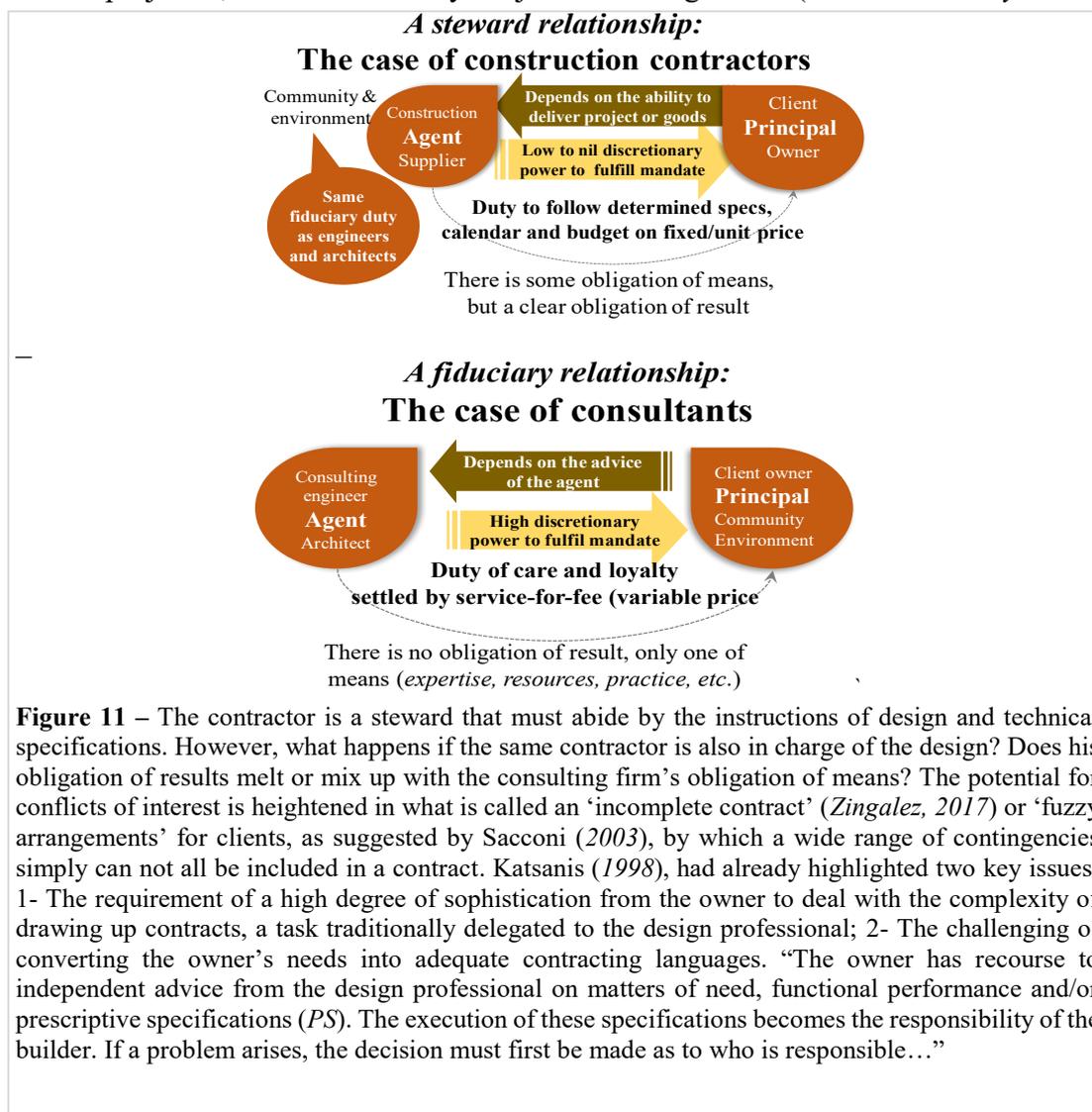
The **Real Asset Market** case involved three dynamic components:

First, the wave of **globalization** following a series of bilateral and multilateral free trade agreements triggered by the birth of the European Union and the Euro currency by the turn of the millennium (*Wong et al. 2010*). The three major financial crises of 1997, 2000 and 2008 incentivized AEC firms to seek greater opportunities abroad. The



international design firms (*IDF - mainly engineering consulting firms*) saw their revenue triple from 2003 to 2011 and reach nearly \$58 billion (*Jiang et al. 2016*). Design firms from Europe, America, Canada, Australia, Japan, China, and Korea control 95% of international market share. Yet, the market remains fairly competitive, with high concentration levels registered mainly among high density sectors (*manufacturing, hazardous waste and telecom all sharing a concentration rate in excess of 50% among 4 leader IDFs*). The case of 10 mega infrastructure projects by the Hong Kong Authorities in 2008 shows that joint venture partnering can lower market concentration for smaller and active contractors.

For occasional (*and larger size*) contractors however, forming JVs increases market concentration. Kreitl (2002) shows that joint ventures (*JV*) accounted for only a fraction of consulting engineers' growth over the 1990-1998 period, unlike what the Rolodex approach in *Horizon 2020* series had projected, except for small and partnership firms that used JV (*yet for only 4% to 13%*) as an easier step towards virtual consolidation around a single project. The reluctance to use JVs or an alliance mode, according to Kreitl (2002), was due to the higher risk perception of JVs by survey respondents. Nonetheless, Ingram (2016) notes a “growing use of joint ventures and alliances to deliver projects”, a fact that many major consulting firms (*BCG, McKinsey, Bain*



Capital) confirms today. It remains difficult to say which of the construction or engineering firms are taking the lead in the M&A play. Shuster (2011) outlines the fact that FMI corporation, acting as a merchant bank in the AEC field, recorded in 2010 alone that construction firms took over engineering firms in 11 percent of the M&A cases, whereas 9% involved engineering firms taking over construction firms. Market risk was the main driver, recalled a director of FMI Corp. Michael Landry: “If you lose money in one section, you can make it up in another activity” (Shuster, 2011).

The supply side of countries eager to restore or build their infrastructures intensified this competition and fueled a significant rise of commodity prices worldwide. While the infrastructure market dropped significantly after the 2008 financial crisis, the momentum persisted across developing countries until 2012.

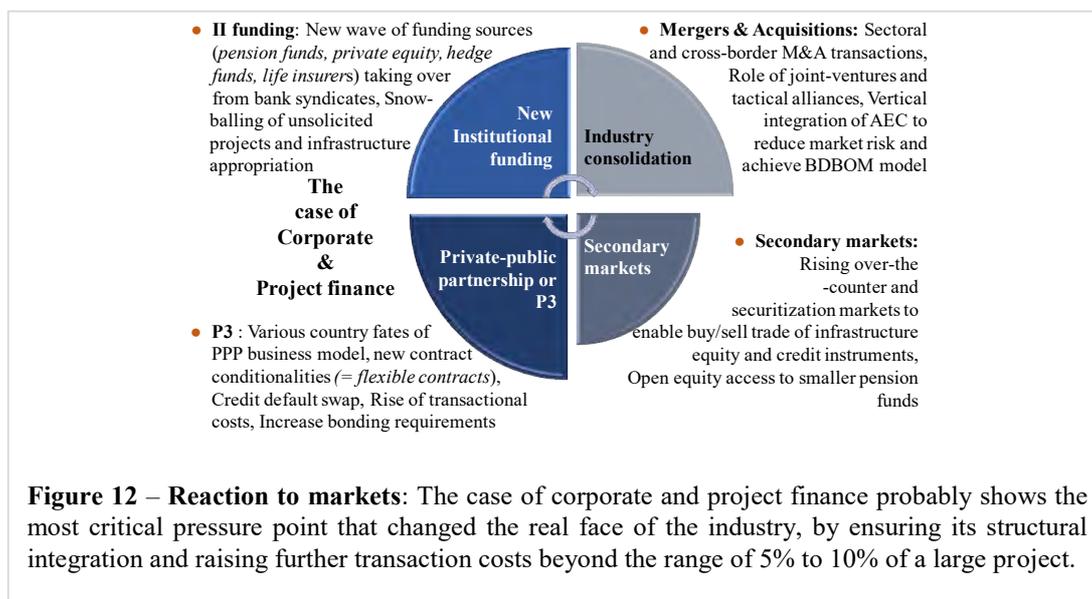
Second, the case of **Corporate and Project finance** is the most critical pressure point that helped most transform the AEC industry.

Consolidation – The combination of regulatory and commercial pressures in a rather low economic cycle of public expenditure triggered a major consolidation wave worldwide with little organic gains overall (*Lu, 2014; Choi 2004; PwC 2015; Bleßmann 2012*). Three major waves of mergers and acquisitions (*M&A*) marked the period of the 80s, at the start of the new millennium and after 2010. From 1995 through 2017, some 33,208 AEC companies changed hands around the world, mainly in industrial countries, with a cumulative value of \$758 billion. Over 2000 companies changed hands since 2010 (*Mullen, 2016*) for well over \$400 billion. Of the total, civil engineering leads the pack and 40% of mergers and acquisitions (*M&A*) were powered by private equity institutional investors instead of more obvious strategic partners from the industry. Whereas North America remains the largest market in absolute size, annual compounds growth of global *M&A* was the highest in Asia-Pacific (*annual compound rate of 27% vs 13% in Europe and 10% in N. America*). In Europe, most of the growth happened during the 1990s amongst the top 100 design firms where staff increased by 120% and turnover (=sales) by 170% (*Kreitl, 2002*), with listed companies (=PLCs) showing the greatest increase (*average of ≈ 250% in staff and ≈ 270% in sales*). No wonder that nearly half (≈ 49%) of PLCs' growth was attributed to *M&A*. Short of securities that could be used partly as means of payment for an acquisition, smaller unlisted companies and partnerships relied on *M&A* for only 10% to 28% of their expansion.

Unlike other manufacturers, where process and systems overtake cultural and ethnic factors, the degree of multiculturalism (*cultural aspects and personal issues*) of a target company is far more attractive to a service firm, such as architectural and engineering firms, than to a manufacturing one (*Kreitl, 2002; Pablo, 1994; Pablo, 2004; Greenwood, 1994*) because of the much higher contribution of people than systems to sales and profits.

On the contracting (=stewardship) side, *M&A* were much less popular for four reasons. First, because they

brought little change (19% according to a survey of 1000 IT executives by Ingram, 2016), except in France (41%). Second, because multiculturalism is already present but has no effect on the business development side. Third, because contractors are ‘job companies’ with little medium to long term financial rent, unlike design professionals (Leiringer, 2010). Fourth, because they represent the greatest source of systematic risks within the Architecture-Engineering-Construction (AEC) triangle for any investor.



The case of three North-American engineering groups is a good illustration of the consolidation wave that propelled so many firms. Most of those M&A waves, especially the second and third waves, were funded by large institutional investors that merely accompanied their investee firms by matching their equity share for each new acquisition. These consolidations became the major stepping stone for international groups to expand their services and move into a fully integrated supply model of Finance, Design, Build, Operate and Maintain (*FDBOM* or what is called *DBOO*, the last *O* for own), without – in a growing number of cases – any option to transfer an infrastructure to the public authorities.

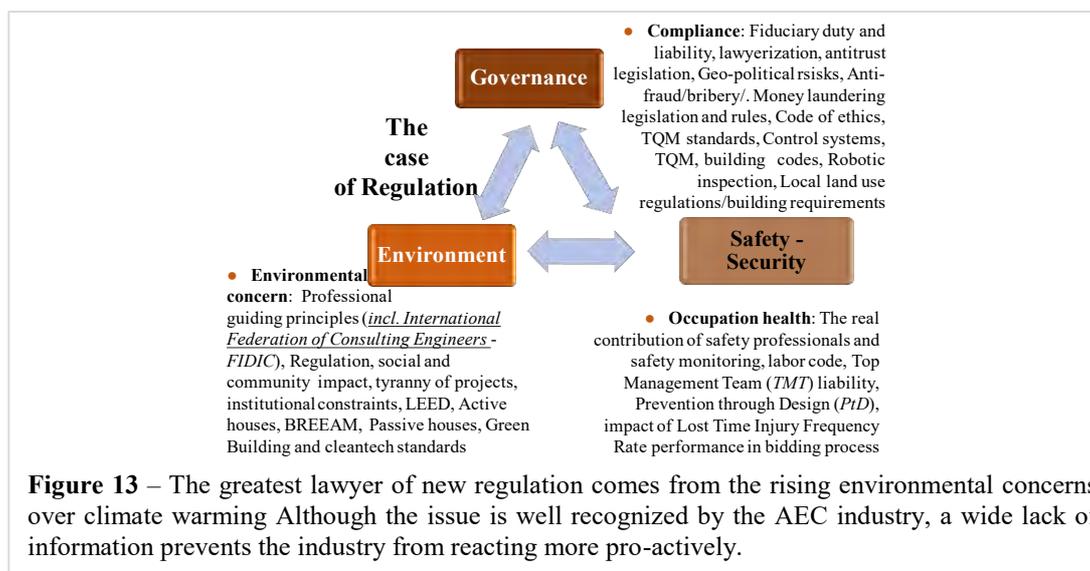
Engineering firms World rank <i>ENR-2016</i>	Turnover in USD billion		Net profits in USD millions <i>MultipleMultiple</i>	
	1995	2015	1995	2015
Fluor Corp. - 15 th as contractor	9,3	18,1	232	475 = 6
WSP(ex-Genivar) - 1 st as designer	0,13	4,5	17,4	441 = 25
SNC Lavalin - 41 th as contractor	1,03	9,6	31,3	404 = 13

Table 5: Sources : annual reports, Bloomberg, « *M&A International Inc. Infrastructure Construction M&A : Opportunities in Adversity* », M&A International, August 2010, « *US Engineering & Construction Sector (E&C)* », Steven M. Fisher, UBS, August 2011

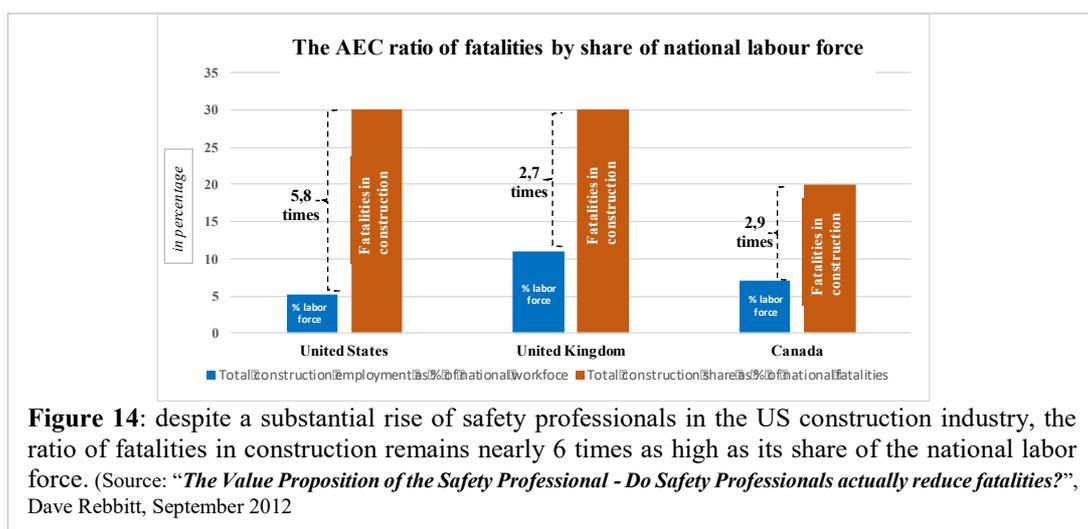
Institutional investors’ funding – Aside from investing heavily in the AEC industry, pension funds, life insurers, sovereign funds and university endowment funds started to invest into infrastructure projects, either through private equity funds (*PEF*) or directly through a growing number of unsolicited projects (*Hodges and Dellacha, 2007*), including Grand Public Interest (*and often complex*) Projects (*GPIP*). Across developing economies, up to 23% of PPP projects were unsolicited, “which raises some concerns about transparency in project selection. Lack of competition in contract award, in the form of direct negotiations, is also prevalent in the energy sector (33%) and among projects in low-income countries (39%)” (*World Bank, 2016b*).

The rise of this new finance is a sort of a relay, inasmuch as those new players took over from credit bank syndicates who could not afford anymore to sustain such high level and long duration projects on the basis of their shareholders’ funds. Although credit banks are still involved in infrastructure finance, their role has shrunk to one of seed or bridge money for an initial period until long term capital can be secured by project promoters. This growing financialization of engineering explains why reputational risk (*Di Guardo, 2016*) has gradually overtaken most other corporate hazards on the eve of the largest infrastructure refurbishing about to take place in history across OECD countries.

The build-up of the P3 market – The Private-public partnership market started in the early 1990s with the Built-Operate-Transfer model in Australia and the Private finance initiative in the United Kingdom. Although P3 models varied significantly around the world with no clear standard recognized (*World Bank, 2016b*), the wave took off around 1995 to reach its peak in 2008, at the height of the GFC in the UK and most developed countries. However, it continued across emerging markets with a post 2012 slowdown, including in Chi



Over these 25 years, investment commitments totaled \$1.5 trillion in over 5,000 infrastructure projects in 121 low- and middle-income countries (*World Bank, 2016a*), which enabled the top five countries (*Brazil, China, India, Mexico, and Turkey, whose market share of those investments varied between 81% in 2009 and 51% in 2015*) to forge and propel their own procurement industry on the international market. Hence, the P3 momentum triggered the real take-off of the PEF at the turn of the millennium and more actively since 2005.



The rise of a secondary market – The ability for pension funds, PEF and sovereign funds to exit projects at an advance or operational stage came with the emergence of an over-the-counter market, off official stock exchanges, in the UK. In practice, institutional investors don’t need to wait anymore until a project is completed or becomes fully operational to liquidate their investments. Thanks to the growing popularity of infrastructure investing or what is called the ‘real assets’ investment class, there are enough investors in the market to take over the shares of those who need to exit for all kinds of reasons (*finding of a better opportunity, re-allocating their portfolio of assets, needing liquidity because of a corporate event, etc.*). This ‘curb’ or ‘over-the-counter’ market, away from established stock exchanges, has grown significantly in size to allow smooth exits at reasonable transaction costs. The density of the british PFI market and marketability of medium size projects eases the possibility of offering pieces of projects to third parties either directly, from hand to hand via a dealer, or by securitizing units of a project, the same way as other credit instruments (*mortgages, car loans and credit card liabilities*) are being offered by banks to institutional investors eager for higher yield opportunities than classic bonds. From 1998 through 2016, equity stakes in some 980 special purpose entities changed hands for an estimate of \$ 20 billion (*Whitfield, 2016*). Based on 110 transactions involving some 277 infrastructure projects, the average yield stood at 28%, a slight drop from 29% for the period of 1998-2012. No wonder the Finnish project of Fortum Oyj in energy distribution managed to be sold for €2,5 billion in March 2014 at a multiple of 18 times its gross revenue before interest, taxes, depreciation and amortization.

The case of **Regulation and Governance** has left much less visible scars on AEC. Three areas are mostly concerned:

The environment – Environmental hazard is where regulation has increased the most since the turn of the millennium, especially as carbon emissions are concerned. It was found that a more stringent environmental regulation in AEC, measured by inspection frequency, provides a positive impulse for increasing investments in advanced technological equipment and innovative products and on business performance. Moreover, a well-designed “direct regulation” appears to be the most effective policy instrument for prompting the positive impact of environmental policies on innovation and intangible performance, while economic instruments do negatively affect business performance (*Testa et al., 2011*). On the other hand, the 1990 Amendments to the Clean Air Act on the U.S. Portland cement industry have significantly increased the sunk cost of entry, leading to a loss of between \$810M and \$3.2B in product market surplus (*Ryan, 2012*). Multilateral environmental accords, such as the late 2015 Paris climate agreement, and several recent legislation pieces and regulations [*the Canadian Environmental Assessment Act of 2012, US update of the Toxic Substances Control Act in 2016 - Bearden, 2013*] had a double and deep effect on compliance practices. While new and stiffer enforcement rules impose increasing cost on both risk control and operations, wide new business opportunities have emerged for environmental engineers involved in infrastructure construction.

Occupational health, safety and security – Safety hazards (*OHS*), the industry’s most vulnerable flank with close to 100.000 fatalities (*Zhou 2013, Zhou 2015, ILO 2015*) per year around the world, is falling under increasing scrutiny both by public authorities and private industrial owners. Construction accounts for one in every six fatal accidents recorded at work annually (*ILO, 2015*). Further, the ILO estimates that the construction sector in industrialized countries employs between 6% and 10% of the workforce but accounts for between 25% and 40% of work-related deaths (*Lingard, 2013*). In industrialized countries, construction workers are 3 to 4 times more likely than other workers to die from accidents at work. In developing countries, the risks associated with construction work are estimated to be 3 to 6 times greater than in industrialized countries.

Fatal injuries in construction dropped in the US from a little over 1200 in 2006 to less than 800 in 2011 but have moved back to 937 in 2015 according to the Bureau of Labor Statistics, despite a fast rising population of safety professionals. The industry that complains most about over-regulation in OHS is the offshore oil and gas operators. Such bolt tightening, illustrated by the new culture regulators want to implement (*Kim, 2016; Sakurai, 2012*), the new European Construction (*Design and Management*) Regulations 2015^V (*CDMR*) and the international harmonization effect (*Eastern Europe, Middle East, Africa, Asia-Pacific and Latin America*) of the EN Eurocodes^{VI},

^V Replaces the CDM 2007 regulations and aiming to put a greater onus on the clients to think earlier about health and safety matters on construction projects and to encourage those with design responsibility to take better ownership of health and safety matters when schemes are first conceived, by solving the concerns whereby CDM coordinators were often perceived as peripheral with limited impact on design decisions, particularly at an early stage of the design process (*Anslow, 2015*).

^{VI} The En Eurocodes, mandatory since 2010, are the ten European standards, developed by the European Committee for standardisation, specifying how structural design and other civil engineering works

is spreading across the world, feeding a shadow economy (*Chancellor;15*) and affecting directly pre-qualification tender criteria that engineers and contractors must attain to win business. Such pressure combines with the growing integration of three ISO standards, 9001 (*quality management*), 14001 (*environment management*) and the new ISO 45001 safety standard (*previously known as occupational health and safety assessment series - OHSAS 18001, 1999 updated in 2007 to become obsolete in April 2021*) implemented in June 2018, by medium and large size AEC firms^{VII}. Most smaller to medium firms will simply meet public owners' minimum requests for a 9001 standard of quality management, which also doubles up as a basic risk control mean^{VIII}. Some relief came with electronic building permits and mobile inspection technology reducing approval rate by 30% and on-site inspection time by 25% (*WEF, 2018*).

Oddly enough, the greatest pressure for disclosure over occupational hazards performance comes from the private owners and industrial clients rather than from public-owned organizations or governments. According to several contracting sources, the cost of a fatality on a building site (*work stoppage, inspection period, recovery delay, insurance premium, litigation, etc.*) has become too high for the industry to bear. Another important reason outlined by lawyers and standard auditors is that an ISO certification lowers the liability of a firm by demonstrating that it took the necessary means to instill the right culture and prevent unsafe misconducts, even though its compliance system may not be adequate. One important reason is that a much larger share of variable cost contracts comes from the private sector (*specially the industrial one*) while most, if not all public-sector awards are made on fixed terms, under the lowest bid approach. Fixed price contracts transfer a much greater burden of risks to contracting firms than under variable cost arrangements, where owners bear a higher share of risk. Under such conditions, private owners are eager to exert a higher control on risk management. And since OHS ranks amongst the highest critical factors for a construction project (*Alzahrani 2013; Puri 2014*) and ranks first for all metrics in operational risk disclosed by the ACE industry, several metrics and disclosure formats such as the Total recordable injury rate (*TRIR*), lost-time incident^{IX}, personal injury frequency, dark rate, lost Workday Rate (*2 previous meanings under the US*

(geotechnical aspects, structural fire design, situations including earthquakes, execution and temporary structures) should be conducted with the EU with some 58 parts.

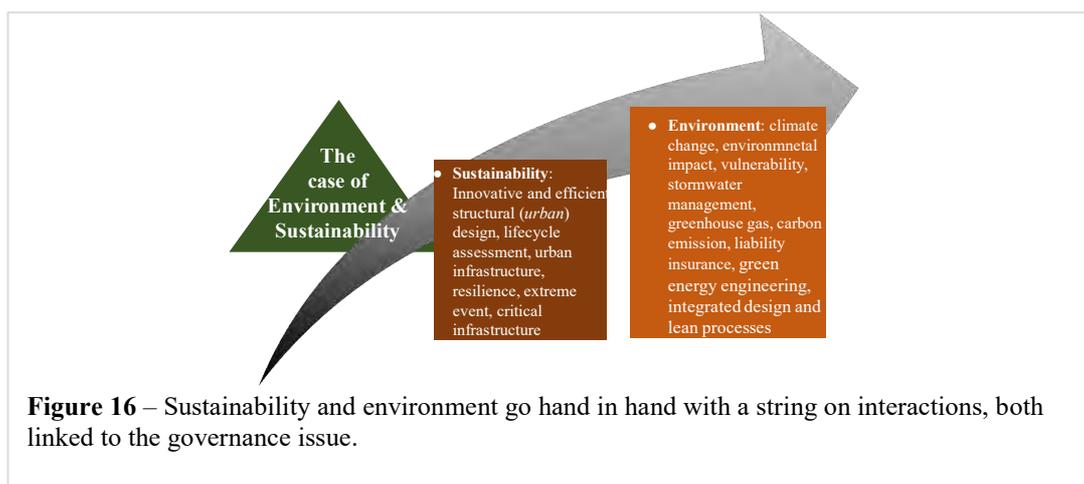
^{VII} The 45001 standard is easier to implement than the previous OHSAS 18001 because of the upgrade of the 9001 and 14001 in 2015 from a process-based approach to a risk-based one. Those changes contributed to lighten the new standard, which is now expected to grow faster. As a general rule, most OHSAS 18001 AEC firm already has adopted the 9001 and 14001 standards. In Canada, SAI, which records 4000 OHSAS 18001 clients in North America, estimates the share of construction firms to be about 25% among a wide range of sectors (*Manufacturing, forestry, agriculture, etc.*). As for the share of all construction firms adhering to the OHSAS 18001 standard, it is estimated to be more or less 10%, concentrated among middle and large size companies (*from semi-structured interviews by the authors*).

^{VIII} Interviews with small size engineering firms in Montreal, Canada by O'Neil 2017, which one of the present authors attended, confirms such practice.

^{IX} The lost time injury frequency rate (*LTIFR*) is calculated using two numbers: the LTI within a given time frame, and the amount of hours worked in that time frame. For example, the LTIFR is calculated as follows per 1,000,000 hours for a quarter: 5 lost time injuries were recorded last quarter, and 1,584,391 hours were worked on construction sites. Then a) $5 \times 1.000.000 = 5.000.000$; b) $5.000.000 / 1.584.391 = 3.15$, meaning that there were 3,15 lost time injuries every 1.000.000 hours worked last year.

Occupational Health & Safety Administration - OSHA) and fatality rate for direct and contract employees, are now required for pre-qualification purposes.

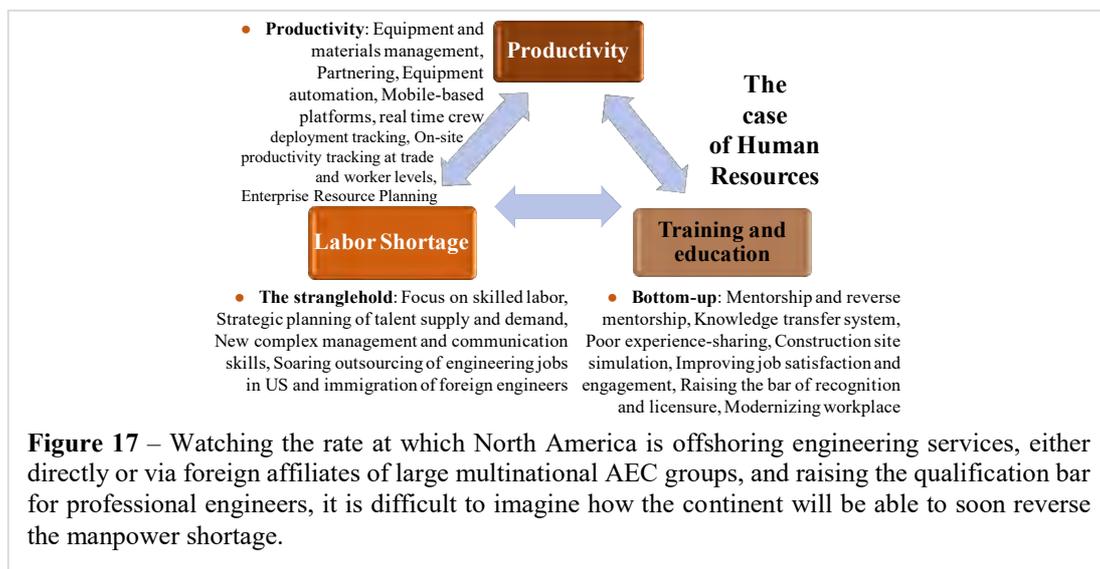
Compliance – The board of directors and Top Management Team (*TMT*) responsibility of large AEC corporations has grown significantly following the waves of mergers and acquisitions and cross-border expansion. As this section will demonstrate, the integration of fiduciary and stewardship models of design and contracting operations is making governance more complex and confusing with regards to the liability of the organization. The old model of pure consulting play, where the accountability of engineers could be well distinguished against that of contractors, has faded with the increased integration of consulting and contracting activities, fewer niche players and more sector diversity to reduce market risk (*Ye 2017*), creating more confusion in the market between the trusteeship and stewardship of large international groups.



To some extent, such melding could be compared with the 1999 abolition of the US the Glass-Steagall Act to allow credit and investment banks to merge. The design fiduciaries (*the investment banks*), who regulate themselves through their professional code of conduct, merged with contractors (*the credit banks*) supervised by straight building codes, thus blending two different sets of culture, attitudes and risk management systems. Although the AEC industry complains about growing regulatory constraints, 26% of professionals feel that governments remain a most influential driver of innovation (*Ingram, 2016*), after customer demand (*including the State as a client*) and insider C-level officers. A case in point is the UK government, which is prioritizing BIM as part of its Digital Britain initiative (*Ingram, 2016*). Moreover, Loosemore (2014) argues that construction is a compliance-based sector with a long-tail of low performing firms which must be encouraged to change through regulation and legislation by prescribing minimum standards with incentives to innovate.

The case of **Environment and Sustainability** remains a major sticking point in the AEC industry, because of the “tyranny of the projects” or “project-based thinking”, as Koch (2004) suggested. As Berns et al. (2009) remind us, sustainability seems to change the AEC industry more than the industry is changing sustainability. Although the residential and commercial sectors use more than 40% of the US energy, structural engineers don’t seem to integrate sustainability into their choice of structural system.

A survey conducted in Oregon and Washington states by Rodriguez-Nikl et al. (2015) in 2010 indicates an important lack of information was a major barrier, with respondents requesting data that was standardized, current, reputable, and useful in the context of codes and standards. The quick pace of innovation was also identified as a challenge in obtaining adequate information. Results indicate that the client is the single most important influence on what a structural engineer can accomplish.



The case of **Human Resources**: The enhancement of training and postgraduate requirements for recognized professional engineers, together with the resurgence of the infrastructure market in North America are reinforcing pressures on architect, engineer and skilled-labor supply to the point of harming productivity and project delivery.

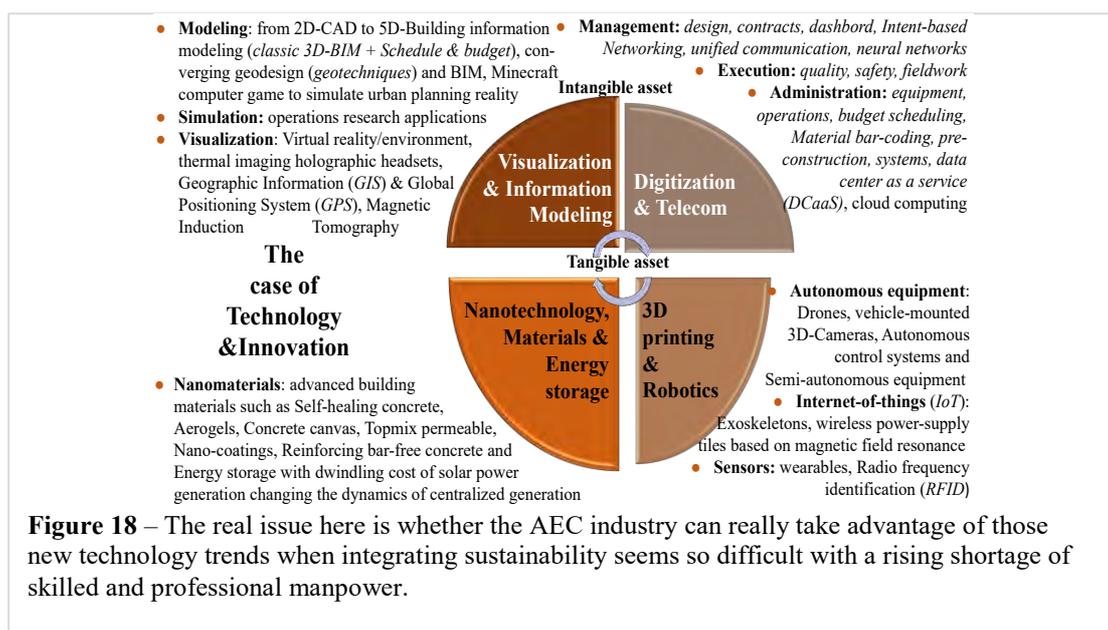
Shortage: The infrastructure and urban development (*IU*) industry, with its main core of engineering and construction, employs about 100 million people worldwide (>22 million engineers). According to the US Chamber of Commerce, 95% of contractors have serious problems finding skilled workforce for their projects in 2017. Reuters ads that the construction worker shortage is at its highest since 2007. The Associated General Contractors claim that 86% of building firms aren't able to cover their severe workforce needs. Worse still, 56% of US contractors express doubt about the reliability of their current workforce because of a lack of training. The United Kingdom hard-to-fill vacancies have more than doubled since 2011. The industry has an entrenched gender gap, with women accounting for a mere 13% of the overall workforce and even less for senior management positions (*WEF, 2018*), even though such 'jobs in the construction industry can be done by women' (*Ness, 2012*). The share of employees who are aged 60 and older is increasing faster than any other age group while the share of employees under 30 is falling, according to the World Economic Forum (*WEF, 2017*). The workforce hovers around the 40-70 age bracket (*Ingram, 2016*).

Training and education: The popular perception of the industry has remained very low, with 11% of people in the UK viewing the industry as 'exciting' (*WEF, 2018*). Less than half of young workers and employers think education providers do an

adequate job of preparing people for entry-level positions in the infrastructure and urban development industry. Stouffer (2004) reminds us that “engineers are not commonly perceived as creative professionals. A recent Harris Poll sponsored by the American Association of Engineering Societies and IEEE-USA found that “only 2 percent of the public associate the word ‘invents’ with engineering; [and] only 3 percent associate the word ‘creative’ with engineering” (Bellinger 1998; Wulf 1998)”. “To remain competitive with international institutions and engineers, Stouffer adds, U.S. colleges and universities must foster creativity in their faculty and students... Incorporating creativity into student assignments promotes teamwork, communication, knowledge retention, ability to synthesize and make connections between courses and fields, and a smooth transition from formal education to practice.”

Productivity: Rising cost pressures and constrained R&D budgets are driving the offshoring service trend. The global engineering services outsourcing (ESO) market, of which construction is still a tiny but fast growing part, is expected to reach USD 1.49 trillion by 2025, according to Grand View Research (2017). Companies prefer to outsource the service as it enhances efficiency, improves processes and lowers time to market products. On the tech-side, many AEC firms have begun incorporating new construction technologies into their daily activities, but most of their efforts only focused on software tools for digital collaboration. Such narrow interest can be explained by the struggle they had to wage to deploy new tools at scale with limited impact. The modest returns they’ve earned so far make these companies reluctant to explore additional productivity-enhancing technologies, especially those requiring substantial investment (Blanco, 2017). The McKinsey Global Institute (Woetzel et al, 2014) argues that innovations such as value engineering, standardized designs, and prefabricating components could encourage productivity and reduce construction costs by about 30% worldwide

The case of **Technology and Innovation:** A question of great importance is : Can the AEC industry truly profit from the tremendous technological breakthroughs that have occurred over the last 10 years given the shortage of professional and skilled labour, and poorly informed and ill equipped sustainability measures ? A case in point is Arditi’s claim (.) that techniques and especially foreign technology developments had little if no bearings at all on productivity. Four major areas have opened the door to a technical reshaping of the industry:



- Digitization and telecom:** IT and data center delivering the right service, at the right pace, from the right provider, at the right price. Intent-based Networking involving pieces of networking software helping to plan, design and implement/operate networks and improve network availability and agility. **Unified communication integrates** mobile devices, remote devices, on-board devices or various information bits on these devices to amplify the productivity of today's 'Always-connected' and 'Always-collaborative' environment.
- 3D printing and robotics:** Sensors to monitor traffic patterns, detect accidents and diagnose structural weaknesses, with video devices monitoring construction/operation sites, embedded devices and sensor wearing, wearable devices acting as amplifiers to augment, reinforce or restore human performance and prevent accidents and insure safety. Driverless trucks used at highway construction sites, as in Florida, or automate hauling, dozing and drilling as in mining and agriculture.
- Nanotechnology, materials and energy storage:** To replace traditional materials such as concrete, cement and asphalt, which make up most of the building demand. Nanomaterials are superstrong, ultra lightweight materials that can be substituted for steel reinforcement in structures and foundations, though still in a research stage. Induction Tomography and other geophysical technologies are rapidly improving the capability to "see" underground. These technologies will improve with the result of high quality underground surveys and cut into the riskiest part of any tunneling or excavation project. For instance, the hyperloop (*hyper fast low pressure transport modes*) projects in Canada, the US, Europe and China will rely heavily on

tomography as well as on geotechniques to reduce the need of large and high-risk excavation and foundation work.

- d. **Visualization and information modeling:** This is to assess design and project major infrastructure projects in a 180° model via “mixed” or “augmented reality”, as Bane NOR with St-Gobain did in Norway to familiarize the public way before the project start, or for planning complex medical and industrial projects. Geodesign involves design and planning methods that tightly couple the creation of design proposals with impact simulations informed by geographic contexts – BIM implements a continuous use of 3D digital CAD model over the full life cycle of a project - from design, through the planning and execution to operation and decommissioning.

IV- HOW INFRASTRUCTURE PROFESSIONALS PERCEIVE RISK

In order to connect the review of literature with the perception of practitioners, a survey, coupled with semi-structured interviews, was conducted in March 2017 among of the 10th Global Infrastructure Leadership Forum held in Montreal. The questionnaire (*see appendix 2*) was sent by e-mail and delivered by hand to 340 attendees. Out of the total, 90 responded providing a reasonable sample of 26%.

Engineering and construction firms (*E&C*) formed the largest group with 34%, with consultants second, owners third and financial institutions (*'funders', either commercial banks, investment banks or portfolio fund managers*) fourth among respondents. Survey participants served mostly North America, followed by Asia-Pacific and Europe (*see appendix 1 for details*). In terms of activities, transportation led the majority of respondents followed by oil and gas, electric power and social infrastructures. Operators of more than \$1 billion led the way while funders with less than \$5 billion responded most.

The main results of such soundings were as follows:

Rising risks on 2020 horizon: Political risks lead by far, followed by competition, market conditions and environmental constraints.

Most critical risks oversight in P3 model: Time and budget overruns rank nearly twice as high as the other critical risks

Leading contract models by 2020: The Design Build Finance Operate and Maintain (DBFOM), three times more than any other following model. The trend is very clear, with increasing suspicion towards traditional P3 and a rising preference for unsolicited infrastructure projects perceived to be easier to manage and control.

The fate of Greenfield project risks: Stable with a fair trend to rise, which confirms World Bank statistics.

Performance over the last 3 years: Less than half performed budget and timewise between 90 and 100% of the projects they handled.

Riskiest type of client: Public-owned organizations or Governments, yet the least sensitive client to occupational health. Indeed, the private owner sector is seen as extremely sensitive to health and accident hazards in project management, because of potential extra cost, delays and litigations.

Table 6 – Professionals projecting their favorite business model for 2020 through the survey. The integrated real asset management is voted the most popular.

5 Leading contractual models by 2020

- ▶ 65% **DBFOM** – *Design – build – finance – operate – manage*
 - ▶ 25% **BD** – *Build and design*
 - ▶ 22% **EPC** – *Engineer-Procure and Construct*
 - ▶ 21% **DBFO**
 - ▶ 19% **DBB** – *Design – bid – build*
- Key respondents are Funders (67%) with equally shared trend by E&C, Consultants and Owners (53-56%)
- Key respondents are Consultants 10% Funders 4% EC 9% Others 4%

Rising risks:

71% Political risks – *Change of government, unclear strategy /planning, protectionism, regulation* – with fair trend (22%) towards stability. At the time of the survey, the greatest uncertainty lied with the new presidency of the United States. Consultants were the most worried (>88%), followed by engineering and construction (E&C >60%), funders (≈60%), public /private owners (59%).

56% Competition – *Dwindling fees, more players, stiffer award conditions* – with strong trend towards stability (38%).

51% Market conditions – *Economy, volatile price of commodities/materials* – with great trend (42%) towards stability.

41% Environmental – *Increasing regulation, constraints and public reaction* – with strong trend (35%) towards stability.

Stable risk but rising trend:

48% HR recruitment (*craft labor/project manager*) with nearly as high probability of rising trend (46%). The greatest worries came from E&C and consultants (52-53%) and least (42%) from funders.

44% Excessive funding (*chasing too few good projects*) with strong trend to rise (37%) with widely shared concern by all sides (41-44%)

Stable risks:

54% Financial estimation forecasts with trend to rise (35%). The greatest concern came from consultants ($\approx 60\%$), followed by owners and funders (50%) and least worried (41%) by E&C.

49% Corruption and fraud with strong declining (33%) trend. Here, the greatest worries over persistent (=stable) trend came from funders and owners (50%) with less pessimism from E&C (stable at 41%) and more optimism from consultants (declining at 41%).

Table 7 – How professionals perceive operational risks on site of an infrastructure

Critical risks	Type of most critical risks on site						Aggregate HIGH priority (4+5)
	Aggregate LOW priority (1+2)	Low priority-1	2	3	4	High priority-5	
Project delays, budget overrun	2,53%	0,00%	2,53%	8,86%	12,66%	73,42%	86,1%
Construction, technical, project mgt and complexity	6,33%	2,53%	3,80%	18,99%	31,65%	43,04%	74,7%
Design, implementation, commissioning, decommissioning	10,25%	1,28%	8,97%	26,92%	19,23%	42,31%	61,5%
Operations and maintenance	16,46%	1,27%	15,19%	27,85%	34,18%	21,52%	55,7%
Environment	20,78%	1,30%	19,48%	25,97%	28,57%	24,68%	53,3%

Declining risks:

37% Insufficient funding with great stability (40%) trend. The greatest worries about persistent (=stable) shortage come from clients/owners with declining trends recorded by funders (42%), consultants and E&C (35-37%).

Overall, two major approaches appear for risk management. The first is a proactive stand, practiced by most respondents (88%), to try to uncover as many sources of risks as possible, with the strongest focus coming from owners and consultants (71-73%), followed by E&C (58%) and funders (47%). The second is a more reactive stand. Among those professionals who don't try to chase all forms of risks, 58% (mostly engineers and construction practitioners) focus rather on the weakest links of their organizations to prevent risks from hurting both project management and bottom line.

V- WOULD THE NEW AEC MODEL PLEASE RISE – A SYNTHESIS

Despite formidable sources of pressure, innovation within the AEC industry remains so far limited to management reshuffling, business consolidation and light telecom and digitization changes, especially in the area of OHS. Although 44% of firms claimed to be digitally enabled in 2017, their business was in fact a laggard in the adoption of digital technology and approaches to working, with 55% identified as 'exploratory', 'enhanced' or 'optimized' (IFS, 2017).

Twelve cases studies were drawn to illustrate the business models of major publicly listed AEC firms in Canada, the US, the UK, France and Australia. Those companies, operating in over 150 countries, had a total personnel of nearly 600,000 and combined sales of USD \$153.6 billion stemming from a book of orders of USD180,3 billion in 2015. Those cases are the answer to the apparent contradiction between sudden growth and poor technology integration. Here is how McKinsey (2014) shows why the Chinese construction industry failed to take full advantage of technology advance:

- a) The fast pace of infrastructure development, backed by pouring innovative financial and investment products, kept profits and thus, complacency high, just like what happened in the UK. “For the last decade, the industry has been sheltered by a healthy economy. This has enabled construction to prosper without having to strive for innovation” (Wolstenholme, 2009).
- b) According to the World Bank (2016), some 530 PPP projects were undertaken between 1990 (\$173 million) and 2013 (\$7.67 billion) in China.
- c) Excessive regulation of the industry and its supply chain, which discourages innovation and pushes AEC firms back to standard practice. Unlike western countries, specifications go as far as detailing the types of material to use and their level of thickness.

Table 6: Business model and profile of 12 major engineering groups

Companies	Leadership/ specialties	Home country	Personnel	Presence # countries	Sales	Orders	Shareholders' equity
<i>All amounts in Euro, Canadian and Australian dollars were converted in million USD as of December 31, 2015, except for Australia where the fiscal calendar of Lendlease terminated on June 30 of 2016</i>							
Aecom	World leader in architecture-engineering	USA	92.000	150	18.000	40.200	3.631
Aecon	Energy – mining infrastructure	Canada	12.000	3	2.095	2347	517
Balfour Beatty	Infrastructure	UK	34.000	10	10.293	16.280	1.228
CRH	Materials, procurement	Ireland	89.000	31	25.488	ND	14.628
Eiffage	Infrastructure/concession, construction	France	11.785	70	15.012	12.312	4.750
Fluor Corp.	Oil & gas, pharmaceuticals	USA	38.758	> 80	18.114	44.726	3.113
IBI Group	World's 8 th largest architectural group	Canada	2400	11	235	263	-11
Lendlease	2 nd AUS engineering firm - property	Australia	30.000	12	11.165	15.318	4.154
SNC-Lavalin	1 st CDA engineering firm, infrastructure, nuclear (Candu)	Canada	36.764	50	6.903	6.366	2.005
Stantec	Energy, water	Canada	15.000	6	1491	8.842	952
Vinci	Concessions, property	France	185.452	> 100	41.580	29.916	16.476
WSP	1 st CDA pure play engineering firm	Canada	34.000	40	3230	3743	2030

The review of twelve international firms over a period of 20 to 50 years aimed to capture their shifting values across time and the key factors that led them to establish risk management processes following rapid growth and major compliance defects. (Source: company financial statements, various financial analyst reports)

FEATURES OF THE EMERGING MODEL

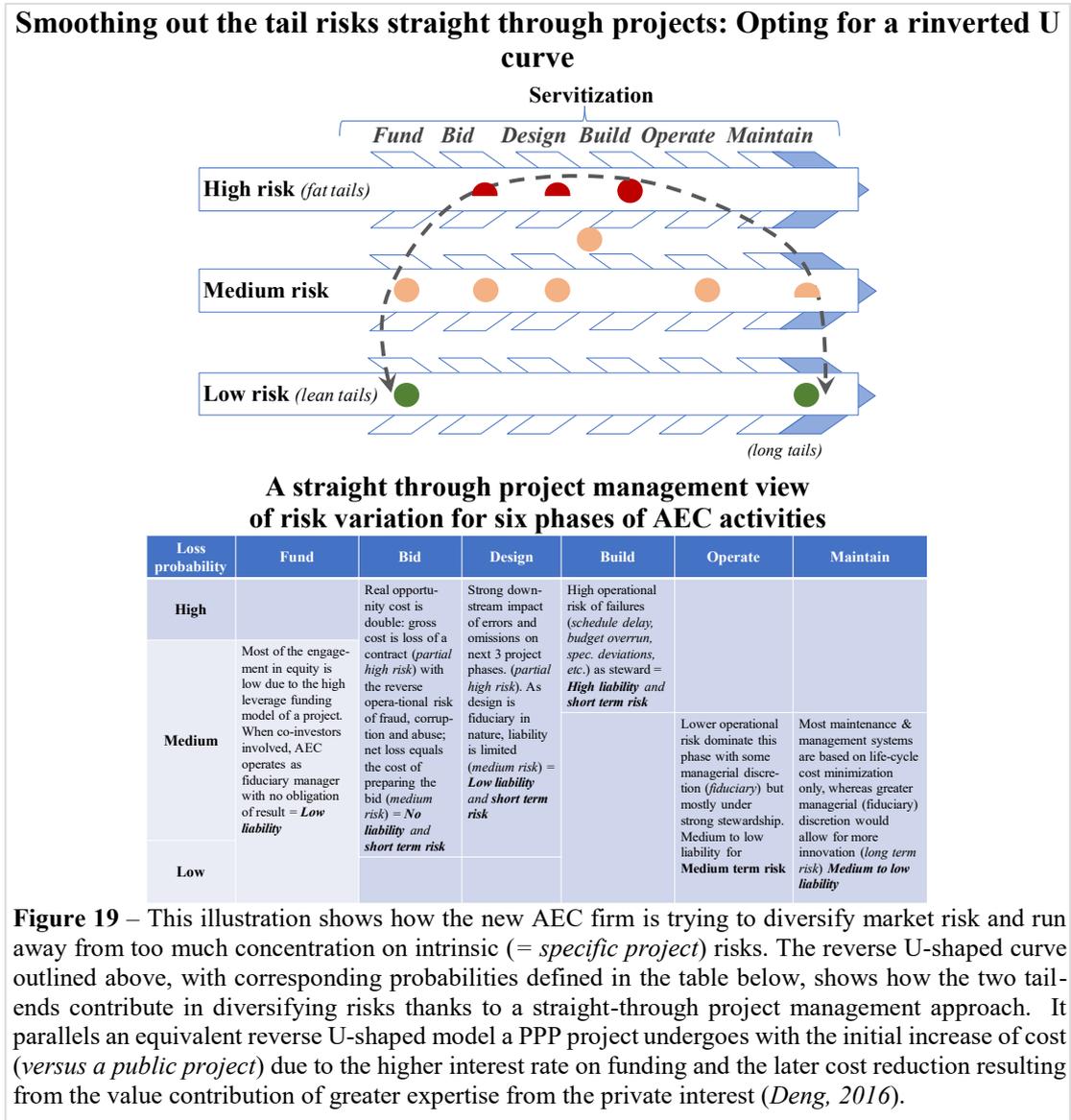
The key features of the new AEC enterprise are thus as follows:

Integration and hierarchy:

from flat, agile and loose networks (*partnerships and joint ventures*) of the 1990s, the new design firm has become integrated into a more diversified organization. The US trigger in the 1980s of the design-build (DB) procurement model gained tremendous ground over nearly 40 years. Already, an analysis by Konchar (1999) showed that out of 351 real estate projects, 23% had moved from the design-bid-build (DBB) approach to the transition stage of construction management at risk (CMaR) and 44% had jumped the wagon for the design-build (DB). A unit cost comparison indicated that the DB method cost 4,5% less than CMaR and at least 6% less than DBB. From 1985 through 2000, the market share of DB over the traditional DBB approach grew from 12% to 35%, while the CMaR model jumped to 13% in 1990 but then dropped back to 10% and remained flat until 2015. From 2000 onwards, DB finally caught up with the classic DBB at 45%-45% in 2010 and then took the lead with 50% in 2015, according to the Design-Build Institute of America. Later on, a study (Altus, 2007) made for Infrastructure Ontario in 2007 went further by showing that the Design, Build, Finance & Maintain model squashed the traditional DBB approach for the owner in terms of risk.

- a. The design coordination and completion risk dropped to almost nil with an absolute transfer to the project company;
- b. Compared with a drop from 132.8% to 46.1% for life cycle and residual risk;
- c. And from 51.5% to 0.3% for operational risks (*technological obsolescence, quality and unanticipated operating costs*) of the base cost (the operations portion of the contract for this category).

Fernane (2011) reviewed 77 public university buildings in the United States to find that DB projects significantly outperformed DBB projects in terms of Contract Award Cost Growth, Design and Construction Schedule Growth, Total Schedule Growth, Construction Intensity, Construction Change Order Cost Growth, and Total Change Order Cost Growth.



Transactional costs have increased significantly from the traditional public procurement (TPP) to the PPP, to a point where the rise of unsolicited infrastructure projects coincides with a growing reluctance from AEC firms and their institutional funders to participate in open bid for PPP (De Schepper, 2015, Rahman, 2010). This is the new attitude of sovereign funds and major private equity players in infrastructures. A recent case is that of the Réseau Électrique Métropolitain (REM) in Montreal, Canada, to be owned, built and operated for an estimated price of CDN6.3 billion by the Caisse de dépôt et placement du Québec, a para-provincial government sovereign fund, which has the option but no obligation to exit the project company or to close a

line that may not be profitable enough after 5 years and gave a buy-back option to the Quebec government after 50 years of operation.

The greatest influence the six pressure points have had on AEC firms is on the risk management, deriving from a very strong rise in risk awareness since the new millennium as a result of three major financial crises, and its subsequent decision-making process, which increasingly mix together on key options and strategy building.

Our findings reveal that the most critical areas of changes happened on three fronts:

First, the organizational model has changed and is increasingly represented by integrated consolidated firms operating from end to end, from financial targets to design, building, operations and maintenance. In short, construction engineering has become a soft industry leaving the hard building work to a world of ongoing small to medium-size firms and craftsmen teams increasingly specialized in the mobilization and management local project procurement. However, as several studies of Lu (2014), Jewell (2014), Ye (2015) outlined on the various aspects of diversification and consolidation of the AEC industry, such integration remains loose and the diversification strategy, both in terms of activities and subsidiary acquisitions, hardly entail full symmetry and full fledge synchronization among units of the same group.

Second, the split of the industry between soft horizontal (SH) and hard vertical (HV) work has helped to mature how risk is being managed. While corporate consolidation and systems integration enabled large and multinational enterprises (LMNE) to diversify their intrinsic (*specific project*) risks and adjust more comfortably to systemic (*market*) risks, much less change seem to have occurred amongst small to medium size enterprises (SME). The traditional frontier between what used to be identified as pure play (*strictly design engineering or strictly construction*) and integrated play is fading thanks to the extension of activities both upstream (*by getting involved in project finance*) and downstream (*in pursuit of servitization way beyond operations and maintenance*), which contributed to smooth out intrinsic fat tail risks (*where moderately extreme outcomes are more likely to happen than what might otherwise be expected from a normal risk distribution*) in construction. (Wolstenholme, 2010; Robinson et al. 2016).

Third, such straight through project management approach is both a defensive act against high-end market risk, which characterized the 1998-2015 period of three major financial crises and instability and an offensive mean to compete on a more globalized market. If the organic and structure of the upper middle and high-end of the industry changed, not much seems to have happened on the process side. Otherwise, total factor productivity measures would have signaled more gains in added value. What really changed are new means of decision-making that emerged among large to multinational firms in selecting and managing their projects thanks to a wide range of new technology and intelligence systems. This is where the process side has changed most, either within organizations or on site. Among new decision-making most significant tools are the building information modeling, a pure digital technology advance coupled with data management and network communication to improve the supply chain management

and the cost effectiveness of various operational phases, and the real options' approach, derived from the options securities market in the 1970s, to provide greater flexibility in managing uncertainty and measure management options and control cost.

FUTURE TRAJECTORIES OF THE AEC ORGANIZATIONS

The future possible trajectories liable to affect further a viable model for AEC firms are:

- a) The increasing transfer of supply chain accountability (=devolution) to small and medium (*SME*) size enterprises to take advantage of their control over human resources.
- b) By extending such control over a wider range of resources of all kinds, *SME* could be able to reduce the concentration of their exposure to high specific risks (*project risk*) by introducing some elements of servitization (*managing people, materials and local facilities during the construction phase*) and diversifying marginally their sources of income. Australia is a good example of such trend (*Bankwest, 2017*).
- c) The shift towards an increasing trend of outsourcing real asset management execution, operation and maintenance by owners and promoters could further reduce resistance to innovation by providing greater discretion to *LME* under the servitization business model (*Ivory, 2005*).

VI- DISCUSSION, FUTURE RESEARCH, AND CONCLUSION

It is difficult to imagine a globalization slowdown, short of major political turmoils, the current model of large to multinational AEC enterprise (*LME*) will most likely pursue its growth trajectory to provide greater diversity of design, build, operate and maintain. However, in the shadow appears an increasingly strong and hungry new generation of stakeholders eager to acquire a growing piece of financial rent from the infrastructure world.

For behind the twelve leading corporations described in Table 6, appear major institutional investors locking in over 80% of equity that are pushing those players to go on expanding. Not unlike the Swiss company Nestlé, which has become an agro-food international investment fund outsourcing a growing share of its manufacturing to third parties, those firms may indeed become a sort of investment avatar, a reverse of the Macquarie model whereby engineers are taking over the investment side to direct project management across a multi-purpose AEC group, with the support of large institutional investors.

In short, via private equity channels far away from the better-known stock exchanges, institutional investors such as pension funds, university endowments, life insurance groups and country sovereign funds, assisted by family offices and hedge funds, will go on privatizing the universe of infrastructures to a point where Special Purpose

Entities will deal increasingly with users instead of taxpayers. The best illustration is the nascent investment funds created by a wide range of AEC firms to ease their entry into mega and complex infrastructure projects. A cautionary tale is that of the case Enron (in the energy industry) nearly 20 years ago, whereby the engineering company operating gas pipelines gradually converted into a financial group that managed and operated various projects from which it extracted a wide range of financial derivatives, with all the conflicts of interest that it involved.

It is also important to consider the risk impact on humans and the environment when assessing the growing trend of financialization and servitization of infrastructure projects. First, as political geographer David Harvey notes (2014), in drawing attention to the rapid rate of development, “concrete is everywhere being poured at an unprecedented rate over the surface of planet earth”.

As projects become prevalent in large international markets (both financial and labor), knowledge transfers and flows of capital, it will become harder to assess the social and environmental impact these developments have on the livability of the urban environment. AEC firms may should consider evolving and developing mechanisms to foster community engagement and consider the impact on all stakeholders implicated in the projects undertaken.

Second, the rise of PPP often muddles the understanding of whether infrastructure and spaces in urban environments are public or private. The larger economic trend of privatization since the 1980s has seen a decline in publicly-owned or ‘common’ spaces. On a neighborhood level, we see this process already occurring through gentrification: building projects and improvements to infrastructure. The proliferation of ‘private’ public spaces, or para-public spaces, such as Google’s Sidewalk Labs in Toronto, malls in cities across the world and increasingly green spaces, results in a grey area where questions of governance, ownership, and land-use become murky.

Finally, an emerging emphasis and excitement with ‘smart city’ initiatives, for which infrastructure projects will be necessarily undertaken should raise concerns about how big data is used by cities, governments and private companies. As new technologies are deployed in public spaces (e.g. Wi-Fi), and innovative uses of already existing infrastructure are rolled out, it will be important to monitor the use of this data.

This article is in part, a postscript on the evolution of the world view on the AEC industry that was presented in a series of Horizon 2020 papers published on the wake of the re-engineering trends, the advent of the Internet, the promising future of Information Technology, the acute awareness of the fragmentation of the AEC industry with its ensuing impact on productivity and the wave of globalization in the late 1990s by Katsanis and Davidson when the industry was only starting a major consolidation. Nearly a generation later, a review of over 120 research papers summarizes the various pressure points liable to further alter the model of the AEC firm and provides a new perspective on likely trends. The AEC industry has become a true real asset investment class with its own financial markets and exchange platforms to a point where it has bent classic theories of structured capital and finance via the Special Purpose Entity

vehicle. Risk awareness has become a key driver of decision-making across the industry, as it was observed by the first author during the 10th and 11th Global Infrastructure Leadership Forums held in Montreal in March of 2017 and 2018. The survey staged in 2017 already pinpointed some key directions in terms of servitization and risk perception. And though a wide range of new technology tools have appeared since the new millennium, the jury is still debating the value of their specific contribution to productivity and key performance.

In order to advance the research already presented in this this article the following areas research have been identified:

- a) The quantitative census from the Google Scholar and ASCE knowledge databases (KB), although quite useful to detect mega-trends in research, needs to be fine-tuned to include a wider range of concerns such as: ‘mergers and acquisitions’, ‘project finance’, ‘decision-making’. Furthermore, it would have been more meaningful for researchers to describe the core concerns expressed under each 5-year cascade to provide a sort of epistemological vision. This could have helped to measure better the current gap that prevails between the main academic preoccupations and the actual industry practice. Sure enough, both KBs are technologically biased by the limits of paper digitization and the legacy of the WorldWideWeb that started in the early 1990s. Even though both KBs continue to expand their coverage by digit-mining earlier years, what counted most for this research were the periods post 1990 and the wake-up (=breakout) trends that the two KBs uncovered.
- b) A better synchronization between the quantitative census of research and the combination of semi-structured interviews and survey with practitioners might have contributed to shed more light over the time gap between the academic and professional worlds. It remains indeed difficult to estimate the time difference between prevailing ideas and innovations, both managerial and technical, in academic research and their implementation by the industry. Such asymmetry might explain the weak relevance of many Future/Vision/Horizon papers about what really happened some 15 to 20 years later.
- c) Greater correlation should be tested between decision-making and processes used and the changes that occurred organically and structurally in the AEC industry, with more focus to differentiate design and construction professionals.
- d) Better impact differentiation and evaluation could be made on the new AEC model between the six pressure points and their key components. For instance, did regulation influence more changes and adaptations of the AEC model than market forces and economic conditions? What is the real contribution of technology? How about the growing shortage of manpower?

One major lesson of what happened over the last 25 years is the grave neglect academics have shown towards the intrusive role of finance across the AEC industry.

Further study should also be carried out to distinguish the effect of fiduciarization (*the shifting of obligations of results into obligations of means*) on the AEC industry, on the assumption that design professionals (*the fiduciaries*) are taking over the building activity (*the stewards*) to secure a wider share of the rising attraction of the built-in/infrastructure economic rent.

New research should also look into the tremendous waves of mergers and acquisitions in order to attempt to establish an optimum balance of power between contractors and design professionals. As new roles are expected to ensue from increasingly large institutional investors the question is posed whether the new financial models are having an impact, positive or negative, on the new built environment, the sustainability of our infrastructures and the physical and economic welfare of individuals and society.

The case of Enron should never be neglected nor under-estimated, as its shadow casts dangerously over the future of the industry. Much research is needed in order to better understand the intersection of the domains of engineering, procurement, construction, markets and finance if one wishes to comprehend and effectively manage the dynamics of the forces entrenched in these domains. to be done, but this is where our new AEC model has led us to.

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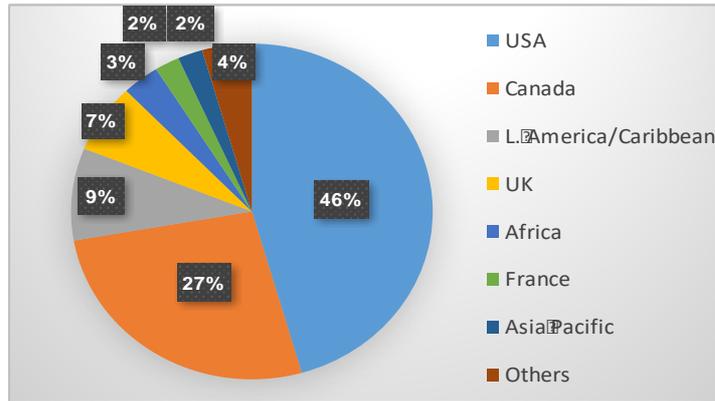
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APPENDICES

Appendix 1 – Highlights of the 2017 Global Infrastructure Leadership Forum Survey

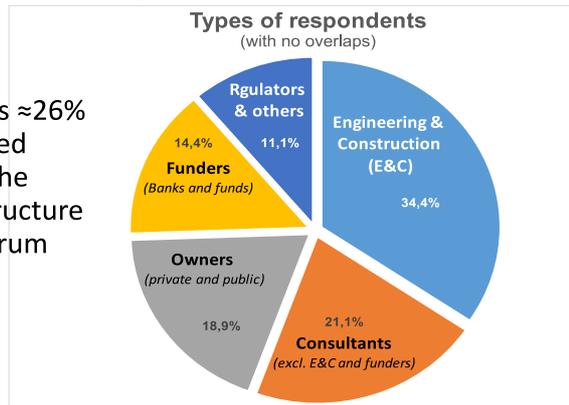
Survey Outline

- ▶ N. America leads in terms of respondents' origin at 47%, with Europe at 11% and S. America/Caribbean at 8% following



Survey Outline

- ▶ 90 participants ≈26% out of 340 listed attendees at the Global Infrastructure Leadership Forum



Leading contractual models
Who expects what by 2020

Contractual Model	Nb	E&C	CONSULTANTS	FUNDERS	OWNERS	REGULATORS/OTHERS	Expectation breakdown by contractual model				
							% E&C	% CONSULT	% FUNDERS	% OWNERS	% OWN
DBFOM	15	15	9	8	10	18	48%	47%	62%	59%	180%
DBOT	7	1	1	3	3	0	23%	5%	23%	18%	0%
DCMF	4	2	2	1	1	2	13%	11%	8%	6%	20%
DBB	6	5	5	1	3	0	19%	26%	8%	18%	0%
DBFO	5	3	3	4	4	0	16%	16%	31%	24%	0%
BF	1	1	1	2	0	0	3%	5%	15%	0%	0%
BOM	1	3	3	1	2	4	3%	16%	8%	12%	40%
BOO	2	1	1	1	2	4	6%	5%	8%	12%	40%
BD	7	5	5	1	2	4	23%	26%	8%	12%	40%
BOT	3	0	0	3	1	3	10%	0%	23%	6%	30%
BOOT	3	2	2	0	5	1	10%	11%	0%	29%	10%
BLT	1	2	2	0	4	1	3%	11%	0%	24%	10%
BBO	2	2	2	0	4	0	6%	11%	0%	24%	0%
EPC	7	4	4	0	1	5	23%	21%	0%	6%	50%
LSC	4	7	7	0	1	4	13%	37%	0%	6%	40%
OM	0	3	3	0	4	1	0%	16%	0%	24%	10%
VPC	1	0	0	0	0	1	3%	0%	0%	0%	10%

Appendix 2 - Vision 2020 - Infrastructure Risk Survey

10th Global Infrastructure Leadership Forum – Montreal 2017

This survey is intended to capture the participants' perception regarding where risks lie by 2020. This 5 minutes survey will help us aggregate your answers and deliver the results tomorrow afternoon. The survey is conducted by postgraduate students in governance and engineering of the École de technologie supérieure (ÉTS) in cooperation with GCLA, the Forum organizers. Your answers will be anonymous. Your opinion as practitioner is critical to us and we are thankful to you for filling it either on paper or through the email addressed to you personally last night. If you choose to answer through the web, would you please send your answers not later than 9h00 Thursday morning.

1-GENERAL PROFILE

a-In which CITY are your headquarters established: _____

b-Leading activity of the organization you represent (please tick):

Engineering: Construction: Consultant: Materials:
 Credit/Investment bank: Pension funds: PE/InfraFund: Other fund/endowment:
 Private Owner/client: Public/Govt Owner/client: Regulator: OTHER:

c-Which sector do you serve the most as funder and/or operator?

(Use numbers from 5 – Greatest focus – to 0 – none)

General building (GB): ___ Manufacturing (MNF): ___ Electric Power (PW): ___ Sewerage / solid waste (SSW): ___
 Industrial process/ petroleum (IPP): ___ Hazardous waste (HW): ___ Telecommunications (TC): ___ Energy (oil, gaz, renewables): ___
 Water supply/ treatment: ___ Transportation (road, bridge, tunnel, airport, port): ___ Social (health, education, public services): ___ Defense: ___

d- Which region do you mostly intervene in ? (please tick - Maximum 3 choices)

Developed countries:  North America: Western Europe: Japan-Australia-NZ:
 Emerging markets:  Africa: India-China: Eastern Europe/Russia:
 Gulf-Middle East: South East Asia: Latin America:

e-What is the size of your company in M\$ (please tick)?

For operators Turnover < \$100 \$100-250M \$250-500 \$500-1000M \$1000-2500M > \$2,5B:

For funders Assets < \$5B: \$5-25B: \$25-100B: \$100-500B: > 500B:

2-WHAT TO EXPECT IN TERMS OF RISKS

a-Which risk/uncertainty do you see rising/declining over the next 3 years (please tick)?

Risk or uncertainty by type	Declining	Stable	Rising
Political (change of govt, unclear strategy/planning, protectionism, regulation)			
Market conditions (economy, volatile price of commodities/materials)			
Competition (dwindling fees, more players, stiffer award conditions)			
Funding (too much money chasing too few good projects, pushing yields down)			
Funding (too little money chasing too many projects, more greenfields than brownfields)			
Financial estimation / forecasts (due to complexity + management shortage)			

HR recruitment of craft labor and/or project manager			
Environmental (Increasing regulation, constraints and public reaction)			
Corruption (fraud, misappropriation, bribery, etc.)			

b- Please rate by priority the critical risks you usually measure for either conventional or P3 projects

TYPE OF RISK	1 = Low priority	2	3	4	5= High priority	Unsure/ Don't know
Project delays, budget overrun						
Supply, procurement security						
Design, implementation, commissioning, decommissioning						
Occupational Health and Safety						
Assets misappropriation						
Compliance, specifications						
Environment						
Technological disruption (<i>absorbing Innovation</i>)						
Construction/technical/project management (<i>due to rising project complexity</i>)						
Labor relation						
Operations and maintenance						

c- Does your organization try to list all possible/probable risks it faces during a project? Yes No
 If No, do you try to uncover and protect the weakest links/units of your operation chain? Yes No

d- Tick the 3 contract models that you believe will dominate the market over the next 3 years (*please tick*)?

Design Build Finance Operate and Maintain (DBFOM)		Build Operate and Transfer (BOT)	
Design Build operate and transfer (DBOT)		Build Own Operate and Transfer (BOOT)	
Design Construct Maintain and Finance (DCMF)		Build Lease and Transfer (BLT)	
Design Bill Build (DBB)		Buy Build and Operate (BBO)	
Design Build Finance and Operate (DBFO)		Engineer-Procure and Construct (EPC)	
Build and Finance (BF)		Lump sum contract (LSC)	
Build Operate and maintain (BOM)		Operate and Maintain (OM)	
Build Own and Operate (BOO)		Variable price contract (VPC)	
Build and Design (BD)			

e- Over the next 3 years, will Greenfield project risks tend to: Decline Stable Rise

f- Over the last 3 years how well did you perform on most of your projects?

Timewise: $\leq 75\%$ 75- 90% 90- 100%
 Does not apply

Budgetwise: $\leq 75\%$ 75- 90% 90- 100%
 Does not apply

g- What is the riskiest type of client/owner (*please tick*)?: Public/Govt Private/Industrial No difference

h- Which client/owner is more demanding on the issue of occupational health-safety on site?

Public/Govt Private/Industrial No difference

i- How will the equity share in a project evolve towards over the next 3 years?

10% 20% 30% Depends on the sector General decline

j- Could the moving discount rate affect the risk / value for money assessment over the next 3 years?

Yes No Uncertain Don't know

NOTES ON RESEARCH METHODOLOGY

Quantification of research on four combinations of three key words paired with ‘Risk’ appearing in Google Scholar and the ASCE Library between 1966 and 2015

Four combinations of key words were used to track down the emergence of research in ‘Risk’ since 1966 to link up with the study of Edwards, 1998. The various combinations reveal both the size of the concern [example: 1.420.000 papers in 2011-2015 in Google Scholar for construction and risk vs 74.000 when two categories (civil engineering and construction) are paired with risk)] and the timing and speed of awareness (growth since the break-out year – Example: CAGR of 108,78% from 39.000 to 741.000 for the pair of ‘infrastructure’ and ‘Risk’, marking a sudden awakening in the early 1990s with 4 periods until 2011-2015). CAGR measures were set on the basis of 5-year periods instead of by single years. The breakout year was defined under two criteria when: 1) the value progression exceeded 75% and reached/exceeded generally 100%, until the end of the series in 2011-2015; 2) the exponential growth became persistent. The compounded average growth rate (CAGR) was calculated from the break-out year (outlined in yellow for each column). Values under Google Scholar are all in thousands of research papers, whereas numbers under the ASCE library are in units. Google Scholar represents a more generalist universe of academics, offering a wider spread of issues and concerns, with however a much greater corresponding noise effect, while the ASCE library is more focused and representative of the design and construction academics and practitioners. Period of computation: May 2, 2018, excluding patents and citations for Google Scholar.

Google Scholar Time Periods <i>(excl.patents + citations)</i>	Construction & Risk (GS in '000)	Infrastructure & Risk (GS in '000)	Civil engineering & Risk (GS in '000)	Civil engineering & Construction & Risk (GS in '000)
1966-1970	17,7	2,5	3,82	2,25
1971-1975	19,8	3,66	5,41	3,58
1976-1980	25,8	9,41	9,44	5
1981-1985	35,9	15,1	12	8
1986-1990	94,2	20,5	16,3	12,4
1991-1995	152	39	24,2	16,8
1996-2000	508	122	38,4	25
2001-2005	889	278	94,8	47,7
2006-2010	1460	685	160	79,3
2011-2015	1420	741	252	74
Compounded avg growth rate	72,05%	108,78%	87,22%	24,55%
Signals a break-out when the delta jumps by about 100%				
ASCE Time Periods	Construction & Risk (ASCE in units)	Infrastructure & Risk (ASCE in units)	Civil engineering & Risk (ASCE in units)	Civil engineering & Construction & Risk (ASCE in unit)
1966-1970	19	0	12	6
1971-1975	17	2	13	7
1976-1980	31	2	23	14
1981-1985	363	58	289	214
1986-1990	879	176	651	498
1991-1995	1138	267	834	665
1996-2000	2320	718	1586	1256
2001-2005	3927	1717	3496	2571
2006-2010	6305	3008	5385	4073
2011-2015	8748	5502	7807	6069
Compounded avg growth rate	69,95%	113,56%	73,22%	138,07%

Quantification of research on four combinations of three key words paired with ‘Finance’ appearing in Google Scholar and the ASCE Library between 1966 and 2015

Four combinations of key words were used to track down the emergence of research in ‘Finance’ since 1966 to link up with the study of Edwards, 1998. The various combinations reveal both the size of the concern [example: 589.000 papers in 2011-2015 in Google Scholar for construction and finance vs 34.500 when two categories (civil engineering and construction) are paired with finance] and the timing and speed of awareness (growth since the break-out year – Example: CAGR 143,2% for only 2 periods under the pair of ‘Civil engineering’ and ‘Finance’ from the break-out year of 2001-2005 through 2011-2015). CAGR measures were set on the basis of 5-year periods instead of by single years. The breakout year was defined under two criteria when: 1) the value progression exceeded 75% and reached/exceeded generally 100%, until the end of the series in 2011-2015; 2) the exponential growth became persistent. The compounded average growth rate (CAGR) was calculated from the break-out year (outlined in yellow for each column). Values under Google Scholar are all in thousands of research papers, whereas numbers under the ASCE library are in units. Google Scholar represents a more generalist universe of academics, offering a wider spread of issues and concerns, with however a much greater corresponding noise effect, while the ASCE library is more focused and representative of the design and construction academics and practitioners. Period of computation: May 2, 2018, excluding patents and citations for Google Scholar.

Google Scholar Time Periods <i>(excl.patents + citations)</i>	Construction & finance (GS in '000)	Infrastructure & finance (GS in '000)	Civil engineering & Finance (GS in '000)	Civil engineering & Construction & Finance (GS in '000)
1966-1970	15,6	28,1	3,79	2,33
1971-1975	16,2	14,6	5,27	2,93
1976-1980	19,2	27,5	6,48	3,93
1981-1985	20,8	21,2	7,98	4,55
1986-1990	33,9	34,6	11,3	7,1
1991-1995	79,2	58,9	15,4	10,8
1996-2000	169	123	21,3	15,8
2001-2005	303	181	46,6	25,4
2006-2010	723	320	57,4	37,2
2011-2015	589	292	126	34,5
Compounded avg growth rate	65,14%	49,22%	143,22%	37,19%
Signals a break-out when the delta jumps by about 100%				
ASCE Time Periods	Construction & FIN (ASCE in units)	Infrastructure & FIN (ASCE in units)	Civil engineering & FIN (ASCE in units)	Civil engineering & Construction & FIN (ASCE in units)
1966-1970	13	0	8	5
1971-1975	23	2	19	13
1976-1980	33	3	17	12
1981-1985	343	72	274	209
1986-1990	764	226	581	458
1991-1995	1095	298	813	651
1996-2000	1817	617	1180	977
2001-2005	2811	1342	2592	2060
2006-2010	4410	2223	3954	3104
2011-2015	5708	3077	4132	4132
Compounded avg growth rate	59,78%	86,98%	57,18%	64,44%

Quantification of research on three combinations of three key words paired with ‘Market Risk’ appearing in Google Scholar and the ASCE Library between 1966 and 2015

Four combinations of key words were used to track down the emergence of research in ‘Market Risk’ since 1966 to link up with the study of Edwards, 1998. ‘Market risk’ (*also known as systematic risk*) may sound redundant with the more generic notion of ‘Risk’, but outlines in fact the reverse of the concept of specific or intrinsic risk that a single construction project represents. The tracking of ‘Market Risk’ over time singles out the growing awareness of the need to diversify organically, geographically or financially to avoid too much concentration on a single basket of specific risks, as to avoid putting too many eggs in a single basket. The various combinations reveal both the size of the concern [*example: 611.000 papers in 2011-2015 in Google Scholar for ‘Construction’ and ‘(Market risk)’ vs six times less -108.000 when two categories (‘Construction’ and ‘Infrastructure’) are lumped together with ‘(Market risk)’*] and the timing and speed of awareness (*growth since the break-out year – Example: CAGR 36,32% for 6 periods under the pair of ‘Civil engineering’ and ‘(Market risk)’ from the break-out year of 1981-1985 through 2011-2015*). CAGR measures were set on the basis of 5-year periods instead of by single years. The breakout year was defined under two criteria when: 1) the value progression exceeded 75% and reached/exceeded generally 100%, until the end of the series in 2011-2015; 2) the exponential growth became persistent. The compounded average growth rate (CAGR) was calculated from the break-out year (*outlined in yellow for each column*). Values under Google Scholar are all in thousands of research papers, whereas numbers under the ASCE library are in units. Google Scholar represents a more generalist universe of academics, offering a wider spread of issues and concerns, with however a much greater corresponding noise effect, while the ASCE library is more focused and representative of the design and construction academics and practitioners. Period of computation: May 3, 2018, excluding patents and citations for Google Scholar.

Google Scholar Time Periods (excl.patents + citations)	Construction & (Market Risk) (GS in '000)	Construction & Infrastructure & (Market Risk) (GS in '000)	Civil engineering & (Market Risk) (GS in '000)	Civil engineering & Construction & (Market Risk) (GS in '000)
1966-1970	8,66	0,5	0,016	1,51
1971-1975	13,8	1,15	3,15	2,12
1976-1980	17,2	2,52	4,35	3,03
1981-1985	18,6	4,74	7,37	4,2
1986-1990	30,4	8,36	12	7,87
1991-1995	75	16,9	16,5	12,9
1996-2000	118	32,6	21	17,1
2001-2005	311	68,3	37,2	22,1
2006-2010	679	97,4	46,6	33,6
2011-2015	611	108	47,3	28
Compounded avg growth rate	82,24%	71,06%	36,32%	28,90%
Signals a break-out when the delta jumps by about 100%				
ASCE Time Periods	Construction & (Market Risk) (ASCE in units)	Construction & Infrastructure & (Market Risk) (ASCE in units)	Civil engineering & (Market Risk) (ASCE in units)	Civil engineering & Construction & (Market Risk) (ASCE in units)
1966-1970	1	0	0	0
1971-1975	1	0	0	0
1976-1980	1	0	0	0
1981-1985	58	15	1	1
1986-1990	223	53	2	2
1991-1995	278	92	2	1
1996-2000	608	236	3	3
2001-2005	753	369	16	13
2006-2010	1216	627	18	14
2011-2015	1832	978	31	30
Compounded avg growth rate	52,38%	79,15%	39,19%	115,44%

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BOUNDARY SPANNING AND KNOWLEDGE BROKERING FOR DIGITAL INNOVATION

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BOUNDARY SPANNING AND KNOWLEDGE BROKERING FOR DIGITAL INNOVATION

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ABSTRACT

The adoption of digital innovations in construction is a topic with growing importance, as organisations restructure to adopt and sustain innovations. Building Information Modelling (BIM) is currently at the forefront of this digital shift in Architecture, Engineering, and Construction (AEC) industry. The relation between knowledge sharing and sustained innovation adoption in organisations has been previously acknowledged by management scholars. There is further room to adopt a structural view of knowledge and focus on how agency contributes to knowledge sharing for increasing digital innovation adoption in firms. This paper uses the theoretical lens of boundaries and boundary brokers to guide the data selection and interpret a rich dataset about boundary brokers of digital innovation. The research aim is to explore how these boundary brokers, referred to as digital innovation champions, facilitate knowledge of digital innovations and BIM to support digital transformation in firms. A single case study of a large international multi-disciplinary consultancy was used as a research setting. Data were collected through interviews with the digital champions as well as with additional data collected from the internal online platform for data triangulation and research validation. Key findings include the multi-faceted levels of boundaries crossed by the digital champions to share knowledge about digital innovation: hierarchical, professional and organisational boundaries. Namely, the digital champions were found to hold multiple memberships in groups, holding both technical and inter-personal competences as well as engaging in conflict resolution. The study concludes with implications for practice and suggests courses of actions to increase knowledge sharing in firms for innovation adoption by developing and incentivising individuals.

KEYWORDS

Boundary spanning, Building Information Modelling (BIM) adoption, digital innovation, knowledge brokers.

INTRODUCTION

Digitalisation in construction recently gains traction in Architecture, Engineering, and Construction (AEC) industry. Building Information Modelling (BIM) is at the forefront of digitalisation in the Built Environment and is being widely endorsed as an approach that will drastically transform the industry. The uptake of BIM technology is of strategic national importance in many countries. BIM radically affects technology, team structure, business processes, organisational culture and the way participants in

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construction perform their work (Gu and London 2010). With the emergence of BIM, which is currently the most popular instance of construction digitalisation, various actors are called to undertake new roles, beyond the disciplines that they were initially trained (Jaradat et al. 2013).

At an organisational level, BIM has been considered an innovative digital platform that changes how services are delivered in the Built Environment. The adoption of information technology is affected by motivation, leadership, technology-readiness and lack of skills across firms and the way large and small firms adopt BIM could induce a “digital divide” (Dainty et al. 2017). This study focuses on how organizations capture and transfer knowledge about digital technologies within their boundaries through individual roles to support the journey towards digitalization and digital transformation.

According to Carlile (2004), the understanding and successful adoption of innovations lies at the boundaries of communication among actors. Managing meaning and knowledge through communication across disciplinary boundaries is crucial for understanding innovation. According to Maaninen-Olsson et al. (2008) knowledge boundaries among different disciplines during communication are more pragmatic and complex than actors perceive them to be. Thus, reaching a ‘common understanding’ among actors is a crucial function of knowledge transfer. The organisational agents that may or may not cross their role boundaries in order to further facilitate knowledge transfer are defined as boundary spanners (Levina and Vaast 2005), boundary brokers (Koskinen 2008), or mediators (Holzer 2012).

With the advent of digital innovations and BIM, the increasing complexity creates pressure for firms to uptake the new digital technologies. Therefore, there is a need to not only manage knowledge but also key relevant roles for knowledge transfer that are emerging in firms. These roles are typified as transient (Akintola et al. 2017) and whereas their contribution to innovation change management is acknowledged, studies have focused more on the technical rather than organisational qualities. This study sets up to explore organisation approaches to sharing knowledge in BIM innovation, drawing upon empirical data and exploratory research through the lens of knowledge brokers. The research question is:

“How do boundary brokers facilitate knowledge of digital innovations and BIM to support digital transformation in firms?”

After this introductory section the paper is organised as follows. The ensuing section presents the theoretical framework of boundaries and boundary brokers as well as conceptualises digital innovation in construction to present how the paper studied digital innovation through the lens of boundaries. Afterwards the methodology and methods are presented. Next, the data and key findings are analysed. The paper concludes with a discussion and a conclusion section offering implications and propositions for practice.

MANAGING BOUNDARIES TO SUPPORT DIGITAL INNOVATION

BOUNDARY OBJECTS AND BROKERS

The concept of boundary objects originates from sociology, where boundary objects are physical or virtual entities that can be attributed multiple nuances of meaning (Star 2010; Star and Griesemer 1989). Boundary objects are good theoretical lenses to

understand innovation (Kimble et al. 2010), Information Systems (IS) (Barrett and Oborn 2010) and new technologies: (Fox 2011) and for different collaborative processes, such as scheduling (Chang et al. 2013; Engwall 2012) or training evaluation (Lee-Kelley and Blackman 2012). By enabling and shaping shared understanding (Star 2010), boundary objects can facilitate communication, information and knowledge exchange, collaboration and innovation adoption. Levina (2005) showed that only focusing on boundary objects provides “insufficient insight into whether an object would be effectively used in practice”. A structurational view of collaboration (Levina 2005), drawing upon Giddens’ (1984) duality of structure and agency, according to which an agent ‘shapes’ the situation and ‘is shaped’ by the situation is thus desired.

Agents are thus very important in joint understanding boundary objects and situations (Star 2010). Agents called boundary spanners may also cross their role boundaries (Levina and Vaast 2005). These agents are also called boundary brokers (Koskinen 2008), or mediators (Holzer 2012) with boundary spanning competences. They also function as “facilitators of design negotiations” using “digital boundary objects” (Alin et al. 2013). In communities of practice field, boundary brokers belong and have trust from different communities and support knowledge transfer among them (Brown and Duguid 1998) by translating and negotiating meaning across knowledge domains. Project managers typically broker across role boundaries and domains, as they are ‘multi-membership’ team members (Koskinen 2008).

Scholars have problematised with the position of these agents and knowledge brokers inside the organisation or the team. Levina and Vaast (2005) argued that only agents centrally positioned in relations and who, possess “a significant amount of symbolic capital” are boundary-spanners-in-practice. According to Swan et al. (2016), boundary roles include five distinct role interpretations: knowledge broker, internal consultant, avant-garde, service provider and orphaned child. For Swan et al. (2016), knowledge brokers, avant-garde and orphaned child broker types are dominant at the back-stage, whereas internal consultants and service providers are at the front-stage. As this paper focuses on the role of brokers for facilitating knowledge in innovation, they might operate primarily at the back-stage, due to the implementation focus of their role and be closer to the definition of knowledge brokers, because neither self-motivated (avant-garde type), not isolated (orphaned child) types (Swan et al. 2016) can support innovation as they do not support communication in teams.

BIM AS A DIGITAL INNOVATION

Innovation refers to a new product, service or process (Abernathy and Clark 1985). The close relation between innovation and projects is acknowledged due to the former being usually observed in projects (Shenhar and Dvir 2007). BIM has evolved through decades of push and pull strategies and efforts to standardise the representation of building information in AEC (Papadonikolaki 2016). Thus, it is not entirely novel as it has evolved from efforts for structuring and representing information about buildings, a predominant line of thought in the 1970s (Eastman 1999). These advancements in *building product modelling* shaped a long-standing debate on the computerisation and construction digitalisation (Eastman 1999). Nevertheless, BIM could still be seen as an innovation because apart from the technology associated to it, the associated processes and methods to implement it are novel and challenging and require change at both organisational and institutional levels (Papadonikolaki 2017).

BIM is currently at the forefront of construction digitalisation. Apart from digital representation of buildings, BIM relates to artefacts that affect the processes that technologies are adopted and implemented through. BIM is a “*multifunctional set of instrumentalities for specific purposes*” (Miettinen and Paavola 2014) and affects various actors across the AEC, while policies, processes, and technologies interact to generate a digital building (Succar et al. 2012). BIM is a set of existing and new digital technologies for generating, controlling, and managing building information. Various digital artefacts such as the Common Data Environment (CDE), an online platform to exchange files, BIM-specific contracts, BIM Execution Plans (BEP), a plan that defines BIM-related roles and team interactions, and so forth, affect how digital innovation is used and increase the complexity of innovation adoption and implementation.

Apart from knowledge and innovation adoption intra-organisationally, BIM and digital innovation affect projects because various multi-disciplinary organisations engage in BIM-based collaborative work (Grilo et al. 2013). The ability to enhance collaboration of these organisations in projects is a priority for increasing BIM adoption (Cao et al. 2017). Nevertheless, due to being highly heterogeneous, firms deploy different strategies towards BIM innovation in a closely-knit network of formal and informal inter-organisational relations (Papadonikolaki et al. 2017; Papadonikolaki and Wamelink 2017). Effective collaboration among multi-disciplinary teams enables organisations to draw on diverse forms of expertise and create new competences and produce synergistic solutions to complex projects (Carlile 2004). As BIM innovation is closely linked to collaboration (Oraee et al. 2017), understanding how individuals enable collaboration is important for innovation adoption. To this end, approaching BIM as a digital innovation influences apart from innovation also knowledge sharing intra-organisationally and collaboration inter-organisationally.

THE ROLE OF BOUNDARIES IN DIGITAL INNOVATION

Typically, project managers, are centrally based in projects and teams, however, in the context of digital innovation, they might not have all necessary BIM knowledge to support innovation adoption. Thus, new functions have emerged or existing ones have been adjusted that attempt to manage BIM innovation adoption in firms and BIM innovation implementation in projects. These roles carry similarities to knowledge brokers and boundary objects as described in the previous sub-section have been found highly efficient in structuring communication, negotiating and overcoming conflict (Ruuska and Teigland 2009). The role of brokers is that of a “balancing act” (Kimble et al. 2010), as they have authority and trust from various groups.

Organisations leverage the knowledge of innovation agents – or brokers – to support innovation adoption. In the context of innovation, Rogers (2003) recognised an innovation champion as an organisational function responsible for driving innovation adoption. Nam and Tatum (1997) stated that innovation champions in construction are perceived as individuals responsible for implementing innovations in and enjoying authority and power. Similarly, in digital innovations in construction and specifically BIM, there are both project-based and organisational definitions of BIM specialist roles. There exists a plethora of new terminologies to describe BIM specialist roles (Akintola et al. 2017) and typically these are either project-based or organisational (Davies et al. 2017). From the above, this study focuses on *Digital Champions* as an organisational role, in keeping with the organisational definition by Rogers (2003).

Digital innovation and BIM Champions guide project teams to improve their processes by contributing to the development of BIM execution plans (BEPs), managing the quality of BIM model(s) and facility information, timely sharing of model(s) and chairing and facilitating meetings. This study defines a *Digital Champion* as an individual who guides teams to improve their processes by ensuring implementation of digital innovation and BIM, and managing resistance to change. This individual might be working on multiple projects simultaneously and be available for advice and input at key project stages. These Champions would help ensure pitfalls are avoided, and would present to clients as appropriate, to show what BIM can deliver.

Because of the affinity between boundaries and communication function, the theoretical lens of boundaries is used in this paper to explore how the afore-described brokers facilitate knowledge of digital innovations and BIM to support digital transformation in firms. In keeping with the emphasis on the agency of communication, the study views digital champions as knowledge brokers that facilitate and nurture knowledge-sharing and act as central conduits for forging new relationships and connections (Swan et al. 2016). Therefore, the role of a boundary broker in the BIM domain might display the following boundary and communication features: (1) multi-membership, (2) facilitation of knowledge transfer and (3) facilitation of collaboration.

RESEARCH METHODOLOGY AND APPROACH

RESEARCH RATIONALE

The study follows an interpretative approach and a case study methodology. The study draws upon a single case study to provide a rich, “real-life context” and inductive character to the research (Yin 1984). The research methods and data used were qualitative and the epistemological paradigm followed interpretative (Merriam 1998). As knowledge brokers in the context of innovation are typically firm-based roles, the study used a single firm as a ‘point-of-entry’ to access a wealth of data by studying various teams and projects. To this end, selecting this single case is of major importance.

This study focuses on one international multi-disciplinary firm that offers rich empirical data for further analysis and research. This company was selected – hereafter referred to as the Firm – for their strong digital and BIM strategy, and directed significant efforts towards assessment of digital innovation. They also have dedicated Research and Development (R&D) which is strong in researching, prototyping solutions and developing research agendas. It provides different services that cover different aspects of the built environment including architecture, engineering, consulting, planning and project management. The firm was established in the 1950s and has currently over 15,000 staff from diverse backgrounds and disciplines located in offices in 35 countries across Africa, the Americas, East Asia, Europe and the Middle East. For this study, the data will be derived from their branches in the United Kingdom (UK), 15 offices, to present a deep contextual description.

The context of the study is also crucial for research analysis and interpretation. The data were collected in the UK branches of the Firm, where BIM is required in governmentally-sponsored projects from 2016. The UK government has required a fully collaborative 3-dimensional BIM as a minimum for all government projects by 2016 (GCCG 2011). Currently, BIM use has been mandated or strongly recommended for governmental buildings from policy-makers in various European countries, such as

the UK, Germany, France, the Netherlands, and the Nordic countries. For this reason, the study focused on the UK branch of a large international firm, that could increase transferability of the findings across other countries starting their digital journey.

As deduced from the case, the Firm, does not simply try to raise the minimum bar to meet new government requirements, but has a long tradition of R&D and efforts to lead in digital innovation in construction. Previous studies have researched the Firm's development and use of an online knowledge management system, or an expert 'yellow pages' (Criscuolo et al. 2007) to capture and manage knowledge. Dodgson et al. (2007) studied how digital innovation such as simulation technologies used in the Firm facilitate communication and collaboration across disciplines.

DATA COLLECTION AND ANALYSIS

The single case study was studied over a period of 10 months. Two sets of data were collected from (1) interviews and (2) validation through an online forum. Through embedded research (Angen 2000), the research team had access to the Firm's online platforms, used for validation. More than one source of data supports data triangulation and adds to research validation (Creswell 1994). The first data was from interviews with knowledge brokers of digital innovation, also referred to as *Digital Champions*. The interview questions were on digital innovation, their contribution to sharing relevant knowledge across their firm, as well as other intra-firm channels for knowledge sharing and the interviews lasted 30-45 minutes.

The Digital Champions, who direct work on BIM implementation in projects, were ideal informants for the qualitative dataset. Given that the aim was to increase the wealth of data and not generalisability (Creswell 1994), interviews were considered the most appropriate means to capture their input. As the focus of the study was the UK branches, all 24 Digital Champions based in the UK were contacted initially. From these, 8 were available due to time restrictions and agreed to participate in the study. This sample size is considered representative of the UK context of the Firm. The profile of the interviewees including key characteristics of their background and roles is presented in Table 1. For anonymity their identifiers are assigned pseudonyms.

Table 1: Profile of the Firms' BIM Champions interviewees.

Pseudo-nym	Background	Position in the Firm	Location	Present job title
Adam	Building Services Engineering	Associate	London	Mechanical Engineer
Barb	Building Services Engineering	Associate	Midlands	BIM Manager
Colin	Structural Engineering	Associate	Edinburgh	Structural Engineer
Debra	Civil Engineering	Director	London	Civil Engineer
Ewan	English	Senior Technician	Bristol	Building Information Manager
Filip	Mechanical Manufacturing	Senior Technician	Manchester	CAD Technician
Gina	Psychology	Associate	London	BIM & CAD Lead
Hans	Manufacturer Engineering	Senior Technician	Belfast	CAD / BIM Co-coordinator

The interviews were conducted in London for the 3 participants who were based in the Greater Area and via video teleconference, for interviewees based outside London, between July and August 2017. The list of questions was designed to reflect the aim and objectives of this research project. It included ten semi-structured open-ended questions, which allowed for additional follow-up questions, if needed. The first set of questions was descriptive and addressed the background of interviewees, their routine and involvement in projects, the soft competences and hard skills a BIM Champion might need. The second set of questions was reflective, as to how their daily routine unfolds, how they transfer knowledge across projects, what specific innovations and contributions they add to projects as Digital Champions, and how digital innovation could accelerate project improvement through BIM and digital innovation.

The interview data were transcribed and the transcripts were analysed through coding (Miles and Huberman 1994). As there is not a definitive manner to rigorously analyse qualitative data (Robson and McCartan 2016) the theoretical framework from the second section of the paper was used as an indication of concepts for first-level coding to analyse the data according to (1) multi-membership, (2) facilitation of knowledge transfer and (3) facilitation of collaboration. Descriptive and in vivo codes were used (Saldanā 2009). In vivo codes, drawn upon words or phrases directly from the data (Saldanā 2009), were used to present quotations, for being more personal.

DATA VALIDATION

Secondary data from the internal online forum was used to triangulate the findings and validate the findings offer a rich representation of the phenomenon. Validation is an opportunity for the informants to reflect on their feedback and comment on the preliminary research findings. Mixed methods increase the communicative validity of research (Sarantakos 2005) by allowing the participants to check the accuracy of data and add depth and richness to the data. Merriam (1998) also stressed the need to increase the validity of case study methods. To this end, after the data collection and the preliminary data analysis, the research team used the internal online forum, similar to the online knowledge management system, or an expert ‘yellow pages’ analysed by Criscuolo et al. (2007). It namely addressed the question:

*“How do you think we can better share the knowledge we create?
And if knowledge has been shared, what is the best way to apply it
and make the most of new initiatives that we get introduced to?”*

This online forum that functions as a knowledge platform of the Firm was used to both share some of the preliminary findings and also seek validation and additional feedback from the Firm employees. The preliminary findings and data were presented as direct quotations. This process aimed to validate the existing findings and collect new insights not visited before. The data validation part prompted participant’s input, which took place over a period of one week, after posting the question in the thread. Apart from validation, this approach also provided new data.

DATA PRESENTATION

DIGITAL CHAMPIONS' AREAS OF ACTIVITY

Consistent with the characteristics of boundary spanners, the digital champions explained the varying degrees to which they belonged to different internal and external and project teams. All of them acted within the Firm, however, their activities varied depending on their penetration beyond mid-level project teams and specifically connecting with senior executives and business managers. Table 2 presents the data on the multi-membership and boundary spanning of the interviewees (first column), and namely internal (second and third column) and external engagement (fourth column). The digital champions crossed different boundaries. The eighth interviewee, Hans, stated that a more open organisational structure for leading innovations is needed and namely stated that *“with lots of rules we lose innovation. (...) BIM and innovation do not go hand in hand”*.

Table 2: Multi-membership and boundary spanning of the Digital Champions.

Name	Internal engagement with project teams (number of projects and comments)	Internal engagement with senior management	Project-related engagement with external stakeholders
Adam	6 projects, but not all as a champion	-	-
Barb	8 projects, mainly at the front-end of projects	-	-
Colin	4 projects, from which only 1-2 as a champion	-	Yes
Debra	10 projects, mainly at the front-end of projects	-	Yes
Ewan	7 projects formally and many more informally	-	Yes
Filip	6 projects at varying stages	Yes	Yes
Gina	5 projects, 2 of which are project bids	Yes	Yes
Hans	2 projects	-	-

After delving more into the data, it was revealed that whereas the digital champions crossed various boundaries, they were involved in different phases of the projects. All of the interviewees stated that they are primarily members of internal teams and additionally became involved informally in projects, after all according to the first interviewee, Adam, the Firm does not formally identify the role of digital champions and he added: *“I put myself forward to be involved with BIM; I volunteered as I saw it as a key part of how the industry was going”*. Also, Ewan stated that involvement in projects comes *“via relationships not through formal structure”*. Similarly, their degree of involvement in projects varied from only being involved bids to only supporting technical tasks. Few digital champions went further into engaging with senior management internally for *“mediating with the top managers”* (Gina) and raising awareness of champions *“to acknowledge them”* (Filip). Simultaneously, most of the interviewees engaged beyond their teams to *“lead relationships with clients”* (Debra) and *“deal with resistance from collaborators, suppliers and client teams”* (Gina).

DIGITAL CHAMPION AS KNOWLEDGE SHARING FACILITATORS

From the design of interviews and the questions, the digital champions were asked on their roles and daily routines on sharing knowledge are supported from their skills and competences. To ensure that the interviewees will provide a detailed account of their contribution to sharing knowledge in the Firm, they were asked to reflect on both the competences that allowed them to share knowledge, as well as provide the research team with concrete examples of sharing knowledge. The data on daily routines were particularly requested to confirmed and contextualise their roles. Table 3 tabulates the data per interviewee. The first column from the left contains the interviewee identifier and the second their competences and daily routines using in vivo codes.

Table 3: Knowledge transfer competences and daily routines of Digital Champions.

Name	Competences (in vivo codes)	Daily routines (in vivo codes)
Adam	<i>Awareness of how disciplines work, change management</i>	<i>Writing BIM documents, integrating digital data</i>
Barb	<i>Open-mind, mind-set of sharing, soft skills, knowledge is power, questioning ability</i>	<i>Centrally sharing knowledge across champions through repositories, meetings and social media, training teams</i>
Colin	<i>Knowledge of BIM standards, soft skills, change management</i>	<i>Delivering digital innovations, leading from the front-end of projects, engaging with stakeholders, selecting appropriate people for BIM teams</i>
Debra	<i>Use of technology, understanding and selecting software packages, communication, negotiation, influence, persuasion</i>	<i>Meeting with clients and co-workers, leading internal teams, developing and mentoring graduates, sharing good practices across the board</i>
Ewan	<i>Knowledge dissemination, understanding technology and BIM standards, understanding of the interfaces between people and processes</i>	<i>Upskilling people, meeting with clients, mentoring appendices, writing macros</i>
Filip	<i>Deliverables management, time management, project management, salesman's pitch, knowledge spreading</i>	<i>Meeting with internal teams, transferring knowledge from experienced people to the whole project team</i>
Gina	<i>Hard skills, work with different people and tools, mediation, engagement with people, delegation, soft skills, salesman</i>	<i>Meeting with clients, calling and emailing people, offering training, promoting BIM and digital</i>
Hans	<i>Changing people and their ethics, knowledge of developments in the firm, communication</i>	<i>Training and meetings with internal teams, promoting knowledge sharing among individuals</i>

The data from Table 3 reveals that the digital innovation champions mobilised soft skills and competences to manage individuals, teams and projects. Some of them were focused more on technical tasks, e.g. Adam and Hans stated that routines evolve around working with Navisworks (BIM management software) and maintaining the CDE on a

day-to-day basis. Contrariwise, Barb, Debra and Filip stated that they could not define their routines as they varied enormously daily and consisted by many meetings. Ewan and Colin were involved in daily routines comprised by both hard, technical and implementation of innovative ways of working as well as many meeting and people-focused activities.

DIGITAL CHAMPIONS AS COLLABORATION FACILITATORS

Apart from knowledge sharing, communication and the role boundary brokers are mobilised in collaboration facilitation. Drawing upon Table 2, all of them influenced collaboration in internal teams, ranging 2-10 teams at any given moment, and collaboration of project teams, beyond their organisational boundaries. Table 4 presents the data on how the digital champions used communication in their daily work to facilitate collaboration by translating meaning and mediating in conflicts. Although knowledge transfer was the most discussed category of communication emerging from interviews, also resolving conflicts and translating meaning were part of the boundary brokers' routines. The second column of table 4 presents descriptive codes from the digital champions on how they managed conflicts to bridge boundaries among actors. Similarly, the third column presents data on how they translated meaning across internal or external domains, consistent with crossing organisational and project-related boundaries.

Table 4: Analysis of the Digital Champions' role in collaboration (descriptive codes).

Name	Mediation in conflicts	Translation of meaning
Adam	Mediating between the architect and the senior technicians	Bringing the project team together to discuss the execution plan
Barb	Monitoring information exchanges; Keeping track of the project schedule	Delegating work among project team and pushing them outside comfort zone
Colin	Connecting experienced people and recent graduates (reverse mentoring)	Continuously engaging with external stakeholders
Debra	-	Continuously engaging with external stakeholders and then the internal team
Ewan	-	Bringing the project team up to speed regarding client requirements and government mandates
Filip	Managing conflicts arising from time management	Facilitating team's understanding of various datasets and file formats; Continuously engaging with external stakeholders
Gina	Dealing with resistance from external stakeholders	Pointing the project team to the right direction, giving them answers
Hans	Facilitating and supporting the transition of senior designers and engineers; Changing people's work ethics	Answering questions of project team about BIM models

VALIDATION SESSION ON PROMOTING KNOWLEDGE ON DIGITAL INNOVATION

To validate the data findings presented in the previous sub-section, some representative quotations from Barb, Colin and Debra and preliminary findings were presented again

to a wider sample of the Firm. The quotations selected were provocative to trigger reactions in the online forum. For example, Barb had shared: *“The majority of Firm is very good in sharing. But I think there are some people who think that knowledge is power. And to protect themselves they hold into their skills”* and Debra: *“I think there are pockets of great things being done. But at the moment it is pockets, rather than cross the board”*. By accessing the online knowledge platform of the Firm, the research team had access to a wider pool of informants, beyond the network of the digital champions, to validate the data and also potentially enrich them. As described in the “Data Validation” sub-section, the quotations were accompanied by text encouraging the platform users and Firm employees to reflect on how knowledge is shared internally.

As a result, ten Firm employees were involved in the thread by either directly responding or being ‘called’ in the thread by colleagues mentioning them in the thread (action upon which they were notified in the work email to respond). The feedback included suggestions to reward the champions of knowledge transfer, in order to increase their happiness and reputation: *“it would be great if we could identify MVP's ("Most Valuable Players") and then reward them for their efforts”* (User-A). Others, highlighted the fact that the Firm uses over 9 different online systems to share knowledge, e.g. and shared a *“view on active dissemination where telling a story to get the information is across would definitely be an improvement on an information dump”* (User-B).

DISCUSSION AND IMPLICATIONS

CROSSING BOUNDARIES ACROSS GROUPS, KNOWLEDGE, COMPETENCES AND PEOPLE

This paper set out to seek how boundary brokers can facilitate knowledge of digital innovations and BIM to support innovation adoption and digital transformation in organisations. To this end, the paper adopted a structural view of communication (Levina 2005), drawing upon Giddens’ (1984) duality of structure and agency, according to which the boundary brokers as agents shape and are shaped by the phenomenon of knowledge transfer for sustained innovation adoption. Therefore, this paper focused on the role of agents as knowledge brokers to increase the adoption of digital innovation. From the empirical data set, it was established that these agents crossed various types of boundaries in order to communicate, either for knowledge transfer or facilitation of collaboration in teams.

For Nonaka and Takeuchi (1995) knowledge-creating organisations can engage in continuous innovation when the *“consistently create new knowledge, disseminate it widely throughout the organization, and quickly embody it in new technologies and products”*. Project managers’ role is brokering across domains, as is that of ‘multi-membership’ individuals (Koskinen 2008). Indeed, the empirical data revealed that also the knowledge brokers of digital innovation and BIM had influence at four network levels within and outside their organisation, regardless of whether they were centrally positioned in an organisation (Levina and Vaast 2005). The data sample revealed an extended network of internal and external relations of the digital champions (see Table 2). The digital champions casually crossed hierarchical (internally) and organisational (externally) boundaries. Namely, the digital champions were frequently engaging with:

- internal project teams;

- external project stakeholders;
- senior management within their firm;
- intra-firm network of digital champions.

To this end, and by revisiting the assumptions of this paper at the second section containing the theoretical background of the study, arguably the digital champions performed more roles than of the knowledge brokers. Swan et al. (2016) had categorised boundary roles into five roles: knowledge broker, internal consultant, avant-garde, service provider and orphaned child. Drawing upon Table 3 and Table 4, the digital champions also acted as ‘internal consultants’ and ‘service providers’, which are roles positioned more central, closer to the front-end of projects than knowledge brokers, who are positioned at the back-end of the projects, at the client-facing part. Based on their competences and daily routines (see Table 3), Barb, Debra, Filip and Gina were also hands-on service providers, whereas based on their contribution to mediation and translation of meaning, all digital champions acted as internal consultants, crossing thus knowledge boundaries among people.

As the domain of digital innovation and BIM is a young field in scholarship, there is a growing field of study on the background and skills of new or existing specialised roles for digital innovation. Indeed, individuals are called to undertake roles, beyond the disciplines that they were initially trained (Jaradat et al. 2013). Scholars have focused on the emergence of new roles (Akintola et al. 2017; Davies et al. 2017; Liu et al. 2016) and report an ambiguity in naming and categorising such roles. The data from this paper, revealed that these roles were not typically new, but informal additional roles next to existing positions of the interviewees (see Table 1 and quotation of Adam). On the contrary, scholars discussing changes in existing roles (Davies et al. 2015; Jaradat et al. 2013; Papadonikolaki and Oel 2016) report on the discrepancies between the existing or expected competences of these knowledge brokers, which tend to be more technical and mono-disciplinary and the functions they are called to cover in order to facilitate knowledge transfer, e.g. soft skills, change management, communication, negotiation, influence, persuasion (see Table 3). Therefore, these knowledge brokers are crossing boundaries apart from between teams but also of their desired ‘soft’ versus ‘hard’ existing competences. To this end, apart from hierarchical and organisational, they crossed professional boundaries.

Apart from the function of communication to support knowledge transfer, it also facilitates collaboration. Undoubtedly, knowledge brokers translate meaning and can support innovation adoption not only within firms but also across them. After all, the adoption of digital innovations and BIM is a complex inter-organisational exercise (Grilo et al. 2013), which might activate conflicts in inter-disciplinary teams (Davies et al. 2015; Dossick and Neff 2010). According to Table 4, the digital champions not only continuously engaged with external stakeholders, as it would have been expected due to their multi-membership attributes, they shared knowledge by acting as translators of meaning to clients and project members beyond their organisation. Because, their role was primarily intra-organisational, they used their brokering qualities and communication tools to facilitate how teams internal in the Firm and across projects, beyond the Firm, collaborated. At the same time, they translated meaning and acted as salespersons to increase awareness of BIM and digital innovation across hierarchical levels (see Table 3, third column and Table 4, third column). The

boundary brokers were also activated in the resolution of team conflicts internally and externally (see Table 4, second column) that might emerge due to disciplinary fragmentation (internally, see Adam and Hans), generation gap (internally, see Colin) or commercial interest (externally, see Gina).

CONTRIBUTION TO THEORY AND KNOWLEDGE

This paper added to theory in the fields of organisational management and construction innovation. At a higher-level, it re-visited the theory of boundaries and boundary brokers and reaffirmed its relevance to management science (Alin et al. 2013; Chang et al. 2013) and especially innovation (Kimble et al. 2010). To this end, it emphasised on the importance of agency on transferring knowledge to increase innovation adoption. The study contributed to the theory of boundary brokers by providing rich empirical data and evidence from construction innovation and in particularly digital innovation (see Tables 2, 3 and 4). At a ‘field’ theory level, the paper contributed to the body of knowledge of digital innovation adoption and namely, BIM adoption and its organisational repercussions. The study confirmed the socio-technical nature of digital innovation champions (Davies et al. 2017; Emmitt 2016), thought the theoretical lens of boundary brokers, as opposed to the technical view of emerging BIM roles (Akintola et al. 2017). From a methodological point of view, the study added to scholarship, by combining an original synthesis of data collection, comprising both participants’ interviews and validation and additional data collection through online platforms, specifically designed for knowledge management.

RESEARCH LIMITATIONS AND FUTURE RESEARCH

Apart from contributing to theory knowledge and methodology, this paper outlined throughout the methodology and data presentation sections, possible ways to extend this study by additional data collection and validation points. One of the limitations of the research design, was the focus on interviewing only the digital innovation champions as a source of information. This was done intentionally, to delve into their qualities, skills and routines. As this study progresses, interviewing project managers, consultants or other similar roles that have experience engaging with multiple digital champions, would be useful for understanding how these boundary roles are perceived, especially due to their limited time of involvement as digital innovation champions might engage in multiple projects with differing roles (Table 2).

Indeed, the validation component of the methodology attempted to engage with more roles in the Firm and sought input from various other roles. However, a research limitation was that the short period (one week) that the feedback from the online platform was collected. In the future, the validation component could be extended and replicated over a period of time to seek more participants and discussions. Naturally, due to the in-depth single case study focus, the study attempted to present rich descriptions of the firm, through embedded research. In the future, this study could be replicated in similar-sized firms to gain more insights into how issues of knowledge transfer, boundary spanning and brokerage are mobilised.

PRACTICAL IMPLICATIONS AND PROPOSITIONS

The secondary set of data, which expanded and included feedback from various employees, additionally contained insights on the challenges of disseminating knowledge across the firm. Some challenges reported were rigid organisational structure, impression management (see previous sub-section). The new challenges emerging from the validation session was the lack of incentive schemes to recognize the knowledge sharing efforts from all employees, as well as the volume of new knowledge and the type and governance of knowledge management systems. Whereas this study focused on a large-scale inter-disciplinary firm, the following strategies for nurturing and supporting knowledge brokers and developing their boundary spanning competences might be relevant to other firms in the AEC:

- Holding a horizontal structure for knowledge transfer within firms;
- Increasing firms' awareness on the contribution of knowledge brokers;
- Providing training to develop knowledge brokers' leadership potential;
- Creating appropriate channels and procedures to disseminate knowledge;
- Incentivising to establish and cultivate a culture of shared knowledge.

The implications for practice and other project-based organisations is that agency and boundary spanning individuals are key for transferring knowledge across projects and firms. Whereas their role could be ephemeral, there is a need to increase their intra-firm boundary-spanning capabilities and their inter-firm coordination and their contribution to management, education and policy-making.

CONCLUSIONS

Sustaining innovations is an important organisational challenge for firms that decide to adopt new processes and technologies. The study focused on the adoption of digital innovations in AEC and how these are disseminated and sustained through the organisational role of boundary brokers. Due to the strong link between intra-firm communication and innovation spread, these organisational roles carry knowledge and boundary brokering attributes. Namely, after studying a sample of eight out of the 24 digital innovation champions from a single multi-disciplinary design, engineering and management firm, it was revealed that these champions cross apart from knowledge boundaries, additionally hierarchical boundaries, by engaging with both the work-floor level and the senior management, organisational boundaries, by directly engaging with clients and external stakeholders to facilitate teams' collaboration in projects, and professional boundaries, by developing soft competences and engaging in tasks that typically were not prescribed in their job descriptions.

The study set out to address the question of how boundary brokers facilitate knowledge of digital innovations and BIM to support digital transformation in firms. Arguably, apart from crossing the knowledge, hierarchical, organisational and professional boundaries mentioned above, the digital champions acted as not only knowledge brokers but also as internal consultants and at instances as service providers, in a hands-on fashion. Theoretically, this paper revisited theories of boundaries and emphasised on the agential aspect of knowledge transfer and expanded the body of knowledge of construction innovation and in particular with regards to digital

innovation and BIM. The practical implications of the study relate to the need to activate organisational mechanisms for breaking rigid horizontal structures in firms, developing knowledge brokers' leadership potential, create and maintain channels and procedures to transfer knowledge as well as incentivising and rewarding individuals to establish and cultivate a culture of shared knowledge in organisations.

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DETERMINING RESOURCE-NEEDS IN REFUGEE CAMPS: A STUDY OF REFUGEE CAMPS IN GREECE

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DETERMINING RESOURCE-NEEDS IN REFUGEE CAMPS: A STUDY OF REFUGEE CAMPS IN GREECE

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ABSTRACT

Globally, millions of refugees are managed in a refugee camp, as refugee camps are the preferred means of managing displaced people. Within the camp environment, refugees are not expected to make demands, thus their resource-needs are often neglected and misunderstood. Neglecting refugee needs in the camp environment has a detrimental effect on both short-term and long-term recovery and psychosocial wellbeing. Furthermore, it is not known how these needs differ with age, gender, and nationality. To address this problem, this research asks: (1) *What built environment resources are valuable to refugees in refugee camps?* (2) *How do these resource-needs vary with age, gender, and nationality?* Using a combination of interviews and surveys, this research identified and then ranked the needs of refugees in Camp Moira and Eleonas. Interviews (N=30) were used to identify resource-needs in the camp environment and analyzed using grounded theory. The identified-resource needs were used to create surveys to rank and determine how needs vary with age, gender, and nationality. The surveys were analyzed using AHP and linear regression analysis. This research shows policymakers that identifying and designing around the resource-needs of refugees will result in better camps that will help with recovery and integration into the host country.

KEYWORDS

Refugees, Greece, Resources, Camps

INTRODUCTION

Since 2015, more than one million refugees have fled to Europe and they have been hosted in refugee camps (UNHCR 2016). This refugee crisis has been a major factor in producing a shift in the humanitarian aid sector's approach to refugee crises (Gabiam

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2016): a focus on emergency humanitarian aid is giving way to a focus on refugee recovery. Indeed, with the number of forcibly displaced people at an all-time high (Miliband 2017; UNHCR 2016) and the increasingly long time that it is taking to find durable solutions to refugee situations (the average time one remains a refugee is now more than 20 years), the United Nations High Commissioner for Refugees (UNHCR) is pushing for an approach that focuses simultaneously on refugees' immediate needs and long-term wellbeing.

Refugee camps seek to provide immediate needs such as basic as water, shelter, telecommunications and sanitation. However, these resources are generally scarce in the built environment and limit refugees' quality of life and ability to recover (UNHCR 2016). The built environment of refugee camps represents the human-made surroundings that provide the physical space for activities (e.g. water, shelter, sanitation, public space, roads). The camp provides refugees with basic resources and space in the host country for what is supposed to be a temporary period. This period may extend only through the asylum applications process or may last until a more permanent solution is found, which can take years or even decades (Gabiam 2016). Understanding the resource-needs of refugees is essential because camp experience can affect psychological distress after being resettled (Briant & Kennedy 2004, Chung & Kagawa-Singer 1993). Moreover, when considering the resource-needs of refugees, they are often conceptualized as universal. In other words, all refugees have similar needs when transitioning to a host country and escaping war. However, this is not necessarily the case as previous research has shown that demographic groups have different experiences and expectations in refugee camps (Briant & Kennedy 2004, Rasmussen & Annan 2009).

To address this issue, this research identified essential resources to refugees in the camp's built environment and how age, gender, and nationality affect a refugee's resource needs. Specifically, this research asked: *What built environment resources are valuable to refugees in refugee camps? How do these resource needs vary with age, gender, and nationality?* To answer these questions, the research employed interviews and surveys in two refugee camps in Greece, Camp Moria and Camp Eleonas. This paper presents the research design for answering the two research questions and will include preliminary data analysis in the final version of this paper. Data collection included three phases. First, refugees were interviewed (N=30) to identify their resource-needs in the camp environment. This method created a comprehensive list of resource-needs. Second, based on these identified needs, surveys were created and distributed out to the entire camps to assess the relationship between resources and age, gender, and nationality. Third, survey data was analyzed using analytical hierarchy process (AHP) and linear regression analysis. This analysis showed how the resource-needs vary based on the diverse demographics in the camp. By identifying and modeling what resources refugees need, this research can better inform development organizations and local governments regarding camps' planning and design.

RESEARCH RATIONALE AND THEORY

Globally, millions of refugees are managed and helped in a refugee camp (UNHCR 2016). These camps are generally the standard approach to helping displaced people because they attempt to provide temporary order and shelter. While the intent of refugee camps is to provide the space and resources for facilitating transition to the host country, the camps can be problematic for refugees' transitions for two primary reasons. First, refugee camps are perceived as the immediate response to migration and often seek to address short-term needs while neglecting the long-term needs (Briant & Kennedy 2004). Second, refugee camps are usually located far from cities and they are often bound by fences to indicate a distinction from the host country (Turner 2015). As such, refugees are often portrayed as victims and provided with basic services such as shelter, food, and healthcare (Turner 2015). Because refugees receive aid and shelter from the country of asylum, refugees are not expected to make demands in the camp environment (Turner 2015). This status strips refugees of political capacity, which results in the ignoring or failing to understand their resource needs (Turner 2015).

While refugee needs are often ignored, addressing them is important for adaptation within the country of asylum, as it greatly impacts their wellbeing and long-term recovery (Chung & Kagawa-Singer 1993, Rasmussen & Annan 2009). In a study of Southeast Asian refugees who had resettled in America, Chung & Kagawa-Singer (1993) found that pre-migration trauma events and refugee camp experiences were significant predictors of psychological distress even five years or more after migration. These negative effects on wellbeing happen because refugee camps represent the space in which refugees adapt to both their host countries and to the events that caused them to flee their countries (Turner 2015). Because the camp experience can have a significant impact on refugee health, it is critical to understand what the resource-needs of refugees are in order to mitigate potential stressors and provide appropriate resources.

Existing frameworks and processes have been developed to help with assessing what is important to refugees (Briant & Kennedy 2004), but they do not account for variation in needs based on refugee demographics. Because of this gap, Rasmussen and Annan (2009) studied stressors in the built environment based on different demographic groups among Darfur refugees. The study showed that factors such as age, gender, and marital status all affect how a refugee interacts with the built environment. For example for men, being employed and providing for families was essential. As a result, men who were unemployed and unable to provide for their families suffered high levels of stress. (Rasmussen & Annan 2009). The complexity of these interactions shows that there needs to be further studies on what refugees consider important. As such, this research seeks to identify how refugees' needs differ across age, gender, occupation, and nationality. To do so, this research expands previous literature by taking an intersectional perspective to identify the needs of refugees. Intersectionality asserts that race, class, gender, sexuality, ethnicity, nation, ability, and age operate not as unitary, mutually exclusive entities, but as

reciprocally constructing phenomena that shape complex social inequalities (Collins & Bilge 2016). Expanding on this, this research will show that refugees' demographics are critical when to addressing their resource-needs within the camp environment.

RESEARCH PLAN, METHODS, AND METHODOLOGY

To determine the priorities of refugees in refugee camps, this research employed a mixed-method approach. First, fifteen refugees in the camp were interviewed and asked about resource-needs in the camp environment. Second, these interviews were coded using grounded theory to determine what their resource-needs were. Then, the identified resource-needs were used to create surveys, which were then distributed to refugees in the two camps to compare resource-needs and collect demographic data. Data from the surveys was analyzed using AHP and linear regression analyses. The AHP was done to rank the resource-needs while the linear regression was done to examine relationship between ranked needs and demographics.

RESEARCH CONTEXT

The work in this paper was conducted in the context of two refugee camps in Greece: Camp Eleonas and Camp Moria. Data collection occurred between May and August 2018. Greece currently hosts around 60,000 asylum seekers in refugee camps and the latest reports show poor conditions and lack of institutional support (UNHCR 2016). Over 70% of these asylum seekers in Europe are from countries in the Middle East (Syria, Iraq, and Afghanistan) with the other 30% are from Northern Africa (Nigeria, Libya, Eritrea). Of this group, about 40% are men, 20% are women, and the other 40% are children.

Camp Moria and Camp Eleonas were chosen based on Office of the United Nations High Commissioner for Refugees (UNHCR) reports which show stressed conditions within these camps (UNHCR 2016). The two camps were managed by UNHCR. In addition to UNHCR oversight, the camps receive ancillary support from NGOs and the local government. Despite this ancillary support, Camp Moria is grossly overcapacity because it is the first point of entry into Europe for many refugees fleeing the Middle East. Because of the overpopulation, the camp services such as shelter, water, and sanitation resources were strained (UNHCR 2016). Camp Eleonas was the first camp opened on the Greek mainland and its conditions are less stressed than those in Camp Moria but are still poor (UNHCR 2016). The camp was chosen with the goal to increase generalizability of the study. Because of the inadequate resources in these two camps, we chose this case as it allowed us to identify a comprehensive list of resource needs.

RESEARCH TIMELINE

The research in this paper is ongoing. Data collection occurred between May 2018 and August 2018. This paper will present preliminary data from the data collection Table 1 outlines the proposed research plan.

Table 1 – Research Timeline

	Task	May 2018	June 2018	July 2018	August 2018
RQ1	Conduct interviews in Camp Eleonas	X			
RQ1	Analyze interview from Camp Eleonas	X	X		
RQ2	Survey Camp Eleonas		X		
RQ2	Analyze Survey Data from Camp Eleonas		X		
RQ1	Conduct interviews in Camp Moria		X		
RQ1	Analyze interviews from Camp Moria			X	
RQ2	Survey Camp Moria			X	
RQ2	Analyze Survey Data from Camp Moria				X

IDENTIFYING RESOURCE NEEDS

To first identify resource-needs, refugees were interviewed and asked to describe the resources that are important for their quality of life and recovery. This study utilized snowball sampling and recruitment flyers to recruit participants. Snowball sampling and the flier allowed the team to establish initial contact with the refugees in the camp. Next, emergent sampling (Palinkas et. al, 2015) was used until the data was saturated. Emergent sampling occurs when the researcher makes sampling decisions during the process of collecting data. This commonly occurs in field research. As the observer gains more knowledge of a setting, he or she can make sampling decisions that take advantage of events, as they unfold (Palinkas et. al, 2015) We recruited for interviews at each camp. The sample population included refugees off all demographics above the age of 18.

We interviewed 15 refugees at each camp until theoretical saturation was reached. Example of interview questions included: *What are the resources that important to you in the camp environment? Why are these facilities important to you in the camp environment? What facilities that are not in the camp are important for your everyday activities?* These questions were chosen and developed to assess what refugees consider important in the built environment. We conducted most of the interviews in English. When the interviewee

did not speak English, a translator helped translate the interview. The interviews were then transcribed verbatim.

Due to the explorative nature of the research, interview data was coded using grounded theory to identify important resource-needs (Glasser and Strauss 2008). Grounded theory is a methodology that works inductively and studies contexts and topics that have had limited exploration. We developed new codes and themes based on the responses in the interviews. We interpreted the data to create a list of refugees' resource-needs. Interviews were coded using QSR NVivo, a qualitative coding software.

SURVEY PROTOCOL

Using these identified resource-needs, a survey was sent to refugees in the two camps with two sections and research goals. The first section compared and ranked the identified resource-needs. The second section determined how refugees' resource-needs vary with age, gender, and nationality. Surveys were distributed out to the entire camp to capture a complete profile of how resource-needs vary. Data from the surveys was analyzed using AHP and linear regression analysis. AHP showed the relative importance and ranking of these resource-needs. Linear regression analysis showed how resource-needs vary between age, gender, and nationality.

COMPARING AND RANKING RESOURCE-NEEDS

Participants were asked to complete pairwise comparisons, indicating how important each selected resource was. This allowed them to rank all of the resource-needs identified in the interviews against one another. Questions included comparisons such as *“Rate on a scale from 1 to 9 how much more this resource is than this one”*. We then used AHP to rank and compare the different resource needs refugees. AHP is an effective method for group decision-making and for obtaining consensus among individuals between a range of alternatives with in-depth rigor that both reveals and analyzes contextualized priorities (Saaty 1994). The AHP uses pairwise comparison to develop an ordered list of priorities in the context of a decision (Saaty 2008). In pairwise comparison, judgments are used to determine one priority's relative importance over the other. These judgments have numerical values and range from indicating two priorities that are equally important to one priority that has extreme importance over the others, a value from 1 to 9, respectively. AHP allowed us to understand what resource-needs were most important to refugees in the camp. The analysis will reveal the top five resource-needs among refugees in the two camps.

COMPARING RESOURCE-NEEDS TO DEMOGRAPHICS

To evaluate how a refugee's resource-needs vary based on age, gender, and nationality, survey data was analyzed with linear regression analysis. The survey included

questions such as “Rate on a scale from 1 to 10 to what extent is this resource is important to you in your camp?” These questions provided numerical values to a resource-need, which was then compared against age, gender, and nationality to determine correlations. This analysis allowed us to see the resource-needs was most important to each demographic group.

EXPECTED CONTRIBUTIONS

This research contributes to scholarship on displaced people by identifying the needs of the refugees according to intersectional demographics. In terms of theoretical contribution, this research is expected to validate theory of intersectionality in times of humanitarian crisis. In other words, this research argues that the needs of people are not universal in the times of humanitarian crisis. For example, it can be expected that men and women will have different resource needs (Briant & Kennedy 2004; Rasmussen & Annan 2009) and those needs will also differ across nationalities. Furthermore, by identifying essential resources and how the importance of these resources differ with age, gender, and nationality, this research will make refugee needs more visible to the organizations that manage these camps. The findings will allow organizations to better understand and identify vulnerabilities within the camp, thus they will be able to better design and plan camps to address these vulnerabilities.

Overall, the research challenges existing camp designs and opens conversation regarding whom participates in the design of these camps. As a result, this research challenges the idea that crisis is attached to survival. Crisis needs to be conceptualized and understood through the lived experiences of people and by listening to their stories and challenges in times of crises.

CONCLUSION

Globally, refugee camps manage millions of refugees; however, the organizations that manage these camps often neglect and misunderstand the resource-needs of refugees. Prior studies and literature have shown that when refugee resource-needs are misunderstood or ignored, a refugee’s long-term recovery and adaptation are impeded (Chung & Kagawa-Singer 1993; Briant & Kennedy 2004). In addition, the complex relations between demographics and resource-needs are not well understood, which can be detrimental to specific demographic groups (Rasmussen & Annan 2009).

To address this problem, this research asked (1) *What built environment resources are valuable to refugees in refugee camps?* (2) *How do these resource-needs vary with age, gender, and nationality?* Using a mixed methods approach comprised of interviews and surveys, the team identified, ranked, and correlated the resource-needs of refugees in Camp Moria and Camp Eleonas in Greece. These camps were chosen because of their overpopulation and strained resources (UNHCR 2016). Interviews (N=30) were used to

identify resource-needs in the camps. The interviews were coded and analyzed using grounded theory because of the exploratory nature of the research (Glasser and Strauss 2008). The identified-resource needs were used to create surveys with two sections and goals. First, the survey asked refugees to rank the identified resource-needs against one another. The second section asked refugees to identify their age, gender, and nationality and then it asked which resource-needs were most important to them. Surveys were distributed out to the entire camp to capture a complete profile of how resource-needs vary. Data from the surveys was analyzed using AHP and linear regression analysis. AHP showed the relative importance and ranking of these resource-needs compared to one another. Linear regression analysis showed how resource-needs vary between age, gender, and nationality.

Like previous studies aimed at assessing refugee needs, this study is expected to have limitations. For example, this study did not examine how refugees access resources within the built environments. Refugees can navigate around formal institutions such as the UNHCR to access resources on their own their informal networks (Yassin et al. 2016). If refugees have already addressed their resource-needs, then the data may not accurately show the needs of refugees (Rasmussen & Annan 2009). Furthermore, it is possible that that refugees did not tell the interviewer their needs due to shame or belief that they will be ignored (Briant & Kennedy 2004).

Despite these limitations, this research shows that identifying and understanding the resource-needs is important when planning for refugee camps, which are typically designed to be generic regardless of the context. This research shows policymakers that identifying and designing around the resource-needs of refugees will result in better camps. This is because the camps will address needs that refugees consider important for their recovery.

Future studies should build off these identified needs and study how refugees navigate formal and informal institutions to access these resources. In this context, institutions are defined as “system[s] of established and embedded social rules that structures social interactions” (Hodgson 2006). This process is poorly documented and is invisible to both policy makers and local governments (Yassin et al. 2016) but essential since refugees have limited political power. Future research would seek to map the process that refugees use to contest local institutions to gain access to resources (Yassin et al. 2016).

This research would reveal the importance of both formal and informal institutions that provide access to infrastructure in refugee camps (Yassin et al. 2016) and the coping mechanisms that refugees use to navigate these institutions. For policy makers, the research would make the invisible decisions that refugees adopt visible and map the coping mechanism that people with limited political power use. In addition, it shows the gaps in coordination among institutions in crisis situations. As a result, policy makers can integrate these decisions to design frameworks that can better accommodate refugees’ resource-needs.

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WORKER ENGAGEMENT ON CONSTRUCTION SITES – TIME FOR A NEW LOOK

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Proceedings Editors

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WORKER ENGAGEMENT ON CONSTRUCTION SITES – TIME FOR A NEW LOOK

Steve Rowlinson¹

ABSTRACT

This paper builds on prior work by the research team and others on health checks, safety climate, heat stress and the ineffectiveness of voluntary safety schemes on construction sites (Tin et al, 2016, Ju & Rowlinson, 2014, Yi & Chan, 2016) . These research projects identified issues in workers' HSW. Health, safety and well-being are grouped together as during research undertaken with MTR the concern shown for workers' health and wellbeing was seen to positively affect workers attitudes towards their own safety (Rowlinson et al, 2015).

Managers and supervisors on construction sites are not engaging meaningfully with workers who are not encouraged to participate in planning working practices and procedures. This finding came to light during the MTR Health Checks in May 2014 and 2015 and was corroborated in recently completed, **GRF funded research** on safety climate.

KEYWORDS

OHSW, worker engagement, Hong Kong construction sites, culture, power distance.

CONTEXT

There have been incessant calls in recent years for stricter regulation and enforcement.

“Commissioner for Labour Carlson Chan Ka-shun said earlier that the 11 fatalities at construction sites across the city in the first four months of this year had “sounded alarmbells”, compared with a total of 18 deaths for the whole of last year.“ If all of society and the Legislative Council think that beefing up punishment will bring about better deterrence, we are definitely happy to study the matter,”²(Leung, 2017)

Carrie Lam (CE HKSAR) repeated virtually the same in more detail in her policy address

Insert here Table 1

Insert here Table 1

Industry change

At the current time HKG Development Bureau is promoting more collaborative working and moving towards integrated project delivery and NEC. These changes in procurement are high level, aimed at changing the procurement system and integrating information management technologies, such as BIM, with process change

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² This viewpoint is disputed

in order to move toward the goal of integrated project delivery. This is laudable but should not this collaborative process also be funnelled down to the lowest level, the construction operations? By so doing there is scope for collaboration and engagement of the worker at the workplace. This would also show a concerted and inclusive effort to improve the industry's performance and image. We are approaching a watershed in the way the industry organises itself. It is important that this opportunity for inclusion and engagement is not missed.

Issues

Currently, accident investigation methods and models of accident causation use inadequate models and are not holistic. Originating influences (as shown, for example, in the ConCA model, Haslam et al, 2005) such as client requirements, physical demands, risk and construction management, peer pressure, subcontracting and site constraints are all out of the workers control. Yet these are originating influences and shaping factors that lead to the immediate circumstances are not adequately covered in the accident analyses. Existing thinking tends toward the blame game, often focusing on workers actions and violations rather than the distal originators of the problem. It is time that safety was viewed through the eyes of those exposed to risk, the workers. This change of viewpoint can assist in refocussing our approaches to HSW. It comes hand-in-hand with the use of digital technologies (including VR and AR), modular and volumetric construction and collaborative contracting that can facilitate design and plan for safety. This provides a new platform to focus on workforce engagement and stimulate a sea-change in industry attitudes.

Outcomes

As we have little or no engagement nor empowerment of workers many obvious safety issues pass by the gaze of the supervisor or manager. Cultural issues, such as power distance, face and pragmatism produce a social and psychological distance between workers and supervisors and managers. As Hofstede (1983) explains cultural orientations pose " anthropological problem areas that different national societies handle differently: ways of coping with inequality, ways of coping with uncertainty, the relationship of the individual with her or his primary group". Hong Kong has an ageing workforce of diverse ethnic origins. The novelty of this proposal is in exploring these issues on the construction site.

Consequences

At the moment Hong Kong does not have robust knowledge transfer practices in order to transfer HSW knowledge, expertise and good practice across projects, embed the knowledge in the firm and transfer this across to the existing, ill performing supply chain of SMEs in construction. Without this capability there will be no impact of this knowledge base on the day-to-day management of projects. The consequences of this are a fragmented and unmanageable workforce. To date, the relationship of workers to their direct employers and the "main" contractors has been poorly researched and documented.

The Current Situation

The Hong Kong construction industry is famous worldwide for its pace of construction and impressive skyline but also for its poor safety record. There are many reasons put forward for this poor performance including the risk-taking propensity of construction workers, the pace of construction, the multilayer subcontracting system and the ageing workforce. However, the response to this poor safety performance has been piecemeal, with no vision nor strategy, and is characterised by a whole series of weakly related initiatives. Attempts to improve safety performance started with the Airport Core Projects and provision of basic safety infrastructure in the mid 1990s and this was followed up with the Safety Management Regulation that came into effect in 1999. However most of the other initiatives have been voluntary, such as morning exercises, safety buddy system and others. In recent years there has been a trend to focus on behavioural safety management with the goal of changing the attitudes of workers and the workforce. It is apparent that supervisors and management expect change but do not engage effectively in promoting the desired changes.

Behaviour-based safety management

The behaviour-based approach has been widely used to develop interventions for construction accident prevention (Lingard and Rowlinson, 1998; Zhang and Fang, 2013; Zohar and Luria, 2003). However, Lingard and Rowlinson pointed out that, in construction, without the basic safety infrastructure being in place alongside a well-developed and effective safety management system (SMS) the behaviour-based approach cannot be effective. Any attitude change will be short-lived if the SMS and safety infrastructure are ineffective, thus thwarting attempts to improve safety performance. The actual impact of such interventions is not as effective as expected. Unfortunately, this raft of initiatives, legislation and behavioural interventions has not reduced the accident rate to a level much below 50 accidents per thousand workers per annum. Indeed, the decline in accident rate has plateaued over the past 10 years and there is a desperate search in the industry for more solutions. The moving average of the fatality rate is virtually static, as can be seen in Fig. 1.

Insert here Fig.1 Five year moving average fatality rate

The construction worker is on site with all sorts of activity and idling going on around him that he has no control over so he just gets on and does his task in his own sweet way. Yet, so often the worker is blamed for causing the accident. Why is he in such a predicament? Who has the power, authority and know how to remove hazards and structure the site, the tasks and the interfaces? These are key questions in the construction industry that don't arise in the manufacturing industries. Recent studies look beyond the immediate circumstances of accidents to shed light on systemic and institutional factors that prevent, permit or cause the occurrence of accidents. The comparison with manufacturing industries will be addressed later.

Uniquely construction industry pressures

Commercial and regulatory pressure from clients, shareholders and regulators drives construction companies to attempt to satisfy conflicting objectives. Grassroots pressure arises from the workforce, the supply chain, the worksite and the work itself. The orthodox approach to management of HSW is to quantify risk, impose procedures and retrospectively search for root causes of accidents. Compliance is demanded from a workforce that is held to be liable for safety violations. There is a lack of engagement, effective communication and collaborative problem solving between workers, supervisors and managers. The HSW management system is reactive.

The typical construction project has a unique, incomplete design and is won in a competitive bidding market of low profit margins. This leads to a structure comprising a network of loosely coupled specialist contractors and subcontractors with contracts only for specific elements of the project and with no interest in the work of other specialists. This is the “hollowed out firm”. In such a firm a construction management expert with HSW knowledge is a scarce resource (whereas account controllers abound) The temporal (often haphazard) nature of the work (and contracts) leads to consequences such as: uncommitted and unengaged workforce; low levels of investment in safety and training except at lead contractor level; consequent low skill levels and lack of multi-skilling; low levels of innovation and mechanisation; weak organizational learning; a culture of litigation (Harvey et al., 2016). In such a context blame and intolerance are the inevitable outcomes and time, cost, quality and HSW all suffer. The interdependence and uncertainty problems associated with such temporary mutli-organisations (TMOs) has been recognized long ago (e.g. Cherns & Bryant, Higgin & Jessop 1965, Crichton 1966, Stringer 1967). The sociotechnical systems approach of the Tavistock Group still provides an appropriate lens through which to observe these problems but in a technologically more advanced context. In the past millennium technology was a problem whereas as now it is a potential provider of solutions.

Sociotechnical systems

Central to the problems on site are the relationships and engagement between workers, supervisors and management within the sociotechnical system of these TMOs. The consequence is inconsistency in policy and procedures and conflicts of interest. On top of this is the governance system of stakeholders and client organisations constrains or directs actions. Such organisations individually struggle to manage both their place in the TMO and their employees. There is no continuous learning from each project and little innovation in both processes and product, below is an illustrative example:

Case study

Two workers died and others were seriously injured when a working platform fell from a bridge pier. The workers were attached to the guardrails of the working platform by lanyards and were unable to detach these as they plunged into the sea and drowned. The platform was being manoeuvred from above by another gang of workers using pressure jacks and wooden packing. The workers below and the workers above had not communicated with one

another about the operation. The workers above were attempting to manoeuvre the platform in a highly dangerous manner but they had no technical knowledge as to how to do this. The supervisors and managers appeared not to be aware of the situation or, incorrectly, assumed the procedure was safe. The outcome was tragic and reflects: a lack of engagement of supervisors and management with the workforce; a failure to communicate clearly to the workforce the technical and administrative aspects of moving the working platform; a lack of communication amongst fellow workers; poor directions by the enforcement authority regarding attaching of safety harnesses rather than using lifejackets.

This is an example of failures in the sociotechnical system, in that work was not administered and managed effectively and workers were not adequately trained and aware of the risks and wrong directions given as to a safe method of working. No engagement and no sense of empowerment. HSW in Hong Kong is administered through risk management, engineering interventions, compliance procedures and punishment. This goes completely against the current approach of high reliability organisations that adopt a holistic approach to people, their tasks, work itself and the systems within which they operate (Wilson 2014). The goal is to develop a culture of ensuring safe working, **not** preventing accidents, through individual employees' engagement, thus enabling their resilience and responsiveness to be harnessed (Hollangel 2014). This approach would represent a sea-change in HSW management in Hong Kong.

Engagement

*O, wad some pow'r the giftie gie us
Too see ourselves as ithers see us.* Robert Burns

Here lies the crux of the matter in Burns' quote. The people on site are currently blind to others' views. This research aims to uncover the issues and biases that help maintain this viewpoint. This is a structural problem and also a governance problem. It is a set of problems that the industry must debate if it is to identify and remove barriers to change. This is currently being facilitated by a process change towards collaborative integrated project delivery. This change, of course, requires a social change in the move towards collaborative contracting and access to federated information databases. Thus, the sociotechnical lens provides an appropriate viewpoint for this research in identifying barriers and facilitators of engagement at the worker level as part of this change process.

Hong Kong has long lost its manufacturing industries to China and South East Asia. Manufacturing industries are more stable and predictable than construction and are able to introduce safety management systems that are replicable from plant to plant and can be learned and understood by a stable workforce. In this way, companies can become high reliability organisations. Construction is not like this. Workload is unpredictable, all sites are different, the workforce is transient and thrives on initiative and being left unsupervised. Hong Kong contractors have few role models

to look up to and to imitate. Hence, safety management is much more difficult and worker engagement an imperative.

Accident causality viewed from a sociotechnical systems viewpoint

This research focuses upon the relationship between HSW in an industry consisting of a partly indigenous and ageing workforce. It is cross-disciplinary, covering the domains of social and cultural research, public health, organizational behaviour and governance in the challenging and high risk environment of construction. As previously noted, the industry is at a point where major changes in organizing and procuring public works is taking place. Technologies such as BIM, volumetric and modular construction, IoT, drones and others will not only bring efficiencies but also drive collaborative working and early contractor involvement. These changes affect relationships and technology and so a sociotechnical systems viewpoint is an appropriate lens through which to view these process innovations. By focusing on a key operational area, workforce engagement, there is opportunity to drive an attitude change at the grassroots (workface) level at the same time as change is taking place at a more strategic level.

Institutions, as socially constructed orders of behaviour, are patterns of connections between components of a system, signifying “what works” within a system. A systems viewpoint focuses research attention on the risks embedded in how the components of a system work together in operation. While it is important to examine the effectiveness of interventions and initiatives to prevent occupational accidents (van der Molen et al., 2012), Hasle et al. (2014) advocate that interventions should be viewed “*as a part of social programmes consisting of a number of different policies, regulations, enforcements and other attempts to change workplace practices*” (p.74). Thus, instead of trying to evaluate the effect of a particular intervention strategy on HSW performance, Hasle et al. (2014) call for more research addressing the mechanisms that turn the collective effort of a multitude of stakeholders into concrete workplace practices that actually improve the HSW conditions. The aim is to better understand what actors should take into account and how they collectively influence contractors’ safety management strategies.

Manpower shortage

Hong Kong is currently experiencing a manpower shortage from professional, through technician to front line worker. Resources are valuable in that they allow the organisation to outperform competitors or reduce its own weaknesses (in this case its HSW management system). Resources, to be of value, must be scarce and currently in the market experienced and talented safety managers are in short supply. The inimitability of a resource explains why organisations without the scarce resource cannot compete with organisations that have such a resource and so this is one cause of widely varying HSW management performance. In the domain of construction site safety management there is no substitute for the scarce resource. Hong Kong is currently suffering a serious labour shortage, exacerbating the weak engagement of the workforce, and compounding the weakness in sociotechnical skills of supervisors

and the lack of social engagement skills of managers and directors. In framing their research questions Rowlinson & Jia (2015) provided an eight level taxonomy of factors contributing to incidents and accidents: individual, task, team, project, organisation, industry, society and ecosystem levels. The first four of these will be of use in this research as an *aide memoire* to the many levels that can affect HSW management.

The tension between productivity and HSW goals at the workplace level has been frequently pointed out as a critical contributing factor to occupational injuries and fatalities (Haslam et al, 2005; Lingard & Rowlinson, 2005). In a current GRF project (GRF17206514) initial findings indicate that culture, in the form of weak safety climate and a strong risk taking propensity of construction site workers and supervisors, is associated with poor safety performance. This is an expected outcome but why safety climate is poor was the focus of the research: visibly felt safety leadership and engagement (see Figs. 2 and 3) were both found to be missing on the studied sites yet project directors and managers initially denied this. Eventually, after discussions with senior managers and directors, this was accepted as a problem area and as a priority area for further research. Successful research in the area of worker engagement brings with it the opportunity to vastly improve HSW performance.

Insert here Figs. 2 & 3

Methods

Semi-structured interviews and case studies will be conducted to address the research objectives. Researchers will, wherever possible, sit in on site and main office meetings as observers. Two sampling strategies to select interview respondents are proposed, theory-driven and convenience sampling (Miles & Huberman, 1994). Different sizes of organisations may experience institutional pressures differently (Greenwood et al., 2011). The ownership of organisations and the position/role of interviewees in an organisation also affects individual experience of institutional pressures (Greenwood et al., 2011). These factors will be taken into account in the selection of the range of interview respondents from each organisation. It is imperative that a representative sample of workers is selected and it is anticipated that these will be drawn from key trades: steelfixing; formwork; concreting. As noted above, practitioners working in project developers, consultant companies, industry associations and professional bodies will also be selected, as these people are in a position to observe the responses of various types of contractors in developing and maintaining their HSW management systems.

Once the characteristics of interviewees have been determined, interview invitations will be addressed to those organisations that have already expressed support for the research. Around 30 interviews will be conducted in the respondent's native language, tape-recorded, transcribed and translated into English. The interviews will last for an average of 40 minutes. Interviews will continue until the analysis becomes saturated i.e. no new issues arise. Semi-structured interviews involve the implementation of a number of predetermined questions, but interviewers are permitted to probe beyond the answers to their prepared questions (Berg, 2007). Our semi-structured interviews will consist of small number of general questions that can be explored by both

interviewer and interviewee. These will explore: perceptions of communication with and engagement of the workforce; involvement of workers in setting goals and work procedures; the discussion and allocation of tasks and targets; the role and effectiveness of safety training and initiatives; the experience of “distance” between worker and supervisor and manager.

Interview data analysis will follow the logic of abduction. Abduction involves a process of creating a novel type of combination between features presented in data as well as in extant theory (Bendassolli, 2013). It allows for intuitive interpretations of empirical observations and creative ideas that might account for them (Charmaz, 2008). When using abduction, Brinkmann (2014) described qualitative researchers as a tool-user, bricoleur or craftsperson rather than “collector” in induction and “framer” in deduction. The theoretical background presented above provides useful guidance in data analysis. However, the aim of this study is neither to verify dimensions of cultural distinction between players nor to count numbers of each type of strategy. By maximising the variation between interview respondents, we hope to identify as many factors as possible that influence contractors’ mechanisms for actively engaging the workforce in decision making and for maintaining and developing their HSWMS.

Outcomes

This research so far has been to put together a group of contractors and two to address this issue of engagement. The industry is incapable of rapid change. Hence, a strategy of pilots interventions dealing with engagements on safety and productivity has been adopted. The logic behind this is that both the contractors and the subcontract workers Believe that productivity is king. Thus, this attitude has to be addressed at multiple levels within the organization and with the institutions that given the industry. A series of pilot studies have been developed with the intention of providing case studies of positive engagements and, hopefully, proving productivity and safety improvements. These case studies will be reported during the conference.

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BUILDING IN UNCERTAINTY: DILEMMAS THAT NATIONAL LEADERS FACE IN NAVIGATING COMPETING AGENDAS OF PROJECT SPONSORS

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BUILDING IN UNCERTAINTY: DILEMMAS THAT NATIONAL LEADERS FACE IN NAVIGATING COMPETING AGENDAS OF PROJECT SPONSORS

Michael R. Hanneken¹

ABSTRACT

Populations within regions of limited essential services are subject to greater civil unrest and a lower quality of life. The United States' reconstruction efforts abroad to manage capital-intensive, project-based organizations over an unprecedented two decades of conflict have been plagued by failures despite tremendous funding. Recent research indicates that conflicting priorities between public agencies, such as the direct delivery of infrastructure assets versus training the local government in asset management, make for devastatingly counterproductive engineering efforts, yet few analytical tools exist to support organization leaders (executives) in navigating the competing agenda of stakeholders to unify project participants in an uncertain operational environment. Our study reveals hidden empirical relationships driven by organizational design that impact reconstruction outcomes. Our research approach separates this inferential problem into identification and statistics by first identifying likely explanatory variables through thematic analysis of open-ended, long-format, interviews of senior leaders in the public and private sector with career-length lived experience in being responsible for prominent reconstruction efforts worldwide. We analyzed matched-pair variables as latent constructs under a structural equation model, offering a graphic depiction of complex causal inference paths set up for future regression analysis. Our preliminary research results suggest that the combinatory effect of seven interdependent pairs of tradeoff dilemmas faced by project leaders creates path-dependent outcomes responsible for repeated project failures by trapping reconstruction organizations into well-worn, counterproductive, ruts. We posit a novel framework to explain and predict second-order effects of competing tradeoffs for enhanced informed decision-making and optimal positioning of project-based organizations beyond those in uncertain environments.

KEYWORDS

Institutional projects, reconstruction, path dependence, capacity-building.

INTRODUCTION

CHALLENGES IN DELIVERING ESSENTIAL SERVICES TO PEOPLE WHO NEED THEM MOST

The stakes are high when infrastructure fails. Clean drinking water, reliable power, hospitals, schools, mass transportation systems and cellular communication are some of the essential services necessary to support people in the built environment in which we live, work and play. Delivery of these services is possible through infrastructures

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such as water treatment plants, building facilities, electrical service grids with redundancy, a series of fiber optic and cellular transmission towers, and trains and roads. It is not until any of these infrastructures are compromised, especially for extended periods of time, that their importance is fully recognized and the difficulty of repairing and rebuilding becomes apparent. In conflict-affected economies (CAEs) the difficulties are compounded by the inherent uncertainties of war or regions in persistent conflict.

The current water crisis in Cape Town, Africa, contaminated drinking water in Flint, Michigan, dilapidated buildings in Detroit, and natural disasters such as the 2011 tsunami in Japan—all are examples of compromised infrastructure, in some cases due to long-deferred maintenance, in others to instant catastrophes. In all of them, the breakdown of infrastructure and essential services negatively impacted communities.

This brings to mind several general inquiries: In what ways can program leaders improve the delivery of essential service to those who need it most? What are some prominent dilemmas leaders face? And finally, how do they navigate environments of uncertainty to unify partners? To study how project-based organizations are structured to meet these challenges, we analyzed reconstruction programs in CAEs that have taken place over the past sixteen years. The urgency and complexity associated with combat zones make for poignant and powerful cases (Brinerhoff, 2014) of delivering essential services to populations trapped in war-torn regions.

With uncommon access to national leaders and seasoned executives in public and private sectors responsible for the delivery of infrastructure, we performed interviews to gain insights from executives in charge of some of the world's largest reconstruction programs. The qualitative approach we used revealed hidden processes that suggested why some reconstruction organizations succeed while others fail to support the long-term sustainability of a region. In CAEs, civil and environmental engineers have a particularly critical role to play in the design, construction, and management of infrastructure projects to support CAEs today and in the future.

Access to essential services may also be associated with higher quality of life [X], reduced civil unrest, and the U.S. effectively operates under the hypothesis that it is necessary for regional stability. Moreover, the restoration of essential services is one of the most tangible manifestations of donor aid and foreign direct investment by the international community (IC). However, when promised reconstruction projects fail to achieve their stated objectives, this greatly impedes the IC's ability to secure future funding for new projects. Therefore, understanding why so many reconstruction projects fail is critical to securing future sustainable capital formation for CAEs.

THE CAPABILITY GAP IN KNOWLEDGE AND PRACTICE

In an attempt to curb regional instability and foster economic development in countries defined by the United Nations as Fragile, Conflict-affected Situations, the US and other nations have performed reconstruction programs to deliver essential services. However, independent government oversight entities (IG, 2012) with authority to report directly to the U.S. President have documented object failures in reconstruction projects abroad despite unprecedented international spending (CBO, 2012) on reconstruction over the past the last fifteen years.

Despite knowledge of disparate agency goals and associated reconstruction project failures, few studies have interviewed national leaders actually responsible for such projects in order to explore causal conditions that may have led to these disappointing

outcomes. This knowledge gap is addressed here through a thematic analysis of empirical observations. Eighteen national leaders from the public and private sector that spent their careers responsible for the delivery of multibillion-dollar programs were interviewed. We identified six pairs of conflicting priorities faced by executives in program-based organizations that appear to impact the outcome of reconstruction projects.

STATEMENT OF PURPOSE

The purpose of this study is to develop a theoretical framework that unpacks how dilemmas faced by program leaders (at the national level) due to competing agency agendas impact the reconstruction organization's ability to deliver infrastructure projects.

We will achieve this purpose by

- (i) Gaining insights from known national leaders responsible for multibillion-dollar programs to unpack how competing priorities within the reconstruction organization, termed dichotomies, faced by program executives impact organizational effectiveness in conflict-affected economies.
- (ii) Extending management theories of contingency framework and path dependence through an empirical study of reconstruction programs in CAEs to make sense of repeated project failures despite high funding.
- (iii) Developing a novel theoretical framework based on Structural Equation Modeling through which tradeoffs on engineering programs can be studied.

RESEARCH QUESTIONS

The central question is: How do tradeoff decisions by project executives constrain the reconstruction organization's ability to achieve intended capability and capacity outcomes?

Sub-questions:

- RQ #1: What are some constraints placed on the reconstruction organization that are unique to conflict-affected economies?
- RQ #2: What are some combinatory effects of tradeoff decisions by project executives that impact the reconstruction organizations' outcomes?
- RQ #3: What are some indicators of the reconstruction organization's ability to achieve intended outcomes?

Significance: Understanding the impact of multiple competing priorities within the organization allows the executive team to more closely align organizational design with program objectives.

We hypothesize that executives are hampered by the lack of a framework to consider competing priorities in reconstruction. The research questions arise from the Statement of Purpose to gain new insights (Marshall & Bresnen 2013) and deeper appreciation of the actualities of practice (Marshall 2014, Nicolini 2012). The

questions are integrated into the research design and are intended to narrow the philosophical assumption, method, and data collection of this study.

OBSERVED ENGINEERING PROBLEM

RECONSTRUCTION COSTS OVERRUN

Reconstruction failure is commonly associated with a lack of fiscal discipline. In 2012, the U.S. Congressional Budget Office reported tremendous cost overruns on reconstruction projects related to the war-on-terror, and the Special Inspectors General for Reconstruction in Iraq and Afghanistan have criticized the US Department of Defense for poor fiscal management. They reported that despite spending in excess of \$160 billion on reconstruction in Iraq and Afghanistan, access to essential services is very limited, and the desired level of stability in the region has not been achieved (IG 2011, IG 2012). According to the CBO, in today's dollars, "The United States has spent more on reconstructing Iraq and Afghanistan than it did rebuilding Germany [under the Marshall Plan] after World War II." The relatively high funding to federal contractors in Iraq and Afghanistan has not resulted in economic development, whereas by 1949, just four years after the end of WWII, Volkswagen began exporting Beetles to America. (CBO 2011). In fact, it is reported that the Beetle was popular in the United States because of VW's post-war recovery in Germany. (Bernhard Rieger, Corsia)

DISPARATE GOALS OF COMPETING AGENCY SPONSORS

In 2016, the Truman Center for National Policy made a call for a new approach to fragile states, and it followed up with a new report in March 2017 that reiterates the need for a new approach "because scholars and policymakers have often approached the concept of fragility in competing ways and with disparate goals in mind." (Albertson, Moran, 2017) Government oversight reports detail that program-based organizations operating in environments of uncertainty repeatedly fail to achieve the desired outcome. Our own participant observations (DeWalt, 2011) and the findings of our study support the Truman Center's assertion that disparate goals between agencies are a major impediment to reconstruction.

We then began to explore what are the prominent dilemmas faced by executives in the context of reconstruction due to the disparate goals of agency sponsors. Our study looks beyond this inquiry to explore tradeoff decisions faced by executives that may best align with reconstruction objectives. Such dilemmas inhibit unified action toward the supposedly shared objective of building the local population capability or capacity such as practitioners' working at cross-purposes on Afghan Girls' Schoolhouses.

Several interview respondents recounted the detrimental impact of agencies' disparate goals on the delivery of schoolhouses for girls in Afghanistan despite the high-visibility of such a politically-charged reconstruction program. At times, the lack of coordination for a shared goal meant individuals failed to coordinate with one another when delivering new infrastructure assets in a region. This led to redundant schoolhouses within the same area, which eventually fell into the hands of local warlords, while other regions had no schoolhouse. Figure 1 summarizes the steps that led to the misallocation of schoolhouses and thwarted the objective to educate Afghan girls.

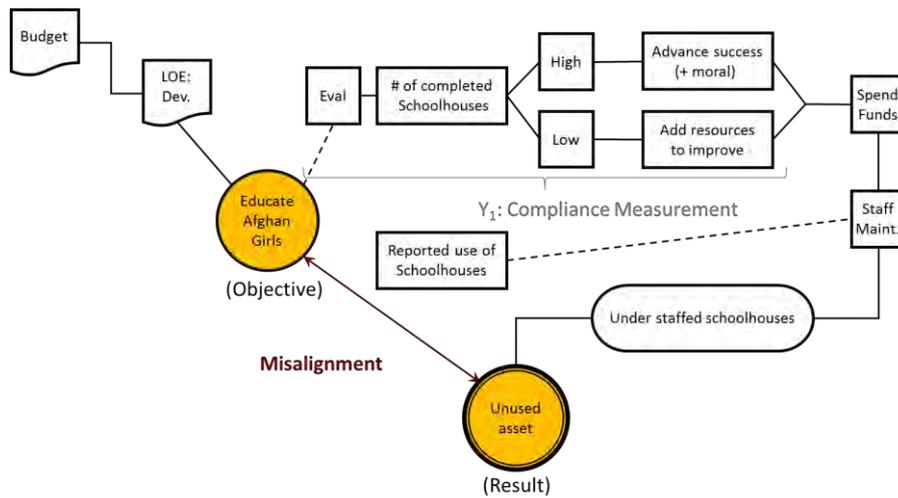


Figure 1: Steps leading to redundant and unsupported schoolhouses

Figure 2 depicts multiple US agencies and multilateral organizations maintaining influence over reconstruction programs within conflict-affected economies. The orange colored arrows represent agency-specific goals placed on the program organization leadership, represent by the green boxes, which deliver multiple types of infrastructure projects as represented by blue boxes.

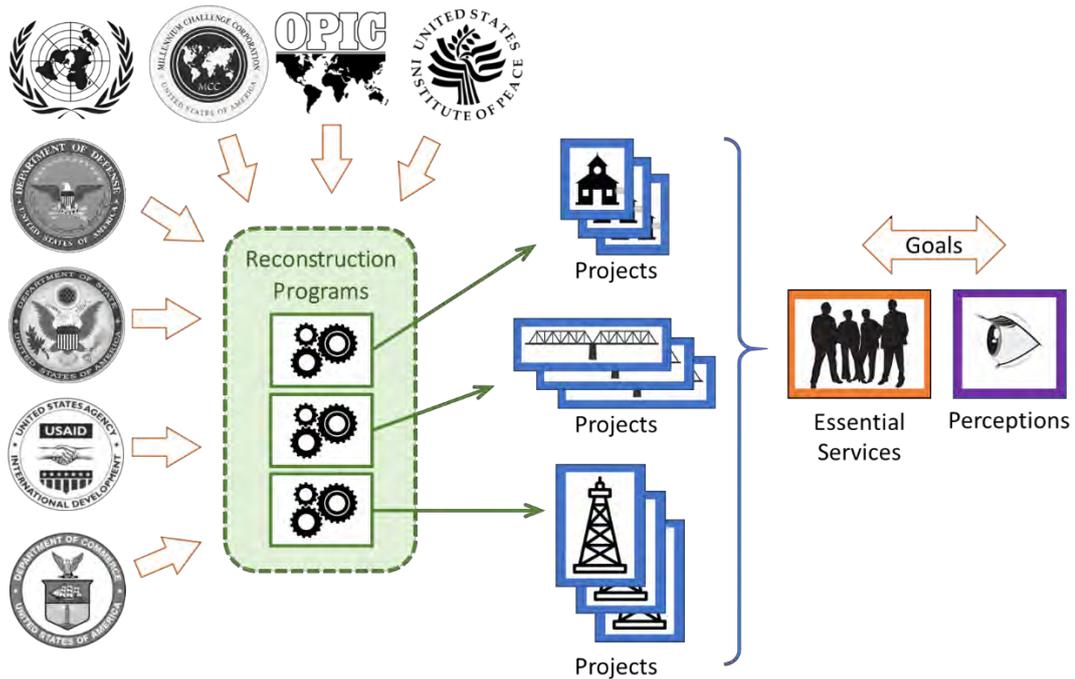


Figure 2: Stakeholders in Reconstruction Social Arena

RESEARCH METHODOLOGY

RESEARCH MODEL

The study has three process groups to organize empirical material collection efforts starting with participant observation, interviews and review of extant literature, and a model building literature review in the pursuit of a new analytical framework. To refine, and ultimately answer the research questions, the following research model was created to guide the progress of the study. David Otley's contingency framework theory (1980) was used as the basis of the research model of correlations between Reconstruction objectives, organizational controls, and program effectiveness. Figure 3 is a diagram of our study's research model.

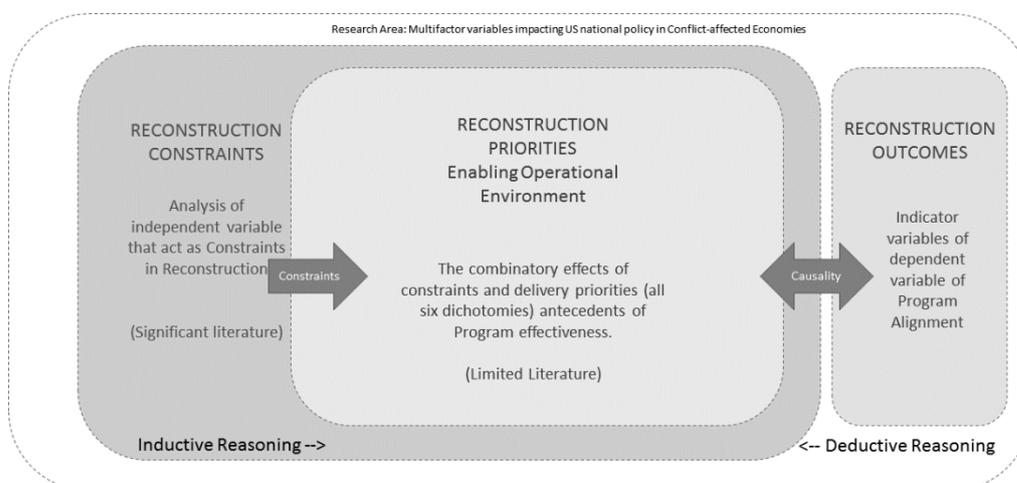


Figure 3 Conceptual framework

CAUSAL INFERENCE EXPLORATION AND PROPOSITIONS

The economist Charles Manski in his book *Identification Problems in the Social sciences* advocates that "...it is useful to separate the inferential problem into statistical and identification components." (Manski 1995:4) He goes on to explain that: "empirical research must, of course, contend with statistical issues as well as with identification problems. Nevertheless, the two types of inferential difficulties are sufficiently distinct for it to be fruitful to study them separately. The study of identification logically comes first...Positive identification findings imply that one should go on to study the feasibility of statistical inference." (Manski 199:5) We followed this advice in our study.

INSIGHTS FROM NATIONAL LEADERS RESPONSIBLE FOR IMMENSE PROGRAMS IN THE WORLD'S MOST DANGEROUS PLACES

In conflict-affected economies, reconstruction program executives face an overwhelming number of high-stakes tradeoffs of one priority over another. The implications of their decisions on the effectiveness of the program are not well understood. For this reason, we conducted open, semi-structured, long-format interviews (McCracken 1988) of eighteen executives across multiple agencies from the public and private sector. Not only recruited experts, but their responsibilities were at the national level, up to US undersecretaries and military general grade officers and

executives in the commercial sector, all of whom were responsible for the delivery of multibillion-dollar reconstruction efforts during an unprecedented period of spending.

Often interviews went over 90-minutes and “demand more complex categories and more sustained inquiry.” (Charmaz 2014, p. 215) We used participant observation experience to “engage interviewees in conversations that reveal their narrative constructions rather than gloss over them” (Charmaz 2014, p. 86) to gain insight from their career-long, lived experience in international development and reconstruction. Interviews were treated as individual cases. Moreover, such cases located in the world’s most challenging, dynamic, war-torn regions offered a uniquely revealing setting to study stark conditions and outcomes. Through our analysis, we gained key insights from the interviewed leaders responsible for immense programs that are generalizable beyond reconstruction to other environments of uncertainty.

These interview respondents are the Unit of Observation in this study and are identified by name and position in accordance with approved institutional review board (IRB) protocol. The Interview Protocol (Appendix A) consists of twelve questions covering the following subject areas:

ROLE—interviewee’s responsibilities and transitions between government service and professional practice

ASSETS—infrastructure projects vs. commercial real estate assets vs. Private Equity

INVESTMENT—Foreign Direct Investment (FDI) vs. Official Development Aid (ODA)

NETWORKS—integration and lack of integration between multilateral and USG agencies

IMPACT—program/project effect on host nation and exemplary successes and failures

PERCEPTION—evolution of public opinion and reflection over a career spent in service

CODING OF EMERGENT THEMES

From the thematic analysis (Braun, 2006) of these interviews, we identified several pairs of conflicting priorities, such as cultivating regional stability through security versus development operations; and, centralized versus decentralized project authorities faced by executives in program-based organizations that appear to impact the outcome of reconstruction projects. The emergent theory is driven by comparing empirical material (data) gleaned from interviews with extant literature and U.S. policy and doctrine, continually “returning to evolving theory to fill in the gaps and to elaborate on how it works.” (Creswell 2013, p.85)

Empirical material from interviews was used to “construct inductive conceptual categories” (Charmaz 2014, p. 87) and theory development. An important emergent theme from interviews was that all major decisions are tradeoffs. Executives and their staff struggle with sets of tradeoff decisions concerning program priorities with competing objectives on a near-daily basis. The notion of competing priorities was later reflected in the literature review.

In this study, our unit of observation was the individual person. We engaged in

theoretical sampling (Saldana 2016) while conducting interviews, responses were coded as suggested by psychologists Braun and Clarke (2006), who proposes six phases of thematic analysis, culminating in “thick description” (Geertz 1973). We performed initial coding in Dedoose software, and a research assistant recorded the same information in QSR International’s NVivo 11. Results were compared and contrasted. We coded each passage of the text with one or more codes. Codes were derived from third-party generated transcript interview responses and codes were added or modified as necessary as new meanings or categories emerged. Once the codes were established, each piece of text was systematically compared and assigned to one code. Finally, we rechecked the codes and assigned text to assess coding consistency.

PARTICIPANT OBSERVATIONS

As a service member and participant observer, the author² worked on infrastructure and economic development projects in Afghanistan in 2011/12. The participant observation data collection method (Jorgensen 1989) allowed for close and "long-term contact with the people [leaders] under study." (Fetterman 2010, p.39) The type of participant falls into the category Active Participation (Spradley 1980), which embraces skills and mitigates the risk of hidden bias by acknowledging subjectivity in the striving for an in-depth understanding of the observed unit of analysis and observation. Below we describe our adherence to Howell’s (1972) four stages of observation.

Stage 1. *Establishing Rapport*. As a service member responsible for creating lessons learned, the author was in an ideal position to engage with regional military and diplomacy senior leaders.

Stage 2. *In the Field*. The author used his professional experience in real asset management and service experience supporting missions of the U.S. Defense and State Department. As an integral member of units operating in theater, the author was “talking the talk” and “walking the walk” (DeWalt & DeWalt, 2011) with other participants.

Stage 3. *Recording Observations and Data*. The author maintained handwritten fieldnotes as reflexivity journals in which he had made and continued to make, personal entries over the years about the central phenomena of this study.

Stage 4. *Analyzing Data*. The author has performed narrative analysis to construct a coherent story from my participant observations. Thematic Analysis has revealed recurring themes found in interviews and other empirical material.

DISCUSSION OF KEY FINDINGS

Our research resulted in three findings: First, reconstruction programs are plagued by a series of competing priorities faced by leaders; second, decision making around these priorities has an unintended combinatory effect; and third, the combinatory effect leads projects to be stuck in a rut regarding path-dependent outcomes.

² The first-person, plural form, is used throughout this paper to reflect the community of social scientists who contribute to this paper. However, specific to this section, it was the sole author of this paper who performed participant observations in Afghanistan.

Together, the causal conditions that we explored appear to adversely impact both project objectives and, more generally, the reconstruction organizations' outcomes.

THE OSTENSIVE DICHOTOMY IN BUILDING HOST NATION CAPABILITY AND CAPACITY

Institutional programs require multiple agencies to deliver infrastructure projects in conflict-affected economies. This is due to the complexity and scale of reconstruction programs which require a number of experts usually not employed in any single agency. This is especially true in environments of uncertainty such as fragile states where reconstruction has been undertaken.

Several US federal agencies have a mission to assist nations in rebuilding infrastructure that provides essential services like drinking water and electricity to local populations in an effort to foster stability in regions of US interest. Some agencies work to achieve this mission by directly contracting teams of international firms to deliver infrastructure—what is called “capability building.” Other agencies work to achieve the mission through “capacity building,” which is the training of the local population, commonly government employees, to manage the delivery of infrastructure themselves. While the ultimate outcome of providing essential services is the same, the ways and means by which different agencies achieve their respective mission are vastly different, and as our research suggests, are often counterproductive.

Our research findings revealed an ostensive dichotomy between providing host nation capability and capacity. As such, capacity and capability became the dependent variables to measure the effects of four mediator variables (sourcing, authority, incentives, and agility) on in the reconstruction organization's ability to achieved intended project outcomes.

THE CONTINGENCY FRAMEWORK THEORY IS APPLIED TO LATENT CONSTRUCTS

To claim causality based on empirical material (data) alone is challenging. This study explores the idea that two latent constructs may be represented by one dichotomous latent construct, and that multiple dichotomous latent constructs may be subject to causal path analysis. This allows for more accuracy in illustrating the complex network of reconstruction.

There are seven latent constructions, each measured by a matched pair of conflicting priorities that, in order of effect, cascade down from the observed engineering problem of disparate goals between agencies to the impact on project outcomes. The first two constructs are Finance and Stability. They represent national policy guidance that governs multiple program-based organizations within a specific geographic region. The next four latent constructs are Sourcing, Authority, Incentives, and Agility. They represent a single program-based organizational controls that may be modulated by program executives to achieve intended project objectives and optimize reconstruction outcomes.

The final latent construct is the project's achieved Objective. This construct is a measurement of outcomes for reconstruction programs. For the sake of parsimony, the study limits the number of dependent variables to capability and capacity. The level of effectiveness in achieving these objectives is measured by comparing the intended and achieved objective. In other words, if the intended objective of the reconstruction organization was to build host nation capacity to deliver its own infrastructure projects, but due to scope complexity or externality the organization instead managed the

delivery then those projects would be deemed less effective, despite the fact they may have been successfully executed and currently in operations.

Identification of variables and latent constructs flow from emergent themes in a mix of empirical material, extant literature, and participant observation. The “parsing of state fragility into its component parts and the development of related indicators reflect efforts to tame the wickedness of the problem set” helps “take account of what is necessary to achieve their intended aims.” (Brinerhoff 2014) Table 1 identifies eight latent constructs as they fit within the Contingency Framework Theory (Otley 1980), and the resulting dichotomies are listed below.

Table 1: Eight program controls analyzed as latent constructs.

Independent Variables	Intervening Variables	Dependent Variables
Intended objective: Capability or Capacity	Reconstruction organizational Design	Achieved objective: Capability or Capacity
Constraint constructs 1. <i>Finance</i> 2. <i>Stability</i>	First mediator constructs 3. <i>Sourcing</i> 4. <i>Authority</i> Second mediator constructs 5. <i>Incentives</i> 6. <i>Agility</i>	Effectiveness construct 7. <i>Objective</i>

Each of the seven-latent constructs has an associated matched pair of competing priorities (match-paired variables):

1. *Finance*—aid versus investment funding
2. *Stability*—security versus development efforts
3. *Sourcing*—advisor versus partner agreements
4. *Authority*—centralized versus distributed control
5. *Incentives*—compliance versus efficiency measurements
6. *Agility*—assessment versus adaption planning
7. *Objective*—capacity versus capability building

Each ostensive dichotomy represents two competing latent constructs. For example, the dichotomy Sourcing incorporates both the Advisory latent construct with its own indicator variables and the Partner latent construct which also has its own, separate, indicator variables. We posited these ostensive dichotomies for the difficult act of exploring causal inference in solely qualitative data. Ostensibly dichotomous latent constructs reveal the complex processes at play in large programs, which may explain the discrepancies between intended and achieved reconstruction objectives.

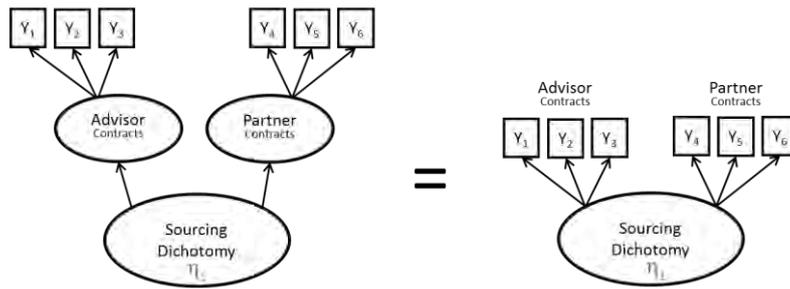


Figure 4: Ostensibly Dichotomous Latent Constructs

THE INFERENTIAL PROBLEM SEPARATED INTO IDENTIFICATION AND STATISTICAL COMPONENTS

While our study identifies the relationship between latent constructs and their associated indicator variables to help us explain the hidden processes that impact reconstruction outcomes, it does not (at this stage) quantitatively measure the impact. As stated above, this approach is supported by the economist Charles Manski (1995), who advocates in his book *Identification Problems in the Social Sciences*, that "...it is useful to separate the inferential problem into statistical and identification components." Manski (1995:4) He goes on to state: "empirical research must, of course, contend with statistical issues as well as with identification problems. Nevertheless, the two types of inferential difficulties are sufficiently distinct for it to be fruitful to study them separately. The study of identification logically comes first...Positive identification findings imply that one should go on to study the feasibility of statistical inference." As a qualitative research study, we first performed the step of identifying causal variables for future statistical-based analysis, such as Exploratory Factor Analysis (Child, 1990).

ANALYSIS OF MATCHED PAIRS OF LATENT CONSTRUCTS THROUGH SEM

The impact of latent constructs is measured in a structural equation model (SEM) (Byrne, 1998, Hoyle 1995) based on the construct's associated matched pair (X) of variables. Figure 5, is a pictorial representation of considered causal conditions. The SEM causal path aids in identifying the component parts of reconstruction. Applied reasoning (drawing on inferences and conclusions) was used to explore relationships between executives, the priorities they emphasized, and the resulting intended and unintended consequence. Indicator variables (not shown) determined the dominate latent construct (shown in rectangles) for each matched pair through inductive reasoning, while factors (shown in ovals), were primarily identified through deduction.

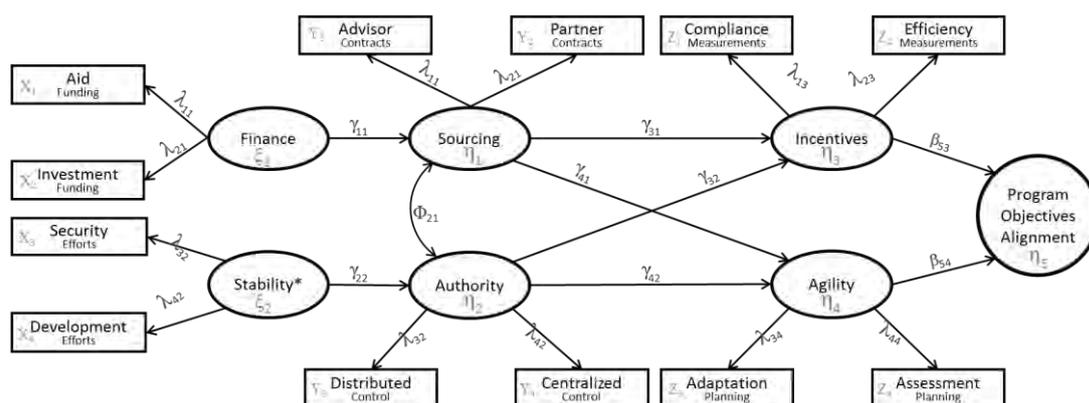


Figure 5: Structural equation model of variables

The causal chain starts on the left with determining financing and stability approaches and moves through the four-factor dichotomies faced by national leaders to the circle indicating the causal termination and measurement of effectiveness. Note that variables associated with the latent constructs Financing and Stability are assigned to the set of Contingent Variables because they constrain the reconstruction program and are not under the control of the program executive.

IMPLICATIONS OF FINDINGS

THEORETICAL POINTS OF DEPARTURE

In this section, we extend the implications findings through the application of selected theoretical points of departure identified in our critical literature review and insights gained from our empirical material (thematically coded interviews) analysis. For example, extant theories from David T. Otley on Contingency Theory Framework (1980), Adele E. Clarke on Situational Analysis (2005) and Sewall Wright on Causal Path Analysis (1919, 1934) are expanded on to explain the studied central phenomena of repeated project failures despite high funding.

David T. Otley: Contingency Theory Framework

We hypothesize that Otley's Contingency Theory Framework (1980) (figure 6) can explain the likely effectiveness of the reconstruction organization to achieve its intended objective of building host nation capability or capacity. To test this reasoning, we assigned variables into groups according to the framework that logically flows from the first set of independent variables that Otley terms "contingent variables" through sets of mediator variables that represent the "organizational design," which in this study are the dilemmas (tradeoffs) faced by leaders of the reconstruction organization that ultimately impact the "organizational effectiveness" as measured by dependent variables "in relation to objectives" originally intended in the "contingent variables" set. The corresponding latent constructs from our study are shown to the right of Otley's framework.

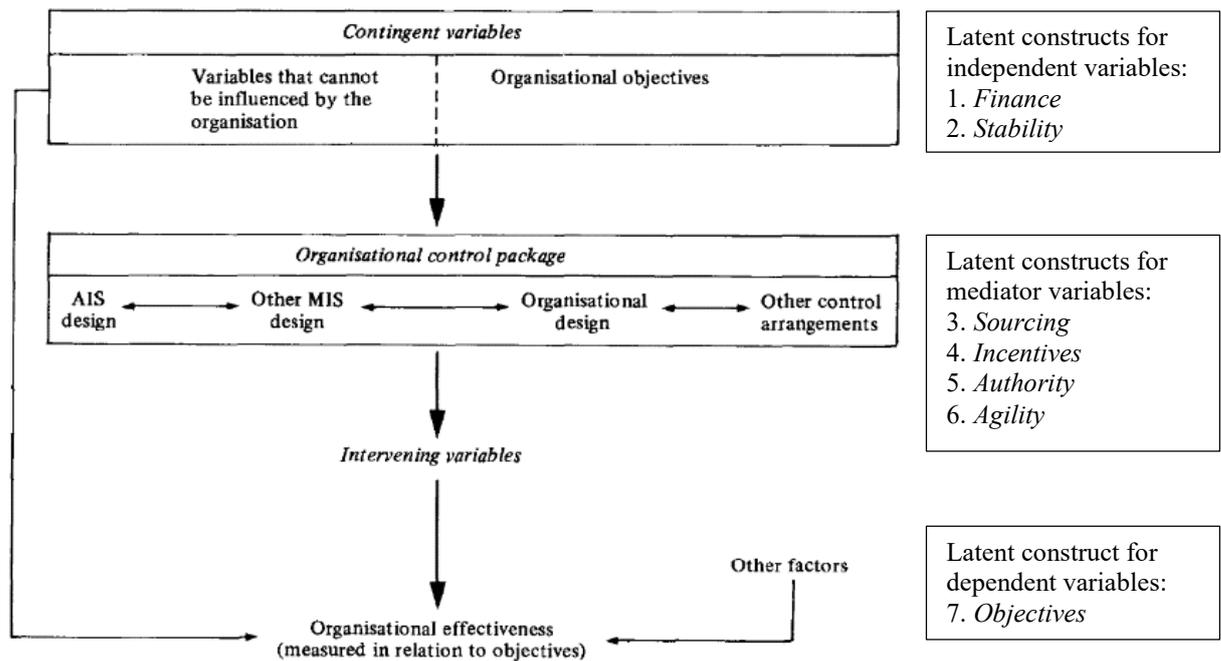


Figure 6: Contingency Theory Framework (Otley 1980)

The contingent variables, such as the level of aid and security from the Finance latent construct, are considered to be outside the controls of the reconstruction organization, although as Otley points out, organizations may try to influence these variables (e.g., by government regulations). The mediator variables under the control of the reconstruction organization are not in the Contingent variables set but rather in the reconstruction organizational design for use as Otley describes it. The reconstruction organization's objectives, capability and capacity, due to their "special nature as the criterion by which organizational effectiveness will be assessed" (Otley 1980) are held outside the control of executives and contained in Contingent variables.

This means the reconstruction "organization adapts to the contingencies it faces by arranging the factors it can control into an appropriate configuration that it hopes will lead to effective performance." (Otley 1980)

Lastly, a more recent publication on the net versus combinatory effects (Leishnig, et al. 2015) of variables supports Otley's "Organizational design" group of variables as antecedent conditions of organizational effectiveness. Leishnig's theory supports considering the combinatory effect of multiple variables in an organization and their impact on organizational control outcomes.

Adele E. Clarke: Hidden processes of implicit meaning and tacit assumptions

The purpose of this paper is not merely to draw attention to the fact that tradeoffs exist between competing objectives in the manipulation of program-based organizational controls—an observation that is quite intuitive for most practitioners. Our qualitative study explicitly seeks hidden processes based on commonly held beliefs that are seldom considered, yet lead to unconscious bias actions within the

reconstruction field that may help explain counterproductive activities from the individual to intuitional levels.

The study of engineering projects in the exceedingly challenging environment of CAE proved to offer a heightened reality to explore hidden relationships and processes at work behind the scenes of complex, capital-intensive projects through both observed variables and unobserved latent constructs. By formulating the existence of ostensive dichotomous problems besetting reconstruction projects as resulting from the conflict of opposing institutional forces, we hope to provide a powerful and generalizable framework to understand and attempt to make explicit the "implicit meanings and tacit assumptions" (Clarke, 2005, Charmaz, 2014) in the social worlds of engineering endeavors in other settings.

Sewall Wright: Causal Path Analysis through SEM

Researchers have at their disposal several data analysis tools to study causality. Each has unique attributes that better support certain types of unit of observation and analysis. Our study reveals emergent themes that are too complex to measure directly, so the use of structural equation modeling's (SEM's) latent constructs, which are measured indirectly by associated observations that indicate the existence of the latent construct, allowed study of many variables that make up an otherwise loose construct such as "sourcing" or "authority." Figure 7 depicts how indicator variables (in boxes) of the latent constructs of Aid and Investment make up the factor of Finance. The factor of Finance leads to the Sourcing factor made up of Advisory and Partner constructs leading to the Effectiveness outcome measured by the level of Capability and Capacity.

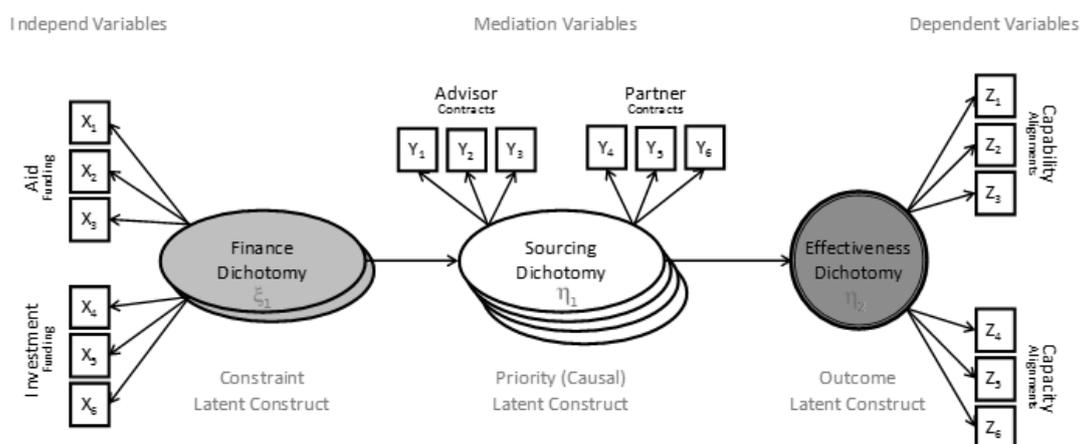


Figure 7: Dichotomies and variables

Not unlike fuzzy-set Qualitative Comparative Analysis (fs/QCA), SEM allows an interval between 0 and 1 when analyzing dichotomous variables. Christopher Westland (2015) writes that over the past two decades he has witnessed a remarkable acceleration of interest in SEM in many areas of research. While a comprehensive statistical approach to testing hypotheses about relations among observed and latent variables (Hoyle, 1995), Diana Suhr (2017) writes in her tutorial: "Finally, a graphical language [that] provides a convenient and powerful way to present complex relationships in SEM. Model specification involves formulating statements about a set of variables. A diagram, a pictorial representation of a model, is transformed into

a set of equations. The set of equations are solved simultaneously to test model fit and estimate parameters."

Building on the aspects of latent constructs, this study treats seven themes concerning competing priorities in reconstruction, such as program funding via aid vs. investment or planning reliant on assessments vs. adaptability on the ground as ostensibly dichotomous latent constructs. The pattern of competing priorities emerged strongly in the interviews and literature review. National leaders report seemingly countless tradeoff decisions faced daily by reconstruction organizations. Diana Suhr goes on to write, "SEM is a multivariate technique incorporating observed (measured) and unobserved variables (latent constructs) while traditional techniques analyze only measured variables," which in this research are Sourcing, Incentives, Authority and Agility. Most importantly, "SEM allows researchers to recognize the imperfect nature of their measures" (Suhr 2017).

A PROPOSED THEORETICAL FRAMEWORK TO ADDRESS DILEMMAS

The conceptual framework (figure 8) organizes indicators of organizational effectiveness as measured by the level of discrepancy between intended and achieved program objectives so that competing priorities may be adjusted depending on dynamic conditions within the current operational environment.

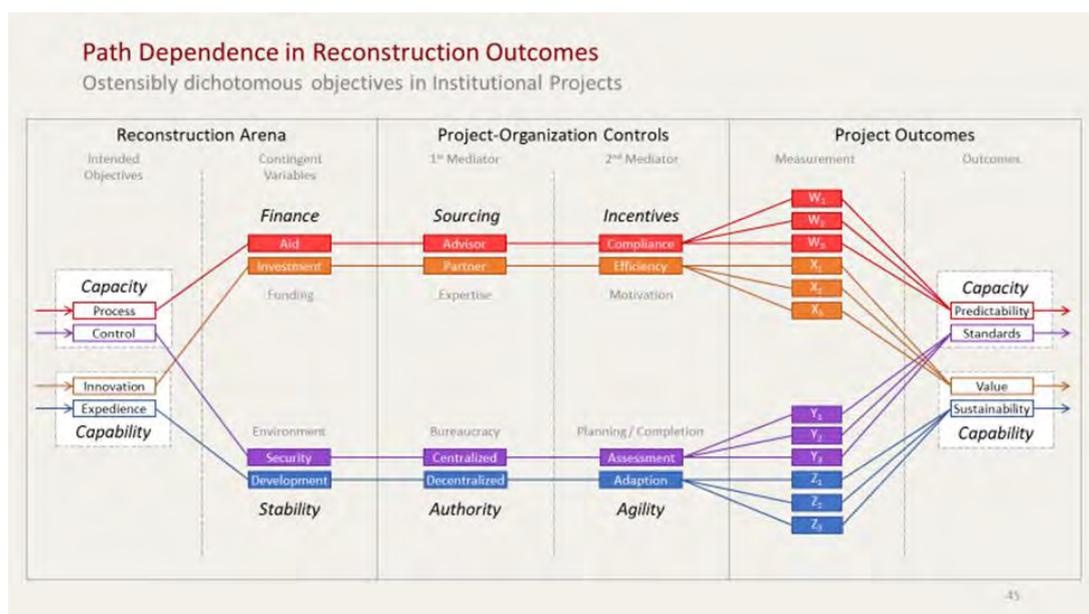


Figure 8: Conceptual Framework

As mentioned earlier, the "parsing of state fragility into its component parts and the development of related indicators reflect efforts to tame the wickedness of the problem set," which leads to "take account of what is necessary to achieve their intended aims." Thus, the framework diagram depicts groups of competing priorities along a causal path of variables. The causal paths start on the left by determining financing and stability approaches continue by moving through the four ostensible dichotomies faced by leaders and proceeds to the measurement of effectiveness on the right. This framework intentionally steers clear of macro assessment of "success" or "failure" in traditional terms. Lastly, note that variables associated with the latent

constructs Financing and Stability are assigned to the set of Contingent Variables because they constrain Organizational Controls and traditionally have not been under the purview of leaders of reconstruction organizations.

WORKING PROPOSITIONS TO EXPLORE IMPLICATIONS OF FINDINGS

As we have already observed, most studies on large-scale reconstruction have tended to concentrate only on inefficiency and waste in reconstruction-value-based differences without paying attention to the nature of competing priorities that bring about dilemmas faced by leaders in the first place. Moreover, reports from the Inspector General and other oversight bodies characterize concerns about reconstruction as arising from apparent breaches in federal acquisition regulations (FAR) of “waste and fraud” without fully unpacking the hidden processes at play which underlying conditions that may have caused the concerns. To unpack the notion of dilemmas faced by national leaders, we have introduced seven factors that flow from sponsor conflicting goals on reconstruction.

Based on the causal paths, several theoretical propositions are made (Jaccard, Jacoby 2010, p.169). Our study uses a six-part rhetoric argument (Toulmin 1958) to build a more robust "if-then" statement in support of our propositions. The structures we developed are based on induction, deduction, and abduction (Principles of Rhetoric, Jaccard, p.277, 279) and elaborate on the logic underlining each causal path (p.171). We further analyzed findings based on theories by Otley (1980), Leischnig (2015) and Douglass North to make the following tentative propositions of causal inference:

Posit #1. The internal dilemmas (conflicting priorities) are common across different types of capital-intensive projects in different settings within the same set of competing agendas.

Posit #2. The cascading series of conflicting priorities are interrelated and exhibit a combinatory-effects that impact the program-based organizations' outcomes.

Posit #3. The combinatory effect of conflicting priorities leads to path-dependent outcomes.

THE POWER AND GENERALITY OF EXPLORED PROPOSITIONS

The proposed conceptual framework (figure 8) is expected to have the power to explain (possibly predict) the consequences of organizational design on the effectiveness of the reconstruction organization. The uniqueness of conflict-affected economies only accentuates the relationship between organizational design and organizational effectiveness. These relationships, we posit, are generalizable to comparable, immense, complex, infrastructure programs located in emerging markets and OCED countries.

CONCLUSIONS

CONTRIBUTIONS

The intended contribution of our research is two-fold: Use of a causal inference model for future quantitative inquiry of our qualitative study, and creation of a novel conceptual framework designed to assist leaders in navigating competing agenda of project sponsors in order to unify the efforts of project partners toward desired outcomes.

We hope that the private sector, government and NGOs active in conflict-affected economies throughout the world will abandon the preconceived notion of an ostensibly dichotomous choice between providing local governments receive capacity-building training versus international conglomerates direct-delivery of infrastructure assets capacity. And instead, use the conceptual framework to assist leaders and their staff in making sound, informed tradeoff decisions to better align project-based originations' design with the desired project objective.

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USING THE CASE METHOD IN TEACHING PROJECT MANAGEMENT AT GRADUATE LEVEL: EARLY LESSONS

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ABSTRACT

One of the Grand Challenges identified by the Engineering Project Organization Society is “The New Project Manager,” which challenges the current curriculum and teaching methods of project management education (Sakhrani et al., 2017). As project management evolves from being an accidental profession where project managers “fall into” it (Richardson et al., 2015) to becoming a recognized profession (PMI, 2017), the natural questions that emerge are 1) How can the future project managers be best prepared for a successful career in project management? and 2) What pedagogies are most effective in equipping them with necessary skills?

In this context, the case method has been successfully developed and applied as the principal teaching at Harvard Business School. Given the similarity between two disciplines, project management education can take a page from business management education. Inspired by this, in the last two years, the case method has been used in one of the courses at the Master of Project Management program at RMIT University in Australia as a pedagogical experiment.

This paper reports on the early findings of a research project investigating the effectiveness of the case method in a master’s level project management program. Findings affirm the existing body of knowledge in relation to the impact of the case method on the student learning experience. Our findings reinforce that the case method is effective in fostering learner engagement and in helping students develop a breadth of industry ready skills and knowledge including critical thinking, negotiation, and communication. Our findings are also considered within the unique context of the delivery of a project management program within the built environment.

KEYWORDS

The new project manager, project management education, the case method, project management pedagogy.

BACKGROUND

Teaching in higher education presents many varied and complex challenges for educators. Large classes, an increasingly diverse cohort and continual changes and advances in the use of digital technologies represent some of the key and ever-changing challenges facing educators. These challenges parallel the expectation that universities will prepare students for their future lives and work, and in doing so

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foster a breadth of capabilities that are developed within, yet transcend, the discipline domain.

Commonly, the professional practice graduate capabilities which universities and industry aspire to include critical thinking, professional communication, problem solving, team work and negotiation skills. Similar to many professions, in the discipline of project management, these graduate capabilities are essential to effective professional practice. Notably, what underpins achieving the aspiration to foster work readiness is the imperative to ensure that learners are engaged in active and authentic learning, which enables the co-creation of knowledge and ensures deeper rather surface learning approaches.

Notably, as a pedagogy that promotes active and authentic learning, the case method fosters authentic learning environments that support students to “become actively engaged in the learning process, rather than passive receptors of content knowledge” (Burke, 2009). In doing so, the case method fosters learning that has a real-world relevance as students critically engage in issues and problems that are complex. Each case study requires students to contest idea, to approach problems and scenarios from multiple perspectives, and to integrate and apply their developing knowledge and skills in learning contexts that simulate professional practice.

Collaboration, negotiation and critical thinking are integral to the learning experience facilitated through the case method. Importantly, it supports earners to reflect on their learning as individuals and as members of a team. Such critical reflection is vital to developing self-efficacy and to promoting autonomous, self-managed learning. Among its benefits, the case method recognizes the complex and nuanced nature of professional practice, with cases presented to encourage interdisciplinary and diverse perspectives. Integrative thinking across different domains underpins the active learning process. Aligned with the notion of ‘flipped teaching’ students are active participants in the class activities. Commonly, the case method involves providing students with key readings prior to each session and guiding by their teacher, supporting students to participate in a facilitated discussion where ideas and knowledge are explored and tested. The case method enacts a pedagogy that is intended to promote deeper learning.

This paper reports early findings from 37 end-of-semester course experience survey responses and 11 one on one semi structured interviews that were designed to capture the student learning experience of the case method. The surveys were conducted over three semesters (two semesters of 2016 and the first semester of 2017), the interviews over a six-month period during 2017. Students who undertook the course over the same period (3 semesters) were invited to participate in this study. By examining the student perspective of their learning and development through the case method in project management, this paper seeks to contribute knowledge of the nature of learning which arises as a result of this pedagogy. In doing so, the authors seek to contribute to research led teaching that, as Bentley et al. (2012) identifies, provides a critical lens through which educators can understand the impact of pedagogic practices to better inform the student learning experience and the quality of student and graduate learning outcomes. It is such knowledge that lies at the heart of enhancing learning and teaching in higher education for our academy and its students. Whilst examining the case method in the context of project management, this paper also resonates more broadly with a breadth of disciplines across Higher Education.

THE CASE METHOD IN ACTION

The project management course that is the subject of this study is delivered as a core course that forms part of the first year of the Master of Project Management program's generic stream structure. This course is an elective for the streams of engineering, information technology, or post disaster management that are also offered as part of the master's program. The program is delivered to a diverse cohort comprising a mix of local and international students. There is a relative balance between the numbers of international and local students. Many of the students have professional experience.

The course is designed to deliver the following course learning outcomes:

- Analyse and apply front end planning theories and best practice to undertake effective front end planning in local and global contexts;
- Analyse, utilise and communicate project success factors and success criteria to deliver project success and value;
- Critically analyse and evaluate the effectiveness of the front end planning process to advise key decision makers engaged in the front end planning process; and
- Develop and apply front end planning techniques to enable the effective management of projects.

At the time of the study, the assessment design consisted of the following: 1) class discussion participation, 2) a group project or a case critical essay, and 3) a case study critical essay.

This assessment design is underpinned by the principles of authentic, experiential learning with each assessment incorporating a feedback and feedforward cycle. The assignments were designed to help students develop a 'complex network that connects important facts, concepts, procedures, and other elements'' in coherent and meaningful ways (Ambrose et al., 2010). They are designed for both formative and summative assessments.

The principal learning activity in a class is the case discussion session, during which the teacher leads the discussion with probing and follow-up questions and engaging students by inviting them to respond to the questions or comment on other fellow students' responses. Students use case facts and their own arguments and reflections to articulate and support their comments. The teacher systematically records student's comments on white boards in an organized manner, which is informed by a teaching plan prepared prior to class. Sometimes, students are asked to form smaller discussion groups to have a mini discussion on a particular issue or to develop an action plan that needs to follow a decision to address the issues presented through the case. The mini discussion is followed by either whole class discussion or a group presentation.

Students are evaluated by the teacher for their critical thinking, problem solving, and professional collaboration expressed in class. The teacher provides individual feedback to students around mid-way through the semester. The intensity of the class discussion requires students to read and prepare the case carefully prior to class.

The second and third assessment tasks require students to individually write a critical essay in response to guiding questions for an assigned case (in some semesters,

a group project was used for the second assessment task and is not discussed further here). These tasks are both formative and summative in nature. The essays provide further opportunities for students to develop and demonstrate their subject matter knowledge and critical thinking, problem solving and written communication skills.

RESEARCH APPROACH AND METHOD

The key research question this paper explores is to what extent the case method is effective in fostering and deepening knowledge of project management and in promoting core graduate capabilities which are essential for professional practice. The qualitative approach was chosen to enable the research team to collect in depth data from an early stage with a limited, small sample. The study was designed to explore student's perceptions of their learning and development.

Data was collected through two main sources: official end-of-semester course survey administered by the university (online) and post-semester one on one interviews. All students were invited to participate in interview after the semester was officially over. The semi-structured interviews were arranged and conducted by a research associate. They were voice recorded, anonymized and transcribed by the research associate.

Over three semesters, there were 88 students enrolled in the course. Thirty-seven (42%) of them responded to the official survey; twenty-two of them were full time students, fifteen part time; twenty-two of them were local students, fifteen internationals. All of the eighty-eight students were invited to one on one interview. Eleven (13%) of them participated in the interviews.

Content analysis was performed for the data collected. Student feedback was analysed to identify patterns and themes. The authors adopted an analytical approach, conducting comparisons across answers using the six-phase process outlined by Braun and Clarke (2006). This analytical approach entailed an iterative cycle of identification, analysis and review.

The next two sections report on the key findings of this preliminary study. First, the benefits of the case method are presented and discussed. Second, observed challenges in the use of the case method are discussed.

THE BENEFITS OF THE CASE METHOD

The case method seems to bring about numerous benefits to the experience and skill development of students in project management. At this early stage, we provide some evidence and discussion on six major benefits identified.

INCREASED LEVEL OF STUDENT PREPARATION

Case discussion requires students to have in-depth understanding of the case to be an effective contributor to the class. The nature of the questions asked in class and the extent to which the discussion goes to requires to students not just to remember the details in the case but also to think, question, and make sense of the case events, facts, people and issues. This requirement pushes them to spend more time to prepare for the discussion. As a student described: "I finished all the reading before going to that class... You can't just walk into the classroom without reading it, otherwise there is no point in going to that class."

The case method is perceived to be “forcing you to do the reading and understand it so that you could participate.” However, this forcefulness is perceived as positive and helpful in raising student’s commitment to learning, especially when the method is used every week. Many acknowledged that they spent a lot of time on preparation for this course and that’s something that they “have never done” in their previous and current studies. For them, “it was a significant commitment throughout the semester.”

A student explained how they prepared for class in a systematic manner³:

“It’s not just about reading through the article before I go into the class, I would actually write down all of my thoughts... I have it systematically. So, before I go to class I have already organised my thoughts. So, it is all because of that preparation. That helped me a lot.”

INCREASED CLASS ENGAGEMENT

All students participated in the interviews, and most students who responded to the class survey found the course more interactive and engaging than lecturing. The nature of the discussion required students to be well prepared for the class and, more importantly as commented by students, “pushed you to do some active listening” and “to be very attentive in class” as they may be invited to respond to a question posed by the teacher or a comment made by another student.

Student engagement is helped by the fact that cases are written from or based on real situations. Knowing the cases are real provokes student’s curiosity about the cases. However, the case outcome is not necessarily predictable and therefore interesting to students. Students are eager to know more beyond the facts presented to them. Sometimes, they “thought it would be something; and it was very different; it was fascinating, so that itself was a teaching.” One student said: “it was certainly a great way for me to engage in the learning.”

Not all students are comfortable engaging with the whole class. To address this issue, small group discussion was used to diversify engagement opportunities. They are asked to work in small groups to make a challenging decision or develop an action plan with incomplete information, give a presentation and participate in a follow-up debate. This technique seems to improve the level of engagement for those students who otherwise would hesitate to speak up in the bigger class setting.

Apart from engaging with learning material, the case method and the various techniques used tends to promote engagement and interaction among students. Students react and respond to the teacher’s questions or to other fellow participant’s comments. In many cases, the facilitator lets students to debate among themselves with little intervention for a short period time (e.g., five minutes). These activities provide value venue for students to engage with one another, as articulated by a student:

³ Some quotes are edited for continuity and brevity without changing the meaning.

“You’re actually hearing other people speak and getting more of a feel about who they were and where they were working, because they would always bring up examples from their work, or how it applied. So, it markedly improved engagement with the fellow students.”

IMPROVED REFLECTION AND REAL-WORLD APPLICATION

It was common for students to relate the issues discussed in class to the problems in their real-world practice. Many students credited the case discussion for helping them understand and apply the knowledge in their work place, as for one student: “I have taken some examples from the case studies and applied [them]; so, it has helped me in my current work.”. Conversely, students can relate their past experiences with the issues discussed in class. Some of them found the cases “resonated with past experiences that were similar.” This two-way relationship is particularly useful in dissolving the barrier between what is learned in class and what is experienced in the work place. Students find case discussion “really useful and really relevant” because “it provides a practical example of how the theory can be applied.”

The interactive nature of class discussions can motivate students to learn because they can see the connection among the theory, the situation in the case and the practice in the real world. It is not uncommon for students to ask themselves “Well, how does this work in this situation?”

With their interest sparked in class students are encouraged to reflect more and, seek further knowledge. One student explained how they followed up with a famous project after discussing the case in class: “Because of the discussion, after class – I don’t usually do that – I did go to dig out some more information. It’s just out of pure interest, not because of the assessment, not because I was asked; no one’s pushing me to do that. I want to learn more about [the project].” This finding importantly suggests that the case method offers the potential to also foster lifelong learning.

ACQUISITION OF HOLISTIC PROJECT MANAGEMENT KNOWLEDGE

A project management course normally has a focus on a specific area of knowledge out of necessity. However, rarely do project managers approach issues in isolation. The case method provides the opportunity to help students see project management from a more holistic perspective and appreciate the interdependence of issues in a project environment.

In one of the class discussion sessions, students were asked to advise a protagonist in a situation where project had been delayed and made headlines. They had to consider how various stakeholders would react, what were the contractual constraints, how much budget would be available, to name just a few, while developing technical solutions and considering options to speed up the project. And because there could be more than one good way of handling the situation, different students had different approaches (due to different experiences, priorities, problem solving styles, etc.). The follow up debate on how to best improve the situation provided the students the chance to appreciate the closely interdependent nature of project constraints. With multiple opportunities like this, students can gradually develop more holistic views of managing project.

One student related to the complexity involved in the cases in an interesting way:

“At a high level, what’s really involved, and how intense it can be; or the nitty gritty bits are like, oh my god, all these stakeholders that we need to maintain and keep a good relationship with. And there was a lot of leadership skills involved in navigating through those sticky situations, so it was not just managerial, but it was more like really living through a case that a lot of aspects are involved in.”

KEY SKILLS DEVELOPMENT

One student summarized the importance of key skills in project management: “when you’re out there in the real world, your technical skills are important, but your communication skills, your negotiation skills, and your people skills are very important as well.” Technical skills in this context are project management domain skills such as scheduling and risk management. It is understandable that project management programs should equip students with the domain specific skills, but not only these skills. Effectively project managers should be adept at key skills, as pointed out by the interviewed student.

The interviewed students unanimously cited analysis and critical thinking as an important skill they had the chance to improve. The case method sparks student interest and drives curiosity in the case while forcing them to think critically because their thoughts and comments are constantly challenged by the teacher and the fellow students. It has become expected that students bear the burden of explaining, elaborating and, and “supporting with evidence” the point they are making even without being asked “why.”

Given the diversity in background and opinion, students are regularly challenged by “different ways of viewing things.” Engaging with a range of views, students learn “to be open minded” and to communicate effectively to negotiate for a point of view. One student explained that when knowing people have different views, students will “think about where they might be coming from and asking them questions” so that communication can be targeted more effectively.

Similarly, a student explained how the case method provides a chance to develop negotiation skills:

“I do remember a couple of times where we needed to sit together in a group, we needed to come up with just one statement, one argument. You need to give one position, you cannot just give – not, you have five people there, you have five statements. No, you just come up with one position. And that’s how you learn how to negotiate, and how to debate with some concrete facts.”

Apart from the appreciation of different views, the empathy for people surprisingly seems to be subtly developed as evidenced in the following statement by a student when asked whether people coming from different perspectives engage with one another:

“I thought it was fantastic. It’s certainly one of the things that I loved when I was getting into the studies because people would have varying views, or someone could make a statement and someone else in the class could feel exactly the opposite. The discussions were great and certainly effort was made by the class and the lecturer to make it a safe environment to be able to disagree, and present perspectives about why. And that was often called out: ‘Does someone feel differently? Do you agree? Don’t you agree? Why?’ And people bring up elements that I hadn’t thought of or seen from that perspective, and that was really useful.”

Even with the very limited number of in-depth interviews, it suggests that the case method could help equip the learners with many key skills that are useful for their professional life. This paper reports on a number of the major ones and it is expected that further research will continue to shed light in this benefit of key skills development.

THE CHALLENGES IN USING THE CASE METHOD

There are numerous challenges in the adoption of the case method at both the course and program level. Those who contemplate adopting the case method in teaching project management topics should carefully consider the benefits and the challenges.

The first challenge relates to both the physical and academic environments. The interactive nature of the case method requires classroom settings with are purposefully designed with seating and boards that promote interactivity. This requirement can be too demanding in many schools especially when the case method is not one of the principal teaching methods. Furthermore, dominant disciplinary ways of knowing and prevailing pedagogies may run counter to the student centered learning approach that characterises the case method. The case method thus may require a pedagogic and cultural change for educators. Such change is complex and if unsupported will fail. If teaching quality and innovation is not supported and rewarded, teachers will be more reluctant to adopt new ways of teaching.

Second, an obvious challenge that the lecturer in this study experienced was the lack of suitable cases for the course’s topics, and as a result, sometimes the cases used were less than optimal for a class. This challenge will take a long time to overcome and require the project management education community at large to tackle. A teacher may choose to write cases to teach in their classes, it will require many case writers, over many years, to develop a pool of cases that can be used by the wider community.

The third challenge relates to student readiness. For most of the students who took the course in this study it was the first time they were exposed to the case method. The level of preparation, engagement, public speaking, critical thinking can be overwhelming to students. The case method requires the teacher to provide extra support to students along the way through formative feedback and one on one guidance via tutorials. Fortunately, with time most students can learn to overcome these challenges, especially when they are encouraged and given chance to participate,

and when they are supported by the teacher to take risks as they explore and contest ideas.

The last, and probably the biggest, challenge to the successful use of the case method is the teacher. Using the case method requires a student centered pedagogy. The case method requires significant preparation, laser focused concentration during discussion and a paradigm shift. In case discussion, the teacher's opinion is insignificant (if not irrelevant) and their knowledge is subtly felt as the discussion is facilitated with student interactivity and critical engagement. One of the quickest ways to jeopardize the integrity and effectiveness of the case discussion is when the teacher reveals what is the "correct way of doing things." The teacher's role is no longer teaching but facilitating.

These challenges could be prohibitive. Not until the benefits are well articulated and communicated to educators and a network of professional teaching support is put in place can the case method be more widely adopted.

IMPLICATIONS

Whilst the impact of the case method is well reported in the literature (Christensen et al., 1991; Brookfield and Preskill, 2005), our findings also reflect the unique context of the delivery of a project management program within the built environment. As pedagogy, the case method is intended to foster active and student-centered learning. As students examine the particular elements of each case, and how these elements intersect, they are steeped in the process of identifying options, evaluating choices and reflecting on the impact of such choices. Discussion and debate is at the core of the learning process and the student experience. Within our context, the project management discipline sits within a built environment school. Whilst students enter the program with wide ranging aspirations representing diverse project management backgrounds, the program has a reasonably significant technical/project management techniques orientation, with a number teaching faculty coming from an engineering background, along with a cohort of students from a similar background. Whilst the case method is a well-established pedagogy, its emphasis on exploring and contesting ideas through discussion and assessing the impact of the choices made marks a point of departure from the problem-based learning approaches commonly employed within the built environment and its allied disciplines including engineering. A focus on transferable soft skills through the case method approach can and does represent a different way of learning for the students within the program. It is within this context that we consider the implications of our findings and the challenges in using the case method.

Teachers in today's higher education sectors are under increasing pressure to reinvent themselves. Digital technologies greatly improve the ability to standardize and package the content that students can study at their own time and pace. The access to knowledge available to contemporary learners means teachers have to keep up with the most up to date knowledge that is ever changing. And at the same time, university education is under pressure to equip students with marketable skills and knowledge that prepare them for life and work. Higher education in general and project management education in particular must respond to the challenge that how they can stay useful and relevant.

As the literature attests (Biggs, 1987), effective teaching is not just about imparting knowledge. The teacher has to spend time to facilitate the activities that cannot be replicated easily by technologies or learners cannot do in solitude.

As discussed here, the case method can be effective in addressing these concerns. It provides means for students to contribute to the knowledge creation process and develop graduate capabilities. As a pedagogy, it can foster critical reflection and higher order learning, as explained by a student: “So it’s turning data into information, into useful information, then we have a thought process into a knowledge and understanding of that situation, and therefore we can identify the next step, which is what we call wisdom.”

While adopting the case method in project management education is not without challenges, the reported benefits suggest it may be well worthwhile. And if students’ satisfaction is an indicator of teaching success, the following comments may serve as a motivation:

“I was overseas that week, so I missed that class. I have never felt so much that I want to be in the class. I can’t remember when was the last time that I would be telling myself ‘I really want to be in the class.’ It was purely because of the case [method]. I think in project management courses, we should use this method more often.”

LIMITATIONS

With 37 participants completing course surveys and 11 undertaking an interview, this study has a small sample size, with its findings limited. The participants, especially the interviewees, could potentially be those who had positive experience with the course and the case method; therefore, the tendency is that more benefits than drawbacks are reported. While these limitations, including the sample size is acknowledged as limited, student’s responses provide useful insights into the use of the case method in the discipline of project management education. The insights captured here warrant further investigation and possible future publications.

CONCLUSIONS

As a pedagogical experiment, the case method has been taught at the Master of Project Management program at RMIT University in Australia. The early findings from the study of its effective in project management education suggest that it has the potential to respond effectively to the “The New Project Manager” Grand Challenge identified by the Engineering Project Organization Society. The preliminary data analysis from the end of semester course surveys and the semi-structured interviews reveals a number of benefits that case method can bring about. These benefits are critical to improving the student’s learning experience and work readiness. While it does not come without challenges, educators may look to the benefits for motivation and consider, as Herrington (2010) argues, designing authentic learning environment requires educators to go beyond didactic instructional methods. The case method could potentially be used with other established and emerging pedagogical methods to improve the effectiveness of project management education.

Even though the early findings from the study, as reported in this paper, suggest that the case method can be effective in project management education, further

investigation and richer data are needed for the favorable pedagogical argument for this method to be more grounded and valid. Therefore, the authors plan to explore in more depth of the data collected and the teacher's reflections, in a subsequent paper. It is also expected that more research continues to shed further light into the nature and effectiveness this pedagogy in project management education.

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DESIGNING PROJECT MANAGEMENT FOR NEXT GENERATION PROJECT MANAGERS

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DESIGNING PROJECT MANAGEMENT FOR NEXT GENERATION PROJECT MANAGERS

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ABSTRACT

Project management education seems still to be mainly focused on training in using prescriptive instruments such as PMBOK, PRINCE etc. while the increasing complexity of projects requires also a different set of competences. Our purpose is to refocus education from learning the systems of project management to learning how to be a project manager. It is our view that project managers are above all expert problem solvers, and that project management is an appropriate field for the application of Design Thinking. We first review the literature on Design Thinking in management and project management. Followed by a review literature on project management education. We then introduce the ADaPteR Cycle consisting of the elements: Awareness, Design, Performance and Reflection. As a means to help students and young project managers to develop their skills in design thinking and habits of thought that will help them develop into expert project managers.

To explore the validity of the ADaPteR Cycle for project management we conducted an interview study of project managers. We then interpreted an existing data set of observations of a project manager in his daily work to identify elements of the ADaPteR Cycle in practice. For this study ante-narratives were constructed extracting coherent stories from the messy data of everyday practice. Both studies demonstrate that the elements of the ADaPteR Cycle are recognizable in practice. Further that cycle can be identified at different levels of problems or situations in project management work.

Finally we conclude from literature and our research that the ADaPteR Cycle can serve in training designing project management for the next generation of expert project managers.

KEYWORDS

project management theory, expert intuition, design thinking, project management education.

INTRODUCTION

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In this paper, we introduce the concept of Designing Project Management as a domain specific approach to the management of architectural design and construction projects in an ever-changing environment, and to training students and young project managers in developing their skills as, eventually, an expert project manager.

Much recent research points to the importance of understanding projects, especially construction (Svejvig 2015), as social systems in which there is a complex interplay and alignment of different goals, meanings, and perspectives (O'leary 2013). This research suggests that it is important to take the personal, professional and business situations of project partners, commissioners and stakeholders into account when attempting to manage project teams. Many of the leaders in the rethinking project management (Cicmil 2006; Hodgson 2006; Morris 2013) have come to the conclusion that as yet little of this research has led to significant advances in project management tools, practice, or education. Nor does the so-called classical approach address issues of daily practice or career development of project managers structurally do. In this we believe that current approaches to project management, while containing much essential material are not entirely adequate to the task of helping project managers to carry out their work (Heintz et al. 2015). Our purpose is to refocus education from learning the systems of project management to learning how to think like and to lay the basis for development into an expert project manager.

To do this we propose an approach to project management that is based on the agency of the project manager rather than on the integrity of project management systems. It is not that we believe that the project management systems are irrelevant, but that we place the emphasis on the project manager's agency and expertise in selecting tools and actions from those systems and enacting courses of action using them. More specifically, we choose to see project management as a process of designing and enacting courses of action in order to achieve "preferred situations". In doing so we are shifting attention from project management as "an ostensive (the idea) ... [to] a performative (the enactment of the idea) dimension" (Carlgren 2016).

We call this approach Designing Project Management. The research intention is as much to provide a lens through which to view project management action as to confirm the use of designerly approaches to problem solving by project managers. The educational intention is to offer a model for and an approach to training students in management of design and construction projects in how to enact the systems and theory of project management in the management of complex building projects. Further we believe that this approach will support (future) project managers in developing their professional capabilities.

We first review the literature on Design Thinking in management and project management. Followed by a review literature on project management education. We then introduce the ADaPteR Cycle consisting of the elements: Awareness, Design, Performance and Reflection. As a means to help students and young project managers to develop their skills in design thinking and habits of thought that will help them develop into expert project managers.

To explore the validity of the ADaPteR Cycle for project management we conducted an interview study of project managers. We then interpreted an existing data set of observations of a project manager in his daily work to identify elements of the ADaPteR Cycle in practice. For this study ante-narratives were constructed extracting coherent stories from the messy data of everyday practice. Both studies demonstrate

that the elements of the ADaPteR Cycle are recognizable in practice. Further that cycle can be identified at different levels of problems or situations in project management work.

Finally we conclude from literature and our research that the ADaPteR Cycle can serve in training designing project management for the next generation of expert project managers.

DESIGN THINKING

Design Thinking is difficult to define (Dorst 2010). Its meaning depends on its context and epistemological roots (Johansson-Sköldberg et al. 2013). Within the design realm a rich variety of approaches has emerged, making it better to speak of ‘designerly thinking’ (ibid.). Within the management realm Design Thinking is used as ‘a paradigm shift’ in approaching innovation and creativity in business (Muratovsky 2015). Starting with apparently obvious definitions of Design Thinking as ‘thinking as a designer’ or “defin[ing] courses of action aimed at changing existing situations into preferred ones” (Simon, 1969: 55) the meanings of Design Thinking summarized below in a short review of the literature on Design Thinking research.

In the early 1960s design research started with the Design Methods movement (Goldschmidt, 2014: 10). Designing was seen as a logical rather than intuitive process, one controlled by rules that could be explicated and prescribed, hence many of the proposed methods took the form of prescriptive models comprising operational design steps (or stages). (Lawson 1997). One basic model of the design process gained consensual acceptance by the entire Design Methods community, the Analysis (of the problems)-Synthesis (of the solutions)-Evaluation- or ASE-model. (Goldschmidt, 2014: 11, 12). Based on the paradigm of problem solving as information processing –similar to the paradigm underlying cognitive science (ibid, 21) – the ASE-model, particularly in the variant of a spiral model, is meant to convey the movement from a wide (abstract) problem space to a specific (concrete) solution (ibid, 13), in which designing can be usefully interpreted as a variety-reducing process. The most influential attempt to devise a complete system for the analysis of design problems and the synthesis of solutions was proposed by Christopher Alexander (1964) in his Notes on the Synthesis of Form.

Another milestone was reached by the publication of Hebert Simon’s “Science of the Artificial” (1969). In this book Simon proposes that most design problems are ill-structured and ill-defined. Simon proposed that intellectual process of design was not limited to activities such as architecture but was an essential character of sciences such as management as well. Then in 1984, Donald Schön proposed that designers frame and reframe the problems at hand until the design task is clear. Although both these publications were primarily conjectural in nature, they were –and still are- very influential in both the Design Thinking debate, and in debates around professional expertise because of their innovative concepts.

Parallel to these publications, research into design thinking continued. By the mid 70s researchers considered that the notion of intuitive design thinking might not be so objectionable after all and began to talk about ‘descriptive design models’, which they contrasted with prescriptive models or methods (Goldschmidt, 2014: 19), inducing a change of paradigms in design research from prescriptive to descriptive,

from explaining to understanding design thinking by describing practice. Hence one of the early descriptive design research texts in Britain – Brian Lawson’s *Design Thinking* (1980/2005), was based on extensive observations (ibid, 22). Another example of influential descriptive empirical research is a workshop among designers at the Faculty of Industrial Design Engineering at the Delft University of Technology (Dorst & Cross, 2001). They concluded that the ‘problem-solving’ aspect of design can be described usefully in terms of the co-evolution of problem and solution.

The final example of influential research on Design Thinking is the work of Gabriela Goldschmidt, e.g. described in *Linkography* 2014. Observing designers Goldschmidt traces ‘design moves’ (Goldschmidt, 2014: 41,47), comparable to chess moves, and studies their design activity by a registration method that visualizes the connection of these design moves into a network of links, the *linkograph*. From this emerge patterns of design moves. The patterns show that each designer’s patterns differ to some extent from those of other designers. Patterns personal, but they all show that the synthesis (design) is to achieved during the early phase of the design process through a series of cycles of divergent and convergent thinking in which ideation and evaluation follow each other in frequent proximity (ibid, 46).

DESIGN THINKING IN MANAGEMENT

Approximately 20 years ago, Design Thinking became a topic in management discourse. Based on the different backgrounds of their advocates, Johansson-Sköldberg et al. (2013) distinguish in three types of design thinking in the management discourse:

1. Design Thinking as design company IDEO’s way of working with design and innovation, e.g. (Kelly 2001);
2. Design Thinking as part of management theory (Boland & Collopy 2004);
3. Design Thinking as a way to approach indeterminate organizational problems, and a necessary skill for practicing managers, e.g. (Dunne & Martin 2006)

In the first type, Tim Brown the CEO of IDEO, described design thinking as process consisting of a series of steps which can be applied to anything from product design to business strategy. They also provide examples, or stories, to help their readers use IDEO’s methods, particularly business people and social innovators (Johansson-Sköldberg et al. 2013: 128). Inspired by the way of working of architect Frank Gehry the second type of Design Thinking in Management is characterized by a design attitude, distinguished from the usual decision attitude of managers. This approach to design thinking emphasises opening up the range of possibilities to be considered, and reasoning backwards from solution to problem. Scholars such as Carl Weick have used this notion of design thinking to application of their own frameworks of thinking and theorizing (ibid. 129) to a wide range of problems. In the third type, Design Thinking understood as an ongoing cycle of generating ideas (abduction), predicting consequences (deduction), testing, and generalizing (induction). The third type has been promoted as a useful process in different disciplines, including library administration, legal practice management, HR and in the management area strategy and organizational change and development. (ibid 128, 129).

Hassi and Laakso also attempt to set out a framework for design thinking and discuss the use, application, benefits and limitations of Design Thinking (Hassi & Laakso 2011). Muratovski (2015) describes the new role of design in business and society as

a paradigm shift, based on in documents from several companies such as Apple Inc., Nike Inc., Coca-Cola, IBM, PricewaterhouseCoppers (PwC), Deloitte, Accenture, Barclays, Facebook Inc. and Google, even the Bill & Melinda Gates Foundation and The World Bank. Muratovski shows that they adapt design thinking as a way of dealing with complex problems with two key features: engagement of stakeholders, sometimes called ‘Human-centred design’, from the very start; and focus on the definition of the problem, or better ‘problem-finding’ (ibid 135). The editors of the Academy of Management Journal endorse Muratovski’s findings, writing that over the past two decades, the importance of design and the value of design thinking as a tool for innovation have been recognized by both business and government (Gruber, M., et al. 2015). They further provide a model contrasting the approach of business-, engineering and design-led innovation. All three approaches are appropriate depending in context, with the latter being best applied where breakthrough thinking and disruptive innovation is required, or to address “wicked’ problems (ibid: 2). Meanwhile, new publications on Design Thinking in Management continue to appear e.g. (Carlgren et al. 2016) and (Mahmoud-Jouini et al. 2016). We conclude that despite some critique, Design Thinking is still seen as a valuable tool the Management discourse and although there is still relatively little empirical verification, it appears to be a way to deal with ill-defined, indeterminate or wicked management problems.

DESIGN THINKING IN PROJECT MANAGEMENT

We focus here on how project managers make interventions in steering projects towards completion. Such interventions occur at a range of scales from major tasks such as development of project organizations to ‘smaller’ daily problems such as conflicts between project team members. These problems may be planning problems, or they may be problems requiring interventions in already ongoing events. Indeed project management can be seen as a process of situated inquiry in which the project manager must interrogate the situation he or she finds themselves in, and through processes of sense-making arrive at judgements about, or design, what to do (Lalonde 2012).

Seen this way, project management is a form of problem solving (Ahern 2014). Anticipating the current interest in design thinking Herbert Simon connected problem solving in areas such as management with design in areas such as architecture (Simon 1969) He proposed that design was a approach to general problem solving across a wide range of fields, and defined design as itself “defin[ing] courses of action aimed at changing existing situations into preferred ones.” (Simon 1969) A more recent and more specific definition is: “A design can be defined as a model of an entity-to-be-realized, as an instruction for the next step in the creation process.” (Aken 2007). This highlights the fact that design often generates both models of the desired outcome and processes to reach it.

Design problems facing design and construction project managers include developing briefs and budgets, composing the design teams, specifying tendering approach and project organization, and creating construction schedules. However, design is also required in order to solve the day-to-day problems that face building project managers, such as: conflicts between stakeholders, changes in scope, or

suppliers suggesting alternative products. In each case the project manager must inform him or herself about the current situation (the problem and the context) and determine a course of action that is very likely to lead to the desired result. Both kinds of design problems, the mapping out of the future course of the project, and the resolution of day-to-day problems occur under a high level of uncertainty, and in dynamic situations where hidden and exogenous factors will likely play a significant role in driving the project off the current plan. Design thinking is required to find courses of action that will yield the desired results but will be robust across a large range of possible futures.

DESIGN THINKING IN PROJECT MANAGEMENT EDUCATION

Kimbell signals a growing interest in design in management academia including experiments in teaching design to MBAs and executives at e.g. the Fox School of Business (Temple University 2011), the Rotman School of Management (University of Toronto, 2011), Said Business School (Kimbell 2011), and the Weatherhead School of Management (Case Western Reserve University 2011) (Kimbell 2011: 293, 294).

Similarly, to the theoretical discourse with its distinction between the ‘Designerly’ discourse (Carlgren et al. 2016) of design-based researchers and the Design Thinking discourse of management ‘theorists’, the education streams have remained separate, with design thinking within design-based education drawing on Schön or Simon for engineering applications, and management-based offerings being concerned with pedagogical foundations (Johansson-Sköldberg et al. 2013: 128).

Dunne and Martin see the application of Design Thinking in education as approaching management problems in the same way as designers approach design problems (Dunne & Martin, 2006: 512) – as solving wicked problems through collaborative integrative thinking using abductive logic (ibid: 513). This, we believe, is the essence of design thinking: solving wicked problems in a coevolution of problem and solution (Dorst & Cross 2001), where wicked (or ill-defined or indeterminate) concurs with complex, because of the uncertain or unpredictable character of complexity (cf. Bosch-Rekvelde et al. 2010; Verhees 2013: 69).

In the debate on project management education the lack of training student project managers in dealing with this complexity is observed by Thomas & Mengel (2008: 304): their review of the literature and of project management training programs demonstrates the focus on standardization of the field and on preparation for the professional designation of project managers. This is confirmed by (Pant 2007; Ojiako et al. 2008; Ramazani et al. 2015), and by research into the actual practice in project management education in the Netherlands (Nijhuis forthcoming). Hence, project managers must be taught to “seek first to understand” the increasingly complex environments they are operating in as opposed to our current focus on applying prescribed techniques. Rather than training project managers to apply tools and techniques, we need to prepare them to diagnose situations, adopt appropriate tools and techniques, adapt the tools and techniques as necessary, and to learn continuously (Thomas & Mengel 2008: 311). Although not always made explicit as such, within this debate there appears to be a growing attention for (aspects of) design thinking in complex, sometimes innovation, situations in (project) management, e.g. the introduction of an experiential learning model (Berggren & Söderlund 2008), the

approach of Project Managers as Reflective and Creative Practitioners (Ojiako et al. 2008) or Project managers as reflective practioners (Louw & Rwelamila 2012), the use of Guided reflection on project definition (Cano & Lidon 2011) or A problem solving perspective as a continuous learning perspective (Ahern et al. 2014) and finally Linking Design Thinking with Innovation Outcomes through Cognitive Bias Reduction (Liedtka 2014). For example Berggren & Söderlund, 2008 and Ojiako et al., 2008, discuss rethinking Project management education by respectively emphasizing articulation and reflection (Berggren & Söderlund, 2008: 289) or reflection (Ojiako et al., 2008: 4, 5) in the development of project managers from trained technicians to reflective and creative practioners (cf. Louw et al., 2012) or finally the use of reflection as a learning aid in the definition of a real life project by project management students that had a positive effect on their learning (Cano & Lidon, 2011).

THE ADAPTER CYCLE

A TOOL FOR DEVELOPING EXPERTISE

Project management education seems still to be mainly focused on training in using prescriptive instruments such as PMBOK, PRINCE etc while evidence is mounting that the increasing complexity of projects requires a different set of competences (Pant & Baroudi 2007, Berggren & Söderlund 2008, Thomas & Mengel 2008, Ojiako et al., 2008; Ramazani et al. 2015; Nijhuis, 2017). But professional expertise consists not of simple rule following, but of recognizing and adapting a body of knowledge to the specifics of any given problem or situation.

There is a long tradition of research in the role intuition plays in expertise. Beginning with the work of Simon (1969), through work with medical professionals (Benner 1982), and into work on professionals, AI and learning (Dreyfus & Drayfus 2005; Gobet 2009). This research shows that expertise cannot be captured in rule based systems, and that some form of intuition or intuitive judgement plays an essential role in expertise. Novices learn and work by rule and practice, applying the rules they know too well defined situations. Experts have internalized both the theory or their discipline and their experience in such a way as to be able to act in any situation based on an “immediate intuitive situational response” {Dreyfus, 2005 #3494}. The process of skill acquisition and learning to be an expert “incorporates a progression from analytic to intuitive knowledge but also an increased ability to deal with abstractions. Thus, an expert in physics will both recognize concrete patterns rapidly and understand the problems at a higher level of abstraction than a novice.” (Gobet 2009) This corresponds to evidence previously found by the authors of a clear distinction between the bureaucratic and rule based work characterising the beginning project manager, and the more intuitive, socially oriented work of the senior or experienced project manager (Lousberg 2017).

We propose the introduction of the ADaPteR Cycle as a means to teach project management students to deal with this complexity, and to help them cultivate habits of thought that will speed their development of expert reasoning. Others have

proposed similar tools using step by step methods to facilitate the development of expert judgement with some success, e.g. Lizzio and Wilson's (2007) tool for the development of critical professional judgement among behavioural science students.

The ADaPteR Cycle

Design whether in the more generalized sense described by Simon, or in the more specific architectural sense, is a cyclical process. In the simplest sense this is a cycle of generate and test (Simon, 1969), but the design cycle also bears similarity to Deming's Plan-Do-Check-Act cycle (Deming, 1952) and the Kolb Learning Cycle: Concrete Experience – Reflective Observation – Abstract Conceptualization – Active Experimentation (Kolb, 2000). These similarities are not coincidental, design and management both rely on learning and feedback from the situation to arrive at better outcomes than might otherwise be realized. For the purposes of illuminating the role of design in building project management the following formulation of the cycle may be most helpful:

Awareness – Design – Performance – Reflection

i. Awareness

The cycle begins with establishing awareness of the current situation. This awareness encompasses not only the formal project as captured in so called "project information", but also, and importantly, the social situation (situational awareness), including the status and state of the various actors and stakeholders in the project. Awareness of what is going on, who is doing what, etc. Also of intentions, goals, and plans. Awareness also encompasses the determination that 'something needs to be done' i.e. deviation from the intended course of the project in some way. Awareness has a very significant component of sense-making.

ii. Design

Out of awareness flows an understanding of both the current state, a need for change and perhaps a desired outcome. Having determined that action is required, design refers to the shaping of a course of action. Design thinking here is important in its open and free approach to generating alternatives and possibilities. But Design should include both generate and test. A designed course of action is also one that has been in some sense tested.

iii. Performance

The designed course of action must be performed by the project manager. The choice of the word performance refers to the performative aspect of management. It is not just a matter of carrying out the design. A performance is required in that project management requires that one changes people's minds and actions. This requires that one reach them in the same way an actor does. Here we define performance as acting/ putting on a mask to change behaviour.

iv. Reflection

Finally, there is a reflection upon the outcome, attempting to draw any lessons about the designed course of action or its performance that may be useful in the future. We use Reflection in two different senses. In the first sense reflection refers to reflecting in a separate moment after the performance is completed, reflection-after-action. This type of reflection is used by e.g. Deming's (quality) management cycle and Kolb's Experiential Learning cycle (Kolb, 2000). The second sense in which we use reflection is reflection while performing, referring to reflection-in-action, introduced by Schön and defined as thinking about doing something while doing it (Schön, 1983). It's this reflection in- and on action that links the ADaPteR Cycle to project management education.

INTERVIEW RESEARCH

If the ADaPteR Cycle is to have any pedagogic value we must determine if the way of thinking supported by the ADaPteR Cycle is present in the everyday work of project managers. As discussed above, as professionals achieve higher levels of expertise their thinking process becomes more intuitive, more tacit, and it is increasingly difficult to either observe their thinking process through vocalisations or for them to explain it themselves. Still, our first attempt to gain insight into the potential applicability of the ADaPteR Cycle was a series of interviews of experienced project managers.

METHODOLOGY

Next to the case study but with the same attempt to determine if the elements of the ADaPteR Cycle can be recognised in the practice of project managers, and to what extent these elements function together as a cycle, we conducted an additional explorative research.

In the period from February 2016 to March 2017, two researchers conducted nine interviews with experienced project managers, four of which were employed by the municipality of Amsterdam, three at a consultancy firm and two were independent. The interviewees were selected on the basis of the following criteria: functioning at the level of senior project manager and experienced with simple and complex projects. At the beginning of the interview, only one question, our central question, was put to these project managers: "what do you actually do?". Depending on their answer follow-up questions were asked, but with each time on the background this central question. From these interviews transcriptions were made and by two researchers independent of each other qualitatively coded and categorized using Atlas-Ti. After this analysis, the researchers have discussed each other's analysis results and reached the following findings.

DATA AND FINDINGS

Differences

First of all, the difference in language between the project managers is remarkable. Almost all the interviewed project managers tell their story on the basis of a concrete

project of their own, on different levels of abstraction with different personal accents. Says one project manager on the basis of the concept of '*connecting people*' that she in that way '*tries to find the ultimate answer to the question of the principal*', while the other under the same concept '*connects people to get support for a change or amendment as realization of an ambition*'. This makes it tricky when coding one interview to use encodings that are found in the other interview. We have solved that by not using the found concept as a code, but to use the essence of what is meant as a code "answering clients' requirements by the design team" in the one and "create support in the design team" in the other. We explain this difference between project managers from their different position relative to the project team. The first project manager gives daily guidance to the project team while the other one is leaving day-to-day management to a junior project manager.

Furthermore, it is noticeable that there are differences in personal focus between the project managers; the one is more focused on the (user) processes, the other on setting up with margins and then finishing a project plan and a third on trying to keep all the frogs in the Barrow. Another difference is that a number of project managers, in particular those of the municipality, sees themselves as an '*Advisor to the client*', while another speaks about his relationship with the client as '*contributions to the ambition of the client*' or '*give him only rubber-stamp situations*'.

Summarising, differences seem to emerge mainly by the type of project (on what lies the focus), the type of client (municipality or otherwise), the position of the project manager (daily management or not) and the personality of the project manager (differences in level of abstraction).

Similarities

A first similarity between the project managers is that they all use a '*framework*' or '*model*' to shape the management of the project. In seven of the nine interviewees, this '*model*' was "Working by means of Projects", something expected, because the consultancy firm where this method comes from has trained the project managers of the municipality. All use this '*framework*' for '*the project to establish*', '*to shape*' or '*to make*'. Everyone seems to work with one or other structure of agreements from which they take their daily work to relate to. This is often a standard which is modified on the project. One of the project managers replied, "*I start with identifying ... the program of requirements [including] the environmental factors i.e. stakeholders who can influence the project, feasibility studies, risk analysis, ... and then I walk through all management elements. ... [then] I start with a Plan of action.*" Another project manager described his role as "*determining frames ... My role in this is: making it a project. ... I look at it from the point of view of project hygiene. My role is very much to agree, capture and make people stuck to their role. ... I'm not going to start with a project if I don't have written my own project plan. You need to formulate your own assignment as it were. This includes explicit creation of what I do not. ... First you focus the project on what do you want to achieve, then you need to set it up and then you go do.*" Both project managers start with gaining awareness of the project and environment, and then create a Plan of action or determine and establish the frameworks within which the project can be carried out; the first steps in a large project design cycle.

In addition to the framing of the project in more or less measurable terms as money, time and quality, many project managers speak of the *'shaping of processes'* and *'create/generate support'*, as activities arising from the setting of (modified) frames with a client, or as an activity in coping with *'surprises'*. One of the project managers describes how she treats a 'surprise' in the daily work: *"I try to advise the client as well as possible, because in the end it is not my risk, but that of the client. I draw up scenarios, and the client then asks me 'what do you think?'. First, there is a problem signalled, that problem is extensively unravelled on what risks we actually have and there are possible measures (Design), where each choice has all kinds of consequences, up to and including the procurement strategy. So you will have to think about very well."* And another says about 'surprises': *"I manage decision making, by my client, but also by myself. However, if something happens, I always ask myself: 'is this bad, is it an issue? ', because what everyone does when something is an issue – especially in a meeting with techies – is to solve, without thinking at all whether it is necessary. I sharpen the problem in terms of consequences, I see that as my role compared to other team members."* To which another project manager adds: *"Actions such as letting clients choose where the paintings may hang – together with the architect – are deliberately designed [to create support for the project]."*

A third similarity is that a number of project managers speaks about *'reducing, removing'* or *'mitigating risks'* as an important task. This not so much in the interest of themselves as project manager, but, as they put it, *'in the interest of the client'*. Finally, we noticed that usually, but sometimes not, in the analysis one of the four concepts of the Project Design Cycle – awareness, design, performance and reflection- could only be used as a code, if we asked about it in the interview, but in veiled terms. As for instance with regard to the element Performance, when asked to elaborate on acting out his role as project manager, one interviewee responded: *"I have been trained to think of yourself as a tool. That is, to be aware of what you can do and what you can't, also of how you look, what you're wearing, for example, a suit and sometimes a tie. The rule is that you never are underdressed."* Another: *"Yes. I act absolutely. For instance, in a meeting where I enter and think about the place where I sit down, and meetings where I say nothing or only two things. What I'm going to do, mainly depends on the others."* And another: *"Sometimes you need some sort of decisiveness. This has to be called a form of bluff sometimes, because you still do not know exactly what's going on."* And e.g. regarding Reflection one interviewee said: *"I think about work when I'm in bed at night. It's about responsibility. Whether did you do things well as a team, or did you have enough control ..., did we do things well – you always doubt of course – did we make the right choice, could we have done it not better in another way?"* Most of the project managers said they think it's important to reflect with colleagues, e.g.: *"Often this is in conversations with colleagues who were there. We discuss how it went, what the next steps are that we need to take, what those are in six weeks. ... It is sharing what you are going through, that mutual collegiality, that reflection is very important to be able to grow. That you should do as much as possible."* Or: *"Moments of reflection are those in which I am away with my assistant on to or off from a meeting. We also here internally with colleagues do very much to exchange knowledge, both structurally at meetings every month as it happens to come across or look for each other, with us is that essential."*

Summarizing, findings suggest that project managers draw up frameworks in order to make a project out of the otherwise as chaotic perceived reality, then ensure that the project remains within the framework and, if necessary, adjust the frames. In addition, that generating support/shaping processes for the (amended) project and, to a lesser extent, mitigating the risks for the client seem to be important tasks. Finally, that the elements of the ADaPteR Cycle, are recognizable only after asking about them in veiled terms.

8.3 Reflection

Just as the case study, the goal of the explorative research is to determine if the elements of the ADaPteR Cycle can be recognised in the practice or project managers, and to what extent these elements function together as a cycle. Therefore we compare the findings from the analysis of this research with the theoretical framework of the ADaPteR Cycle. Especially the similarities between the interviews show that all project managers draw up frameworks, often using a standard model that is adapted to the project. This activity would be considered as a design activity, where the problem is explored first and then a design is created. This design is established with the client and then the aim is to keep the course of the project within the framework of the design. If circumstances so warrant, the design is reflected upon and eventually adapted, so partly redesigned. In this general sequence the ADaPteR Cycle can be recognized, with its succession of Awareness, Design, Performance and Reflection. So in the big picture over a longer period of time, the ADaPteR Cycle can be recognized; in daily actions, however, only fragmented: elements can be recognized, but not in their cohesion.

In addition to using frameworks it seems to be that generating support/shaping processes is one of the most important activities. The interviewed project managers seem to open here, they seem especially doers – performers- that "realizing things with people" (Leeuw 2002). In this they seem to be architects, on the basis of their analysis of the situation (awareness) they design measures that are performed from which they learn of the extent to which they work (reflection). That the processes for support take place as in this order, does not appear from the interviews, that the elements awareness, design, performance, reflection are recognizable, though.

AN ANALYSIS OF WORK FLOOR EXPERIENCES

INTRODUCING THE CASE AND METHODOLOGY

In order to determine if we could observe the elements of the ADaPteR Cycle in the everyday experience of a project manager on the work floor, the researchers took the opportunity to reinterpret a data set that had recently been collected for a different research project.

The observations collected for a study of Supply Chain Partnering (Venselaar et al., 2013; Venselaar, 2017) was made available for use as a second case study. We used 22 observation journals of a bigger set of data containing observations of a project leader in a Dutch housing association, HA, going about his daily work. The observations were made without a specific observation scheme, taking all aspects of daily work life into account, and ensuring the capture of individual behavior

(Venselaar 2017). The role of the observing researcher can be best described as consulting observer.

For the current research, the data was coded using the phases of the PDC (Awareness, Design, Performance and Reflection). 13 journals were analyzed at sentence level. Some sentences had multiple codes, because they were multi-interpretable. Then we decided that more coding at sentence would not gain more insight. The rest of the journals were used to construct the ante-narratives.

For this study two ante-narratives (Boje, 2001) were constructed, representing the messy story line of daily work life. The first ante-narrative is about a project team meeting between a project leader at the housing association, we'll call him John, and other representatives of the housing association, contractors, subcontractors, an architect and a BIM-consultant. This is one of the first meetings that John organized in this setting, since the managing-director of his department introduced BIM-software, and the principle of supply chain partnering, thus the method of working was new to all the attendees. The second ante-narrative describes the process that John and his network undergo in their search for a smoother supply chain partnering processes.

The reason for constructing two ante-narratives, was that it allowed us to analyze the application of the ADaPteR-Cycle in a snapshot (ante-narrative 1) as well as in a longer-term process (ante-narrative 2). The ante-narrative about the single meeting allowed us to analyze our data at a micro-level, while the second ante-narrative allowed us to see if ADaPteR-Cycles is applied over a longer period of time in a long-term project. We think that both approaches reveal interesting aspects concerning applying the ADaPteR-Cycle in daily work life of project managers.

ANTE-NARRATIVE 1: A MEETING INITIATED BY PROJECT LEADER JOHN

John initiated a meeting with representatives of the housing association and representatives of the contractor and subcontractor, an architect and a BIM-consultant. In total 9 people (including the researcher) attended the meeting. Before the meeting starts, John told the researcher that he is a bit nervous. Last meeting did not go well. There was a lot of discussion and too little structure. Therefore, people got irritated. For this week, John gave homework to everybody, and he expects that that will help to make decisions more easily.

John opened the meeting and said that the target is to fill in an 'intervention matrix'. This was an excel-sheet with technical interventions for the renovation project that they are working on. But first, the architect showed three designs for the project that they work on. The attendees started to discuss social safety and locking a few compartments in the designs. A contractor's representative asked John what the organization's policy on safety and locks. John could not answer this question. After 20 minutes of discussion, John proposed to get back to the intervention matrix. But a new discussion about replacing gas for cooking and heating arose. Someone asked for the organization's policy on gas, but again, John could not answer the question. A BIM-consultant asked '*Why are we talking about gas, while according to the intervention matrix we should be talking about facades?*' The meeting goes on like this. Discussions started and finished without clear conclusions. Several times people asked for the organization's policy on different topics, but John could not answer.

The contractor became irritated, *'What's all this about, it's not a game we're playing! You must say something about your policy!'*

At one point, John asked if they needed a break. But the contractors needed to leave early, so they just went on. Discussion continues and at one point the contractor says *'We should not think in impossibilities, rather we think in possibilities. [...] We should think differently.'* He asked the architect to sketch what the gallery would look like, if they would entirely rebuild it. Another attendee said: *'But the director has to make these decisions, right. If he likes it, we'll do it.'* (He was referring to the housing association's internal process, in which that the project leader may propose an intervention but needs approval from the director before implementing it).

Meanwhile, John seemed to become impatient. He wanted to round things off. John tried to bring the meeting to an end. *'Guys, you'll be leaving in a bit...'* But the contractor said *'We still have seven minutes to go'*. John replied *'Ok, we go on then'*, but he seemed as to get more and more impatient. Then a several attendees left and the rest took a break.

The researcher spent the break talking to John and the BIM-consultant. John said that he is satisfied. *'It goes effortlessly. I don't have to guide this at all'*. John thought about how he could make the process even more smoothly. Doing homework is very important to him.

We resumed with the meeting. Several scenarios were discussed, and new discussions about specific aspects of the scenarios arose. For example, there was a discussion about heating systems and installations. John says about a certain solution: *'If we choose to exploit this building for 15 more years, we should intervene as little as possible. It costs a lot of money, and for 15 year you don't want all the fuss with plumbers and stuff.'* To which one of John's colleagues replied *'If we want to replace these systems, we have to have a very good reason to convince the director.'* Related to this discussion, John searches for the organization's policy on heating services. Then, the meeting came to an end. John proposed homework assignments and everyone left the room.

ANTE-NARRATIVE 2: FOLLOWING PROJECT LEADER JOHN IN HIS DAILY ACTIVITIES

After the meeting described in the previous ante-narrative, we kept following John in his daily work activities and his search for more effective supply chain partnering by using BIM-techniques. We followed John in his normal, ongoing daily work life, and we also attended more special events.

The data show that in general John, his colleagues, and the researcher spent a lot of time talking to each other and analyzing the situation that they were in. They came up with ideas to solve the practical problems that they face. It is possible that the presence of the researcher influenced this behavior, perhaps making it more collective and explicit. In one of those conversations John, Matthew (also project leader of renovation projects) and the researcher brainstormed about questions that John was confronted with in the first meeting, such as the policy on social quality. They tried to collect certain questions in a mind map.

One of the ideas, that John and the researcher had developed, was to create a manual for supply chain partnering. John took the lead in this, and the researcher acted as a sparring partner. John and the researcher went to John's manager to ask for

time to do this. An underlying purpose of getting time allotted to writing the manual was to get acknowledgement. John's manager agreed, under certain conditions. One of the conditions was that the process design should accommodate HA's existing administrative accounting system and another condition was that colleagues should be involved in developing the manual. At a certain point in the process, John actually produced a preliminary manual. In this manual John wrote that he observed that people believe in the success of supply chain partnering, but knowledge and clarity about basics is needed to make it a success. The aim of the manual, as John wrote, was to share his experiences *'in order to help you guide your supply chain in the right direction to get the best results'*.

Meanwhile, John's normal daily work life just went on. For example, he spoke to his colleague from the department of 'regions'. After this conversation, John became convinced that his manager was an important bottleneck in their internal supply chain process. John and the researcher discussed his options to deal with this new insight, but John could not decide at that moment what he would do. We also gathered with different colleagues to talk about various related topics, such as whether the purpose of the BIM-sessions was producing a proposal for investment or a feasibility study for different scenarios. At a certain point, John and the researcher organized a team meeting in which John tried to start a discussion about barriers that they face in their development towards supply chain partnering. It became a very lively meeting that flew off in all directions. One of the outcomes of this meeting was that John and the researcher were assigned with organizing a pressure cooker meeting.

This meeting, and the process of talking informally to colleagues felt meaningful for John as well as for the others. For example, at some point in the process John said that he felt that *'he finally is developing himself. It does not concern my job, but still'*. Also, Matthew was very enthusiastic about the creative process. *'This is real project management'*, he said. Later on in the process, the researcher noted that she thinks that *'everything in the organization will change'*. One of the attendees of the project team meeting said afterwards: *'Finally, we talked about what it's really about'*.

A few months later the pressure cooker meeting took place. After a few struggles, John and the contractors managed to come up with ideas for the renovation complex that they worked on. John showed the results to his colleagues from the department of 'regions', but this colleague was not satisfied with the results. The colleague had been expecting something different. John's managers also expected something different and expressed their disappointment. John was angry about this situation.

ANALYSIS OF THE ANTE-NARRATIVE

Awareness

It is not possible to directly observe another person's awareness. For this reason, the coding process was highly problematic. The experience of awareness might arise suddenly (a so called *Eureka moment*), or it might simmer semi-consciously for a longer period of time. Below we will explain how we interpreted our data in terms of awareness.

An example that we labelled as awareness is when John says that he is nervous. We interpreted this as John being aware of his physical sensation and implicitly the anticipation of experiencing difficulties in the meeting. It also encompasses the determination that something needs to be done. One of the things that John

determined (designed) that he needed to do was assigning everyone homework to prepare for the meeting. ‘Assigning homework’ can also be labelled as part of the performance phase. After all, this action is intended to design the process and make it smoother. And this example also involves reflection, John was aware of his nervousness and started reflecting on the previous meeting, which developed into awareness of the difficulties likely in the new meeting. The example ends with John reflecting on the meeting. We can, therefore, consider this as an (natural) example of the ADaPteR-Cycle.

Another example of awareness is when somebody says that the director has to make decisions. By saying that, this person shows he is aware that the attendees are discussion matters that they cannot decide themselves. His utterance is a performance designed to interrupt and end or redirect a discussion that cannot be fruitful. However, at the same time, this sentence can be interpreted as a design proposal, because it can also be read as ‘*Let’s just propose it to the director, and see how he feels about it*’. The data don’t show whether this process design proposal is accepted or not.

Concerning awareness, another important aspect in this meeting was that John was confronted with different kinds of questions about the organization’s policy. For example, one of those questions was, ‘*What is your policy about safety of hardware?*’ John could not answer these policy questions. Without a larger context, the researchers would not label this as the ‘Awareness-phase’ of the ADaPteR-Cycle. However, the second ante-narrative shows that such policy questions were an important driver for John to do take actions, for example brainstorming with a colleague and collecting the variations of these policy questions. Actions such as the brainstorming can be seen as a complete ADaPteR-Cycle or Awareness, Design, Performance and Reflection, nested within the ongoing cycle.

The combination of the first- and second ante-narrative gave a new insight concerning awareness. In the first ante-narrative John is concerned with how time consuming such a meeting is, and he gets impatient. He also wonders whether this new way of working is quicker than the traditional way. Many actions follow to reduce the amount of time spent on such meetings with external partners. But when we also analyze the other data, we observe that John spends a lot of time on, for example, talking and discussing his ideas with his direct colleagues, his managers, and others. However, John never questions how much time these actions with his colleagues take. There seems to be an implicit assumptions that says something like ‘*Formal meetings should be quick, organized and effective, and it is ok to spend a lot of time on informal meetings and that does not necessarily have to be organized and effective*’. We do not assume that this is a right or wrong implicit assumption. We only observe an example that shows a seemingly arbitrariness of *what* people are (becoming) aware of.

The actions that such awareness provokes in terms of design, performance and reflection, are therefore not based on an explicit reasoning process. While additional research would be required to demonstrate this, it is consistent with the notion that they attendees are ‘seeing’ issues in the intuitive manner Dreyfus and Dreyfus (2005) attribute to experts.

Design

John's decision to develop the intervention matrix as a means to make the meeting run more smoothly is an example of a design. Although that purpose seems clear, the attendants didn't behave as anticipated in the design. At several points, John (and also the BIM-consultant) proposed to go back to the intervention matrix, but quickly people resumed discussing topics not in the intervention matrix. This example shows that there is not only a design, there is also the performance of the design: the communication of intent and the chairing of the meeting of the meeting. At this point, John became aware that the attendees are not sticking to his design, and feels a need to intervene. This results in a decision to act (design) and a performance, although it is likely that the design step is entirely tacit. This can be considered as an ADaPteR-Cycle at a micro level, a cycle within a cycle.

We observed that design, especially if it is an explicit process, often encapsulates an ADaPteR-Cycle within it, but one in which the performance is simulated. This goes for technical design, as well as process design. While talking about design options, for an object or a process, the anticipated performance and results of these options are delineated and reflected upon in order to be able to make a decision. In the discussion of the hardware attendees proposed ideas and others responded anticipating and evaluating the performance of each solution. In these conversations, the participants did not explicitly display all four steps of the ADaPteR-Cycle, for example the awareness step, the description of the problem, was often tacit or implied by in acts of designing and reflecting. The argument is that, before people propose solutions, they must have become aware of a problem they are trying to solve.

Another sentence that was labelled as design was when a contractor said: '*We should not think in impossibilities, rather we think in possibilities. [...] We should think differently.*' It concerns design of how he thinks that people should be thinking both in and beyond the meeting. This is a design-proposal for a way of thinking in general and therefore transcends the level of the meeting itself.

Performance

Concerning the third phase of the ADaPteR-Cycle, we understand that performance is never solely performance. Attending a meeting can be labelled as performance as such. What people *do* in a meeting is actively contributing to the discussion, putting design proposals, sometimes put something in the intervention matrix, present ideas, etc. but by doing that, they always design, reflect and/or become aware of something at the same time.

Another observation is that not only in the meeting of the first ante-narrative itself, but also throughout the longer-term process people constantly, formally as well as informally, discuss, put design proposals, present ideas, etc. If it is not done face-to-face, they use emails, phones, or other communication tools. Daily work life is an ongoing stream of actions and reactions. That makes processes at work floor messy. There is one performance after the other. ADaPteR-Cycles are recognizable, but also at many times remain unfinished. For example, John started to write a manual for supply chain partnering and involved his colleagues in this. A lot of time was spent on this, but this action was never finished (as far as the data show).

Reflection

An example of reflection is the conversation that John and the researcher have during the break of the meeting. Here we can see a cycle spinning off from the main cycle.

The performance is interrupted by a cycle of RAD – leading to changes when the performance is resumed. This reflection transcends the level of this particular meeting, but is at a higher abstract level of what the most efficient way of collaboration is. John’s words show that he is aware that this meeting is part of a bigger new strategy of collaboration and he questions whether this is a good strategy.

As discussed before, during the meeting, people discuss possible technical interventions. Each individual makes comments in an apparently arbitrary manner, unrelated to what has gone before, and without announcing their reasoning. Again, they seem to be ‘seeing’ in the manner of experts according to Dreyfus & Dreyfus (2005). In their reflections they used different criteria, based on their individual points of view, but these remain implicit. Arguments for technical interventions are based on, for example, technical-, financial-, esthetic-, and safety-reasons. The reflection criteria arise on the spot. In this argument, reflecting becomes an act of politics and convincing each other, instead of a rational assessment of a design. This applies as much to the process design (at the level of the meeting but also at a higher abstract level) as it does to the technical design.

DISCUSSION

Summarizing these observations we find the following

- 1) The behavior of project managers does not come in clearly identifiable blocks which can be associated with ADaPteR steps without interpretation. Any attempt to understand the flow of action in the behavior of a project manager involves interpretive selection and ordering similar to that necessitated in making an ante-narrative, and for the same reasons, life is messy.
- 2) Individual phases of the ADaPteR-Cycle are fairly easy to recognize, but at first may seem to occur without order or pattern. It is sometimes both reasonable to necessary to infer that phases have occurred on the basis of observable phases – no one tries to solve a problem they are not aware of. Phases may also occur tacitly, or unconsciously. Or it may seem to a project manager that the design is implicit in the awareness. However, people are capable of reflecting on their previous awareness, design and performance even when these were tacit. However, interpretations of the same situation may vary from person to person.
- 3) We can rarely speak of one ADaPteR-Cycle at a time. Rather there are cycles running parallel to each other, cycles within cycles, and cycles splitting off of each other. Thus, there may be design and (simulated) performance within reflection, or reflection within design.
- 4) That in any collective effort, each individual will be experiencing their own cycles, which will overlap and spin off of each other.

Further, although limited to some extent by the manner in which the data were collected, we can see examples of the project manager and other project team members reasoning in the manner of proficient and expert professions. That is, not by carefully describing all aspects of any situation, and seeking a rule to apply, but by ‘seeing’ what aspects are relevant, and going directly to proposed solutions without appealing to general rules or explicit reasoning.

CONCLUSION

The intention of this study was to provide a lens through which to view project management action as to provide confirmation of the use of designerly approaches to problem solving by project management. In order to do that, literature research was used to develop the ADaPteR-Cycle. We analyzed the use of the ADaPteR-Cycle in daily work life of a project manager.

The analysis shows that phases of the ADaPteR-Cycle are recognizable, but the phases are highly interdependent and integrated. Therefore, it is difficult to separate the phases. We also observe that people go through multiple cycles at multiple levels at the same time, and the levels affect each other. People might go through ADaPteR-Cycles collectively. Individually, going through an ADaPteR-Cycle of one person, might initiate or affect the ADaPteR-Cycle of another person. Project managers are not always aware that they go through an ADaPteR-Cycle. Lastly, going through ADaPteR-Cycles does not guarantee success.

The approach of this study appeared useful to gain insight in project managers' actions and their use of designerly approaches. But more ethnographic study into project managers' daily work activities is needed to understand how they operate, why they operate like that, and what the results of their operations are. Such research should focus on themes like rationality, rhetoric, power, emancipation, and autonomy. Also, deeper understanding and phenomenological research about how awareness – and the processes that follow - works is needed.

As we can see here, any attempt to identify the ADaPteR-Cycle in the data is similar to the construction of an ante-narrative – it is a selection and ordering of portions of the action not a complete representation of the whole.

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ASSUMPTION-BASED THINKING FOR PROJECT RISK ASSESSMENT

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ASSUMPTION-BASED THINKING FOR PROJECT RISK ASSESSMENT

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ABSTRACT

It has been widely acknowledged that risk assessment based on P-I ratings, has its limitations in that it does not in general capture hidden factors behind the risk ratings, mainly the “assumptions” and “background knowledge”. In this paper, it is argued that utilization of assumption-based thinking may improve risk assessment process by revealing assumptions behind risk evaluations. The illustrative case study about a mega project in Turkey demonstrates that some of the critical risk factors may be excluded from detailed analysis due to invalid assumptions. A method for assumption-based risk assessment is proposed as well as a sample format for an assumption log. Matching risks with assumptions has a potential to improve the reliability of risk ratings and updating risk management plans by checking validity of load-bearing and vulnerable assumptions.

This paper presents some of the initial ideas of an on-going research project about assumption-based risk assessment. The proposed method will be tested on real projects to explore whether it has a potential to improve quality of risk-based decisions.

KEYWORDS

risk, assumption-based thinking, project management, construction.

INTRODUCTION

The Project Management Institute (PMI) defines risk as “an uncertain event or set of circumstances that, should it occur, will have an effect on achievement of one or more of the project’s objectives”. Risk assessment (RA) is about understanding uncertainty and evaluating the potential impacts of uncertain factors on the project. RA is critical to give reliable decisions under conditions of uncertainty and vagueness. The Society for Risk Analysis (SRA) defines RA as “a systematic process to comprehend the nature of risk, express and evaluate risk, with the available knowledge”, stressing the importance of “background knowledge” behind the risk evaluations. RA is carried out by using available risk data (if exists) and expert knowledge (subjective judgments). The two factors that affect the risk evaluations by experts are “background knowledge” and their “assumptions about the future”, which are also interrelated. Risk assessment is essentially about quantifying risks based on “assumptions” about

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likelihood of occurrence of risk events and their impacts on the project as well as evaluating how “deviations” may affect the project under different scenarios. Experts try to answer the question of “what may happen in the future?” to estimate probability of occurrence of risk events and also try to respond to the question of “what would be the impact on the project if the risk event occurs?” considering the project vulnerability and capability of the company/team to manage risks. The major aim of RA is to provide the necessary inputs to a risk management plan, which will be updated throughout the project considering the changing needs and objectives, newly acquired knowledge on risk and checking the reliability of assumptions. In this paper, it is argued that risk management can be improved by systematically incorporating the assumptions into the risk assessment process. Assumption-based thinking (ABT) can be used to reveal assumptions and background knowledge of experts “hidden” in risk assessments so that decision-makers can check their validity and consistency, improve the knowledge base if needed and risk-related information is communicated better between team members. An illustrative case study is presented to demonstrate how principles of ABT can be utilized to improve RA.

RESEARCH BACKGROUND AND MOTIVATION

It is a well-known fact that within the project management context, due to the lack of statistical data regarding risk-related factors as a result of one-off and complex nature of projects, usually qualitative and semi-quantitative techniques are employed for RA (Baloi and Price, 2003). In the semi-quantitative approach, quantitative measures for probability (or possibility measure in the possibility theory, or belief in the evidence theory) are used along with qualitative judgements (based on knowledge and justified beliefs). In the construction project management context, risk rating and P-I (probability vs. impact) matrices are widely used during risk assessment. Results of qualitative RA provide input for detailed risk analysis and further preparation of the risk management plan. RA results are based on background knowledge, phenomenological understanding, and expert statements which are “hidden” in risk ratings (Berner and Flage, 2017). Aven (2017) argues that RA must be seen as “judgements” made by the analyst group and the experts that have been used to carry out the assessment. These judgments are conditional on a specific background knowledge which covers data, information and justified beliefs often formulated as “assumptions”. The RA based on P-I rating, has its limitations in that it does not in general capture all aspects of concern, mainly the “assumptions” and “risk understanding/attitude” required for decision making. Berner and Flage (2016) define “assumptions” as conditions that are fixed in the assessments but known to possibly deviate to a greater or lesser extent in reality. Assumptions can be about the future or consequences of risk events. Dikmen et al. (2008) also argue that assumptions of the risk assessor on “vulnerability” of the project to risk factors cannot be captured in P-I ratings. A system’s vulnerability represents the extent or the capacity to respond or cope with a risk event. The actual consequences of risk events on the project depend on a project’s vulnerability to risks and an organization’s capability to manage risks; therefore, the company factors as well as the project characteristics are usually taken into account by the experts while assigning risk ratings during RA. Thus, for the same situation, different risk assessors may assign different ratings based on their “assumptions” regarding “future”, “vulnerability of the project (project-related

factors)” and “level of controllability (company/organization-related factors)”. To obtain trustworthy risk analysis, it is essential that judgmental dimension of risk and underlying assumptions are understood well.

It is believed that in order to eliminate the shortcomings of RA based on subjective risk ratings, a better “process” should be designed to elicit the knowledge of experts about project risks and underlying assumptions (Dikmen et al., 2018). A multi-stage process can be designed, similar to the ones as proposed by Aven (2016) and Berner and Flage (2016) in which assumptions made, background knowledge on which the assessments are based, belief in deviation from assumptions and sensitivity of the risk metrics to changes in assumptions are asked from the experts and reported as well as their opinions on probability of occurrence of risk events and consequence on the risk metrics. Aven (2016) proposed a two step risk assessment process which takes into account of risk metrics, assumptions made and background knowledge on which the assessments are based in the 1st step, consequences/risk events and strength of knowledge at the 2nd step. Berner and Flage (2016) also developed a RA methodology that takes into account of “belief in deviation from assumptions”, “sensitivity of the risk index to changes in assumptions” and “overall strength of knowledge”. Similar studies are needed in the project management domain where the risk metrics is usually a subjective risk rating that includes various factors such as background data/knowledge, assumptions, risk attitude and cognitive biases. In this paper, only the “assumptions” are considered neglecting the effects of bias and attitude, which certainly should not be ignored and requires further research. It is argued that “Assumption-based thinking” (ABT) and processes of assumption-based planning (ABP) as advocated by Dewar (2002) can be a solution for incorporating assumptions into the RA process. Although ABT is originally used for planning (before, during and after planning) to mitigate the risks to a plan, Dewar’s (2002) approach can be used for treatment of uncertain assumptions during risk management.

ASSUMPTION-BASED PLANNING AND THINKING

ABP was developed by Dewar (2002) as a tool for strategic planning for the US Army, focusing on the reduction of avoidable surprises. In ABP terminology, an assumption is “load-bearing” if its failure would require significant changes in the organization’s plans and an assumption is “vulnerable” if plausible events could cause it to fail within the expected lifetime of the plan. Load-bearing, vulnerable assumptions are considered important, as changes in these would threaten the success of the plan. When identifying assumptions, those that are load-bearing should be addressed first, followed by vulnerable assumptions. A signpost is defined as an event or threshold that indicates an important change in the validity or vulnerability of an assumption. Signposts are developed to detect changes and make necessary revisions in the plans. An important aspect of signposts is that they need to give an indication of potential changes in time for potential re-planning or implementation of measures to secure the success of the plan. If there is not enough time to perform re-planning after a change is detected, then shaping actions or hedging actions should be used instead of signposts. A shaping action is an organizational action to be taken in the current planning cycle and is intended to control the vulnerability of a load-bearing assumption. Shaping actions focus on success and try to identify actions (measures) that can be taken to ensure that the assumption comes true or stays true. However,

shaping actions are not a guarantee against the failure of an assumption. For some situations it might be better to develop hedging actions which are used to reduce the degree to which an assumption is loadbearing. The aim is to reduce the consequences, should an assumption fail, preparing the organization for the failure of an assumption. ABT is the perspective that helps decision-makers to systematically define and manage assumptions.

Although ABP has been developed for strategic planning where the planning period is long, it is believed that its principles can also be used for management of projects carried out in turbulent environments, under conditions of high uncertainty and complexity, although it involves a shorter period (project duration) when compared to strategic planning. ABT can assist risk assessors while preparing the project risk management plan. Identification of assumptions is important to understand risk ratings assigned by the experts and also to check their validity. Besides, what is also critical is to check consistency of various assumptions as well as their individual validity. Assumptions about probability of occurrence of risk events (scenarios about the future) should be revealed to understand whether the risk events are correlated. Also, risk consequences may be interdependent due to utilization of the same risk mitigation strategy and the assumption about success of this strategy. If the assumptions regarding magnitude of risk events are based on the same background knowledge, all may succeed or fail. Consequently, identification of assumptions is not only necessary to unhide the “hidden” assumptions in risk ratings to better understand risk evaluations of experts, but also check their validity and the consistency of the plan considering the interrelations between risk events due to similar assumptions. To prepare a sound risk management plan, it is believed that ABT can be utilized during risk assessment so that load bearing, vulnerable assumptions can be systematically incorporated into risk registers as well as signposts and shaping actions to mitigate some risk events. These arguments will be illustrated by a case study given in the next section.

THE ILLUSTRATIVE CASE STUDY

The illustrative case is a real construction project still being carried out in Turkey. It is a part of a mega construction project known as “Marmaray”. The Marmaray project, having a budget of around 2 billion Euro provides full upgrading of the worn out commuter rail system in Istanbul, connects the European side with the Asian side with an uninterrupted, high-capacity commuter rail system. Two existing railway tracks on both sides of Bosphorus are upgraded to three tracks and connected to each other by a two track railway tunnel under the Bosphorus. The entire upgraded and new railway system is approximately 77 km long of which approximately 13.4 km is underground. The main structures and systems include the immersed tube tunnel under Bosphorus, bored tunnels, cut-and-cover tunnels, at-grade structures, three new underground stations, 37 surface stations, an operations control centre, yards, workshops, maintenance facilities, upgrading of existing tracks and a new third track at grade, completely new electrical and mechanical systems and procurement of modern railway vehicles.

The Project is divided into three components and awarded to different companies at different times:

- BC1 Contract : The immersed tunnel
- CR2 Contract : The rolling stock
- CR3 Contract : Upgrading of the existing railway on both the Asian and European sides to connect with the immersed tunnel

The Marmaray immersed tube tunnel which links railways on either side of the Bosphorus Strait was awarded on 2004 and opened in 2013, but upgrading of approach routes have been subject to considerable delay. The project under Contract CR3 awarded on 2011, which includes station rebuilding work and triple-tracking on the Asian side is still on-going and the completion date is expected as 2019.

INTEGRATED RISK MANAGEMENT PLAN

The Integrated Risk Management Plan prepared for one of the contracts under the Marmaray Project is discussed in this paper as a case study. The information about the parties of the contract and the party that is responsible for the preparation of the risk management plan are withheld due to confidentiality reasons. Integrated Risk Management Plan is a document which includes the “risk registers” and response strategies. The RA process has been carried out according to ISO 10006-2003, where ;

- the consequences of each risk, should it arise are determined,
- the likelihood of those consequences occurring are assessed,
- the consequence and likelihood ratings are combined to determine risk priorities,
- risk priorities and inherent risk levels are decided.

There are a total of 89 risks entered into the risk register. The probability scores and impact values that have been used in the Integrated Risk Management Plan are depicted in Table 1 and Table 2, respectively. Majority of the risks are specified as “risk events” such as payment delays, performance failure of subcontractors or damages to existing buildings, whereas some of them are actually “vulnerabilities” that increase the risk of cost overrun and delay in the project. It is seen that the vulnerabilities of the project mainly stem from the “interfaces” with other projects and parties (contractors of other contracts, public authorities such as TEIAS and DSI). Other vulnerabilities include space constraints such as insufficient dumping area and absence of storage area for onboard equipment. Location of the project is another factor that increases the risk of archeological findings and accidents due to near train traffic. Although the experts have not considered sources of vulnerability and uncertainty in different categories, some of the factors received a probability rating of 6, indicating that it is almost “certain” that they will occur (as given in Table 1). The risk rating is calculated by multiplication of probability with impact. The risk tolerance is determined as 16, meaning that risk events that have risk ratings below 16 are excluded from further analysis. When the negligible and acceptable risks are excluded, a total of 70 risk events are considered for further analysis. After this qualitative risk assessment stage, a more detailed quantitative risk analysis has been conducted to estimate the schedule risk of the project using Monte Carlo Simulation.

Table 1: Probability scores

Descriptor	Explanation	Probability	Score
Highly likely	Almost certain that it will happen	80-100%	6
Likely	More than 50:50 chance	51-79%	5
Somewhat likely	Less than 50:50 chance	35-50%	4
Unlikely	Small likelihood but could happen	21-34%	3
Very unlikely	Not expected to happen	11-20%	2
Extremely unlikely	Just possible but would be surprising	<10%	1

Table 2: Impact scores

Descriptor	Explanation	Cost impact (Euro)	Scope	Time impact (weeks)	Score
Disastrous	Unacceptable	>50M	6	>26	6
Severe	Serious	20M-50M	5	13-26	5
Substantial	Considerable	5M-20M	4	4-12	4
Moderate	Moderate	1M-5M	3	2-4	3
Marginal	Small impact	250.000-1M	2	1-2	2
Negligible	Trivial impact	<250.000	1	<1	1

The major “sources” of risk identified by the experts which may lead to delay and cost overrun can be listed as;

1. The Employer (leading to risk events such as delay in the decision-making process, site handover etc.)
2. Bureaucracy (leading to delays in permits and approvals, relocation of utilities, delay in power supply, delay in training etc.)
3. Interfaces with other projects (leading to delay in these projects, inconsistency of design, non-integration of systems, late handover of some stations, damage to their properties etc.)
4. Supplier X (leading to delay of critical works etc.)
5. Archeological discoveries (leading to considerable delay)

Although not specified in the risk register, it can be understood that the ratings assigned to risk events are based on several assumptions, some of which are ;

- Other projects/contracts of Marmaray will most probably delay.
- Employer’s decision-making process will be slow.
- There will be delays due to other public authorities.
- Problems will be encountered due to poor performance of the Supplier X.
- Some part of the project will be accelerated (verbal order by the Employer)
- Political and economic environments will be stable.

As an example, Table 3 demonstrates how a certain assumption is reflected in various entries of the risk register. Entries are directly taken from the risk register to demonstrate that experts evaluated some risk factors considering the same assumption/scenario, which is “Employer’s decision-making process will be slow”. The impact of identified risk events is also planned to be lowered with good communication with the Employer and proper documentation. For the risk of “Late handover of Station X by the Employer”, it is assumed that its impact may be lowered

by re-scheduling the work programme, which can be certainly identified as a load-bearing and vulnerable assumption.

Table 3: Risk ratings based on the assumption that “Employer’s decision-making process will be slow”

Risk Events	P	I (Time)	I (Cost)	Risk Rating	Response Strategy
Delay of payments	4	4	4	32	Proper application of disbursement procedures in the Contract and Loan Agreement Proper documentation for the Statements
Delay of site access	5	4	3	35	Confirm on time with the Employer for each site access that the site will be given on time.
Delay in decisions regarding time extension	5	5	5	50	Good documentation and communication with the Employer
Late handover of Station X by the Employer	6	4	2	36	Re-schedule the Work Programme to compensate the delay.
Delay in decisions regarding design changes	5	5	5	50	Good documentation and communication with the Employer

It has also been realized that some of the risk factors (overall risk rating <16) do not appear on the final list due to some vulnerable assumptions:

1. Some risk factors are assessed as “low probability” and “high impact”, which are usually uncontrollable events. For example, for the risk event of “political changes”, the probability is assumed to be “low”, thus overall rating is calculated as “low” excluding this risk event from the risk register. The assumption is about the “future”.
2. Similarly, for risk factors which are partially controllable, such as “material failures (failure of any critical material after installation)” or “failure of the welding machine”, the probability is assumed to be low, thus overall rating is “low” excluding this risk event from the risk register. The assumption is mainly about the “controllability/manageability”.
3. Some risks are identified as “high probability” and “low impact” risks where the assumption is about the “impact” of risk events on the project considering the contract clauses. If risk impact may be decreased by referring to a contract clause (time and cost compensation), that risk is also excluded from the register. The assumption is about “compensation”. Some of the other risk events whose overall ratings are “low” due to assumptions of “compensation” are; “cash flow problem due to acceleration of a work package” (it is assumed that they will agree with the Employer on cost compensation), “design requests/instructions that are not in ERQ (Assessed as very high probability-almost certain but low impact as the costs will be reimbursed). These risk events are excluded from further risk analysis.

However, during the project, there have been some changes in the government which significantly affected the project. Also, the assumptions about cost and time compensation did not hold true because the indirect effects of some changes (eg. acceleration) are very hard to document and prove. Vague statements in the contract, especially in unit price definitions also resulted in disputes between the parties.

DISCUSSION

RA using P-I ratings are based on several assumptions about “future”, “controllability/manageability” and “compensation by the contract conditions”. Some critical risk events may be excluded from the risk registers due to load-bearing and vulnerable assumptions which may not hold true, leading to cost overruns and delays which were not taken into account in the risk management plans. The assumptions on full compensation and controllability are usually not realistic and assumptions about the future such as political conditions in a developing country are usually vulnerable as well as load-bearing. These assumptions should be revealed during the RA process so that experts may challenge their validity, collect extra information about the assumptions if necessary (eg. Country risk reports) and check their consistency (eg. If level of bureaucracy is high, all the decisions of Client regarding design changes, time extension, site access etc. will be delayed). Signposts may be defined to monitor validity of assumptions on the “future” and shaping actions can be defined for assumptions on “controllability”. In the next section, a method is proposed to manage these assumptions.

A METHOD FOR ASSUMPTION-BASED RISK ASSESSMENT

Assumption-based risk assessment requires identification of risk factors and assumptions together so that realistic evaluations can be done about likelihood and impact of risk events. The steps of traditional risk assessment and assumption-based risk assessment may be compared as follows:

- Traditional risk assessment: identification of risks, risk assessment, formulation of strategies, quantitative risk analysis concentrating on critical risk factors, updating response strategies, preparation of the risk management plan, updating the risk ratings as well as strategies throughout the project.
- Assumption-based risk assessment: definition of assumptions (based on background knowledge or collection of data), preparation of an Assumption Log, identification of risks, match the assumptions with risks, risk assessment considering underlying assumptions, formulation of strategies, quantitative risk analysis, updating response strategies and shaping actions, preparation of the risk management plan, checking validity of the assumptions, updating the assumptions and risk ratings as well as strategies throughout the project.

In order to match the assumptions with risk events systematically, different types of logs and taxonomies may be utilized. An example about how this matching process can be carried out in practice is depicted in Figure 1. It is clear that different log and register designs may be preferred by companies. Part of a sample “Assumption Log” is given in Table 4.

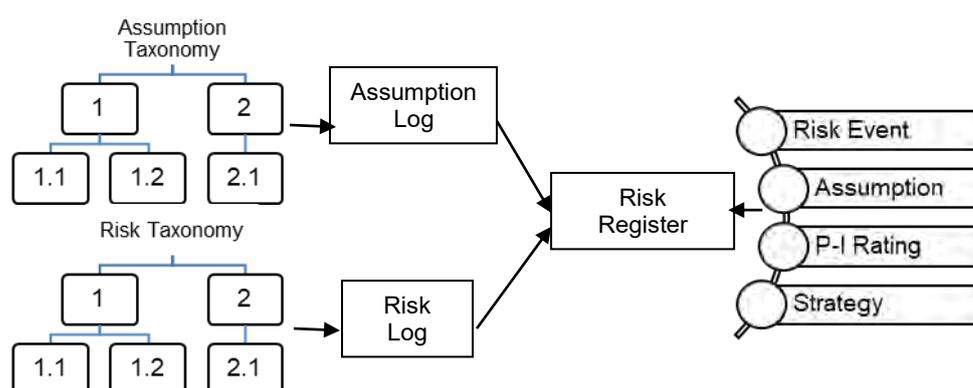


Figure 1: Assumption-based risk assessment

Table 4. A sample assumption log

Code	Category	Assumption	Knowledge Source	Vulnerability	Load bearing	Shaping action	Responsibility to Monitor Signpost
1.	Future						
1.1	International Relations	The relations between Country X and Y will be positive	Country Report	M	Yes	None	Business Development Department
1.2	Economic	There will be minimal change in foreign exchange rates	Economic Forecast Reports	M	No	None	Finance Department
2.	Controllability						
2.1	Alternatives/ Substitutes	Alternative suppliers can be found in Country Y	Market research report	L	No	Market research	Procurement Department
2.2	Resource	Part of the work can be accelerated	Meeting with Project Management Team	L	Yes	Resource allocation	Project Management
3.	Compensation						
3.	Contract	Delay of works due to Client can be fully compensated	Contract Clause(s)	L	Yes	Communication and Documentation	Contract Department

Based on Table 4, Assumption 1.1 may be assigned to the risks of “bureaucratic delay”, “cancellation of the project” and/or “delay in the delivery of materials imported from Country X” in the risk register, implying that probability of occurrence of these risk events are interrelated. By incorporating the related assumptions into the risk register, decision-makers can understand why and how P-I values are selected and update plans when it is observed that some of the assumptions lose their validity during the project.

CONCLUSIONS

It is argued that assumption-based thinking may be utilized during project risk assessment to unhide the assumptions and knowledge behind risk ratings and also update risk management plans by checking the validity of assumptions throughout the project. The risk management plan of the case study project reveals that some of the risk events that are critical may be excluded from further analysis because of the assumptions. If these assumptions were highlighted rather than embedding them in risk figures, validity of these assumptions could be questioned and knowledge sources behind them could be critically reviewed. Assumption-based risk assessment can be systematically carried out by matching the identified risks with assumptions in the risk register using risk and assumption logs. The risk assessment sessions and systems (taxonomies, log, decision support tools etc.) may be designed so that experts consider risks and assumptions at the same time during risk rating process and they have a common understanding about the assumptions as well as knowledge sources.

As a final remark, this paper presents some of the initial ideas of an on-going research project where the research questions are whether assumption-based risk assessment increases the success of risk management plans and improves the quality of decisions. The proposed method will be tested on real projects to explore its potential benefits and shortcomings.

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COLLABORATIVE DELIVERY PRACTICES, GOAL ALIGNMENT, AND PERFORMANCE IN ARCHITECTURE, ENGINEERING, AND CONSTRUCTION PROJECT TEAMS

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COLLABORATIVE DELIVERY PRACTICES, GOAL ALIGNMENT, AND PERFORMANCE IN ARCHITECTURE, ENGINEERING, AND CONSTRUCTION PROJECT TEAMS

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ABSTRACT

Collaborative project partnering, as an integrative project delivery practice, provide collaborative feedback cues to individuals during project delivery. The link between partnering practices and project success are prominent in the literature, yet the elements of partnering practices should be examined separately. The primary aim of this research is to explore the relationships between project risk factors, collaborative project delivery practices, goal alignment, and performance outcomes in AEC project teams in the context of partnering. To achieve its aims, the study collected data from six partnered case study projects. Structured interviews, analysis of case study documents, and qualitative methods were employed in data collection and analysis. Case study tactics ensured data quality. The results showed that project teams should focus on a core set of goal alignment metrics that are detailed around a clear project objective, anticipate goal alignment deviates over projects with longer durations and make provisions to continuously reinforce them, and avoid competing goal objectives within partnering charters. Directions for future research were also provided.

KEYWORDS

Partnering, goal alignment, collaborative delivery practices, project performance.

INTRODUCTION

The Architecture, Engineering, and Construction (AEC) industry is increasingly challenged with improving the efficacy of project team performance through collaborative working arrangements. Collaborative working arrangements such as integrated project delivery, design-build project delivery method, and collaborative project partnering are all comprised of interorganizational project teams. These teams, according to relational governance theory, generally function with flexibility, solidarity, mutual respect, and openly share information.

Collaborative project partnering, as an integrative project delivery practice, provide collaborative feedback cues to individuals during project delivery. The intensity of collaborative partnering can vary depending on project size and duration; however, project goal alignment and feedback mechanisms and tools to keep progress in line with those goals are consistent across projects. Some goal alignment and feedback characteristics of partnered-projects are generally in the form of partnering workshops, establishing clear goals and objectives, and early involvement of key stakeholders

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(e.g., owner, designer, contractor, subcontracts). These are some of the top reported practices that occur during project delivery which help increase goal alignment within project teams.

The link between partnering practices and project success are prominent in the AEC literature, yet the elements of partnering practices should be examined separately. This research asserts collaborative project delivery practices affect goal alignment and performance in AEC project teams.

BACKGROUND

Goal alignment is engaged by involving key participants early on and jointly developing project goals which build collaboration and trust. In this manner, projects team begin to align their knowledge and intentions with those of the project, rather than working from individual silos (Pishdad-bozorgi & Beliveau, 2016). The construction industry generally relies on relational/collaborative project delivery arrangements to facilitate better goal alignment between project teams and project objectives (Zuo, Chan, Zhao, Zillante, & Xia, 2013).

Project delivery approaches such as IPD and project partnering clearly incorporate collaborative practices and processes that affect organization and management strategies, contracts, project team communications and their behaviors.

As the focus of this study, a summarized list of partnering practices is given in below:

- Kick-off partnering workshop used to develop the partnering charter;
- Partnering charter that outlines:
 - Mutual goals and objectives;
 - Partnering maintenance and close-out process, partnering sessions and attendees, the frequency of meetings; and,
 - A clear dispute resolution plan mutually agreed upon by partnering participants;
- Partnering specifications;
- Engagement of a professional neutral third-party partnering facilitator;
- Partnering training;
- Executive sponsorship demonstrating top management commitment and support for partnering process;
- Early involvement of key stakeholders in the decision-making process;
- Multi-tiered partnering (i.e., executive, project team, stakeholders);
- Subcontractor on-boarding/off-boarding where relevant parties participate in partnering sessions;
- Focused Action Strategic Teams empowered for field-level decision-making as a means of timely issue resolution
- Scorecards for continuous feedback on project team performance; and,
- Dispute resolution ladders.

According to the IPI (2017b), partnering should be implemented based on certain perceived risk factors such as project value, complexity, political significance, and the experience of the team. Thus, it is important to adequately assess this risk and ensure the level of partnering practices are fitting for the project (Eriksson, 2010). The primary aim of this research is to explore the relationships between project risk

factors, collaborative project delivery practices, goal alignment, and performance outcomes in AEC project teams in the context of partnering.

METHODS

Focusing on partnered projects as a type and subset of collaborative AEC project delivery approaches, the specific objectives of this study are to develop:

Qualitatively examine the following at partnered-project level:

1. The collaborative project delivery practices instituted to detect variation among levels of collaborative partnering; and,
2. The links among project risk factors, collaborative project delivery practices, and project performance.

Research Strategy: Sound empirical research is grounded in a strong understanding of pertinent literature, identifying the gaps for research, and posing an “interesting” research question to fill the gap (Davis, 1971; Eisenhardt & Graebner, 2007).

According to (Yin, 2003), various strategies are available to researchers which can help answer the research question. The different strategies are unique to the research question explored. These research strategies are experiments, surveys, archival analyses, history, and case studies.

Given that partnered construction projects are unique endeavors, it is challenging to randomly assign individuals to distinct control and experiment groups to assess effects across AEC project teams and projects. Therefore, multiple case studies are investigated to explore project team dynamics within the context of partnered-projects.

In this format, structured interviews of key project team members and content analysis of case documents (e.g., partnering charter, partnering scorecards, project meeting minutes, partnering session documents) were performed. These project-level data were analyzed in parallel with survey data using pattern-matching, content analysis, and cross-case synthesis to help integrate findings.

Study Population: The population considered for this study consists of project participants and stakeholders involved in construction projects working under partnering arrangements in the U.S. The objective was to collect data from partnered-projects and subsequent project teams. The project teams were represented by owners, design engineers, contractors, and subcontractors.

Study Propositions and Variables: Three propositions (represented in Figure 1) guided this study to achieve its aims:

Proposition 1: *Project risk factors and the level of collaborative project delivery practices in partnered-projects are positively related.*

Proposition 2: *Collaborative project delivery practices and individuals’ goal alignment perceptions in partnered-projects are positively related.*

Proposition 3: *Individuals’ goal alignment perception and project performance in partnered-projects are positively related.*

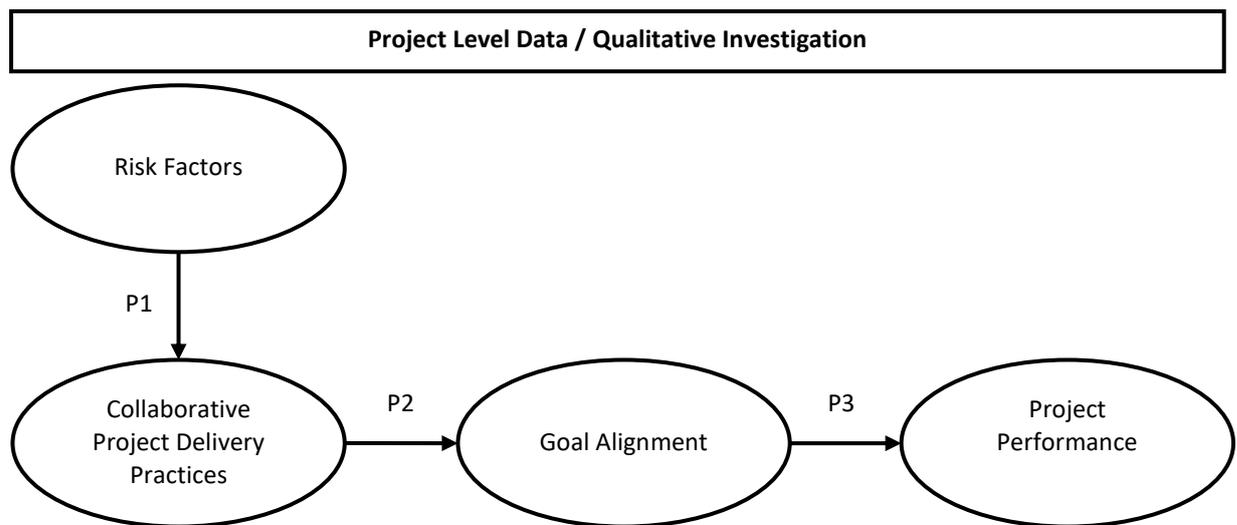


Figure 1: Theoretical Framework for Relationships among Project Risk Factors, Collaborative Project Delivery Practices, Goal Alignment, and Project Performance.

Data were collected on the following study variables via structured interviews: Project risk factors, collaborative delivery practices, and project performance.

Project risk factors are assessed using best practice guidance and AEC literature which assert key attributes involved in the effectiveness of partnering (Gransberg et al., 1999; IPI, 2016). Utilizing these risk factors, structured-interview questions are developed to ascertain the desired level of partnering anticipated for the project. These variables are assessed using a scoring system to differentiate between certain factors such as project risks with potential impacts on cost/time, complexity, and political significance. To do so, each category is scored from 1-Not important to 5-Very important. The questions also include a contextual portion related to the specific case study project. As an example, schedule risks with potential impacts on cost/time includes options to select from such as none, limited, and many.

Collaborative project delivery practices are measured using metrics developed in a partnered-project delivery framework and AEC literature review (Mollaoglu & Sparkling, 2015). Based on the literature, some of these practice elements are the use of partnering workshops for project teams, establishing mutual goals and objectives, and project surveys to monitor partnering processes (Chan et al., 2004; D Hughes, Williams, & Ren, 2012; Deborah Hughes, Williams, & Ren, 2012). These formal and informal governance strategies help project team members align their goals and objectives based on previous experiences. The structured interview questions also use yes, or no responses to certain items. Additionally, the survey intends to capture the importance of each practice using a Likert score ranging from 1-Not important to 5-Very important.

The **project performance** construct used in this study is developed from extant AEC literature. Project performance entails three first-order variables or elements from which measures are determined. The three elements are cost, schedule, and quality and safety performance. These also include owner satisfaction perceptions. Cost

refers to outcomes regarding cost growth and additional expenses as a result of changes or other conditions during project delivery (Grajek, Gibson Jr., & Tucker, 2000; Gransberg et al., 1999; Yeung, Chan, Chan, & Li, 2007). Schedule refers to time performance such as being ahead or behind as compared to original contract completion dates (Grajek et al., 2000; Gransberg et al., 1999; Yeung et al., 2007). Quality and safety performance is concerned with the quality ratings, reducing the amount of wasted work or rework, and end-user satisfaction of the project. Meanwhile, safety performance is centered on accident rates (Yeung et al., 2007). This study investigates this construct using a five-point Likert scale (i.e., 1-not satisfied to 5-very satisfied), among other things, to rate perceptions of owners on their responses to questions within the survey. Table 1 presents these study variables.

Table 1: Latent variables and measures used in the structured interviews

Study Variables: Evaluation Method (Multiple Choice: Likert Scale)

Project Risk Factors (Gransberg et al., 1999; IPI, 2016)

Number of project risks with potential impacts on cost/time
 Schedule risks with potential impacts on cost/time
 Project team relationships
 Team partnering experience
 Political significance and community interest
 Complexity

Collaborative Project Delivery Practices (Chan et al., 2004; IPI, 2016; Mollaoglu & Sparkling, 2015)

Professional facilitator was used in this project.
 A shared equity arrangement was indicated in contracts.
 A partnering charter was used in this project.
 A proactive conflict management tool that added structure to collaborative problem-solving processes was used in this project.
 Equal power/empowerment was afforded to all project teams and team members in decision-making processes.
 An incentive/fee/risk-reward/ or gainshare-painshare agreement was established in contracts.
 Parties were selected based on partnering experience.
 We selected team members based on previous work experience with other team members.
 Parties were selected based on technical expertise.
 There was early involvement of key participants (e.g., designer/contractor/specialty subcontractors) during schematic design (SD).
 Partnering workshops were held for this project.
 Partnering scorecards were used in this project.
 There were two or more project teams located together in a common office (i.e., colocation).

Partnering training/team-building sessions were held for this project.

Measurable and achievable milestones were established to determine the success of the project.

Project teams openly exchanged information across organizational boundaries (e.g., Building Integrated Modeling (BIM))

Quarterly partnering meetings were used in this project.

Monthly partnering meetings were used in this project.

Multi-tiered partnering was used in this project (i.e., executive, core team, stakeholders)

Specific task force used for conflict and issue resolutions

Project Performance (Grajek et al., 2000; Gransberg et al., 1999; Yeung et al., 2007)

Owner satisfaction with cost performance

Owner satisfaction with schedule performance

Owner satisfaction with quality performance

Owner satisfaction with safety performance

Goal alignment was measured by assessing the congruence among individuals working in AEC project teams. The process of collaboration and goal alignment across organizational boundaries involves learning curves in working as a team, bringing together varied skills, and investments in time and resources. Based on the literature, there are many collaborative practice elements used to align project teams such as the use of partnering workshops, establishing mutual goals and objectives, and involving key project stakeholders early in the design and construction project process. This study intends to use a measure of goal alignment to investigate causality among coordinated efforts across organizational boundaries. The measure is based on goals and objectives elicited in case study partnering charters, therefore, is specifically aligned to each case study project. For example, some projects included safety, schedule, budget, and submittals as goals in their partnering charters with well-defined performance metrics (Table 2). These items were used to measure this construct using a five-point Likert scale (i.e., 1-strongly disagree to 5-strongly agree) to rate perceptions of individuals on their project specific goals. This study collected partnering scores from case studies to indirectly investigate goal alignment.

Table 2: Sample case study project charter goals and performance metrics

Goal-aligning Objectives	Performance Metrics
Safety	Zero accidents Excellent housekeeping
Schedule	Early completion Substantial completion by xxxx Final completion by xxxx
Budget	Potential Change Orders and Change Orders minimized Contingency not exceeded Cost savings documented
Submittals	Submittal process timely and well-managed
Environmental Compliance	No non-compliance notifications Focused on cleanliness
Green Infrastructure Quality	No rework Green Infrastructure (GI) supplier plans and specs clearly defined
Communication/Coordination	Organization streamlined Responsive decision-making process
Community Appreciation	No community complaints Timely notifications of scheduled work Project's progress documented and communicated regularly
Team and Project Recognition	Respect and trust for all team members No issues escalated above field project team Project recognized for GI advanced work achievements

Data Quality: There are effective case study tactics available to ensure validity and reliability criteria are satisfied. In case studies, the researcher is concerned with four design tests being construct validity, internal validity, external validity, and reliability (Yin, 2003).

This study addresses construct validity by using multiple sources of evidence (e.g., partnering meeting minutes, partnering workshops, and scorecards) and establishes a clear chain of evidence during data collection. Reliability, important during data collection, was controlled by closely following a clear case study protocol and maintaining a database for all case study information. In order to Meanwhile, pattern-matching, explanation-building techniques, and cross-case synthesis were used to develop internal validity. Last, multiple case studies were investigated and synthesized to provide for generalization to other studies or external validity Well-done theory building from multiple-case studies, similar to experiments, can be very objective and allow formal analytical modeling (Eisenhardt & Graebner, 2007).

RESULTS

The final study sample for structured interviews was 12 respondents representing six case study projects. Data from the six case studies was collected beginning in January 2018, over a period of three months. Case study characteristics are presented in the Table 3 below.

Table 3: Characteristics of Case Study Projects

	Project Size (*\$M)	Schedule (**Workdays)	***Project Type	Location in the United Stated	No. of Partnering Participants	No. of Partnering Workshops
Case Study #1	5.59	345	Horizontal	West	6	3
Case Study #2	4.96	255	Large Infrastructure	West	17	3
Case Study #3	149.96	595	Horizontal	Midwest	30	9
Case Study #4	272.99	1303	Large Infrastructure	Midwest	52	10
Case Study #5	3.10	257	Vertical	West	9	3
Case Study #6	5.00	270	Vertical	West	11	3

Proposition 1: Project risk factors and the level of collaborative project delivery practices in partnered-projects are positively related.

Table 4 shows case study scores and is sorted on project risk scores from highest to lowest against collaborative project delivery practice scores.

Table 4: Results from Structured Interviews and Project Scorecards sorted by Project Risk Scores

Case Study Projects	Structured Interviews			Case Study Partnering Documents		
	Project Risk Factor Score	Collaborative Delivery Practices Score	Project Performance Score	Goal Alignment Score	Project Charter Goals	Goal Alignment Actions
Case Study #2	80	71	100	92	8	13
Case Study #3	75	41	85	71	13	49
Case Study #4	64	64	85	78	10	43
Case Study #6	57	36	55	93	7	14
Case Study #5	44	43	100	93	9	23
Case Study #1	44	43	88	90	9	23

*\$M – U.S. dollars in millions; **Workdays excludes holidays and weekends; *** Project types included among others vertical (e.g., office buildings), horizontal (e.g., roadways), and large infrastructure (e.g., tunnels, bridges, or major highway infrastructure)

Additional Notes:

1- Scores under the structured interviews column were analyzed to generate a score for each variable shown in Table 2. The responses on these items were assigned a level of importance as rated by individuals' (e.g., Few=1, Moderate=2, and Many=3) which is multiplied by the rating of the item using Likert scale ranging from 1-Strongly disagree to 5- Strongly agree. These data were weighted based on the number of choices available i.e., five response options were equally weighted as 0.2 and multiplied by the actual response. This value is, then, converted to a 100 point score by multiply by 100 and divided by the total number of responses for each category.

2- Goal Alignment score is the average of scorecard scores converted to a 100 point scale.

3- Project charter goals are purely a count of the number of goals/objectives in charter.

4- Goal alignment actions are those outlined actions within each goal/objectives.

A noticeable pattern exist regarding *project risk factor* scores for each case study represented in the table. Case study #2 purportedly has the highest *project risk factor* score (i.e., 80) while case studies #1 and #5 both received the lowest *project risk factor* score in these data (i.e., 44). Juxtaposing *project risk factor* scores with *collaborative project delivery practice* scores, it appears four case study projects have clearly aligned their *collaborative project delivery practices* with *project risk factors*. In other words, when *project risks* such as complex design and construction, compressed schedules, and uncommon materials are perceived as low, the importance of *collaborative practices* is minimized. In fact, case study #1 reported the ability to take on additional scope in the form of another two blocks of water main replacement and surface repairs associated with the low risk to the project schedule and budget.

Two of the six cases do not support the proposed relationship in proposition 1: Case Studies #3 and #6. Interestingly Case study #6 has the lowest project performance score while case study #3 has one of the lower performance scores. These results led to the development of a new proposition:

Proposition 1a - If collaborative delivery practice are not positively aligned with the level of project risk in partnered-projects, then project performance will be negatively affected.

Proposition 2: Collaborative project delivery practices and individuals' goal alignment perceptions in partnered-projects are positively related.

Table 5 shows case study scores and is sorted on collaborative project delivery practice scores from highest to lowest against goal alignment scores.

Table 5: Results from Structured Interviews and Project Scorecards sorted by Collaborative Project Delivery Practice Scores

Case Study Projects	Structured Interviews			Case Study Partnering Documents		
	Project Risk Factors Score	Collaborative Project Delivery Practices Score	Project Performance Score	Goal Alignment Score*	Project Charter Goals	Goal Alignment Actions
Case Study #2	80	71	100	92	8	13
Case Study #4	64	64	85	78	9	23
Case Study #5	44	43	100	93	7	14
Case Study #1	44	43	88	90	9	23
Case Study #3	75	41	85	71	13	49
Case Study #6	57	36	55	93	10	43

From initial inspection, no discernable pattern emerges among these data. When *collaborative project delivery practices* are at the highest rating, *goal alignment* scores are also rated highly. The same is true for the lowest scores for these two categories. Despite this inconsistent pattern, another alternative explanation persist.

The *goal alignment* scores are measured using defined goal alignment objectives and actions put forward by case project teams. These are clearly elicited in partnering charters developed at outset of a project either during planning or early during phases of construction. A closer look at the number of goals in each partnering charter and number of goal alignment actions show an increasing trend as *collaborative project delivery practices* decrease. In other words, an inverse relationship appears between these two variables. Case studies with higher *collaborative project delivery practices* appears to require fewer goal alignment actions or metrics to hold the project team accountable. This result leads to a new proposition.

Proposition 2a: Higher collaborative project delivery practices require fewer goal alignment actions or metrics to hold the project team accountable in partnered-projects.

Proposition 3: Individuals’ goal alignment perception and project performance in partnered-projects are positively related.

When examining the relationship between *goal alignment* and *project performance* a clear trend is present (Table 6).

Table 6: Results from Structured Interviews and Project Scorecards sorted by Goal Alignment Scores

Case Study Projects	Structured Interviews			Case Study Partnering Documents		
	Project Collaborative Risk Factors Score	Delivery Practices Score	Project Performance Score	Goal Alignment Score*	Project Charter Goals	Goal Alignment Actions
Case Study #5	44	43	100	93	9	23
Case Study #6	57	36	55	93	8	13
Case Study #2	80	71	100	92	13	49
Case Study #1	44	43	88	90	10	43
Case Study #4	64	64	85	78	9	23
Case Study #3	75	41	85	71	7	14

Generally, when goal alignment is high project performance also receives a high score. Case study #6 appears inconsistent with the trends. In this case study, the team experienced a project set-back resulting from added scope for an unforeseen code requirement. An electrical service was required to be upgraded as part of the renovation work. This required significant communication and coordination with the electric utility, designers, owners, and contractors. As a result, the project was delivered over two years later than originally planned. According to partnering documents, the project was financially constrained due to multiple funding sources and spending stipulations (i.e., 45 percent State grant, 30 percent City Parks and Recreation Department, and 25 percent not-for-profit fundraising by the organization). This can limit the amount of resources available for early site investigations.

Case study #6 also heavily relied on the owners’ team for significant programming guidance during the design phase. As a not-for-profit organization (i.e., in this case the owner), it can be asserted that they may not have been a sophisticated buyer of construction work and may have experienced breakdowns in communication with the designer leading to this unforeseen major scope addition. Given all this, an explanation surfaces as to why the project maintained a high goal alignment level, yet

reported a lower project performance score. In contrast case studies #2 and #5 demonstrate a clear relationship between goal alignment and project performance.

The top two projects (i.e., case study #2 and case study #5) followed common metrics that differed from case study #6. For instance, an emphasis was placed on continuously improving document management systems for processing submittals and requests for information (RFIs). This allows information to move quickly across organizations when decisions are required. Another disparate finding among the top and lowest cases is the inclusion of a monitor to help encourage collaboration and integrated teams to develop, especially around problem-solving. These results led to the development of a new proposition.

Proposition 3a: Collaborative delivery practices should accommodate continuous improvement in facilitating information exchange among team members in partnered-projects.

CONCLUSIONS

This study collected data from six partnered case study projects. Structured interviews, analysis of case study documents, and qualitative methods were employed in data collection and analysis. Case study tactics ensured data quality. The study led to the development of new propositions. The findings showed the following:

- Limited partnering team experience and projects with high visibility are early warning signs for increased collaborative practices.
- Project teams should be cautious when many goal aligning action surface during partnering workshops; leading indication that project team may be strained to align individual goals to those outlined in project charter.
- Project deemed as having reduced project risk and following a limited number of collaborative practices should not fall into complacency. These project may despite the ability to keep their teams aligned are susceptible to undesirable project performance outcomes.
- Project teams should:
 - focus on a core set of goal alignment metrics that are detailed around a clear project objective,
 - anticipate goal alignment deviates over projects with longer durations and make provisions to continuously reinforce them, and
 - avoid competing goal objectives within partnering charters.

Limitations to the study exist. The study was conducted among six case studies and with a limited number of individuals to make inferences on project risk factors, collaborative project delivery practices, goal alignment, and project performance. Therefore, results may vary when larger datasets are instigated. In addition, the case studies were concentrated on the west coast of the United States.

As a guide, this study offers a new direction and methodology to evaluate partnering practices. Future research may expound on this study by collecting observational data to add richness on team dynamics. Further, researchers may find ways to test various theories using inductions or manipulations. For example, researchers can work with facilitators to increase or decrease the number of goal alignment actions inspecting for deviations over time and across case studies. This type of experimentation may offer stronger insights regarding goal alignment and may help project teams learn to focus their efforts on the optimum number of performance metrics.

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EVALUATING THE ROLE OF SOCIAL CAPITAL IN INFORMAL RECONSTRUCTION: A CASE STUDY OF PUERTO RICO AFTER HURRICANE MARIA

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ABSTRACT

Puerto Rico was devastated by Hurricane Maria on September 20, 2017. Due to a delayed and insufficient official response from the local and federal governments and other aid agencies, the effects are still crippling at 8 months after landfall. When official response networks fail, communities often engage in informal reconstruction processes to facilitate their own survival and road to recovery. This paper uses the theoretical framework of social capital, in the form of bonding, bridging and linking relationships, to understand how communities can mobilize to reconstruct on their own. Data collection uses qualitative methods including interviews (N=50) with community members and field observations. Data collection in the form of interviews with community members and observations of community dynamics and reconstruction processes is underway in a 4-month period between May-August 2018 in the rural communities of Barranquitas, Adjuntas and Utuado. This paper presents preliminary results from interviews (N=11) and multiple observations of community events, public spaces and reconstruction activities. . Results will contribute to theory and practice in social capital mobilization for the primarily developing world phenomena of informal reconstruction within the larger US frameworks. Understanding informal reconstruction through mobilization of social capital will help in understanding how communities can become increasingly resilient and respond in times of crisis.

KEYWORDS

Disaster recovery, social capital, community mobilization, informal reconstruction, Puerto Rico

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INTRODUCTION

Puerto Rican communities were heavily impacted by Hurricane Maria which left the island without power, clean water, shelter, and reliable transportation when it made landfall on September 20, 2017. Emergency and recovery response has been insufficient, especially among rural communities where resources are scarce (Meyer, 2017; Jervis, 2018). This lack of response has contributed to widespread health and safety risks especially among rural and isolated communities. As many as 1052 deaths have been reported as directly or indirectly related to Hurricane Maria, and the number continues to grow (Robles, 2017). Aid has been slow and scarce in the reconstruction process due to many factors, including funding, inadequate communication, isolation and damage to transportation systems. However, one of the most severe of these causes is the informal construction in existence before Hurricane Maria made landfall.

Over 50% of houses in Puerto Rico are considered ‘illegal’, acquired through informal agreements, squatter settlements turned into communities, inter-generational housing inheritance without official deeds and permit-less construction (Florida, 2018). Formal disaster recovery programs often include strict regulations on housing aid eligibility, therefore many of these residents are unable to receive necessary resources for repair and reconstruction even though the resources may be available. As a result, communities, particularly those with historically vulnerable demographics, rely on their own resources and efforts to initiate and maintain reconstruction processes. These are often in the form of ‘informal reconstruction’.

Informal reconstruction is defined as design and construction actions carried out by community members in establishing temporary and permanent features of the built environment (e.g. design decision, physical labor), outside of formal construction regulations, codes and organizations. Informal reconstruction relies on informal networks and reconstruction systems, therefore this paper proposes that an essential mechanism for informal reconstruction efforts is the mobilization of social capital.

Social capital is essential in the immediate aftermath of a disaster as it allows communities to mobilize which ultimately facilitates survival, improves access, and creates empowerment in a community. Specifically, community mobilization of social capital in reconstruction ensures that community preferences are considered, local skills are utilized, non-physical outcomes of recovery are maintained, and dependency on external sources are reduced. Additionally, community mobilization helps communities that do not receive any disaster aid to start their own road to recovery. When some communities are able to mobilize and some are not, understanding the antecedents to mobilization in informal reconstruction processes becomes important. In this particular context, mobilization of social capital is characterized in the ability to work as a community to respond and rebuild when other sources of aid are sparse and unpredictable.

Community mobilization is different from community participation, which looks at the use of community skills and involvement in the process as one part of a larger reconstruction mechanism. Current literature has focused on community participation as one facet of a larger reconstruction process (Ganapati & Ganapati, 2008; Zerio et. al., 2016). However, this literature falls short in considering post-disaster scenarios

when formal response systems experience serious setbacks that leave entire communities vulnerable to respond on their own. This is where mobilization of social capital becomes important in ensuring steps are being made towards recovery.

This paper argues that social capital plays a key role in informal reconstruction through mobilization because of the creation of trust, knowledge and resource sharing, and activities aligned with community needs and preferences. This research aims to understand informal reconstruction in the aftermath of Hurricane Maria, particularly in how it was initiated and maintained through mobilization of social capital. This paper presents the literature review and research design, while the final version of the paper will include preliminary findings from data collection and analysis after a four-month fieldwork in Puerto Rico. The research uses interviews and observations within rural communities to identify the relationship between social capital and informal reconstruction. Preliminary data collection and analysis presented in this paper includes data from interviews (N=11) and multiple observations of community events, public spaces and reconstruction activities. Data collection is currently underway and will eventually include 50 interviews. Data collection is located in three rural communities (Barranquitas, Adjuntas and Utuado), that differ in location, scale of damage, and success in mobilization of social capital. This research improves understanding regarding how communities react to disasters when they are left to their own resources. Our findings will help understand how different forms of social capital are critical for communities to respond on their own. This can improve formal disaster recovery policies and action sequences to better align with those in disaster recovery scenarios.

SOCIAL CAPITAL IN POST-DISASTER RECONSTRUCTION

The term ‘social capital’ has been studied extensively in many sectors, including disaster recovery. The term has been defined in previous literature as the ties that individuals create to bring benefit to themselves and others (Portes, 2000), as well as “...features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit” (Putnam, 1995). Results of strong social capital include a sense of trust, sharing of information and knowledge, and creating patterns for participation and collaboration between individuals (Aldrich, 2012).

This paper utilizes the social capital framework for social capital that looks at the resources, information and social norms shared through three specific forms of relationships; bonding, bridging and linking (Aldrich, 2012). *Bonding social capital* is characterized by horizontal connections between individuals within a similar community, such as ethnic, identity, language, family or neighborhood groups. Strong bonding capital can often be seen by lack of privacy among members or disregard of social ‘politeness’. *Bridging social capital* is characterized by horizontal links between communities of similar status that cross ethnic, religious, language, community proximity or other distance factors. *Linking social capital* is characterized by primarily vertical links with an explicit, formal, or otherwise established power dynamic (Aldrich, 2012).

These relationships have been considered extensively in post-disaster recovery and is primarily cited as improving a community’s ability to adapt after a disaster

(Tan & Pulhin, 2014). These studies include but are not limited to Nepali communities after the 1934 Kathmandu earthquake (Bhandari, 2014), Bhuj and Bachhau communities in India after the 2001 Gujarat earthquake (Mukherji, 2014), the Indian Ocean Tsunami in 2004 and 1995 Kobe earthquake in Japan (Aldrich, 2012), multiple disasters in the Philippines (Bankoff, 2007), a tsunami affecting the small village of Llico, Chile (Imilan et. al, 2015), and Hurricane Katrina in New Orleans (Hawkins & Maurer, 2010), among others.

This paper uses the framework established by these three forms of social capital to evaluate community mobilization for informal reconstruction.

COMMUNITY MOBILIZATION IN INFORMAL RECONSTRUCTION

Previous work on community efforts in reconstruction have focused on community participation within the larger reconstruction framework and is often framed from the perspective of decisions of recovery organizations and decision makers (Ganapati & Ganapati, 2008; Zerio et. al., 2016). However, there is little understanding of scenarios where community efforts constitute a majority or entirety of recovery. This can be problematic since this decision making process assumes that communities always receive external aid and they lack agency to utilize resources and initiate reconstruction. The present study addresses these gaps and proposes community-based characteristics that allow community members to initiate and maintain reconstruction efforts, or mobilize. The results of community mobilization in the reconstruction context is most often informal reconstruction, outside of regulatory frameworks (permits, inspectors, etc.), and other established standards.

This research argues that similar positive outcomes arise from community mobilization as effective community participation practices, in which extensive literature exists. Tan & Pulhin (2014) stated that disaster recovery can only be attained if the end users are involved and participate actively, and participation empowers residents to determine goals, make decisions and take the steps to carry them out (Flint & Luloff, 2005). Additionally, involvement of the recipients of the constructed environment improves transparency in the actions of the overriding organization (Tan & Pulhin, 2014), and connects the end user to the final outcome through contributing decisions in planning, design, and management.

There is a broad consensus in recent literature that community participation is important for post-disaster recovery. However, when formal recovery processes have not or cannot be established, it is important to understand how communities initiate and manage recovery themselves, by means of informal reconstruction. Furthermore, literature suggests that there are additional benefits to community mobilization of informal reconstruction over participation within larger initiatives. In past disasters, community mobilized relief efforts have been just as strong, and in some cases stronger than formal networks. For example, after 2 days of relief efforts during the 2011 tornadoes in Pulaski County, Virginia, the formal aid services shut down as they realized the self-mobilized, community-formed response was larger and stronger (LaLone, 2012). Community efforts in Pulaski County took the form of helpful neighbors, ‘concerned strangers’ who offered their skills and knowledge, and church community-centered responses.

Further benefits of informal responses after disasters include the tendency to react faster, effectiveness in unanticipated threats, and ability to adapt quickly to new threats for which formal organizations have not yet been developed (Tan & Pulhin, 2014). Social capital as a resource in disaster recovery also helps ensure fair representation in societies with widespread diversity (Bhandari, 2014), adapting the reconstruction efforts over time to address needs that become apparent after time (Letelier & Irazabal, 2018), as well as maintaining change in vulnerable situations in the long run, which is difficult for networks that are only at the location temporarily and then leave (Tan & Pulhin, 2014). It has also been found that bridging relationships across many sectors are very important and have created the most effective reconstruction efforts (Letelier & Irazabal, 2018). However, there is also a danger that informal reconstruction efforts increase vulnerability to future hazards and traps communities in a cycle of sub-par housing needing continual reconstruction (Parrack et. al, 2014).

Within the USA context, informal organizations and recovery efforts often do not contribute substantially to reconstruction efforts as they are working within a larger formal framework and do not possess the skills or other agency to work within the regulations. That is often left to trained government or other aid entities. While this type of social capital mobilization has been seen in international contexts, it is unprecedented in disaster areas within US territory. Within the international community, current practices in providing shelter often only provide for roughly 10% of needs within the first year, therefore it is ‘inevitable’ that communities build back their houses themselves or by using the ‘informal’ housing sector (Parrack et. al, 2014). However, this is rare within US frameworks. Much of disaster response analysis with US frameworks utilizes community participation within a larger regulatory framework, or if informal social capital organizations are involved it is seen alongside a major response from formal organizations. Furthermore, informal reconstruction in the form of community mobilized social capital is rare within the US context because construction within those frameworks is heavily regulated and must adhere to codes and standards. This research addresses the gap of informal reconstruction within US territory but outside of traditional construction frameworks, and how that is navigated and addressed. There is a need for new rules in official frameworks to improve adaptability to cases with extensive illegal and unpermitted housing. This issue is not adequately explored in the context of an area under US governance.

RESEARCH PLAN METHODS AND METHODOLOGY

RESEARCH CONTEXT

This research has been conducted in Puerto Rico at 8 months after Hurricane Maria. Puerto Rico is an important area to study social capital in disaster recovery because they were one of the hardest hit areas by Hurricane Maria. Furthermore, almost half of the island population lives below the poverty line (US Census Bureau, 2017) and, as a whole, the recovery effort experienced significant shortcomings in resources, particularly funding. Such high levels of social vulnerability and shortcomings in aid have drastically impeded standard recovery processes traditionally supplied by local governments and disaster agencies.

FEMA and the Army Corp. of Engineers have both been on the ground in the recovery efforts, however, the overriding regulations and rigid operation protocol has impeded their adaptability to the unique needs of post-Maria Puerto Rico. For example, FEMA has been taking applications for blue roofs, disaster recovery grants and other resources for individuals and communities. However, in order to qualify one must be able to prove ownership of land and/or infrastructure on that land. Roughly 720,000 (60% of the 1.2 million total received) grant applications have been denied, a majority of which is due to lack of ownership verification (Florida, 2018). Culturally and historically, houses and land have been passed down through generations or acquired through informal agreements, and over half of residents in Puerto Rico, according to government estimates, have ‘informal’ housing, lacking permits and titles (Florida, 2018). The houses that are constructed informally typically do not have official connections to electricity and water resources, and residents do not own legal ownership documents (Woellert, 2017). The houses lack permits, construction adherence to regulations, and regular maintenance. This increases vulnerability of communities to natural disasters, as well as disqualifies them from many official aid resources.

Therefore, this research seeks to understand the means that rural communities use to rebuild when these types of resources are not readily available. Three (3) communities will be highlighted, each noted for their rural characteristics and extensive damage from the storm. Observations and interviews have been conducted with community members in the towns of Utuado and Adjuntas and the municipality of Barranquitas. These communities have been chosen for their rural and low socio-economic status, and the fact that they have not seen much aid from the official response networks. These communities have also seen varying levels of reconstruction from different forms of social capital mobilization, as understood from news reports and established contacts familiar with the area. This research uses the case studies of three communities who have had varying degrees of reconstruction success and reach. They were also chosen to represent different community size. Barranquitas was selected as a case study since it is easily isolated area in the mountains of central Puerto Rico yet have seen successful reconstruction activities associated with a volunteer reconstruction organization. Adjuntas has been selected as it is a rural community with many members lacking reconnection to basic utilities for an extensive period of time after the disaster, but has also has mobilized particularly in the area of solar power implementation. Lastly, Utuado has been selected because it is a slightly larger town and has areas of extensive need, lacking reconstruction. These characteristics are known from anecdotal evidence and confirmed in-field.

These three areas also contained previously made contacts with individuals or organizations who had built significant trust within the communities to aid in reliable and thorough data collection.

DATA COLLECTION

Interviews with Community Members

Data collection includes semi-structured interviews with community members and leaders. They are approximately 1 hour interviews and have been conducted in

English, Spanish or a combination according to the preferences of the interviewee. Interview participants were initially identified through personal interaction with the community and contacts made through the University of Puerto Rico. Snowball sampling has been used to connect with additional participants. This study has also been utilizing emergent/opportunistic sampling methods to continue interviews and observations until the supply of willing participants in the community is exhausted or a saturation point of knowledge and understanding is reached. This technique allowed for additional data collection as opportunities arose and additional populations that are key to the understanding of the phenomena are identified (Palinkas et. al., 2015). For example, throughout the course of data collection the role of community members that worked at local hardware stores in the understanding of community efforts in reconstruction was identified therefore that population was sought out specifically. This technique was chosen due to the exploratory nature of the research and limits of a priori sampling in a setting vulnerable to limitations in power and communication, possibilities of isolation and differences in community size. During the interviews, respondents were asked questions such as “*Can you explain what happened initially after Maria? What are community interactions with FEMA like? Where did you live after the disaster?*” and “*Can you identify any ways in which this disaster may have changed your community?*” The interviews also included detailed stories of events and descriptions of reconstruction efforts. The interviews are recorded with the consent of the participant, transcribed verbatim and translated into English.

Community Observations

Community observation is a key data collection technique for this research in its ability to improve cultural understanding, help make sense of the interview content, show patterns that interview participants have become blind to, record behaviors, triangulate findings, and identify areas of further questioning in interviews (Merriam & Tisdell, 2016). These observations were conducted with a dual focus. The first focus was reconstruction activities; what has been constructed or neglected, which individuals are part of the construction activities and which are not, materials that are used, construction schedules, authority figures and decision makers, and all related details. The second focus was community social capital; dynamics amongst community members, expressions of trust, frequency and reasons for interaction, important interaction points within the community space, topics of conversation within interaction, to what extent all community members are engaged, and all related observations. The researcher is engaged along the full spectrum of full observer to full participant in the observation framework described by Creswell and Poth (2018). Full observer occurs in community meetings and other scenarios where researcher participation is inappropriate, to full participant in scenarios such as reconstruction activities, and occurrences along other areas of the spectrum have occurred when deemed appropriate. Areas of observation include but are not limited to, community meetings, important social areas (such as town squares, recreation areas, etc.), reconstruction areas, and areas left in destruction.

Between May 14-June 1 the primary researcher worked as a volunteer with an international NGO rebuilding roofs in the municipality of Barranquitas (All Hands and Hearts Volunteers). This experience opened doors to gather an insider perspective

on reconstruction techniques, schedules, goals, setbacks and relationships with the local community. With this information the researcher was able to better understand the overall process of reconstruction in the community and gain trust with local homeowners to sit down with for interviews.

Observations were recorded in field notes and photos were collected as appropriate and available.

DATA ANALYSIS

Narrative analysis and cross case comparative analysis was conducted with interview transcripts, field notes and other collected data. Narrative analysis takes the many collected stories and creates a chronology of events into one story, considering characters, settings, conflict, timelines and resolutions. There is also analysis of specific turning points, or ‘epiphanies’ in the story, as well as interaction, evolution of relationships or processes, and situational factors within the events (Creswell and Poth, 2018). Cross case comparative analysis looks for similarities and differences in these factors across multiple communities, analyzing for critical factors for successful or unsuccessful outcomes.

Data analysis for preliminary results was conducted manually. As a next step, the researchers will use NVivo software to formally organize and manage data. Open coding was used initially by freely coding all observed connections to the initial research question within the collected data, as well as the different accounts of the story of reconstruction as told by and observed through community members. Axial coding was then used to group the codes into emerging categories and themes, once interpretations were made and an understanding of the underlying meaning of the data started solidifying. (Merriam & Tisdell, 2016)

Bonding relationships were identified in coding by feelings of trust, mutual sharing of resources, frequency and length of interactions and community dynamics within a single community, including informal response networks and organizations developed inside of the community. Bridging relationships were identified by these same factors but between communities, including informal response networks and organizations developed or accessible across multiple communities. Linking capital was coded by communication with authority and official response network figures, visits to the community, successful access to resources, reconstruction work and ability to obtain media coverage. A coding dictionary was established for the key macro codes: bonding, bridging, and linking, and each with subcodes such as bonding (trust, family, and resource sharing), bridging (informal organizations, migration, transportation) and linking (government, large aid organizations, media). The codebook also contained a timeline based on narrative analysis including identification of key events, characters, decisions, etc. set out chronologically.

RELIABILITY IN DATA COLLECTION AND ANALYSIS

Reliability in data collection was established through spending a significant period of time immersed in the field and conducting continual observations. This includes time working as a volunteer with the roof reconstruction NGO in Barranquitas.

In-field researcher understanding of positionality is also critical. As a foreigner to Puerto Rico and non-native Spanish speaker, the first author who conducted data collection must be acutely aware of limitations in data collection and analysis. The first author has a conversational skill in Spanish and had the ability to conduct interviews in Spanish, yet there is vocabulary and slang native to certain communities and Puerto Rico as a whole that could be misunderstood. Diligence in including locals and those familiar and extensively experienced with reconstruction processes in Puerto Rico in the process is vital. This has primarily been done through research from multiple sources of reconstruction processes and local culture, including local NGO staff members and students from the University of Puerto Rico. The NGO primarily worked with was All Hands and Hearts Volunteers in Barranquitas, an international disaster recovery volunteer organization that focused on roof reconstruction in this context. Staff members that focused on material acquisition and distribution, community interaction and operations logistics were observed and utilized as vital resources for filling in background information of the context. One student from the University of Puerto Rico aided in introducing the in-field researcher to her hometown of Utuado, identifying potential interview participants, scheduling interviews and occasionally assisting with translation. Her perspective was invaluable as an insider in the community, which facilitated introduction to local community members, introductions and background knowledge of the community..

PRELIMINARY RESULTS AND CONTRIBUTION

Data is currently being collected and continual data analysis is being conducted in the field alongside collection. The current results primarily show how residents of Barranquitas have been able to survive and begin rebuilding in the face of widespread frustration to the reach and effectiveness of official aid response.

Bonding Capital

Bonding social capital is defined as the horizontal connections between individuals within a similar community, such as ethnic, identity, language, family or neighborhood groups. This study found that in this specific disaster scenario; family, neighbour and other bonding relationships were essential to facilitate survival and informal reconstruction in communities. Community members in Barranquitas have noted neighbors and family helping the community respond by providing shelter (e.g. allowing family to come live with them or helping make accommodations), emergency provisions (e.g. food, water, etc.), information sharing (e.g. communicating where resources are) and physical labor (e.g. clearing roads, etc.). This has also extended into long term recovery as close relationships continue to be the most important to checking on the progress of others, assisting with skills to rebuild and ensuring that none are being left behind. One community member of Barranquitas noted: *“I am doing nothing now, I am retired. I am a carpenter, I make cabinets, I do electrical work. Somebody needs me, I go. They say ‘what will you charge me?’, I charge nothing... They’re poor, they don’t have the money to pay... When I need their help I can say, ‘hey I helped you, so you can help me now’... We are like family, I know everybody who lives around here.”* Community members frequently mentioned that they had skilled members (e.g. carpenters and electricians) who had the desire to help community members to rebuild but only lacked resources

(e.g. construction materials and money) to do so. A general willingness to help is a form of mobilized bonding capital in the community, and was frequently vocalized in interviews and observed in communities.

Bridging Capital

Bridging relationships are defined as horizontal links between communities of similar status that cross ethnic, religious, language, community proximity or other distance factors. These forms of capital have been mobilized for reconstruction in this context almost exclusively for knowledge sharing purposes. For example, community members in Barranquitas cited bridging in the form of other towns noticing that they had put up signs around town with messages such as ‘Necesitamos luz’ (we need light). Signs similar to these started popping up in nearby towns as people saw the benefit for motivation to continue the reconstruction process. Furthermore, another member noted that people from other towns would let others know when certain areas regained cell service so people from neighboring towns without service could talk with loved ones.

Bridging capital has also been mobilized when an organization was able to unite others who may not have originally had the chance to meet. This phenomena has been seen in the form of Casa Pueblo (meaning ‘The People’s House’), an environmental advocacy and solar energy supplying community gathering space in the community of Adjuntas. The place was helpful to provide community connection in the aftermath of the disaster through educational programs and community gatherings. For example, the organization hosted a weekly documentary screening and discussions that were open to the public for free. Casa Pueblo also spoke to community members in the aftermath of the disaster about community needs. Since the community needed lights and ways to store perishable medicine and business inventory, they started distributing solar lanterns, solar refrigerators and solar freezers. This work has reached many households which lacked access to power supply months after the disaster and managed to bring a local barber and convenience store back into business. Casa Pueblo is an example of bridging capital because they made connections between community members and between the organization and community members who were previously unreached by the services of the organization. These actions exemplify mobilization of bonding capital where organizations reached out to provide useful resources to the community that were not directly related to original organization scope.

The perception of community is continually repeated in everything they do, and reiterates the mindset that no one is alone and they have the ability to do anything when they do it together. This is further strengthened by wallpaper with community members’ faces included in the artwork to symbolize that it is by them and for them, and repeated vocalizations that the space is ready to handle another hurricane and if it does come then they are strong and will remain open. This helps people to know where they can go to for help in a time of crisis.

Bridging capital also takes a unique form in our current context because the use of technology now allows for links between people that previously would not have had any contact. For example, residents of Barranquitas have been going to Google to learn how to build back stronger for the next hurricane. Bridges have been made

between people who previously had no mechanism to meet and share information, through the use of internet and technology. These bridges allowed for knowledge sharing from expertise or previous experience to aid in the reconstruction process. Many people have the desire to build their houses stronger as the next hurricane season approaches, however lack the expertise and experience to do this themselves. These relationships facilitate informed reconstruction.

Linking Capital

Linking relationships are defined as primarily vertical links with an explicit, formal, or otherwise established power dynamic. Linking capital has been successfully implemented in the example of the volunteer reconstruction organization All Hands and Hearts, based in Barranquitas. Their reconstruction efforts relied solely on community members noticing work on neighbours' houses and word of mouth to find new projects to work on. They arrived in the area in January and began repairs on households. Once the community gained trust in the organization, it reached out to the organization to continue work on other houses in the area. This created a trusting and beneficial partnership in the community with close ties being formed between staff members and homeowners. This example shows linking relationships are established when the organizations build a sense of belonging with the community.

The owner of a hardware store in Barranquitas explained that customers would come in with the money and desire to fix their homes but no knowledge of how to do so. In those situations he would assess their house and individual needs, draw plans for the reconstruction and gather the materials from his shop that they needed often free of charge. He further explained that he had the responsibility to help people and help others in his role of facilitating material supply for people to begin reconstruction.

Linking relationships were established with formal organizations, who were able to respond and provide resources because of their bonding connections. Two employees of the hardware store lost their homes and were only able to return to work because of families opening their homes to stay. The mayor's help in certain areas of the town was sped up because two neighbours travelled to his office and informed him of the current situation because a landslide had wiped out the primary connection to the neighborhood. While linking capital plays a vital role in the process of reconstruction, it is only made possible by the underlying bonding capital that facilitates day to day survival, ability for community members to act in their specific roles and the motivation to continue in the process.

Disaster as a catalyst for social capital formation

One of the most extensive findings from this study is the function of a natural disaster in creating social capital and the mechanisms for mobilization in future events. This was a resounding statement from many participants. Many believed that the response after the next disaster will look much different because of the knowledge and ties that have been shared and created in this process. Many also noted that communities interact much differently now, that before people were more isolated and didn't have much need for depending on each other but now everyone knows each other's name and the specific contributions they can make to the community as a whole.

Participant perceptions varied in how much that still exists today, however all agreed that the community became more connected in the aftermath of the hurricane and that will make response to the next one that much more effective.

Continuing data collection and results

This research has presented preliminary data collection and analysis of reconstruction stories and the mechanisms that enabled reconstruction. When completed, the study aims to improve understanding regarding how communities mobilize social capital as a means of voicing and mobilizing their priorities in times of vulnerability. Furthermore, how members can provide for their own survival with resources available to them. Specifically, the results from this paper will specify how different forms of capital could be mobilized at varying stages during the post-disaster recovery, using a more comprehensive understanding of social capital. This also places communities at the center of the crisis response system and the critical importance of their own adaptability and resilience in these situations. For policy makers, the research will show opportunities for official response networks to utilize relationships that empower individuals to initiate and maintain reconstruction efforts, even past the initial construction phases. It further understands the occurrence of informal reconstruction and sheds light on these unpermitted and often unsafe dwelling situations throughout Puerto Rico.

Once the authors have investigated the relationship between social capital for community mobilization in post-disaster reconstruction, policies will be analyzed for how they can be implemented to reflect contextual needs. The authors can also identify efficient methods of connecting needs to available resources and empowering community members to mobilize their own skills for initiating and maintaining a community effort. Informal reconstruction actions and outcomes will be analyzed for resiliency and accomplishment of goals and needs.

CONCLUSION

Before Hurricane Maria, many Puerto Rican residents were dwelling in informally constructed and acquired houses, therefore the strictly regulated official aid networks were ineffective in providing aid in the reconstruction process. Furthermore, other factors such as funding, communication and transportation system damages greatly hindered the official reconstruction networks. This led to the necessity of informal reconstruction through community mobilization of social capital resources in the forms of bonding, bridging, and linking relationships. This type of scenario has been studied within contexts in the developing world but is unprecedented within a US-governed area. Our research has sought to address the gap in understanding community mobilization of social capital to reconstruct informal dwellings, in an informal process with informal organizations, within the larger US framework.

Social capital as a theoretical framework is used to processes of informal reconstruction in the aftermath of a disaster. This research shows that social capital is used as a mechanism to increase community mobilization in post disaster situations where formal recovery networks fail to act effectively. Or, in cases where they do react but are insufficient in meeting needs and priorities, and providing long term benefits to community members.

In this study, preliminary data collection of interviews (N=11) and community observations were conducted to understand the role of social capital in informal reconstruction. Data analysis utilizes narrative analysis and cross case comparative analysis to show the narrative of the reconstruction process including key characters, settings and events. That is then compared between three (3) rural communities in Puerto Rico: Barranquitas, Adjuntas and Utuado.

Preliminary results show the occurrence of community mobilization of bonding, bridging and social capital in the process of reconstruction, including providing a temporary shelter while construction happens on houses, sharing knowledge of best practice reconstruction, and connecting needs to available resources. Continued data collection and analysis will expand upon these findings.

As all disaster research, this research is limited by the specific location and unique context in which it occurred. Specific cultural features, political decisions, economic situations and other factors created a setting that is unlikely to be replicated elsewhere. However, the general conclusions hold true for disaster recovery as a whole in its contribution to understanding informal reconstruction processes when formal organizations fail or are insufficient in the aftermath of a disaster. Furthermore, limitations in researcher and participant bias in interview and observation activities have been mitigated as much as possible, yet remain relevant.

From this point, this research can be furthered by following it into disaster mitigation phases to understand how relationships and the importance of specific relationships change as the stage of disaster recovery changes. Furthermore, understanding how the outcomes of informal reconstruction processes endure when the next hurricane season arrives and the informal mitigation techniques also employed by communities mobilizing their social capital.

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THE HINTERLANDS OF PROJECT MANAGEMENT? PROJECT BOOKENDS AND THE (NEGLECTED) ROLE OF BOUNDARY ORGANISING

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THE HINTERLANDS OF PROJECT MANAGEMENT? PROJECT BOOKENDS AND THE (NEGLECTED) ROLE OF BOUNDARY ORGANISING

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Abstract

The paper explores the strategic front-end and the operational back-end of project organising. Drawing upon the notion of boundary organisation, this study aims to unpack the meaning and management of the initiation and completion/handover activities that typically ‘bookend’ major projects. Paper presents findings from a series of Nominal Group Technique workshops conducted with a selection of expert project leaders drawn from UK government project delivery. Findings suggest distinct clusters of themes that describe project bookends considerations and, further, suggest that there is less of a distinction between the front-end issues and back-end issues than conventional project management thinking and practice would suggest. The paper concludes with a call for reconceptualising project organisations without relying exclusively on (linear) time as the main point of reference.

Keywords: Projects, Front-end, Back-end, Boundary organisation, Digital Projects, Development lifecycle

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“Since when,” he asked
 “Are the first line and last line of any poem where the poem begins and ends?”
 Seamus Heaney, *The Fragment* (2001)

Introduction

It has been long argued how knowledge, people and team experience are instrumental for the delivery of value-adding projects to individuals, organisations, and societies (Morris and Hough 1987, Morris 2013). It is also well established that, to fulfil requirements by governments and large corporate clients, organisations are moving from away from the traditional provision of discrete products and services and into the space of integrated solutions (Brady *et al.* 2005), which can be seen as one-off or small batch bundles of products, technology, and services (Davies and Brady 2000). Such solutions are often delivered in the context of projects, leading to the emergence and recognition of the project-based business or the P-form enterprise, seen as organisations which add value to their customers and society through the delivery of projects (Artto and Wikström 2005, Davies and Hobday 2005, Söderlund and Tell 2009).

Although research on various aspects of project delivery is abundant, there have been repeated – largely unheeded - calls for more research into both the *front-end* (Edkins *et al.* 2013) and *back-end* (Artto *et al.* 2016) of projects; that is, studies of the transformation that projects undergo as they move from an idea into the execution and equally as they move from execution through delivery, handover and activation. Through this study, we will aim to unpack the meaning and management of those initiation and completion/handover activities that typically ‘bookend’ major projects.

Our motivating assumption is that these bookends are a categorically distinct set of activities – not quite the policy phase, not quite business as usual and, critically, not quite the project. This assumption is motivated by the policy level concern that the initiation and handover phases of (major) projects are far more complex and less well understood than conventional knowledge and prescriptive practice of project delivery suggests. For a typical project practitioner – focused on ‘getting the job done’ - the bookends often only appear in their “peripheral vision”. There is a need to recognize and better understand the process of agreeing and establishing boundaries – what we might call ‘boundary organising’ as a critical part of bookend activity, alongside risks, processes, governance, and leadership, to manage the project from its margins. We therefore formulate our research question as:

To what extent do front-end and back-end activities necessitate the development of separate or shared conceptualizations of projects and their management?

The paper is structured as follows. Following a review of the extant literature on project bookends and boundary organising, we present the findings from a series of Nominal Group Technique workshops (Rohrbaugh 1979, Gallagher *et al.* 1993, Cunningham 2017) conducted with a selection of expert project leaders drawn from within a particular area of UK central government project delivery. After reflecting on the conceptual and practical implications of these preliminary findings, noting the limitations of a single context for the projects under consideration, the paper concludes with a discussion of future work.

Project Bookends and Boundary Organising

Projects are traditionally defined as discrete ‘chunks’ of work in time (Lundin and Söderholm 1995) in temporary organisational settings that can be understood through the product development lifecycle lens (Morris 2013). Similarly, the discreteness or ‘chunkiness’ of the project only makes sense if we create some boundaries around the object we are trying to distinguish from its surroundings (Artto 2013), as to understand whether what we are looking at is part of the project or isn’t. The most fundamental project boundaries are its bookends, namely the front-end and back-end, which we will now briefly elaborate upon.

The project front-end is the process where the strategic purpose is being defined. This is the time where different potential versions of the project are being discussed, in terms of its intent, scale and scope until the sponsor or the holder of the business case establishes acceptable project goals and expectations (Edkins *et al.* 2013). Project front-end is also identified as the greatest opportunity for value creation (Artto *et al.* 2016) where the “project will typically lock in many aspects of what will be the final project configuration” (Levitt and Scott 2017). Because many aspects of the project will here be ‘frozen’ as key requirements and taken forward into execution, it is also where the risk of not getting the right project done is greatest: as research has repeatedly shown, in many a project seeds of failure are sown at the very outset (Morris 2013).

One of the many difficulties arising in the front-end is the process of eliciting and integrating different stakeholder needs and wants into a consolidated set of requirements expected to deliver user value through design and execution (Morris 2013). Unfortunately, those requirements are anything but stable over time; indeed they are likely to be as conflicting as the priorities of the stakeholders that define them (Green 1996, Luck *et al.* 2001) and to change through time as new stakeholders get engaged or the context for the design evolves (Zerjav 2015).

While the relevance of back-end issues, project handover and transition into operations, has been documented (Morgan *et al.* 2008), there is still limited empirical work (Whyte *et al.* 2016, Winch and Leiringer 2016) on these issues. Brady and Davies (2010) take a critical perspective on the disrupted operational opening of Heathrow Terminal 5 in 2008 and argue how failures at the point of delivering infrastructure-enabled operations to their end users can create severe consequences for clients and service providers. This study also suggested that the organisational culture of the client played an important role in forming the perceptions about the success of the project’s operational delivery. Whyte *et al.* (2016) focus on the digital data handover that occurs between project and operations. Drawing upon an in-depth inquiry of the London 2012 Olympics and Paralympics, this study set out the analogy of a baton pass in a relay race to argue for the importance of sequence, timing, passing technique and communication within a time-constrained window of opportunity. Similarly, drawing on the empirical setting of the delivery of Heathrow Terminal 2, (Zerjav *et al.* 2018) identified reconfiguration, adaptation, and maintenance of project capabilities as key mechanisms that enabled the client to achieve a seamless transition from project outputs into infrastructure service outcomes.

We can understand project bookends as key areas for project value creation (Edkins *et al.* 2013, Artto *et al.* 2016) as a continuum spanning the project strategic front-end, execution as well as the asset exploitation stage (for early work on the value stream

approach see Davies (2004)). Understanding the project front- and back-end in light of the value creation continuum calls for an understanding of project dynamism and emergence, where the linearity of planning, coordination, execution and delivery processes can no longer be explained and managed in separation from each other and by using the traditional (and prescriptive) task structure associated with organising projects. Instead of clear and discrete tasks, we are looking at a set of complex and interdependent domains of decision-making activity, which can be governed through adaptation and mutual alignment (Thompson 2008/1967) across the knowledge domain and stage-gate boundaries as the project unfolds (Zerjav 2015). These interventions occur at the level of organisational practices (Jarzabkowski and Spee 2009, Nicolini 2012, Marshall 2014), as opposed to the level of discrete and well-defined tasks (Thompson 2008/1967).

To address this complexity and theoretically formulate the notion of project bookends integrating the front- and the back-end phenomena, we draw upon the notion of a boundary organisation (O'Mahony and Bechky 2008) defined as an entity that stabilises relationships and enables collaboration between the disparate knowledge domains. Although various ideas around boundary work have received some attention in project studies, this has been mainly in the context of boundary crossing and boundary spanning activity that takes place across different knowledge communities (see for example Carlile 2004, Ewenstein and Whyte 2009) or the unforeseen adaptation, coordination, and alignment challenges that emerge due to shifting project boundaries (Zerjav 2015) in a non-decomposable problem-solving setting (Simon 1969/1996). We therefore explore whether these boundary organisation principles associated with project bookends are different from the conventional understanding of project delivery and to what extent they have ramifications for the owner/operator's strategic decision-making about projects.

Research Setting and Methods

To learn about the boundary management practices of project bookends, we conducted a Nominal Group Technique workshop involving expert project leaders from an area of UK central government with the aim of identifying the activities, issues, and challenges that these experienced and knowledgeable senior practitioners considered to be unique to the phases associated with front-end project initiation and back-end project completion. Some of the projects and programmes that were the subject of the discussions were of national significance.

The workshop participants were selected from within a distinct part of the UK Civil Service as they worked for the same organisation and were involved in projects that were broadly similar in nature, although managed as discrete programmes of different size and scale and being taken forward to variable timescales and requirements. A common focus on digital and data technologies and a predominant project management methodology ensured further cohesiveness of the workshop group. All participants were selected for their credible experience and expertise and whilst there was naturally a variation in both the age of the participants and their length of employment in their current jobs, they were selected on the basis that they would represent a peer group of project practitioners with significant and deep familiarity with the genre of project being considered. Due to the nature of the Nominal Group Technique, as detailed below, and the data that was expected to be released during the workshop, no further details of the participants or their area of project familiarity can be provided.

The Nominal Group Technique (NGT) can be defined as 'a special purpose group process appropriate for identifying elements of a problem situation, identifying elements of a solution programme and establishing priorities' (Scott and Deadrick 1982, p.26). Three factors motivated the selection of the NGT for this preliminary work. First, the highly structured format provided an opportunity to achieve a substantial amount of data collection in limited time yet required no preparation on the part of the (very busy practitioner) participants. Second, the structure also limited the influence of dominant members who, by virtue of personality or status, can distort small group function. Finally, and perhaps most importantly, NGT avoids, or at least minimizes, implied guidance and over-interpretation from the facilitator(s) whose role is to ensure the smooth running of the workshop (and capture the record), in three key stages:

- The opening phase involves describing the overall process to the participants and then presenting them with the specific framing question: What are the distinct issues encountered during the bookend (i.e. 'front end' and 'back end') phases of a major project? Following the presentation of the group question, the participants work individually on 'silent' generation of ideas, noting any and all ideas that occur to them when considering the question. There is no consultation or discussion at this stage.
- The second stage involves 'round robin' sharing of the ideas generated. Participants contribute one idea at a time - which the facilitator captures (on a whiteboard in this case). Everyone is given equal time to contribute but can decline to offer an idea or re-enter the process at any point. The process continues until all ideas have been captured. The set of ideas, a total of 47 for front-end issues and 35 back-end issues, was then regarded as the product of the group.
- The final stage involves the group prioritizing the ideas in relation to the original question posed. Again, each participant is asked to identify and score their top 5 ideas. The facilitator then collates the scores.

After the event, the researchers compared their three independent sets of notes and negotiated any discrepancies between individual interpretations of the categories emerging from the data. The research team then created a summary PowerPoint slide deck that was sent to the workshop participants and the non-academic research project sponsor for their reflection and comments as an interactive process to strengthen the communicative validity of this research (Sandberg 2005). The result was a refined and amended set of emergent topics, themes and issues that were generated, captured and consolidated by the workshop participants with the assistance and consideration of the researchers. Whilst the process of validation is ongoing, and the coding strategy can be amended and refined as we run more workshops and gather more feedback data, we were able to relatively easily derive the first set of themes arising from the data, set out below.

Key Findings

Analysing the 47 front-end considerations and the 35 back-end considerations in an open coding effort (Strauss and Corbin 1998, Gioia *et al.* 2013) resulted in the thematic clusters presented here. Note: it is important to establish that at this stage, we are only concerned with identifying and labelling the themes rather than assessing their value connotations (for example we neither focused on what type of theme it is – best practice, challenge to be manoeuvred around, nor did we allocate any form of priority or hierarchical importance to themes)

Front-end Considerations

The first cluster of themes identified was around (a) putting in place the leadership and other *capability* needed in the very early stages when still clarifying the project or programme objectives. In the specific context of UK public sector projects, this is particularly about selecting the Senior Responsible Owner (SRO) and the right initial team, and how this drives – or alternatively is driven by - the early definition of the project or programme and associated assumptions, for example about the type of project. The group identified particular challenges arising for projects if there was no clear outcome statement, or if there was weak goal alignment between instigating parties, unclear ownership and governance. Resource constraints (in terms of early leadership and team capability) were seen as a frequent challenge at this point; so too was the risk for projects at this point of becoming ‘Christmas trees’, with proliferating scope and specification creep as different parties seized the opportunity to add ‘just one more bauble’. Implicit here is the assumption that some party at this point *is* clear as to why the organisation is embarking on the project. Flowing from this theme is an emerging principle: that it is imperative that a senior party at the front end has clarity of what the desired or required ‘end-game’ is, as this is critical in helping determine scope boundary, project type, and the resources and structures that will be needed, and thus the feasibility of the project against that expectation.

The second cluster of themes was around (b) the ‘*dogma*’ in play – typically, policy-driven approaches or assumptions dictating a particular way of doing things from the outset of the project with few, if any, opportunities for critical reflection and divergence. Examples given highlighted a concern about being expected to adopt ‘one size fits all’ solutions in circumstances which may be inappropriate: for example, the automatic deployment of Agile methodologies; requirements to use cloud sourcing or disaggregate services determining key technology pathway decisions; or simply being expected to run the project according to the exact structures of a particular project management methodology which may or may not be appropriate. Indeed, participants noted that such expectations can be built into the project from very early on, for example in naming a project in a particular way before it is known what the project will be intended to deliver. Other issues raised concerned a tendency to press ahead on a basis of ‘hope and ambition’ without first establishing enough evidence to support the assumption that the project will succeed: aspects of the universal tendency towards optimism bias (Flyvbjerg *et al.* 2004, Kahneman and Tversky 2013), potentially built into the very premise for the project from the outset and setting up unrealistic expectations which are doomed to fail. Perceptions of ‘dogma’ could also be simply be aligned with the prevailing cultural assumptions - ‘how “we” do things round here’ – leading to a tendency to repeat history in terms of implementing an approach which is not assured to succeed and may indeed fail: projects start wrong, they continue wrong and they end wrong.

The third emerging cluster of themes is about (c) the *pre-project initiation*, in other words all the project activity that happened before any notion of the project in its final form has come to existence. This is reflected in a tendency towards a “rush to structure”, or “jump to solution” mind-set before the project has been properly considered, arguably providing the project leadership, project team and wider stakeholders with a false sense of certainty and confidence that progress is being made, based on potentially shaky foundations. In creating a fixed structure for the project too early, this increases the risk of needing to make adjustments in the project as assumptions, evidence and information change during its execution.

Finally, the challenge of (d) *navigating the nexus* of politics, policy and practice was identified as an area for attention. In their embryonic stage, projects and programmes are driven by very different agendas and goals that may span politics, policy, and practice as different domains. Very often there may be tensions between those domains and navigating those is a challenge to be overcome. The themes in this cluster are also likely to be linked to the *capability* and *dogma* themes noted previously. The motivations and ambitions need to be understood in their context (internal and external) where partial viewpoints, mind-sets, and perspectives abound: a particular issue identified was the imperative for the project team to consider the long-term view in terms of the costs and requirements of operation, as well as benefits realisation, after the project has moved into operational services.

Back-end Considerations

The first cluster of back-end themes we identified was about (e) *defining the end of the project*. Questions were pragmatic: when, who and how is the decision made as to what makes the project finished? When does an ongoing project, for instance one based on agile, iterative development, turn into a new project? These questions were noted to be closely related to decisions around when the focus shifts from the deliverable-oriented outputs of the project, for which the project team and leader are responsible, to the operational outcomes of the project, which become the responsibility of the business. A particular concern was that many modern technology and digital projects do not have a clearly defined ‘end’ as the capabilities continue to evolve throughout their lifetime, making it hard to identify a definitive end point. One of the workshop participants commented that for software projects in particular, identifying the start was going to be far easier than deciding on when they finish: the comment was (to paraphrase the slogan of the Dogs Trust, a UK based animal welfare charity) that ‘a software project is for life, not just for Christmas’.

The second cluster of themes was around the mind-set of (f) *binary states* whereby projects are seen as distinct entities from ‘business as usual’(BAU). This mind-set provokes conceptual tensions around boundaries, for example between building maintenance capability as opposed to new investment in BAU. Rules and culture (particular rigid operating models and silo-based disciplinary thinking) were seen as another obstacle, and a potential driver for the binary states mind-set. There was a concern that maintaining and evolving existing capability in operations is often seen as less important than investment in new capability through the project ‘creation’ exercise, leading to challenges in distinguishing priorities around projects and their relationship with BAU. At the other extreme, challenges were also seen around the confluence of projects and BAU, which may be used as a strategy to justify sub-optimal management

and execution choices, with the dominant paradigm-in-play driving and dictating the decisions;” It’ll be fine – they can sort that out later” mind-set is where development is dangerous if it occurs in a world where there is typically no comeback. If project managers and teams are measured on delivery of the project in terms of time, cost and scope, that is what they will do, with inevitably less focus on the operational outcomes sought from the project.

The third cluster we identified is about (g) *business readiness*, often seen as a safety net to enable a soft landing of the project into functions and operations. Related to the binary mind-set, this is where the project moves from its temporary status and becomes part and parcel of its respective permanent organizational structure. Benefits realisation becomes the key metric as opposed to static project outputs, and the project as a capital expenditure effort becomes conflated with the operational expenditure investment strategy to keep assets current. Too often, however, business readiness is only given ‘lip service’ at the outset of the project, rather than as a critical strategy informing both planning and execution. Business readiness is further complicated when there are a number of projects on which the delivery of the project/programme depends. This may particularly be the case in strategic programme execution, when the programme cannot be launched into operations because of complex interdependencies with other projects that have experienced issues, challenges, problems or delays, disrupting the linearity of the programme in question.

Table 1-Summary of Findings

Front End (FE) Clusters	Specific Themes	Back End (BE) Clusters	Specific Themes
Opaque Capability. The challenge of putting in place leadership, team, resources, etc. before objectives confirmed	Goal alignment, etc. – by definition – difficult without goal. Rush to structure	Imbalance in power/status. Investment in new capability (ie the projects) seen as more important than maintaining existing capability.	Extant rules and culture (e.g. rigid operating models, disciplinary - silo-based - thinking) were highlighted as obstacles/potential drivers for the binary states mind-set.
Growing project ‘Christmas trees’. Official objective may not be finalised but it is very clear to some parties what their partial objectives might be?	The emergence of; with proliferating scope and specification creep as different parties add ‘just one more bauble’	Measurement Myopia.	If project managers and teams are measured on project delivery – that is what they will prioritize.
Project Dogma. Policy-driven approaches or assumptions dictating a particular way of doing things from the outset of the project with few, if any, opportunities for critical reflection and divergence.	Automatic deployment of particular (eg. Agile) PM methodologies, mandating specific technological options, etc. Project naming, implying key criteria, before objectives finalized.	When is a project – especially an agile project - finished? How, who, when is the decision made that something complex is finished?	If dogma (mandated PM methods) is agile – traditional start/stop notions are not part of the overall framing of this approach. To paraphrase a slogan of the UK Dogs Trust, an animal welfare charity, a software project is for life, not just Christmas.

The main clusters of findings (Table 1) in the front-end and back-end beg the question of whether they represent different or similar issues. To begin with similarities, a key theme arising in both the front-end and back-end is the fallacy of the binary mind-set which sees the beginning and end of the project as defined by hard boundaries. Rather, the prevailing view is of the importance of spending more time in the boundary

organising of project bookends, and perhaps seeing them as bridges which link the temporary and permanent organisation and which support an ongoing flow of activity between the two.

Both front-end and back-end, moreover, highlight the critical role of the SRO or senior leader in negotiating the position and content of bookends, and where and how the boundary lines for initiation and closure should be drawn. This also raises further questions, for example about the nature of leadership needed to navigate the project successfully through these ambiguous hinterland zones, where effective ‘boundary spanning’ (Brion *et al.* 2012)– and indeed boundary shaping - are central to the success of the project.

Perhaps the most prominent contrast between the front and back end considerations is that at the front end, the impulsion is primarily one way, driving towards the creation of the project and new capability; the critical need is to ensure that enough time has been spent to ensure that it should indeed progress. This is in contrast to the back end, where there appear to be more complex, competing tensions, between continuing to iterate and evolve the project and the urge to ‘get it over the line’, making navigation trickier in practice than is perhaps recognised (as the relative lack of academic study around the back-end might suggest).

Discussion: Bookends as Artefacts of Organising

Our inquiry into the bookends and boundary organising activities motivated us to reflect on the role of *time* as the most fundamental yardstick for understanding and managing projects. Time has been long acknowledged as the basic structural principle in organising and management (Orlikowski and Yates 2002). This understanding has more recently been expanded to include various organisational levels (Turner and Rindova 2017) and the organisational psychology of time (Kaufman-Scarborough and Lindquist 1999). Different points in time are what we use to differentiate the project from what the project is not. Project initiation and termination are seen as events that occur in distinct points in time and - in fact - often emphasised as punctuation symbols that define boundaries of projects we are managing.

This, of course, does not come as a surprise, because projects are typically conceptualised as a distinctly temporal form of organizing (Orlikowski and Yates 2002); tasks are finite, teams and structures temporary and each ‘chunk’ (Artto 2013) of project work is defined in relation to its ostensive ‘start’ and ‘finish’ (Lundin and Söderholm 1995). For practical purposes, projects are defined by their bookends as groupings of tasks (operationalised through Work and Organisational Breakdown Structures) with temporal dependencies (often operationalised through devices such as the Critical Path Method), and as such they are seen as distinct from permanent organisations they belong to. Project management as a bundle of practices is firmly located in a systems lifecycle ontology (cf. product life-cycle models, etc.) whereby projects are split into phases distinguished in terms of time (Morris 2013, Artto *et al.* 2016). Moreover, the actual (performative) practice of managing projects is centred on the notion of time as *the* scarce resource: projects start and projects finish, project pass through a series of phase-based transformations (using structures such as stage gates, etc.); cost, risk and quality are also seen as functions of the linear flow of time. Recently, however, there have been calls to reconsider the saliency of some of these

conventional characteristics such as end-states (Lundin and Söderholm 2013) and transitions (Jacobsson *et al.* 2013).

Our findings, however, point towards an alternative view. In fact, despite taking the front-end and the back-end phases of the project as the main units to analyse, we found that project bookend management issues are much less a feature of time than the conventional project management wisdom would suggest – and indeed demonstrate a certain degree of circularity. But how can it be that the same management issues pervade the very beginning and the very end of the effort, for which the linear concept of time is the only yardstick we have at our disposal?

From the data captured from our workshop, at least, it appears that not only are the management of front-end and back-end of projects not a feature of time and sequencing in projects, but that how we think of projects may need to change. Using the monochronic and linear model of time leads to thinking that projects either are or aren't and this is clearly delineated by the initiation and termination as distinct points in time. Indeed, in organisations, we try really hard to distinguish between the project outputs and non-project outputs (think of project kick-off and close-out meetings, lessons learned exercises and project closure reports). We often find that projects and business as usual are understood as distinct as if they belong to different worlds – inhabited and managed entirely differently, with different success and performance measures.

Although a degree of separation makes sense in terms of accountability and especially for accounting purposes (as in when the project is funded externally to the organisation and needs to demonstrate outputs as expressly distinct from the business as usual), this can turn into a real problem when demonstrating activity per se becomes a credible measure of productivity. Unfortunately, it is often the case that meaningful indicators of the right kind of work being done in projects only emerge *ex post*, and therefore boards and administrators sometimes have to make do with accepting the mere demonstration of activity as a proxy for the project being on track to realise its benefits. Of course, as Earned Value Analysis has shown for many decades now, and in the same way that the state of being busy doesn't imply anything about the kind of activity one is busy with, demonstration of project outputs should be taken with more than just a grain of salt, especially when project delivery is siloed away from the mainstream business for which the project is providing a new or upgraded capability, indeed as is often the case.

Of course, the question then becomes how these insights on boundary organising of project bookends help us to deliver more value through projects. Clearly, we are not advocating an outlook on projects, management, or life in general free of any notion of the passage of time (although that could be an interesting proposition). We are also not advocating the abolishment of conventional project management methodology – the one that says you should break down the work into tasks and align them against the timeline so you can execute the project. Indeed, here we agree with the conventionally critical reader that such discussion could be more appropriate for a fantasy novel titled *Alice's Adventures in Project Wonderland*. But we equally suggest that the issue with the singular and linear notion of time and the binary idea of project/non-project understanding is real and that it may be misleading in many programmes and projects. By separating projects from the business activities they are contributing to, organisations may be setting themselves up for projects that fail or worse still, 'white

elephant’ projects: cumbersome projects that move slowly and deliver little, while incurring great cost - financial and reputational – to their organisations.

Rather than trying to provide answers, we will pose a (rhetorical) question to conclude this discussion section: can we conceive projects and programmes, not as distinct entities with real and tangible borders, but as a gradual progression in which one kind of organisational activity gradually progresses into the project state and then across to the business as usual model of another kind of core activity, something akin to the military concept of ‘sustainment’?

Conclusions

The aim of this paper was to better understand the relevance of both the early formative and late concluding phases of the project - the ‘bookends’ – focusing particularly on project boundary organizing considerations and their relevance to value delivery in those projects. We conducted an initial empirical study drawing upon the knowledge and experience of an invited small group of expert public-sector project practitioners into the setting of a workshop using Nominal Group Theory. Findings confirmed the importance of both these bookends and, further, suggest that there is less of a distinction between the front-end issues and back-end issues than conventional project management thinking and practice would suggest. They also suggest the existence of an unhelpful degree of detachment between the project and the core organisational activity under accepted project delivery methodologies, where the existence of the right amount of project activity can be mistakenly taken as an enduring post-project value creation indicator. Rather than it being a feature of time and sequence on projects, our findings on the importance of the boundary organising phases potentially point towards the need to develop novel and provocative insights, both for theoretical project studies and also for the practical benefit of project practitioners. We suggest that insight and benefit may emerge if projects are conceptualized without relying exclusively on (linear) time as the main point of reference. The data gathered from a focused inquiry into the role of the project bookends suggests that there is much that connects the front-end to the back-end of projects and that this circularity is further reinforced when the project is seen as an intervention into the operational state of the instigating organization. In sum, this paper sought to explore and, as a result of the exploration, challenge the saliency of the central role played by (singular) perspectives on time.

The project execution structure, with the definition of the sequence of phases, characteristics of each phase alongside its management, can therefore be understood as a convenient social construct, an artefact of organising, that is useful in that creates focus and facilitates collaboration amongst key stakeholders in a project. Although this situation might differ for other kinds of projects, such as in the built infrastructure, for example, where the physical output tends to be better defined at the outset, the key insight of this work is to reaffirm the long standing - but often forgotten - fact, that projects are social constructs as much as they are objective ‘things’ in the same sense as the physical artefact they are there to generate is.

The key notion this work has allowed us to reiterate is that that project bookends as well as the project lifecycle itself can be understood as artefacts of understanding and organising. They are social constructs allowing stakeholders to invest their efforts into a tangible structure, but equally not something that should not be mistaken for laws of nature- unchangeable and all-pervading regardless of circumstances. In this way, we

propose that project structures are to some extent a form of narrative structure - a story people can gather round and share, offering a golden thread through unknown territory, with a clear destination and a golden reward at the end of it.

From conducting this enquiry, we have confirmed our preconceptions that the bookends are critical points in the project's life – key transition points to and from the temporary organisation where the project's viability and successful delivery are in the balance. The successful negotiation of the project through these hinterlands is the difference between the success or failure of the project. These are risky, ambiguous, dangerous and exciting areas for the project and need scholarly and practitioner attention.

There are several potential avenues for future work in this area. The first one is based on the finding on the role of the SRO / project leader at both ends. The key role of project leaders as 'boundary spanners' and the criticality of this activity in terms of project performance is therefore a fruitful way to continue exploring the boundary organising phenomena - not just in negotiating the hinterlands but also to some extent deciding where to draw the boundaries and plant the flag.

As this paper notes, project methodologies are a way of organising to get things done, and most methodologies focus on time as the primary organising principle. Beyond all the logical reasons why we organise things in this way there are some very deep-seated reasons which means that we feel inherently most comfortable with linear organisation through time, which go back to core concepts around storytelling. Another potential direction for future work on boundary organising and project bookends, therefore, may be to learn from the theoretical constructs and concepts around storytelling. Basic folkloric structures are centred on a change of state – or transformation – with a start, an end, a protagonist and a journey over time which results in the desired – or an alternative, surprising - transformation. This may explain why we naturally impose such structures on how we think about delivering change and how project leaders organise and tell the story of that change – even though in practice everyone knows that it is a lot messier in practice.

There is a need for more enquiries in this area and further data has to be gathered and analysed in order to progress or refute the observations presented in this paper. The research team presenting this paper has this intention and in so doing will also examine the role of the both project front-end and back-end considerations in setting the targets and objectives for the 'iron triangle' metrics associated with projects: the scheduled delivery of the project (aka time), the scope limits and specification levels of the project's deliverables (aka quality) and the resources to be consumed in achieving the project deliverable (aka cost).

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INTENTIONS TOWARD FECAL SLUDGE MANAGEMENT IN RURAL DEVELOPING COMMUNITIES

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ABSTRACT

Pit latrines are used by 3.4 billion people around the world, but little is known about how to manage full pits safely and effectively in real-world contexts where human behavior strongly affects outcomes. This imminent problem of safe and effective fecal sludge management (FSM) must be solved to maintain access to improved sanitation services and continue to improve public health; this will require considering how human behavior affects FSM. Through the lens of the Theory of Planned Behavior, this study investigates the behavioral intentions of rural latrine owners toward FSM, describing an important and under-studied part of human decision-making that can be used to predict behavior related to FSM and improve the design of latrines and FSM processes and training. Survey data collected from 3720 households in rural Cambodia between 2014 and 2017 were analyzed using frequency analysis, metrics of association, and binomial logistic regression to answer the question “How do rural latrine owners intend to manage their fecal sludge?”. The results showed that the majority of rural latrine owners (59%) intend to manage their fecal sludge safely and effectively; however, the remainder (41%) reported undesirable FSM intentions, highlighting the impending risk to public health due to poor FSM. Following the Theory of Planned Behavior, which links individual, societal and physical contextual factors to the formation of behavioral intentions, various contextual factors including location, data-collection date, poverty level, past defecation behavior, and satisfaction with the household’s latrine and its supplier were found to significantly affect FSM intentions. A model using these contextual factors as inputs was able to predict the desirability of FSM intentions with an accuracy of 67%. Limitations and future work are discussed. This formative research describes a part of human behavior that affects FSM and provides a basis for future research into understanding FSM behaviors, improving FSM behavior change techniques, and designing safer and more effective FSM processes for rural communities.

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KEYWORDS

intention, behavior, fecal sludge management, rural, sanitation

INTRODUCTION

Pit latrines are the primary form of sanitation infrastructure used daily by approximately 3.4 billion people living in rural communities around the world and are being installed in record numbers throughout Southeast Asia (Strande, 2014; World Bank, 2017; United Nations, 2016). Consisting of a slab where a human defecates and urinates, a pit where waste is stored on-site, and a connecting pipe, pit latrines typically serve individual households in rural developing communities (WEDC, 2014). While pit latrines are effective at containing and storing human waste for a finite period of time (Brouckaert et al., 2013; Todman et al., 2015), pits eventually fill, preventing further use until the pit can be emptied or an additional pit installed (Pickford and Shaw, 1997). However, available effective options when pits fill are typically expensive to rural latrine owners, leading them to choose other cheaper, less effective options that are dangerous to the person emptying the pit (the emptier), other community members, and the environment (Still & Foxon, 2012). These undesirable methods include emptying a pit using a bucket on a rope or opening the pit's lid during a flood, which empties the pit's contents into floodwaters (Hawkins, 1982; Thye et al., 2011). Problems associated with full pits also stem from a lack of considering sludge removal when designing and building latrine pits (Hawkins, 1982). Allowing pits to fill without safe and effective fecal sludge management (FSM), which includes the collection, transport, treatment, and disposal of fecal sludge, and associated technologies can have serious health and environmental consequences (Parkinson, 2008). Management of full pits is thus a critical component of sanitation systems that must be integrated with economic, technological, political, societal, and other systems to maintain access to improved sanitation services and continue to improve public health (Nguyen-Viet et al., 2009; Singh et al., 2017).

Despite an obvious and imminent need for safe and effective FSM in rural communities, studies of FSM have focused on technologies and economics, following the tried-and-failed methods of neoliberalist international development practices of past decades (Desai, 2011). A critical aspect of FSM - human behavior - has been largely under-studied (Jenkins et al., 2015). Of particularly importance in rural communities where latrine owners tend to manage their own fecal sludge, the behavior of latrine owners towards FSM is known to strongly affect sanitation systems, particularly demand, service adoption, and sustainability (Coffey et al., 2017); however, few studies have investigated human behavior in relation to FSM.

To fill these gaps, this study examines how a part of human behavior – intention – affects FSM by answering the question “How do rural latrine owners intend to manage their fecal sludge?”. Rural latrine owners in 7 provinces of Cambodia were surveyed between 2014 and 2017 to describe their FSM intentions, which describe how willing they are to perform certain behaviors related to FSM. Their responses were then analyzed using the Theory of Planned Behavior as a foundation. We then created a model to predict their intentions using individual, societal and physical characteristics gathered from the survey data. By analyzing these data and creating a model that can predict FSM intentions, we hope to provide a basic understanding of human behavior related to FSM that can be used to improve the design of pit latrines and FSM processes

and training that will reduce pathogen transmission, allow for continuous latrine use, improve public health in developing countries, and help to meet the latest global development goals via sustainable sanitation systems (United Nations, 2017)

LITERATURE REVIEW

Human behavior has been studied extensively for decades and is motivated by various contextual factors that can be used to predict behavior. FSM and the context in which it is applied is affected directly by human behavior, particularly in rural contexts where latrine owners tend to manage their own fecal sludge. Thus, human behavior and FSM interact to produce complex outcomes that must be investigated and better understood to improve FSM in rural contexts.

MODELLING BEHAVIOR

How humans decide to perform a behavior, which is defined as a person's observable response in a given situation, has been the subject of many studies. These have resulted in many models of behavior that describe how humans choose to perform a given behavior (Fishbein & Ajzen, 1975; Heimlich and Ardoin, 2008; Darnton, 2008); these models include the Theory of Planned Behavior (Ajzen, 1985, 1991, 2002; Fishbein & Ajzen, 1975, 2010), the Theory of Interpersonal Behavior (Triandis, 1977, 2000), Rational Choice Theory (Becker, 1976), the Needs Opportunities Abilities model (Gatersleben & Vlek, 1998), and the Information-Deficit Model (Dickson, 2005). Darnton provides a good summary of these and other behavior models (2008).

Most behavior models generally agree that behavior is the result of an individual's psychological processing of various factors called behavioral determinants (Mosler, 2012). Of the available models, the Theory of Planned Behavior (TPB), which has strong roots in psychological and behavioral theory, has become accepted by various disciplines and successfully used to model behavior in different contexts, including developing communities (Ajzen, 2011; Mosler, 2012). It has also been used to create the well-respected Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) behavior change framework (Mosler, 2012). These aspects of the TPB make it ideal for use in this study.

According to Ajzen (1985), the Theory of Planned Behavior describes how a person evaluates and decides to perform a given behavior. When considering a behavior, various individual, societal, and physical factors influence a person's beliefs about the behavior. Individual factors include intelligence, emotions, age, gender, income, and religion; societal factors include social norms, culture, economy, and political context; and physical factors include geography, weather, and the environment. The beliefs produced based on these factors are defined as the subjective probabilities that a behavior will produce a certain outcome. Three types of beliefs are described in the TPB: 1) behavioral beliefs, which consider the likely outcomes of the behavior and the evaluations of these outcomes; 2) normative beliefs, which consider the expectations of other people and motivations to comply with these expectations; and 3) control beliefs, which consider the presence of factors that may facilitate or impede the performance of the behavior and the perceived power of these factors. Each of these types of beliefs yield different psychological constructs. Behavioral beliefs form a person's attitude toward the behavior, where attitude is defined as a positive or negative feeling about a behavior or the potential outcomes of performing a behavior.

Normative beliefs form a subjective norm, which is defined as a person's perception of a behavior that is influenced by the judgment of others. Control beliefs form perceived control, which is defined as an individual's perceived ease or difficulty of performing a behavior. When combined, these three psychological constructs - attitude, subjective norm, and perceived behavioral control - are used to form a person's intention, which is defined as the subjective probability that a person will perform a behavior: a more favorable attitude and subjective norm, and greater perceived control produce stronger intentions (Fishbein & Ajzen 1975).

Intentions thus are the motivational factors that influence a behavior and indicate how hard a person is willing to try to perform the behavior (Ajzen, 1991, 2002; Sheppard et al., 1988; World Bank, 2010). The final step - the performance of the behavior - is determined by a combination of intention and actual control, which is defined as having the required opportunities and resources to perform a behavior (Fishbein & Ajzen, 2010; Ajzen, 1985, 1991, 2002, 2006). Actual control also influences perceived control directly by affecting an individual's perception of the easy or difficulty of performing a behavior. A schematic of the TPB is shown in Figure 1 below.

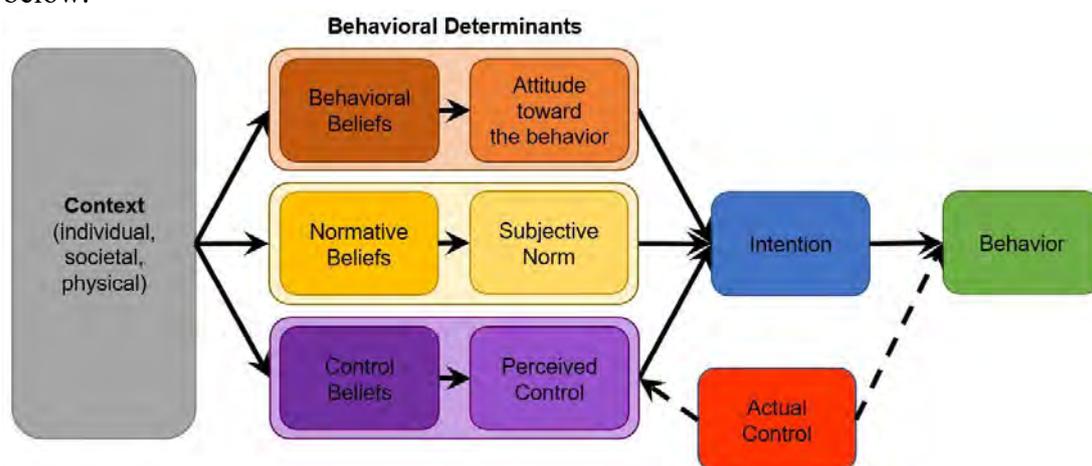


Figure 1: Schematic of the Theory of Planned Behavior (adapted from Ajzen, 2006)

The goal of the TPB is to predict intention and behavior based on behavioral determinants, which are influenced by contextual factors (Ajzen, 2006; see Figure 1). Various studies have shown the TPB to be successful at accomplishing this goal, particularly in infrastructure development in developing communities (Johnston et al., 2014; Lilje et al., 2015; Tumwebaze & Mosler, 2014; Bluemling et al., 2010), behavioral science (van der Linden, 2011; Grieve & Elliott, 2013), environmental psychology (Koger & Winter, 2010; Stern, 2005), and health and nutrition (Albarracin et al., 2001; Sheeran & Taylor, 1999; Ajzen & Driver, 1992; Nguyen et al., 1997; Conner et al., 2003; Ajzen, 1989; Chase et al., 2003). The TPB's foundation in behavioral theory and general acceptance led to its selection as the foundation of this study.

FECAL SLUDGE MANAGEMENT

Fecal sludge management refers to the collection, transport, and treatment of human fecal waste and contaminated water from on-site sanitation systems, which are primarily pit latrines in rural contexts (Strande & Brdjanovic, 2014). Pour-flush

latrines are most common in rural Cambodia, are typically installed one per household, and consist of a slab where people defecate and urinate, a pit where waste is stored, and a connecting pipe (iDE, 2017). While many studies have investigated the transport and treatment of fecal sludge, this study focuses on the collection of fecal sludge (i.e., the emptying of latrine pits).

Many methods for emptying exist. Vacuum trucks operated by professional FSM service providers remove large amounts of fecal sludge efficiently. These large trucks are commonly used in urban contexts but are rarely used in rural contexts due to their high capital costs; the long distances between pits and disposal sites; poor road conditions, particularly during rainy seasons; a lack of roads; and the smaller pit volumes common in rural areas (Pickford & Shaw, 1997; Muller & Rijnsburger, 1994; iDE, 2017; Hawkins, 1982). Smaller vehicles like a motorcycle towing a trailer with a small electric pump and flexible piping, the UN-HABITAT Vacutug (Issaias, 2006), or purpose-built hand pumps (e.g., Gulper, Mapet, Jappy Bicycle Pump) are also available but still require significant capital investment (Still & Foxon, 2012; iDE, 2011). Manual emptying is the simplest, cheapest, and vastly most common method used to empty full pits and involves an emptier using hand tools to remove solid waste and a bucket on a rope to remove liquid waste (Thye et al., 2009; Jenkins et al., 2015). However, this method is also the most dangerous, carrying many negative health impacts and externalities (Jenkins et al., 2015).

Strong barriers including high capital and ongoing costs, and strong social stigma surrounding FSM service provision limit the number of FSM service providers, particularly in rural areas (Thye et al., 2011; iDE, 2011). This lack of professional FSM service provision keeps prices for professional pit emptying relatively high (\$10-\$20 approximately every 5 years; iDE, 2017; USAID & PSI, 2017) and encourages rural latrine owners to manage their own fecal sludge. Understanding the intentions and behaviors of rural latrine owners towards FSM is thus critical to creating safe and effective FSM solutions.

In addition to emptying a pit, building an additional pit can allow for continuous latrine use and allow for safe emptying (Hussain et al., 2017; iDE, 2017). Switching to an additional pit when a pit fills allows the fecal sludge within the original pit to rest for the duration of time it takes to fill up the additional pit, allowing anaerobic processes to reduce pathogen loads within the fecal sludge in the original pit (Tilley et al., 2014). The original pit is then emptied using hand tools by the latrine owner with relatively little risk to health. The latrine is then reconnected to the original pit, the additional pit is left undisturbed, and the process repeats (Brikké & Bredero, 2003). This process markedly decreases the danger to the emptier, neighbors and environment, and allows for fecal sludge to be used as an agricultural amendment (Brikké & Bredero, 2003; iDE, 2017). However, the cost of building a new pit (\$35) is markedly more expensive than paying for professional emptying, and the use of human fecal sludge as an agricultural amendment varies by culture (USAID & PSI, 2017; Buit, 2013). Understanding latrine owners' intentions and behavior towards FSM is again needed.

BEHAVIOR AND FSM

Knowledge and attitude, which are factors that affect intention, as well as behavior have been shown to strongly affect FSM in developing communities (Jenkins & Scott, 2007; iDE, 2017). For example, many latrine owners believe that emptying

will never be required, and most delay emptying until absolutely necessary (iDE, 2017; Jenkins & Scott, 2007). Latrine owners also continue to use latrines with full pits, face high emptying costs even for unhygienic or incomplete emptying, and resort to dangerous behaviors like self-empty or flood release to manage their fecal sludge (Jenkins & Scott, 2007). Demographics (e.g., income, education, marital status) and making household improvements (e.g., building better walls) have been associated with adoption of sanitation infrastructure (Coffey et al., 2017). These and other contextual factors likely influence FSM intentions and must be understood to describe the interactions of human behavior with FSM.

Considering FSM through the lens of the TPB will allow for a better understanding of how latrine owners make decisions regarding their sanitation infrastructure and describes the ability of the TPB to model human behavior in the rural context. The contextual factors that are analyzed to achieve these goals include geographic characteristics (e.g., province, district, commune, village, whether the latrine owner lives near a river or pond), time (e.g., date when the latrine owner was surveyed), past and current behaviors (e.g., whether the latrine owner practiced open defecation before constructing their own latrine, frequency of latrine use), current communal behaviors (e.g., frequency of open defecation in the village of the latrine owner), economic characteristics (e.g., IDPoor status of the latrine owner; job types, requirements, and seasonality), challenges experienced with their latrine (e.g., flooding, lack of water to flush), levels of satisfaction with their latrine and its supplier, including whether the latrine owner has recommended constructing a latrine to a friend; and geophysical characteristics (e.g., rainfall). These and similar contextual factors have been investigated as predictors of intentions and behaviors in other studies (Jung, 2016; Tumwebaze & Mosler, 2014; Lilje & Mosler, 2016; Dreibelbis et al., 2013; Gamma et al., 2017). Each of these contextual factors describes a part of a latrine owner's life that affect their intentions when deciding how to manage their fecal sludge and can be used to predict their FSM intentions, as described by the TPB.

RESEARCH METHODOLOGY

Using questionnaires administered to rural households in 7 provinces of Cambodia between 2014 and 2017, this study uses frequency analysis and metrics of association to investigate the intentions of rural latrine owners toward FSM and answers the question “How do rural latrine owners intend to manage their fecal sludge?”. A model based on the TPB is then created to predict the desirability of FSM intentions based on contextual factors measured in the questionnaire. Past field studies of sanitation infrastructure provide structure for positing explanations to the results found in this study and the opportunity to comment on how the TPB applies to FSM intentions.

RESEARCH CONTEXT AND DATA COLLECTION

Cambodia is a developing country of approximately 16 million people with approximately 80% (12.5 million people) living in rural areas (Asian Development Bank, 2014). Cambodia's economy is largely agricultural with 60% of its GDP based on rice cultivation, which primarily occurs in provinces bordering Tonle Sap Lake and River, and the Mekong River (see Appendix Figure A1; FAO, 2014; World Bank, 2016).

With approximately 14% of its population below the national poverty line, Cambodia's national government maintains a database within its Identification of Poor Households (IDPoor) Programme that identifies poor households throughout Cambodia (Asian Development Bank, 2017; Ministry of Planning, 2018). This database is available to governmental and non-governmental organizations to help target services and assistance to poor households with the goal of reducing poverty and supporting socioeconomic development (Ministry of Planning, 2018). As a result, government incentives and sanitation marketing campaigns by various development organizations, such as iDE Cambodia, have increased latrine coverage, which is defined as the percentage of households in a given region with latrines, in rural areas by 6.4% per year since 2012, reaching 40% in 2014 (iDE, 2017). While latrine coverage varies by region, pits are forecasted to begin filling soon; thus, a strong push to understand FSM is currently underway in Cambodia and around the world (Ministry of Rural Development, 2017; Chakraborty et al., 2014; iDE, 2017). Cambodia was selected for this study because of this strong recent push toward improved sanitation infrastructure throughout the country and the many development organizations, including iDE, that are imbedded within it working on FSM.

Since 2010, the international development organization iDE has studied how latrine owners in rural Cambodia perceive and interact with sanitation systems (iDE, 2017). With the goal of improving its sanitation marketing efforts, iDE Cambodia developed a survey in 2014 to describe the experiences, intentions and behaviors of latrine owners regarding the construction, use, maintenance, and improvement of their household's latrine. Questions specifically asked about their current and past defecation behaviors; intentions when their pit fills; household demographics and locations; latrine construction details and costs; and satisfaction with their latrine and latrine supplier (iDE, 2014). The target population of this survey includes all rural households in Cambodia; for this study, the sampling frame is limited to the rural households served by iDE in 7 provinces (Oddar Meanchey, Banteay Meanchey, Siem Reap, Kampong Thom, Kandal, Prey Veng, and Svay Rieng) that primarily lie along Tonle Sap Lake and River, and the Mekong River (see Figure 2; World Bank, 2016; USDA, 2010). This 67-question, face-to-face survey was given to 3720 rural latrine owners who had purchased their latrine within 6 to 12 months before the survey and were randomly selected from iDE's latrine sales database. This study analyzes the responses to this survey.

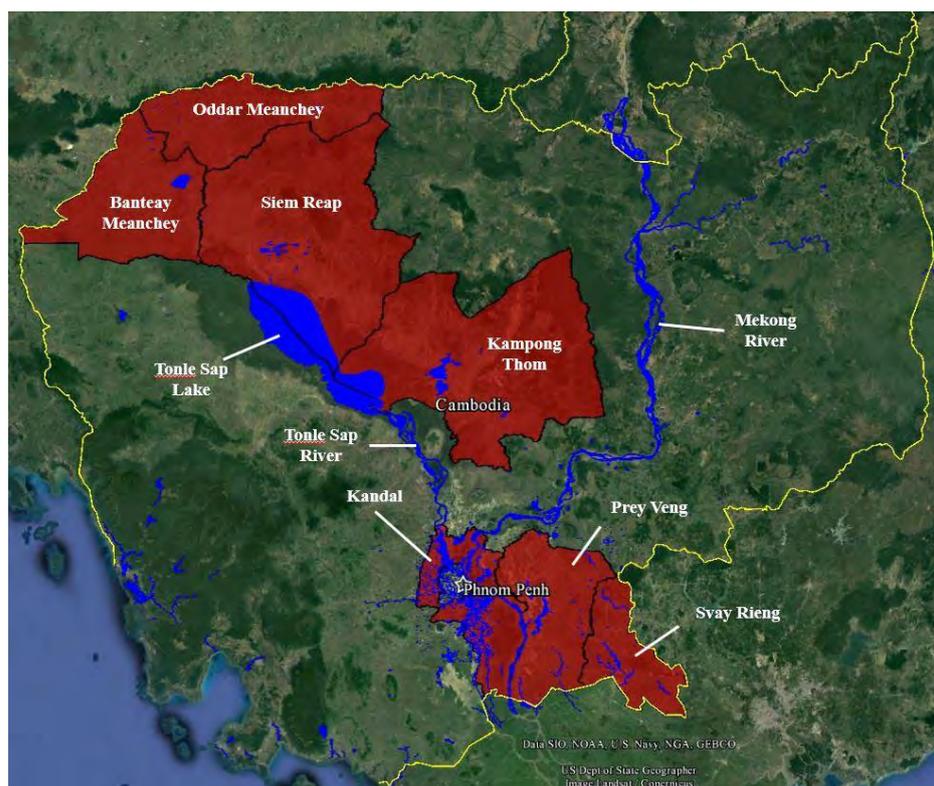


Figure 2: Map of Cambodia including provinces where surveys were administered for this study and major bodies of water (Google Earth Pro, 2018; Humanitarian Data Exchange, 2018; OpenDevelopment Cambodia, 2018).

Although the survey was developed before partnering with the authors of this article, iDE intended to describe the FSM intentions and various individual, societal, and physical contextual factors of latrine owners in rural Cambodia. These data fit well within the TPB behavior model and can thus be analyzed using the TPB as a foundation. Improved survey items targeted at understanding FSM intentions and behaviors and at capturing more relevant contextual factors are planned for future work.

Surveys were administered by trained iDE research assistants that speak native Khmer and that live in the provinces where the surveys were administered. All surveys were given face-to-face to rural latrine owners and recorded using Salesforce software. The requested gender of the respondent was alternated for each survey to mitigate the effects of gender roles. If a respondent was not available when the household was visited, arrangements were made to return to that household. If a household refused to be interviewed, another household was randomly selected from the same region. The data integrity and completeness of each survey were verified by the interviewer and then by the Monitoring and Evaluation Manager of iDE Cambodia.

All data analysis methods were approved by the Institutional Review Board at the University of Colorado Boulder.

DATA ANALYSIS

We focused on a question in the survey that measured the FSM intentions of rural latrine owners: “When your pit is getting full, what do you intend to do?”. The responses to this question were characterized by frequency and analyzed for

associations with responses to other questions on the survey that asked about various individual, societal, and physical contextual factors, as described above. These analyses were chosen due to their ability to produce the results of interest and their relative ease of understanding; more complex analyses are planned for future work. Many questions in the survey allowed for multiple responses (e.g., checkbox items); these multiple-answer responses were recoded into binary responses for each response. All data analysis scripts were written in the R programming language.

The statistical significance of an association was determined using the chi-squared test with a significance value p of less than 0.05. A statistical trend was identified using a significance value between 0.10 and 0.05. All statistical significance values are shown with measures of statistical importance (i.e., its strength or effect size) in the form of either Cramer's v or a point-biserial correlation. Cramer's v varies between 0 (no association) and 1 (perfect association), and a point-biserial correlation varies between -1 (perfect negative association) and 1 (perfect positive association) with 0 indicating no association.

A binomial logistic regression model was then created to predict the desirability of FSM intentions of rural latrine owners in Cambodia. The inputs to the model were contextual factors that were measured in the survey or gathered from external sources, and that showed statistical significance and importance in their associations with the desirability of FSM intentions, as described below. The statistical significance of each factor in the model was calculated using an ANOVA test that compared the full model to the reduced model, which only contains the intercept of the full model.

A training dataset was first constructed using a random sample of 95% of the available data describing the selected factors; the remaining 5% of the data was used to construct a testing dataset. A model was then created using the training dataset and tested for accuracy in predicting the desirability of FSM intentions using the testing dataset. This process was iterated 1000 times, and the resulting accuracies were averaged to determine the predictive ability of the model. Nagelkerke's pseudo- R^2 is reported to describe model quality.

To generalize results and improve statistical importance, FSM intentions were categorized as either desirable or undesirable. Desirable FSM intentions are held by latrine owners that intend to safely (e.g., using personal protective equipment, fully contain fecal sludge) and effectively (e.g., allow continued latrine use, completely empty a pit) manage their fecal sludge. While safe emptying is rare throughout Cambodia, even when performed by professional FSM service suppliers, this study identifies desirable FSM intentions as providing the *opportunity* for safe emptying by considering that without intentions to perform desirable FSM behaviors, undesirable FSM behaviors will likely be chosen (iDE, 2017). Desirable FSM intentions include installing a new pit or paying a professional to empty a pit (i.e., professional emptying). Undesirable FSM intentions do not meet the criteria of desirable FSM intentions and include a latrine owner emptying their own pit (i.e., self-empty), stopping use of their latrine when their pit fills, being undecided, or having other intentions.

RESULTS AND DISCUSSION

CONTEXTUAL FACTORS

The 3720 survey responses analyzed in this study described various individual, societal, and physical characteristics of rural latrine owners. Survey respondents were

56% female, and 23% were IDPoor. Few frequently used a neighbor's toilet before purchasing their own (12%). Most reported practicing open defecation themselves before purchasing their own latrine (79%), and nearly all reported open defecation occurring in their community (95%). Some respondents lived near a river or pond (12% and 8%, respectively). Nearly all adults and most children used their household's latrine frequently (97% and 82%, respectively); however, few respondents that had infants reported dumping their infants' feces into their latrines frequently (18%). Most reported no problems with their latrine (88%), while few reported latrines that did not flush and pits that smelled (6% and 2%, respectively). Very few respondents reported problems with flooding, a lack of water for flushing, or full or overflowing pits (0.6%, 0.6%, and 0.4%, respectively). Intentions to install or improve different latrine structures within the three years following the survey ranged widely: shelter (85%), water reservoir for flush water (41%), shower (37%), and sink (11%). Approximately half reported recommending their latrine to others (45%), and some recommended their latrine supplier to others (27%). Most reported being satisfied with their latrine (81%), and most reported being satisfied with their latrine supplier (88%).

The frequencies at which the survey was administered varied by year, month, and province based on the number of latrine sales within the given time and location. Half of the surveys were performed in 2017 (55%), a third were performed in 2016 (33%), 12% were performed in 2015, and few (5, <1%) were performed in 2014. More than half of the surveys were administered between August and December (60%). Lastly, the number of surveys given in each province ranged widely: Kandal (1002), Prey Veng (720), Svay Rieng (478), Banteay Meanchey (461), Siem Reap (450), Kampong Thom (422), and Oddar Meanchey (187).

FSM INTENTIONS

From the question “When your pit is getting full, what do you intend to do?”, 59% of rural latrine owners reported desirable FSM intentions (see Table 1). Intending to pay for professional emptying was most common (35%), followed by intending to install a new pit (24%) and self-empty (21%). Being undecided was reported by 16% of latrine owners (see Table 1).

Table 1: Frequencies of FSM intentions with desirability reported by households in rural Cambodia between 2014 and 2017 ($n = 3720$)

FSM intention	Desirability (% of all responses n)	# latrine owners with intention (% of all responses n)
Pay for professional emptying	Desirable (59%)	1301 (35%)
Install a new pit		883 (24%)
Self-empty	Undesirable (41%)	781 (21%)
Stop using latrine		77 (2%)
Other		65 (2%)
Undecided		613 (16%)

Most rural latrine owners thus intend to manage their fecal sludge safely and effectively. However, the large amount of rural latrine owners with undesirable FSM intentions (41%) highlights the impending risk to public health due to poor FSM.

Each of these FSM intentions likely vary based on contextual factors, as described by the TPB. Associations between FSM intentions and various individual, societal, and physical contextual factors were thus investigated to describe these variations and develop a model that predicts the desirability of FSM intentions based on readily-measured contextual factors. An overview of the results of these associations are shown below, followed by an in-depth analysis of selected contextual factors.

Associations with Contextual Factors

Various individual, societal, and physical contextual factors were measured in the surveys, providing a theoretical basis to understand the motivations of the FSM intentions of rural latrine owners in Cambodia. These factors include where the latrine owner lives (i.e., province, district, commune, and village, which are administrative regions of decreasing size); the IDPoor status of the latrine owner; the date when the latrine owner was surveyed; whether the latrine owner lives near a river or pond; the past defecation behavior of the latrine owner before constructing their own latrine; the frequency of open defecation in the village of the latrine owner; how often adults and children defecate in the latrine; how often infant feces is deposited into the latrine; what types of challenges the latrine owner has experienced with their latrine (e.g., unable to flush, no water available to flush, flooding); the latrine owner's satisfaction with their latrine and its supplier; and whether the latrine owner has recommended getting a latrine to a friend or recommended their latrine's supplier to a friend. Additionally, monthly average rainfall data was gathered from Thoeun (2015) and compared to the FSM intentions reported in the surveys.

Each of these factors was evaluated for association with the desirability of FSM intentions, the results of which are shown below in Table 2. Most categorical factors allowed for other responses to be reported by latrine owners; however, these responses have been removed from this analysis for clarity.

Table 2: Associations between the desirability of FSM intentions and various contextual factors reported by rural Cambodian latrine owners between 2014 and 2017 ($n = 3720$)

Factor	Data Type	Number of Categories	Association with Desirability of FSM Intentions	
			Significance ¹	Importance ²
Date when survey occurred				
- Year	Categorical	3	0.000	0.10*
- Month	Categorical	12	0.000	0.12*
Location where latrine owner lives				
- Province	Categorical	7	0.000	0.28*
- District	Categorical	66	0.000	0.39*
- Commune	Categorical	484	-	-
- Village	Categorical	1604	-	-
- Near a river or pond	Categorical	3	0.66	0.02
IDPoor status	Binary	2	0.003	0.05*
Defecation behavior before constructing latrine				
- Defecated in bushes or fields	Binary	2	0.000	0.08*
- Defecated in a river or pond	Binary	2	0.25	0.02
- Defecated in neighbor's latrine	Binary	2	0.004	0.05
- Frequency of using neighbor's latrine	Ordinal	3	0.000	0.07*
Latrine usage (frequency of)				
- Adults	Categorical	4	0.11	0.04
- Children	Categorical	5	0.32	0.04
- Infant feces deposited in latrine	Categorical	5	0.02	0.06*
Challenges with latrine				
- Flooding	Binary	2	0.02	0.04*
- Lack of water to flush	Binary	2	0.05	0.03*
- Does not flush	Binary	2	0.65	0.01
- Pit full or overflowing	Binary	2	0.68	0.01
- Smells	Binary	2	0.57	0.01
- None	Binary	2	0.19	0.02
Satisfaction with latrine	Ordinal	5	0.000	0.13*
Satisfaction with latrine supplier	Ordinal	5	0.000	0.12*
Recommended latrine to a friend	Binary	2	0.01	0.05*
Recommended supplier to a friend	Binary	2	0.000	0.09*
Open defecation in village (frequency of)	Ordinal	3	0.13	0.03
Rainfall (monthly average)	Continuous	-	0.03	-0.04*
1: p -value; * Statistically significant				
2: Cramer's v for binary or categorical factors; point-biserial correlation, r_{pb} , for continuous factors				
- Could not compute due to low frequencies of FSM intentions in each category of factor, or not applicable				

Selected factors showing statistically significant and important associations with FSM intentions are discussed individually in the subsections below. The factors describing the district where the latrine owner lives; the latrine owner's challenges with their latrine; latrine usage; defecation behavior before constructing a latrine; the latrine owner's satisfaction with their latrine and its supplier; and whether the latrine owner has recommended purchasing a latrine to a friend or recommended their latrine's supplier to a friend are discussed in the following section in reference to the model.

Year

FSM intentions were found to vary significantly based on the year of data collection, as shown in Table 3. Note that only five responses were reported in 2014 and were removed from this portion of the analysis for clarity.

The frequency of intending to pay for professional emptying remained relatively constant (30% to 38%) between 2015 and 2017, while the frequency of intending to install a new pit doubled (13% to 26%), and that to self-empty halved (33% to 16%). The frequency of undecided latrine owners fluctuated between 11% and 19% over the surveyed timeframe, while intending to stop using a latrine or having other intentions remained low (2% to 4% and 1 to 2%, respectively).

Table 3: Frequencies of rural Cambodian latrine owners reporting FSM intentions between 2015 and 2017 aggregated by year with totals and desirability ($n = 3715$, $p = 0.000$, $v = 0.14$)

FSM intention	Desirability	# latrine owners with intention (% of all responses n)				Significance ¹	Importance ²
		2015 ($n = 619$, 17%)	2016 ($n = 1195$, 32%)	2017 ($n = 1901$, 51%)	Total		
Pay for professional emptying	Desirable	234 (38%)	356 (30%)	708 (37%)	1298 (35%)	0.000	0.08*
Install a new pit		80 (13%)	314 (26%)	489 (26%)	883 (24%)	0.000	0.12*
Empty it myself	Undesirable	206 (33%)	259 (22%)	315 (17%)	780 (21%)	0.000	0.14*
Stop using my latrine		23 (4%)	23 (2%)	31 (2%)	77 (2%)	0.009	0.05*
Other		7 (1%)	21 (2%)	37 (2%)	65 (2%)	0.40	0.02
Undecided		69 (11%)	222 (19%)	321 (17%)	612 (16%)	0.000	0.07*
1: p -value; 2: Cramer's v for binary or categorical factors; * Statistically significant - Could not compute due to low frequencies of FSM intentions							

The observed switch in intentions from self-empty in 2015 to installing a new pit in 2017 was likely caused by latrine owners becoming increasingly familiar with installing a new pit as an FSM solution. This relatively new FSM solution has become more common in recent years in Cambodia (iDE, 2017). There is also likely an associated increase in aspiration to own a new pit that is concurrently spreading through the provinces (iDE, 2017). However, the reasons behind these changes in FSM intentions over time must be verified with additional data.

Another interesting result is the relatively large frequencies of undecided latrine owners. These results imply two possible causes: many rural latrine owners have not considered what they will do when their pits fill, or many rural latrine owners are having trouble deciding between FSM solutions that may be too expensive, ineffective, dangerous or unavailable due to a lack of FSM service provision. Both of these

possible causes have been observed in other studies and are discussed above. Additional research will be required to determine the causes of these variations in FSM intentions by year.

Month

FSM intentions were also found to vary significantly by month during the final year of surveying (October 2016 to September 2017; Figure 3). This timeframe was selected due to the large number of surveys administered, the continuity of surveying, and the distribution across provinces. The desirability of FSM intentions peaked in April (73%) and September (72%), dipped to 50% in November, and exhibited an average of 62% with a standard deviation of 7% across all months. Intending to pay for professional emptying peaked in April (49%) and was most frequent throughout the survey timeframe except in November, when it dipped to 22%, and in September, when it matched intending to install a new pit (36%, its highest value). Intending to self-empty varied between 14% and 22% throughout most of the year but peaked in November (30%). Having other intentions and stopping use of a latrine remained infrequent across all months.

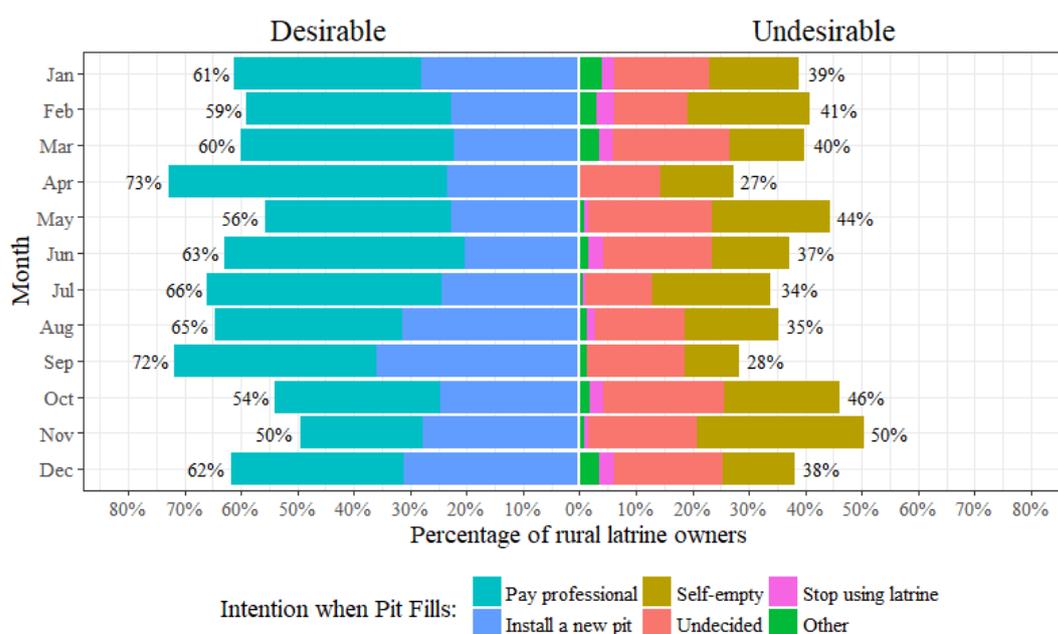


Figure 3: Percentages of rural Cambodian latrine owners reporting FSM intentions aggregated by month and desirability between October 2016 and September 2017 ($n = 2524$, $p = 0.000$, $v = 0.11$)

These monthly variations show interesting associations with seasonal agricultural processes that occur in these provinces of Cambodia. As noted above, rice cultivation constitutes a large portion of the economies in the provinces surveyed in this study. For the primary rice crop, rice is sowed in July through August, growing in September through November, and harvested in December through February (FAO, 2018). If a secondary crop is planted, it is sowed in November through December, growing in January and February, and harvested in March and April (FAO, 2018). Because November is when the primary crop is growing, and the secondary crop is

being sowed, farmers likely earn little income and experience high work demands during this month. Farmers are thus likely busiest and least financially solvent in the month of November. This coincidence may explain the reduction in intentions to pay for professional emptying, the increase in intentions to self-empty, and the lowest frequency of desirable FSM intentions observed during this month. Additionally, harvest brings income and food security, and likely makes rural latrine owners more willing to pay for professional emptying towards the end of harvest (Maskey & Singh, 2017); this mirrors the increase in the desirability of FSM intentions, particularly paying for professional empty, shown in April. The crop calendar of rice can thus explain some of the observed variations in FSM intentions by month.

Additionally, seasonal rainfall patterns in Cambodia may help explain these monthly variations in FSM intentions. The month of September is generally one of the wettest months in Cambodia and lies near the end of the wet season (USDA, 2010). The large amount of rainfall in September and the preceding four months likely increases the level of sludge stored in pits, depending on soil permeability, flooding, and groundwater depth, and may even cause pits to overflow (Strande & Brdjanovic, 2014; Brouckaert et al., 2013; iDE, 2017). With few FSM service providers available in rural Cambodia and this sudden change in sludge levels (iDE, 2017), rural latrine owners may mistakenly favor the increased sludge storage offered by a new pit, yielding the observed increase in intentions to install a new pit in September. However, additional research will be needed to verify this conjecture. Monthly average rainfall is also analyzed specifically below but shows few significant results.

Province

Significant strong variations in FSM intentions were found across provinces ($p = 0.000$, $\nu = 0.23$). The desirability of FSM intentions varied widely from 76% in Banteay Meanchey to 33% in Siem Reap. Intending to pay for professional emptying was very common in Banteay Meanchey (72%) and common in Kandal (48%) and Oddar Meanchey (47%) but uncommon in Svay Rieng (12%). Conversely, intending to install a new pit was more frequently reported in Svay Rieng (44%) than in Banteay Meanchey (5%) and other provinces. Latrine owners living in Siem Reap also reported being undecided (32%) or intending to self-empty (34%) more than those living in any other province.

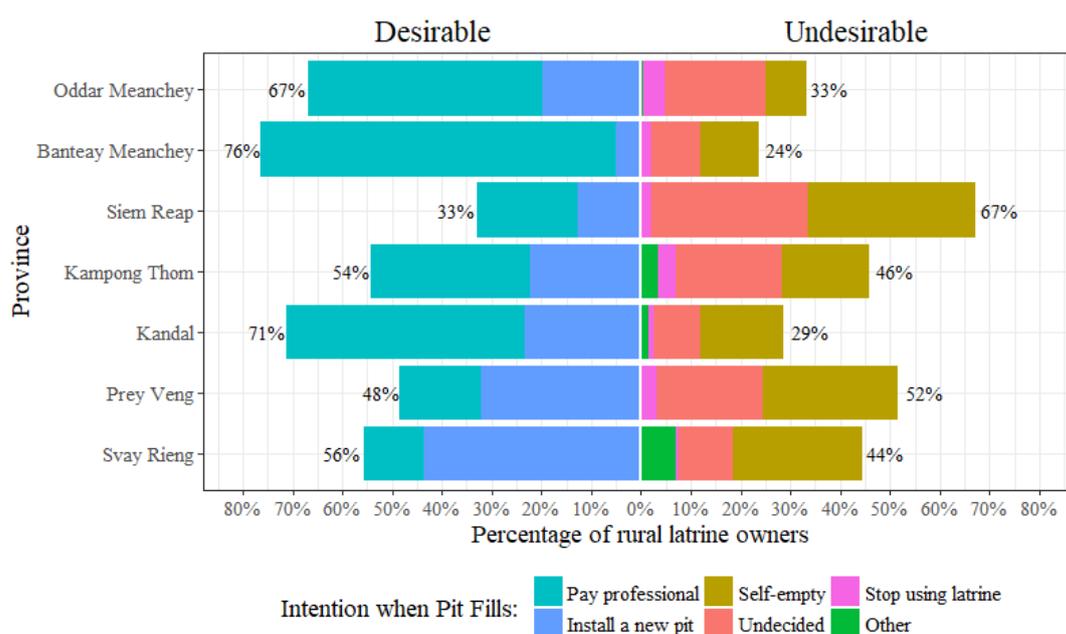


Figure 4: Percentages of rural Cambodian latrine owners reporting FSM intentions aggregated by province and desirability between 2015 and 2017. Provinces are arranged by geographical proximity, starting in the north of Cambodia. ($n = 3720$, $p = 0.000$, $v = 0.23$)

Despite bordering each other geographically (see Figure 1), Banteay Meanchey and Siem Reap share few characteristics. Banteay Meanchey is considered one of the wealthier provinces in Cambodia with a strong international trade economy due to the O'Neang Special Economic Zone via the checkpoints of Poipet and Stueng Bot along the Thailand border (CCI, 2018; National Institute of Statistics, 2012). Conversely and despite its strong tourism economy, which includes the UNESCO World Heritage site Angkor Wat, Siem Reap is considered one of the poorest provinces with a dismal business environment (Asia Foundation, 2007). Thus, because the most desirable FSM intentions were reported in Banteay Meanchey, while the least were reported in Siem Reap, it may follow that a strong economy, higher incomes or more job opportunities or security may yield more desirable FSM intentions among rural latrine owners. Kandal (71% desirable) and Prey Veng (48% desirable) also fit this association: Kandal is a wealthier province that surrounds the commercial hub of Cambodia, Phnom Penh, while Prey Veng has a high poverty index and net negative migration due to poor job opportunities (National Institute of Statistics, 2012; ADB, 2014). However, this association is not supported by the results shown in Oddar Meanchey (67% desirable), a particularly poor province.

The observed variations in FSM intentions by province thus cannot be explained by currently available data, which include the survey responses analyzed in this study, differences in provincial economies (e.g., incomes, crop calendars; FAO, 2018; National Institute of Statistics, 2012), latrine coverage rates (iDE, 2016), and iDE marketing efforts in these provinces (iDE, 2018). Other contextual factors that are currently unknown, such as the availabilities and cost of professional pit emptying and pit installation services, provincial regulations, and work performed by other development organizations in sanitation, will need to be gathered to explain these

variations. This research is currently being performed in Svay Rieng by iDE and will help describe many of these other contextual factors related to FSM intentions; results from this survey will be available later this year.

Rainfall

Rainfall directly affects agricultural production, influencing the incomes of farmers, and rapidly changes sludge levels in pits (Olayide, 2016; Strande & Brdjanovic, 2014). Thus, the association between the desirability of FSM intentions and rainfall was investigated in this study. However, calculations show that average monthly rainfall only trended very weakly with the desirability of FSM intentions across all provinces ($p = 0.06$, $r_{pb} = -0.04$). This likely shows that unless a pit overflows, which was reported rarely, latrine owners do not notice the change in their pit's sludge levels due to rainfall and thus do not change their FSM intentions accordingly.

The association between the desirability of FSM intentions and monthly average rainfall was also analyzed by province (see Table 4). Few results were statistically significant; however, rainfall in Prey Veng did show a significant weak negative association with the desirability of FSM intentions ($p = 0.001$, $r_{pb} = -0.12$), while rainfall in Kampong Thom showed a significant weak positive association ($p = 0.05$, $r_{pb} = 0.10$).

Table 4: Statistical significance and importance of association between the desirability of FSM intentions of rural Cambodian latrine owners and average monthly rainfall by province between 2014 and 2017

Province	Number of Responses (n)	Association between Desirability of FSM Intentions and Monthly Average Rainfall	
		Significance ¹	Importance ²
Oddar Meanchey	187	0.21	0.09
Banteay Meanchey	461	0.22	-0.06
Siem Reap	450	0.39	-0.04
Kampong Thom	422	0.05	0.10*
Kandal	1002	0.98	-0.00
Prey Veng	720	0.001	-0.12*
Svay Rieng	478	0.19	-0.06

1: p-value; 2: point-biserial correlation, r_{pb} ; * Statistically significant

It is unclear why two provinces showed significant results, and others did not. One possible explanation for Kampong Thom's positive association between rainfall and the desirability of FSM intentions may be its economy. Kampong Thom is a large producer of fish grown via small-scale aquaculture, while the other provinces examined in this study are not (USAID, 2008; Ministry of Agriculture, Forestry and Fisheries 2004; Hori et al., 2006). It is conceivable that more rainfall increases water levels in aquaculture ponds, allowing more fish to be produced, incomes to be higher, and more desirable FSM intentions via increased willingness to pay for desirable FSM services. Additional research will be needed to explain these results.

IDPoor Status

FSM intentions were only found to trend very weakly with IDPoor status ($p = 0.06$, $v = 0.05$): the IDPoor intended to self-empty (23%) more than the non-IDPoor (20%), while the non-IDPoor intended to install a new pit (25%) more than the IDPoor (21%, $p = 0.06$). This trend may be explained by the high cost of a new pit compared to self-empty. IDPoor households generally have fewer assets, lower incomes and food security, and fewer income-producing members (Ministry of Planning 2012); this reduces their expendable income and increases their loss aversion compared to non-IDPoor households, likely making them favor cheaper FSM solutions like self-empty (Yesuf & Bluffstone, 2009; Polak, 2009). However, the IDPoor system classifies households based on multiple factors, including non-liquid assets, such as housing value and number of livestock (Ministry of Planning, 2012). Willingness to pay for FSM services is likely linked to income (i.e., a liquid asset) more than to non-liquid assets (Baumgärtner et al., 2017; Aiew, 2004). Additional data about the income of rural latrine owners' households would be needed to verify this association and improve this analysis.

MODELLING FSM INTENTIONS

Using factors that showed statistically significant and important associations with the desirability of FSM intentions (see above), a binomial logistic regression model was created to predict the desirability of the FSM intentions of rural latrine owners in Cambodia. These individual, societal, and physical factors affect the formation of intentions and can be used to predict intentions according to the Theory of Planned Behavior.

The model was developed iteratively. First, the model's inputs included all factors that showed statistically significant and important associations with the desirability of FSM intentions. The model was run, and the results were examined. The factor that had a statistical significance above 0.05 and contributed the smallest reduction in residual deviance was then removed. This process was repeated until all factors included in the model were statistically significant. The factors that were removed during model development included the district where the latrine owner lived (model did not converge due to the small number of surveys taken within each district), the frequency that infants' feces was deposited in the household's latrine (low frequencies in important factor categories), whether the latrine owner recommended a latrine to a friend, whether the latrine owner reported a lack of water to flush their latrine, the monthly average rainfall, and the frequency that the latrine owner used a neighbor's latrine before constructing their own latrine (statistical significances above 0.05 and small reductions in residual deviance). The model was then run with the remaining nine factors, as shown in Equation 1.

The model developed in this study to predict the desirability of the FSM intentions of rural latrine owners in Cambodia is described by the following equation:

$$\text{logit} [P(\textit{desirable FSM intention})] = \alpha + \sum_{i=1}^9 \beta_i x_i \quad (1)$$

where $\text{logit} [\dots]$ describes the log of the odds of reporting a desirable FSM intention, $\log \left[\frac{P(\textit{desirable FSM intention})}{1 - P(\textit{desirable FSM intention})} \right]$; α is the intercept; and β_i are the slope coefficients associated with the factors x_i , which are the province in which the latrine owner lives

(*Province*), the satisfaction of the latrine owner with their latrine (*Satisfaction*), the month the latrine owner was surveyed (*Month*), whether the latrine owner has recommended their latrine’s supplier to a friend (*RecommendedSupplier*), the year the latrine owner was surveyed (*Year*), the satisfaction of the latrine owner with their latrine’s supplier (*SatisfactionSupplier*), whether the latrine owner practiced open defecation before constructing a latrine (*PastOpenDefecation*), whether the latrine owner reported flooding as a problem with their latrine (*Flooding*), and the IDPoor status of the latrine owner (*IDPoor*). Note that responses from 2014 ($n = 5$) in *Year* were omitted due to low frequencies. The resulting equation is:

$$\begin{aligned} \text{logit [P(desirable FSM intention)]} \\ = \alpha + \beta_1 \times \textit{Province} + \beta_2 \times \textit{Satisfaction} + \beta_3 \times \textit{Month} \\ + \beta_4 \times \textit{RecommendedSupplier} + \beta_5 \times \textit{Year} + \beta_6 \\ \times \textit{SatisfactionSupplier} + \beta_7 \times \textit{PastOpenDefecation} + \beta_8 \\ \times \textit{Flooding} + \beta_9 \times \textit{IDPoor} \end{aligned} \quad (2)$$

The model yields a residual deviance of 4224.0 with 3442 degrees of freedom compared to the reduced model’s residual deviance of 4703.9 with 3475 degrees of freedom. A total of 239 responses were deleted due to incomplete data. Various characteristics of each factor in the model, including degrees of freedom, difference in residual deviance, and statistical significance, are shown in Table 5 below; factors are arranged by decreasing deviance, which describes the statistical importance of each factor. Estimates of the coefficients, standard errors, z-values, and significances of all factors in the binomial logistic regression model are shown in Table 6, and confidence intervals are shown in the Appendix, Table A1.

Table 5: Regression parameters of factors in binomial logistic regression model

Factor	DOF ¹	Importance ²	Residual DOF ¹	Residual Deviance	Significance ³
Reduced model ⁴	-	-	3475	4703.9	-
<i>Province</i>	6	287.5	3469	4416.4	0.000*
<i>Satisfaction</i>	5	66.8	3464	4349.6	0.000*
<i>Month</i>	11	37.9	3453	4311.7	0.000*
<i>Recommended Supplier</i>	1	25.1	3452	4286.6	0.000*
<i>Year</i>	2	22.2	3450	4264.4	0.000*
<i>Satisfaction Supplier</i>	5	17.9	3445	4246.5	0.003*
<i>PastOpen Defecation</i>	1	9.3	3444	4237.2	0.002*
<i>Flooding</i>	1	7.3	3443	4229.9	0.007*
<i>IDPoor</i>	1	5.9	3442	4224.0	0.01*

1: Degrees of freedom; 2: Deviance; 3: *p*-value; 4: Includes only an intercept with no factors
* Statistically significant

All factors are shown to be statistically significant in the model, and many of the results described above are reproduced by the model. *September* and *December* in *Month* show significant effects on the desirability of FSM intentions, while *April* and *October* show trends that mirror the results above. Additionally, *Siem Reap* in *Province* shows the most negative effect on the prediction of the desirability of FSM intentions, *Prey Veng* shows the second most negative, and *Banteay Meanchey* (the reference category for this factor) shows the most positive (0); these results confirm the associations between FSM intentions and province discussed above. The factor *Year* also shows the same effects as observed above.

The satisfaction of the latrine owner with their latrine (*Satisfaction*) shows the second highest deviance, and its estimates show that any satisfaction score other than 1 (very unsatisfied) is a good predictor of desirable FSM intentions (Table 6). Additionally, these estimates show that higher satisfaction tend to yield more desirable FSM intentions. Conversely, satisfaction with the latrine's supplier (*Satisfaction Supplier*) is only significant with a score of 5 and has a markedly lower deviance.

Recommending the latrine's supplier to a friend (*RecommendedSupplier*) is nearly as important as the month the latrine owner was surveyed. Feeling strongly enough about the latrine's supplier to take the time and effort to recommend them to a friend is thus a good predictor of the desirability of FSM intentions.

As shown in Table 6, practicing open defecation before constructing a latrine (*PastOpenDefecation*), experiencing challenges with a latrine due to flooding (*Flooding*), and being IDPoor (*IDPoor*) are all good predictors of undesirable FSM intentions.

Table 6: Estimates, standard errors, z-values and significances of coefficients in the binomial logistic regression model

Factor	Category ¹	Estimate ²	Standard Error of Estimate	z-value	Significance ³
-	(Intercept)	-1.56	0.51	-3.053	0.002*
Province	<i>Kampong Thom</i>	-1.21	0.17	-7.298	0.000*
	<i>Kandal</i>	-0.47	0.14	-3.291	0.001*
	<i>Oddar Meanchey</i>	-0.71	0.21	-3.319	0.001*
	<i>Prey Veng</i>	-1.47	0.15	-9.952	0.000*
	<i>Siem Reap</i>	-2.03	0.17	-12.018	0.000*
	<i>Svay Rieng</i>	-1.01	0.16	-6.401	0.000*
Satisfaction	1	-0.53	1.26	-0.418	0.62
	2	1.54	0.57	2.693	0.007*
	3	1.51	0.52	2.893	0.004*
	4	1.83	0.51	3.561	0.000*
	5	2.06	0.52	3.939	0.000*
Month	<i>February</i>	0.09	0.22	0.392	0.70
	<i>March</i>	0.28	0.22	1.285	0.20
	<i>April</i>	0.59	0.31	1.867	0.06
	<i>May</i>	-0.13	0.20	-0.644	0.52
	<i>June</i>	0.14	0.21	0.660	0.51
	<i>July</i>	0.20	0.23	0.859	0.39
	<i>August</i>	0.28	0.19	1.430	0.15
	<i>September</i>	0.56	0.21	2.654	0.008*
	<i>October</i>	0.41	0.21	1.900	0.06
	<i>November</i>	0.15	0.23	0.679	0.50
	<i>December</i>	0.66	0.24	2.772	0.006*
<i>Recommended Supplier</i>	Yes	0.43	0.10	4.480	0.000*
Year	2016	0.37	0.14	2.592	0.01*
	2017	0.82	0.19	4.370	0.000*
Satisfaction Supplier	1	2.48	1.59	1.559	0.12
	2	0.54	0.39	1.376	0.17
	3	0.10	0.33	0.305	0.76
	4	0.43	0.32	1.348	0.18
	5	0.82	0.37	2.211	0.03*
<i>PastOpen Defecation</i>	Yes	-0.28	0.10	-2.944	0.003*
<i>Flooding</i>	Yes	-1.05	0.39	-2.718	0.007*
<i>IDPoor</i>	Yes	-0.22	0.09	-2.436	0.01*

1: A reference category was automatically selected for each factor by the function used to perform the binomial logistic regression. These reference categories are *Banteay Meanchey (Province)*, *Undecided (Satisfaction, SatisfactionSupplier)*, *January (Month)*, *No (RecommendedSupplier, PastOpenDefecation, Flooding, IDPoor)*, and *2015 (Year)*. For these categories, estimates equal 0, and associated statistics were not calculated. The estimates shown for the other categories indicate the relative effect of each category compared to these reference categories.

2: α for intercept and β for all other categories; 3: p-value; * Statistically significant

The predictive ability of this model was then tested using training and testing datasets, as described in the Methodology section. This model is able to predict the desirability of the FSM intentions of rural latrine owners in Cambodia with an accuracy of 67% (Nagelkerke's pseudo- $R^2 = 0.27$). The model's prediction accuracy and its quality are relatively poor: only two out of three predictions based on the input factors used in this study are accurate. Considering additional contextual factors would likely improve the model's accuracy and is discussed below.

Based on the results of the model, there is evidence to show that contextual factors can be used to predict the desirability of FSM intentions, as described by the Theory of Planned Behavior. However, the accuracy and model quality shown must be improved to yield useful results. Using readily-measured contextual factors to describe how latrine owners evaluate a complex decision like what to do when a latrine pit fills will provide invaluable information that can be used by development organizations to design safer and more effective FSM processes, and improve FSM behavior change techniques at relatively low cost.

LIMITATIONS AND FUTURE WORK

This study has important limitations that must be considered when evaluating its results. These limitations also highlight future work in this field of study, some of which is currently being performed by the researchers.

Despite efforts to survey both males and females, it is unclear if the responses recorded were indicative of the respondent or of the decision maker in the household; gender is thus not analyzed in this study and may be a confounder that should be investigated in future work. Additional questions about how decisions are made in the household, who makes them, and who performs certain maintenance tasks associated with the latrine could be asked in future surveys to improve understanding about this factor.

Survey design also likely affected responses and response patterns. The length of the survey (67 questions) likely caused survey fatigue and may have biased responses to questions asked later in the survey; the question about FSM intentions evaluated in this study was question number 61 in the survey. Varying the order of the questions in the survey would help reduce this bias and remove any other bias introduced by the order of the questions. The survey's length could also be reduced.

Social desirability bias also likely affected responses. Asking about sensitive topics that have strong social norms, particularly in developing countries, is known to elicit responses that are not truly representative of a respondent's opinion (Del Brutto & Mera, 2016; Gregson et al., 2002). In addition to using local Cambodians to survey latrine owners, as occurred in this study, surveyors should clarify that the respondent should be wholly honest in their responses and interview latrine owners of the same gender individually.

The poor accuracy of the model developed in this study highlights the difficulty predicting intentions using contextual factors and the need for more research targeted at describing FSM intentions. According to the Theory of Planned Behavior, the model should be improved by considering more relevant contextual factors, which may include household income; frequency of latrine use; the availability and practices of FSM service suppliers; and familiarity with other latrine owners whose pits have filled and their associated FSM behaviors. Relevant contextual factors must first be

identified using qualitative methods, which will inform the development of future quantitative surveys. Additionally, relevant contextual factors may already be available from other sources, including the Cambodian government's Ministry of Rural Development and other development organizations working in Cambodia. These datasets describe population density, latrine coverage, job types, cultural characteristics, education levels, and others. Understanding the contextual factors motivating the observed differences in FSM intentions will provide practical information for sanitation development that will allow for targeted social marketing, behavior change campaigns, and technical designs that will ultimately improve FSM outcomes.

Although FSM intentions were grouped by desirability in this study, specific FSM intentions should be investigated individually. Future analysis should investigate the associations of specific FSM intentions (e.g., installing an additional pit, paying for professional emptying) with contextual factors; this may also improve modeling accuracy.

Additionally, behavioral determinants (e.g., attitude, belief, and perceived control) toward specific FSM intentions have not been investigated to date and must be understood to better predict FSM intentions. These behavioral determinants may include willingness to pay for professional emptying and the installation of a new pit; beliefs about the importance of safe and effective FSM; propensity to adopt new technology; social norms about fecal sludge; and perceived control over installing safe and effective FSM solutions, among others.

Actual control, which may be measured by assessing FSM service availability, household incomes and expenses, or government policies associated with FSM, must also be investigated, as the Theory of Planned Behavior states that it may affect intention. Broadening data collection to examine these complex constructs will require significant time and effort but should produce a more complete picture of FSM intentions.

Factor analysis, multiple correspondence analysis, or structural equation modeling could be applied to highlight relationships between contextual factors and FSM intentions. These methods are planned for future work.

This study used the Theory of Planned Behavior as a foundation; however, this theory is not without its possible shortcomings. Some studies report that the TPB does not explain behavioral variances adequately (Armitage & Conner, 2001), and that behavioral constructs such as habit, roles, emotional state, and physiological needs at the time of decision-making may be important but are not considered in the TPB (Triandis, 1977; Sniehotta, 2009). The TPB may also be vulnerable to self-presentational biases due to its reliance on self-reports (Hessing et al., 1988). Future research should consider these possible shortcomings and perhaps expand the theoretical basis to include these missing constructs to determine their effects on FSM intentions.

It is also important to consider that the associations described in this study may change due to variations in context, behavioral determinants such as social norms, and actual control such as job availability and household incomes. These contextual changes may cause latrine owners to reevaluate their decisions and change their FSM intentions. The model will thus need to be updated with future data to maintain its relevance.

CONCLUSIONS

Latrine owners living in rural Cambodia were surveyed to determine their intentions when their latrine pits fill with fecal sludge. The majority intended to manage their fecal sludge safely and effectively; however, 41% of households reported undesirable FSM intentions, highlighting the impending risk to public health due to poor FSM.

Associations were found between FSM intentions and various contextual factors. The province in which latrine owners lived strongly influenced FSM intentions; for example, latrine owners living in Siem Reap reported undesirable FSM intentions far more than those in Banteay Meanchey and Kandal among others. The year a latrine owner was surveyed also strongly affected FSM intentions: intentions to install a new pit doubled, while intentions to self-empty halved between 2015 and 2017. The month a latrine owner was surveyed also strongly affected FSM intentions, most likely due to the demands of working in rice agriculture and the associated seasonal changes in household income.

Modeling the desirability of FSM intentions using contextual factors proved difficult: the model constructed in this study was only 67% accurate and exhibited low quality. However, certain factors were strong indicators of improved FSM intentions: satisfaction with the household's latrine and its supplier yielded more desirable FSM intentions, while a history of practicing open defecation before constructing a latrine, experiencing challenges with the household's latrine due to flooding, and being IDPoor yielded more undesirable FSM intentions. Understanding how these factors affect FSM intentions provides guidance to target social marketing, behavior change campaigns, and technical designs related to FSM.

While lacking predictive accuracy, the model shows that the Theory of Planned Behavior may be applied effectively to understand FSM intentions in rural developing communities. Additional surveying, particularly of contextual factors and behavioral determinants, will provide the data needed to verify or refute the TPB's application in this context. Targeted surveys are currently being developed using qualitative methods to achieve this goal.

This formative research provides a basis for improving behavior change techniques targeted at FSM and for developing safe and effective FSM solutions that fit within the social, economic, political and other systems in rural communities. In understanding how human behavior interacts with and affects FSM in the rural context, improved FSM solutions can be developed, and the gains of improved sanitation access can continue to be enjoyed by rural developing communities.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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APPENDIX

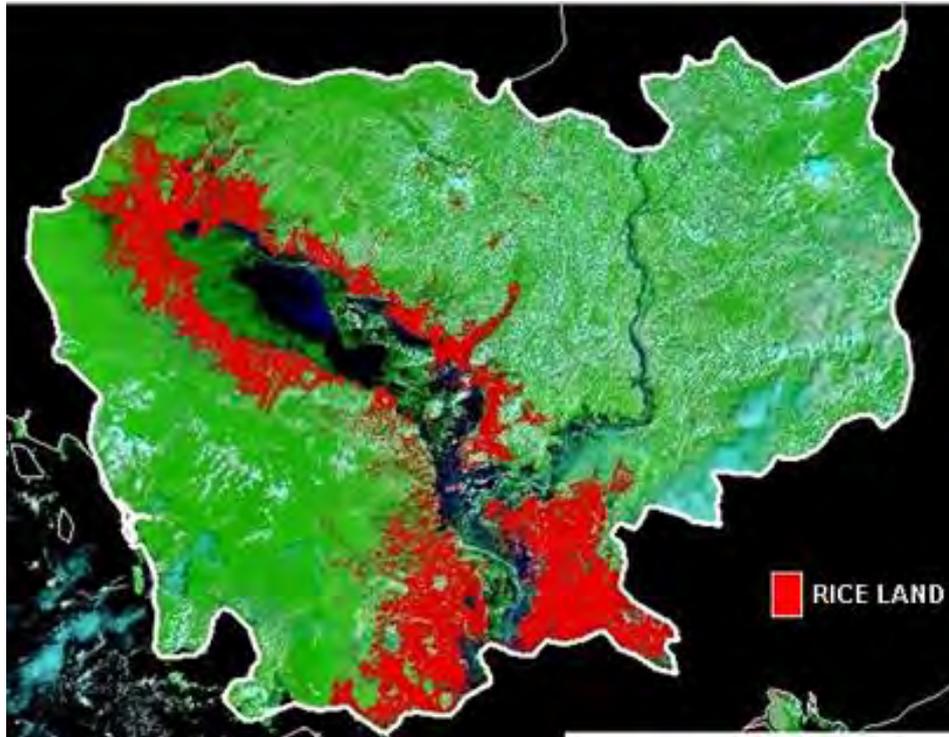


Figure A1: Cultivated land used to produce rice in Cambodia. (USDA 2010)

Table A1: Confidence intervals of factors in the binomial logistic regression model

Factor	Category	Confidence Interval (95%)
-	(Intercept)	-2.63 to -0.60
<i>Satisfaction</i>	<i>Kampong Thom</i>	-1.54 to -0.89
	<i>Kandal</i>	-0.76 to -0.19
	<i>Oddar Meanchey</i>	-1.13 to -0.29
	<i>Prey Veng</i>	-1.76 to -1.18
	<i>Siem Reap</i>	-2.36 to -1.70
	<i>Svay Rieng</i>	-1.32 to -0.70
	1	-3.66 to 1.73
	2	0.45 to 2.70
	3	0.53 to 2.59
	4	0.87 to 2.90
	5	1.08 to 3.14
<i>Month</i>	<i>February</i>	-0.34 to 0.51
	<i>March</i>	-0.15 to 0.70
	<i>April</i>	-0.02 to 1.22
	<i>May</i>	-0.53 to 0.27
	<i>June</i>	-0.28 to 0.54
	<i>July</i>	-0.26 to 0.65
	<i>August</i>	-0.09 to 0.67
	<i>September</i>	0.15 to 0.98
	<i>October</i>	-0.01 to 0.83
	<i>November</i>	-0.29 to 0.60
	<i>December</i>	0.19 to 1.13
<i>Recommended Supplier</i>	Yes	0.24 to 0.61
<i>Year</i>	2016	0.09 to 0.65
	2017	0.45 to 1.19
<i>Satisfaction Supplier</i>	1	-0.16 to 6.34
	2	-0.22 to 1.31
	3	-0.55 to 0.75
	4	-0.19 to 1.08
	5	0.09 to 1.55
<i>PastOpen Defecation</i>	Yes	-0.47 to -0.09
<i>Flooding</i>	Yes	-1.82 to -0.30
<i>IDPoor</i>	Yes	-0.39 to -0.04

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ORGANISATIONAL IMPLICATIONS OF ROBOTICS IN THE MANAGEMENT OF ENGINEERING PROJECTS

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ABSTRACT

Borrowing principles of Cognitive Work Analysis (CWA) we elaborate on the human-robot-interaction (HRI) analysis of both a welding robot and a masonry robot to discuss the ways in which construction work may need to reconfigure. Framing these CWA principles alongside the literature on organisational change management, we offer an approach to understanding the implications of introducing robotics into a construction project. While the implications will vary depending on the specific automation type and the specific tasks within the project organisation, the discussion identifies the areas that escalate to influence project management, and identify potential areas for future definition needed for the unique intersection of project management and automation.

The remaining parts of the paper describe the rationale for the departure points of this as an implementation framework and why utilising theory from the information systems and human-robot-interaction domains is important to distinguish the organisational implications of robotics. These organisational implications are distinct from previous technological developments within the construction industry because of their impact on changing roles at the workforce, not simply application of technology to change performance of a task.

KEYWORDS

Construction robotics, organisational change, management.

INTRODUCTION

Automation, in various forms, has developed rapidly over recent years and has been applied across a variety of industries. Within construction, the increased use of digital technologies - e.g. building information modelling (BIM), mobile computing, and big data - has supported information flow and technology development to the point at which the scope of application of robotics has expanded into the realm of construction. To date, research related to robotics in construction has focused on how to develop and deploy robotic systems into shop and construction site environments, and some work regarding the influence robots will have on the field construction workforce – through supporting or replacing traditional construction labour. However, as the advancement of robotics into construction moves from principle into practical application, the implications of robotics will require the project organisation to evolve, but how?

Recent research into workforce shortages show shortfalls have already occurred in US construction trades since the economic recovery following the 2008 recession (Taylor et al, 2016). Coupled with the potential gains in productivity, investors and

venture capitalists are hoping to invest heavily in the idea of construction robotics in the near future (Glaser and Molla, 2017). Despite low exploration and adoption, the construction industry has immense potential for the adoption of robotic technology to advance the industry. However, the well-documented fragmentation of the construction industry (Henisz et al, 2012), product variability (Ballard and Howell, 1998), and challenges of automation in field construction contexts (Milberg and Tommelein, 2005) have limited the extent of adoption to date. Recently, research by Frey and Osborne (2017) out of Oxford suggests that nearly 50% of construction work could be automated over the next 20 years, using new and emerging technologies to support advancing automation. However, they emphasise the need for tasks to be re-envisioned and re-designed to leverage emerging technology. Beyond field task and information technology development, the re-design of these tasks will be influenced by human-robot interactions – on which this paper expands in order to consider the organisational implications of robotics in the management of engineering projects.

THE CHALLENGE OF IMPLEMENTING ROBOTIC SYSTEMS IN CONSTRUCTION

Construction projects are complex socio-technical systems composed of many highly coupled (i.e. interacting) subsystems that manage the uncertainty of facility design in parallel with the organisation of the project stakeholders (Lessard et al, 2014). Automating a task suggests that the use of human labour will be minimised, or wholly removed, through systems or technology. However, the construction industry has been historically dependent on the use of craft labour to deliver bespoke designs. The impact of introducing a robotic system into the multiple interactions among various subsystems is both pervasive and difficult to define. Robotic systems are typically designed to take on the less desirable work from human workers (Bock, 2015) but there are a number of characteristics distinct to robotic systems that make the replacement of human workers with robotics less than a straightforward swapping of well-defined tasks. Construction tasks typically require: 1) simultaneous sensory perception and mobility capabilities that are challenging to replicate in robotic systems; 2) construction sites are uncertain environments that require a high degree of adaptability; and, 3) bespoke designs create multiple non-standard interfaces.

Despite these challenges to overcome in applying robotics in construction, computing, sensing, and related advancements in the mobility and adaptability of technology is rapidly offering opportunities to apply robots in construction contexts. As Han (2014) highlights in his comparative assessment of robotics applied to construction in different regions, there are more than 170 types of robots being developed or tested in various tasks. While only about 20 of these were practical at the time, the barriers for the others noted are primarily technical and likely to be feasibly overcome or addressed through new approaches. Essentially, this suggests that some level of adoption into construction is highly likely and feasible from a technical standpoint in the near future. The need to re-consider the organisational needs to appropriately consider and integrate some of these solutions into construction projects is thus the next logical consideration.

There are many diverging propagation paths when adopting robotics that disrupt existing processes and require change management support for the effective delivery

of construction projects (Argote and Goodman, 1985). Organisational implications will vary depending on both the defined tasks and the work packaging of the construction project in which the robotic system is situated. In turn, this will have varying degrees of impact on cross-functional units that change or introduce new roles and work activities. Focusing more specifically on the social aspect of organising, organisations are essentially social structures, imperfect systems made up of people (Katz and Hahn, 1966). These systems do not occur naturally, but have a structure usually based upon events rather than physical components, and in which the processes cannot be separated from the system(s), (Kast and Rosenzweig, 1972). While this concept is commonly applied within construction in the context of work-packaging and design of the work-breakdown structure to align the disciplinary skills of firms or subcontracts, the implications of robots to fundamentally change the structure and normative models of organising work in projects has not been previously addressed.

The distinct features of different robotic systems afford and constrain subsystem interactions depending on the process being automated (Slaughter, 1997). Due to the task specific focus of robots they are inherently closed systems where information and materials need to be translated into programmable data in order for a component to be produced. Further, construction robotic systems are not goal-orientated; the path taken to complete a task is programmed and any negative feedback, as well as the corresponding response, is predefined. However, complex sociotechnical domains (i.e. construction) require open-ended, creative, and discretionary decision-making (Vincente, 1999, p26.). Changing contingencies is a normal day-to-day occurrence on a construction site and workers – as craft - “rely on their knowledge of the work domain constraints to explore a variety of ways for dealing with the situation while remaining within the boundaries of acceptable performance,” (Naiker et al, 2005). The potential issues that arise from introducing robotics into a construction domain result from a relatively isolated system (e.g. a welding cell or brick laying robot) requiring very defined information, meeting an open system (e.g. a construction site) that operates in a far more fluid fashion (Bock, 2015). Therefore, introducing a robotic system will inevitably change the structure of the work domain, the work domain constraints and consequently the various ways the workforce can respond to unanticipated events. It requires new understanding of what a robotic supported construction project configuration looks like, what new knowledge is required and to what role that knowledge is attributed to ensure effective interaction between the robotic system and the wider construction project.

THE CHALLENGE OF DESIGNING CONSTRUCTION ROBOTIC SYSTEMS.

Robotics in construction is a growing field requiring new empirical and theoretical approaches to understand it. In the convergence of the robotics and construction domains significant epistemological differences must be bridged in order for robotics to become a normative vision for the future of construction (Dowsett et al, 2017b). In light of this, we draw on information systems and human-robot-interaction (HRI) as reference disciplines to provide the starting point from which to consider the organisational implications of robotics. In doing so, work domain constraints can be understood in relation to the characteristics of the robotic system being implemented. The following section describes the normative approaches to task and work based

analysis that are predominant in the design of information systems. This study builds upon the principles of these approaches but makes a departure to describe the theoretical foundations on which we begin to explore the organisational implications of robotics in construction.

In general terms, the design of new information systems begins with an in-depth analysis of the ‘as-is’ processes of the existing system. Normative approaches investigate what workers actually do and describe every action in complete detail, presupposing that the designers are able to anticipate and determine the response to every possible situation (Benyon 1992). They are also reliant on the workers going through a process of familiarisation with the system and an understanding of the appropriate methods of operation (Reimer, 2013). This approach attempts to provide a complete description of the familiarisation process and of how they develop modified methods of operation (Vicente 1999). However, this fails to address the problem of divergence from a prescribed process that in a construction situation is all too common.

Moreover, the dynamic environment and complex array of organisational interfaces in construction projects require the work packaging and organizational breakdown to be deployed as a custom solution for each project. Therefore, we suggest a more parsimonious approach that draws on the underlying principle of Vicente’s Cognitive Work Analysis (CWA) (1999) that takes an ecological approach to system design. CWA focusses first on understanding the intrinsic constraints on worker behaviours as the unit of analysis rather than how the work is actually performed. The approach consists of five dimensions: work domain (field of work), control task analysis (what must be done), strategies analysis (information flow), social organisation and cooperation (necessary conditions and culture change), and worker competencies analysis (skills needs). Each dimension is explored using specifically designed modelling tools to construct a representation of constraints (Naiker 2017).

However, we depart from the prescriptive aspects of CWA on the basis of the limitations of task/work analysis and modelling processes. Firstly, ‘routine’ activity is laden with the tacit and embodied knowledge of the individuals carrying it out and the ability to articulate this will vary among them depending on their mental model of the activity (Dean et al 1994). And secondly, modelling tools attempt to represent organisational activity in terms that are discrete to the modelling method and cannot articulate the tacit and embodied knowledge situated within the socio-material work environment (Reimer et al. 2013).. In this sense, modelling performs particular realities rather than simply representing a given reality (Cabitza 2014).

In the design of construction robots some aspect of a craft or construction task is translated into a programmable language of which only the process of the isolated system can be accurately modelled (Bernold, 1987). We cannot accurately model the changes this system makes to the organisation of work on the construction site in which it is situated. What we can do, however, is begin to understand the constraints the robotic system places on the wider sociotechnical system and how management tasks and roles may need to adapt to accommodate the predetermined sets of information the robotic system requires to perform a construction task.

While the ability to focus on the task and process design bottom-up is important to considering the dynamics between construction workers and robots, it is the latter organisation of projects that provides the novel implications we begin to explore.

METHODOLOGY

The intent of this paper is to begin to describe an extended framework of construction robotic task analysis building on the work of Dowsett et al. (2017a), not to present the results of testing and/or validation. This paper expands on the work of Dowsett et al (2017) that began to unpack the skills needs and culture change requirements of introducing FRAMBE (Flexible modular robotic assembly modules for the built environment) into the construction industry (see: Dowsett et al, 2017a). FRAMBE is a mobile multi-task robotic cell whereby the robotic system is housed within a flying factory brought on or near to site to produce short run components. In its current design the cell currently houses a pipe welding robotic system.

The Sholtz's human-robot-interaction (HRI) model was used as an analytical framework to anticipate new skills required for the implementation of the robotic system. The analysis was conducted based on a comparison of the 'as-is' welding bay process and the 'to-be' process designed by the consortium. Five interaction roles – supervisor, operator, mechanic, peer/teammate, and bystander – formed the frame of reference through which empirical events were observed. This paper expands on this framework, first by applying it to a second form of automation using a masonry robot on the project site, rather than in the supply chain. The data collection for the masonry robot was developed using secondary sources, including published articles (Dormehl, 2017; Zerndt, 2017) as well as published videos of the robots operations (YouTube, 2016). Secondly, we extend the analysis to management tasks drawing on the underlying principle of CWA to consider what constraints a robotic system introduces at project-level. The intention is to approach automation and robotics from both a top-down and bottom-up perspective to understand what the robotic system requires in order for it to function as designed in relation to how it disrupts the normal execution of work, and how this will reorganise site activities. If the intrinsic constraints of the new system can be envisaged and communicated starting from the known processes of the robotic system construction project work can be contextually redesigned and configured.

FINDINGS

MOBILE ROBOTIC WELDING CELL

Table 1 shows the analysis of human-robot-interaction of the welding bay cell - this was based on current understanding of existing factory processes to make projections around task reallocation among factory operatives.

Table 1: Human-robot interaction analysis: Cell assembly system - welding bay

Interaction Role	Supervisor	Operator	Mechanic	Teammate	Bystander
Proposed Role	Floor Manager	Welder	N/A	Welder's Mate	Other operatives
Key activities	Monitoring production schedules Health & Safety Organising work	Programming robot? Quality checking finished parts	Maintaining and responding to system failures	Collecting and placing components within welding bay stillage	Stock movement Painting
Information req.	Production schedules Stock status Robot operating status Operatives currently working with robots	Assembly module being manufactured Coordinates and path execution parameters	Nature of fault Activity occurring at time of fault	Components specific to the pipe spool being manufactured	Current processes underway within factory and how their activities interact with them and vice versa
Skills Needs	Forecasting abilities to understand the impact of system failure on wider factory operations	Comprehension of robotic system architecture and technical model in order to programme robot execution plans	N/A (Externally defined)	Comprehension of robotic processing capacity to avoid overloading/under-loading the system	Primarily perception & situation awareness to avoid interrupting robotic system and associated processes

ORGANISATIONAL RECONFIGURATION – MOBILE ROBOTIC WELDING CELL

In mapping the displacement of factory operatives from the actual task of welding itself we can begin to understand how this might impact wider factory processes and ultimately project-wide processes. For example, when moving to an automated system robot operatives require an understanding of the path execution parameters of the welding robot for the purposes of quality checking component designs are within the capacity of the robotic system to perform. Or, alternatively, depending on the information management processes in place, to programme the robotic system to perform the task of assembling and welding a component. Whilst it may seem that the introduction of welding robot into a factory environment is a fairly straightforward swap of a human operative to a robotic operative, the automated process is heavily reliant on the quality of information received. In which case, one of the predominant

constraints affecting the effective implementation of welding robots is the quality of the information management processes upstream. The robotic cell functions by translating information from a 3D model, in which the pipe components have been virtually assembled, into programmable data for use in RobotStudio. Technically, this has been achieved but in this case there are a number of stages in the current information management process that will prevent the robotic system operating effectively starting before the drawings reach the factory. When the factory receives the drawings they have to be re-modelled to achieve a co-ordinated and buildable solution using the expertise they have as manufacturers that the designers at the concept stage do not possess. These are then redrawn a second time to provide the cut-sheets that the factory floor operatives use to coordinate the movement and assembly of pipework components around the factory floor. The current division of labour is between the welder and the welder's mate – a human-human team where feedback is through direct observation and verbal communication.

ORGANISATIONAL RECONFIGURATION – BRICK LAYING ROBOTIC SYSTEM

The matrix in Table 2 highlights a few areas of distinct role and task changes that require thought in the planning of its use of a masonry robot (SAM – semi-automated mason). First, while the process the robot uses for installing brick or block masonry is quite similar to the traditional process, the set-up required needs to account for the inherent dynamics of construction sites (Construction-robotics, 2017). Namely, items like scaffold movement from wind requires special laser systems to be set up to provide a control to the robot to insure level and plumb bricks upon installation. This is an element that requires slightly different considerations as it relates to the custom scaffold needed for the robot, rather than allowance for manual adjustment by the mason for each brick from a string-line or level. In addition, the introduction of software is a leap forward, as masonry is commonly a laggard in technology adoption as noted in areas such as BIM. The need to translate the architectural design into the specific software and component library that can feed the robots operations requires someone, likely either the mason as the 'operator' or a BIM modeller as the 'mechanic' to include knowledge related to interoperability and architectural design, in addition to their technical skills. Lastly, the nature of the custom scaffold makes close coordination between trades slightly problematic – the wall assembly elements that precede the brick in sheathing and waterproofing would likely need to use separate timing and scaffolding in their installation. The scaffold used for the masonry robot is custom and would likely only be set up and operated for the period during the robots operations.

BRICK LAYING ROBOTIC SYSTEM

Table 1: Human-robot interaction analysis: Single-task - brick laying robotic system

Interaction Role	Supervisor	Operator	Mechanic	Teammate	Bystander
Proposed Role	Foreman	Mason	(BIM modeller?)	Mason's Tender	Other trades / workers
Key activities	Monitoring production; Health & Safety; Coordinating materials and resources (e.g. scaffold)	Set-up of robot / scaffold to meet tolerances; quality checking of output; manage supply of brick/block and mortar; custom masonry placement	Programming; customize design model for brick / block installation; Maintaining and responding to system failures	Supplying / loading bricks and mortar; changing fuel source (propane); cutting / supply of custom brick or block sizes	Using shared resources (e.g. scaffold, forklift); material movement in nearby space (e.g. wall assembly, window install)
Information req.	Production schedules; CPM schedule; Material / resource on site; Robot operating status; Crew (operatives) currently working with robots	Wall or assembly details; controls or tolerances, (masonry, brick ties, and scaffold); coordination needs with related trades (e.g. framing and waterproofing, windows)	Software / interoperability of design model; Nature of faults that occur, Activity occurring at time of fault	Specific brick / mortar requirements for wall being assembled (mortar mix, quantity & rate of installation); placement of custom sizes; wall tie details	Safety requirements for working near robot; Current processes related to set-up and tolerances; understanding of how any work they perform interacts with robots scope
Skills Needs	Ability to forecast coordination needs, logistical requirements and resource access; production knowledge	Understanding of software capabilities related to custom architectural designs; Ability to interpret details and designs into process for adjusting installation for robot (e.g. sequencing of wall ties)	Technical troubleshooting of robot problems, technology skills related to representing and interpreting design data into robot input	Comprehension of robotic processing capacity to avoid overloading/under-loading the system; detail of loading of components to match installation sequence, wall tie placement, etc.	Situational awareness to limit interruptions to robotic activity; safety knowledge;

DISCUSSION

When considering the application of robotics to the studied tasks, there are, on the face of the analysis, relatively minor changes occurring. However, if taken as common changes across both cases they suggest the need for broader considerations in the temporary project organisation, or the firm organisation, possibly both. First, the introduction of the ‘mechanic’ role is new in both cases. Both examples would have traditionally been performed by craft workers, with primarily non-powered or a limited array of equipment that would require technical support, e.g. mortar-mixer. While there are potential analogous roles in the industry that could be considered, such as BIM or technology managers, neither of these truly encompass the new set of skills and the well-defined role that is needed to perform the identified tasks. The role more closely resembles the equipment operator using an excavator. Assuming the robot is adopted as a standard operational element in the production of either system, the firm would need to identify someone to fulfil this role on a continuous basis, even if it is only part-time in terms of a required time investment.

A second change is the shift of the operator, whether welder or mason, away from a craft performance role to a primarily management role focused on the control of the input, monitoring of the process, and review of the quality and conformance of the final product(s). Firstly, this would require appropriate training regarding the technical skills needed to operate the robot, such as appropriate familiarity with set-up of scaffolding for the masonry robot or jigs for the welding robot. Additionally, the software needed to run the robot would need to be taught both to the operator, and sufficiently to the teammates that need to be able to supply information or interact in some manner.

An additional change that occurred in both cases is the need to broadly consider the interaction of bystanders with the robot. Focusing on the area of safety, all of the personnel that will work in the space or area around the robots will need to be provided with appropriate awareness and training of the robots operations to be able to work safely in the performance of their own tasks. However, this takes on a larger implication at the project site than in the supply chain. Within the supply chain, the personnel that are likely to come into contact or work adjacent to the robot are well defined, generally to the employees of the host firm. On the project site, the robot is likely to be the equipment used by one of multiple trade contractors with continuously changing work areas and personnel. Unless wholly segregated in terms of the work area and personnel interactions, the project site would likely require the need for training to be extended to many, possibly all, of the workers on site.

As these changes, particularly specific to the construction site, are escalated to the project level the implications begin to diversify and propagate. First, one of the commonly noted challenges in construction is the need for interdisciplinary interaction, planning, and adjustment to support the dynamic operations that occur by craft workers on a construction site. While the application of robotics, at least in the short term, may limit the flexibility for interdisciplinary interaction around the trade work that is automated. For example, if trade work is limited to the mason in the area of the robot, there is no flexibility in the schedule and sequencing of the sheathing and waterproofing of the enclosure, the trades performing those tasks need to be complete on time, and need to have their specific scaffolding or other equipment

removed. This reduces the ability for trades to employ shared scaffolding that traditionally is a minor area for coordination. While seemingly a minimal change, this impact needs to be foreseen in the procurement of both trades to ensure the expectations related to scaffolding procurement, schedule durations and timing, and potentially faster pace of work by the follow-on trade (masonry robot). These elements, which would traditionally be coordinated as ‘field’ decisions with only minor repercussions to project management, now require explicit planning in the work-packaging, scheduling, safety training and execution planning.

The HRI model provided a useful framework to discuss each system and begin to compare the organisational changes that are likely required for each. The predominant difference between each of the robotic applications analysed were within the construction process. The implications of this to organisational changes necessarily varies depending on the upstream activities required for information input and downstream construction tasks that are impacted. The changes identified here will vary depending on the configuration of the robotic system employed, which in turn will vary over time as new and emerging technologies improve the feasibility of roboticising construction tasks (Frey and Osbourne, 2017). For example, the re-envisioning and re-design of construction tasks will likely be affected by developments in machine learning. Machine learning has already begun to address the sensory perception and adaptability issues that previously formed barriers to robotics in construction.

The potential benefits of machine learning may be to further reduce the barriers to small batch automated production. It is possible to train a robot to grasp and pick up objects it has never seen before. This will have further implications right across the construction process. For example, if both the masonry robot and welding robot incorporate material handling capabilities this further displaces the human worker from the robotic system. For the welding robot the human work would potentially no longer have to ‘feed’ and place the correct part in sequence. Further, the possible applications for even shorter run components could potentially make the business case for robotics and the related FRAMBE (flying factory) model more viable. Conversely, imitation learning would require further human-robot-interaction but at the cost of more technology, such as laser scanning technology, to avoid human-robot collision.

CONCLUSIONS

This paper has begun to frame and explore the organisational implications of robotics in construction using HRI theory and construction organisation literature to bridge the gap between two distinct domains. There is substantial research required to fully understand the implications of robotic systems in the management of construction projects and this paper has attempted to provide some initial insights to suggest how construction management roles and tasks may be required to change to accommodate automation. These insights provide input to guide the decisions for those adopting and implementing robotic systems into project work. Namely, how to approach issues of reduced flexibility in task completion and how or where this can be accounted for in the wider remit of project management. As well as the importance of skill development, situational awareness, and how to introduce new mental models of the

problem space. More broadly, this research should be viewed as an early effort of using theoretical and empirical foundations of human-robot-interaction, organisational management theory, and task/work analysis to inform implementation strategies and to configure robotic supported project work.

This study also contributes in providing insights into the design of robotic systems for construction drawing on theory familiar to the field. In the design of robotic systems there are distinct differences of conceptual understanding of the problem to be address by both construction practitioners and robotic system designers. By drawing on HRI theory, information systems theory (i.e. CWA), and framing these within a construction context we begin to bridge the gap between robotics and construction by referring to each in their own terms. However, whilst this paper begins to discuss the organisational implications of robotics at project-level, further research is required to socialise the idea of robotics into the construction industry. Construction robotics is very much a fledgling discipline and how it will affect the shape of the industry is yet to be defined. Future research will build upon the insights presented within this paper to address the empirical and theoretical gaps evident in understanding surrounding the impact of construction robotics on supply chain models and industry-wide adaptation.

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DRIVERS OF ‘DATA AND ANALYTICS’ UTILIZATION WITHIN (SMART) CITIES: A MULTI-METHOD APPROACH

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DRIVERS OF ‘DATA AND ANALYTICS’ UTILIZATION WITHIN (SMART) CITIES: A MULTI-METHOD APPROACH

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ABSTRACT

Research on the factors leading to cities’ utilization of ‘data and analytics’ requires a more holistic and systematic approach. This study attempts to identify the potential set of condition variables to predict cities’ levels of utilization of ‘data and analytics’. It employs a multi-method approach (including comparative case studies, content analysis and the Delphi method). The preliminary findings of this study indicate a variety of potential causal condition variables and corresponding measurement techniques, providing the basis for exploring the possibility that several causal pathways may lead to (smart) cities’ utilization of ‘data and analytics’. Finally, the authors propose avenues for further research.

KEYWORDS

Smart city, data and analytics, multi-method approach.

INTRODUCTION, PURPOSE AND RESEARCH QUESTIONS

INTRODUCTION

Data now fall under cities' most valuable possessions (e.g., "the new oil of the digital era" (The Economist 2017). If appropriately deployed, data carry the potential to make a significant contribution to overcome some of the current and upcoming urbanization challenges within cities (Kitchin 2014; Suzuki 2015) (predominantly caused by rural-to-urban demographic migration and population growth (United Nations 2014, 2015). However, many cities seem to underutilize this crucial asset (apart from a few exceptions as mentioned in, for example, Goldsmith & Crawford (2014)). Not surprisingly, a city's path to appropriate data collection, management, analysis and application ('data and analytics') is demanding and marked by various substantial hurdles. Therefore, this study focuses on the determination of potential causal condition variables that may have an influence or (joint) impact on (smart)¹ cities' utilization of 'data and analytics'. The parentheses utilized for '(smart)' within the term 'smart cities' are intended to underline that the city cases utilized in this study have not been selected on the basis of any SC definition, nor are the results of this study only applicable to certain cities that are called (or call themselves) 'smart'. In this paper, the authors utilize the term 'smart city' only to refer to the 'data and analytics' aspects of cities and refrain from providing any holistic definition of such a inconclusively debated construct.

This study aims to identify a set of indicators or drivers that are essential to build a theory around a (smart) city's utilization of 'data and analytics'. The drivers can then be used for systematic examination across (smart) cities. It would contribute to the growing body of literature that actively engages with the issue regarding the complexity of (smart) cities and their 'data and analytics'.

In general, this study is organized into the following sections: firstly, after a short introduction the authors delineate the purpose of this study and its research questions followed by a brief discussion of the reasoning behind the selection of the applied research method and its theoretical basis. Secondly, the authors describe the research structure and the study's methodological procedure. Thirdly, the preliminary results of this research endeavour are debated, and their potential implications explored. Finally, the authors review this study's potential contributions, followed by shortcomings and avenues of future research as well as concluding remarks.

PURPOSE AND RESEARCH QUESTIONS

Prior research from various disciplines (e.g., management sciences, political sciences, urban informatics, etc.) has indicated the significance of selected condition variables

¹ The label 'smart city' (SC) is a fuzzy construct (Mora et al. 2017). The debate regarding what a 'smart city' entails and how it is to be defined is ongoing. Therefore, the authors argue that it will be challenging to build theory on top of a construct (such as 'smart city') when there is still disagreement on the underlying definition itself. Therefore, the authors refrain from attributing significant importance to the SC construct. Moreover, the authors can, in principle, envisage that this study's 'data and analytics' research focus could potentially help to reduce the current ambiguity of the SC term (e.g., by introducing 'data and analytics' utilization of cities as a potential indicator for 'smart cities').

(e.g., structures, strategy, skills) for ‘data and analytics’-related themes, for example, within business organizations literature (LaValle et al. 2010, 2011). However, it has fallen short of examining the potential set of causal condition variables in a systematic and holistic approach. Additionally, the applicability and transferability of condition variables from other disciplines onto a (smart) city context have yet to be explored. While academics focusing on (smart) city research largely studied, for example, (urban) data applications (Kloeckl et al. 2012), the body of literature focusing on drivers of a (smart) city’s utilization of ‘data and analytics’ is limited and stays particularly vague in terms of the identification of these potential factors. These factors would essentially determine the precursors for a (smart) city’s utilization of ‘data and analytics’ that would then lead to cases of urban applications of urban informatics and associated literature.

The current ambiguity around the potential drivers can be seen as a direct result of the considerable length of time cities need to reach substantial levels of ‘data and analytics’ utilization (“no city has achieved excellence overnight” (Wiseman 2016)) and (in part) the inherent variability in cities’ attempts at achieving (a higher) utilization of ‘data and analytics’ (“every city is different in the way it undertakes analytics efforts” (Wiseman 2016)).

Consequently, this research gap calls for a more focused research approach to (1) identifying the set of condition variables (the focus of this particular study) and (2) reviewing the link and causal pathways among potential conditions and (smart) cities’ utilization of ‘data and analytics’ (the focus of a subsequent study). The approach develops an enhanced understanding of the potential set of drivers (this study) and their mutual dependencies and collective interactions (subsequent study), e.g., a comprehensive investigation of what drives ‘data and analytics’ utilization within (smart) cities. As a result, this paper will primarily address the following main research question:

- What condition variables can potentially influence or have a joint impact on (smart) cities’ utilization of ‘data and analytics’? (Main research question)

To examine the proposed main research question, this study is directed by the following sub-questions:

- What causal condition variables emerge from ‘data and analytics’ literature, relevant cross-discipline literature, and semi-structured expert interviews that could enable (smart) cities to utilize ‘data and analytics’? (Sub-research question #01)
- How can the potential causal condition variables appropriately be measured (within and across (smart) city case studies)? (Sub-research question #02)
- How can the outcome variable of cities’ utilization of ‘data and analytics’ appropriately be measured (within and across (smart) city case studies)? (Sub-research question #03)

SELECTION OF RESEARCH METHOD AND THEORETICAL BASIS

SELECTION OF RESEARCH METHOD

Based on preliminary interviews with stakeholders from a limited number of pre-selected cities, it became clear that cities can have vastly diverse sets of drivers (‘condition variables’) with regard to their utilization of ‘data and analytics’, both in

overall type and degree. The wealth of these different sets of elements that cities have emphasizes their distinctive rather than their common features. Therefore, the identification and validation of these potential drivers emerges as a difficult, manifold and rather complex research endeavor. This places severe demands on the research method regarding its comprehensiveness, versatility and fit for the research questions. Consequently, no single research method (neither qualitative and case-based methods (e.g., comparative case studies and content analysis) nor quantitative methods (e.g., Delphi method)) is specifically well applicable to answer explanatory (e.g., identification of potential drivers) and confirmatory (e.g., validation and determination of the significance of potential drivers) questions simultaneously (Tashakkori and Teddlie 1998). Therefore, this study utilizes a multi-method approach (incorporating techniques from qualitative and quantitative methods) to examine the complexity of the phenomenon (Creswell et al. 2003; Morse 2003). Thereby, the specified multi-method approach allows the authors to combine research methods that complement each other, choosing from a comprehensive repertoire of methodological options (Morse 2003).

More specifically, the utilized multi-method approach comprises of the following procedural components: comparative case studies (through exploratory semi-structured interviews), content analysis (through a review of the relevant literature), and the Delphi method (through a multi-stage feedback procedure from a panel of independent experts). Comparative case studies and content analysis were specifically selected as their combination allows the researcher to generate new knowledge and insights (e.g., to identify new potential causal condition variables) while capturing insights from previous works and publications (e.g., to include potential condition variables that have been already introduced in related fields to ‘data and analytics’). The subsequent Delphi method was chosen by the authors to help validate the preliminary findings (e.g., set of condition variables) and to check for completeness. Lastly, all three procedural components of the multi-method approach were carefully selected to avoid any profound threat to validity that an uncoordinated ad-hoc combination of research methods (i.e. ‘muddling methods’) may entail, as pointed out by Stern (1994).

THEORETICAL BASIS OF MULTI-METHOD APPROACH

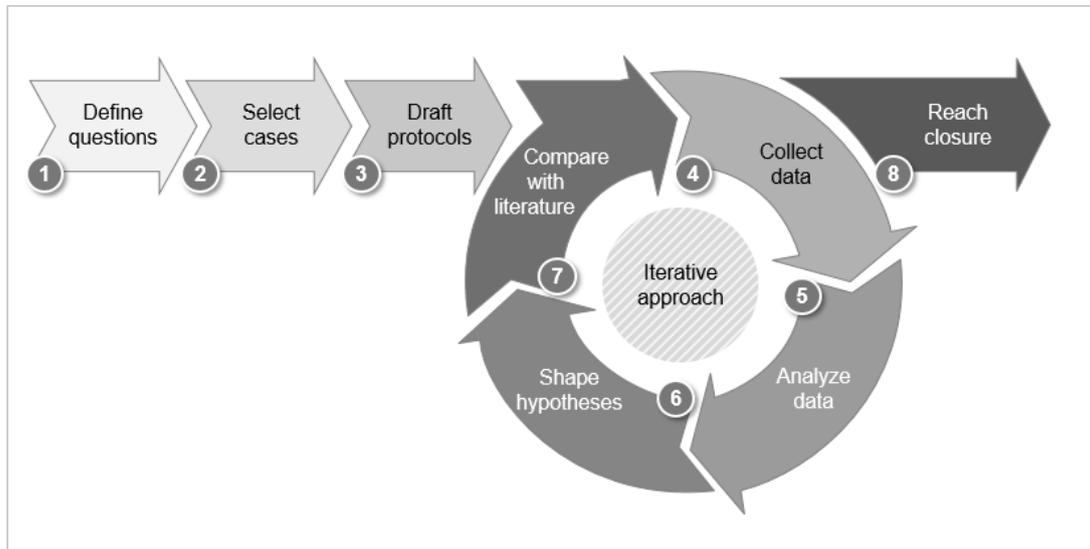
The theoretical basis of the three individual research methods utilized within the multi-method approach will be discussed briefly in the following.

Comparative case studies

Comparative case studies are a methodological approach with systematic guidelines (Eisenhardt 1989) for gathering and analyzing data with the aim of building tentative theory² (Ridder 2017). Typically, the data are qualitative, with a particular emphasis on interviews (Yin 2014). This specific research method is based on the central presumption that scholars are capable of building theories inductively from the

² The ‘theory’ term utilized in this study follows Ridder (2017) (among others, e.g. Weick (1995)) and “comprises components, [...] relationship between components, [...] and [their] temporal and contextual boundaries.”

accurate investigation of case-based, empirical evidence (Eisenhardt and Graebner 2007).



Adapted from Eisenhardt (1989)

Figure 1: Process overview of comparative case study analysis

In this specific case, the collection of qualitative data is premised (predominantly) on several interviews with experts in the field of (smart) cities and ‘data and analytics’. With regard to the proper deployment of case study methodology as described by Welch et al. (2011) and to account for Eisenhardt’s (1991) formulated claim for more methodological stringency, the authors’ case study approach has been informed by several seminal works (Eisenhardt 1989³; Eisenhardt and Graebner 2007; Stake 2005; Yin 2014). A simplified process overview of the comparative case study analysis can be found in Figure 1.

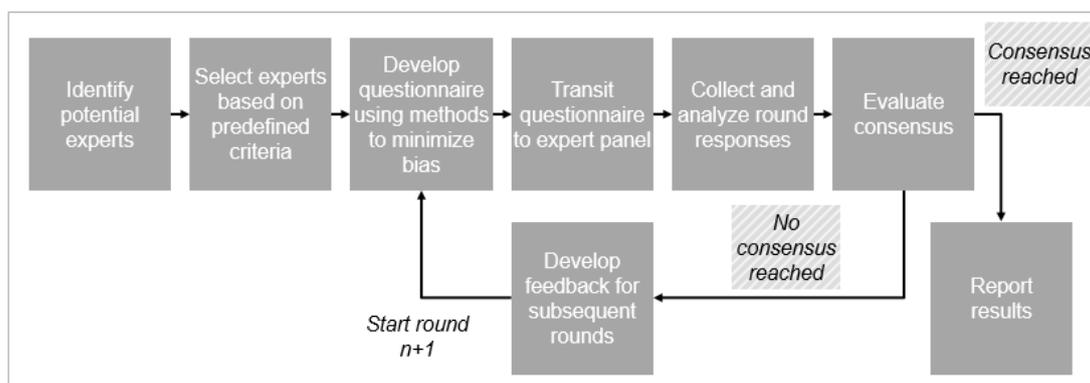
Content analysis

Content analysis has been delineated as a methodical, efficient and reproducible process for condensing and classifying considerable quantities of textual data into distinct subject categories with the help of specific procedures of coding (Weber 1990). Thereby, the authors follow the procedural methodology as informed by several seminal works (Berelson 1952; Crowley and Delfico 1996; Holsti 1969; Krippendorff 1980). More specifically, a ‘summative content analysis’ approach, as explained by Hsieh & Shannon (2005), has been employed. The content analysis method reviews and codes the appropriate literature (journal papers and ‘grey’ literature from a variety of different perspectives and fields in this specific case). Thereby, the specific approach utilizes keywords derived from a review of the literature (before and during the data analysis phase).

³ Eisenhardt (1989) is among the most frequently cited publications in the methods section (Ravenswood 2011)

Delphi method

The Delphi technique (cf. Figure 2), initially developed by the Rand Corporation (Linstone and Turoff 1975), is a systematic multi-stage research process to receive detailed feedback from a pre-selected group of experts on a particular topic (Sillars and Hallowell 2009). Experts are chosen based on pre-specified selection criteria and take part in various rounds of structured surveys (Hallowell and Gambatese 2010).



Generated by authors, drawing from Hallowell & Gambatese (2010)

Figure 2: Process overview of Delphi method

RESEARCH STRUCTURE AND APPLIED METHODOLOGICAL PROCEDURE

RESEARCH STRUCTURE

This study employs a multi-method research approach as defined, for example, by Morse (2003) to determine the potential causal condition variables that may affect cities' utilization of 'data and analytics'. The research endeavor (cf. Figure 3) is carried out in two separate stages, also referred to as 'sequential triangulation' (Morse 2003): (1) identifying potential causal condition variables through comparative case studies and a content analysis as well as (2) a multi-tier 'Delphi' survey of experts to validate and (potentially) supplement the set of potential condition variables. Thereby, the multi-method approach follows a predetermined structure, which has been compiled with the greatest possible care from several seminal works (e.g., Eisenhardt (1989) [comparative case studies], Weber (1990) [content analysis], Hallowell & Gambatese (2010) [Delphi method]).

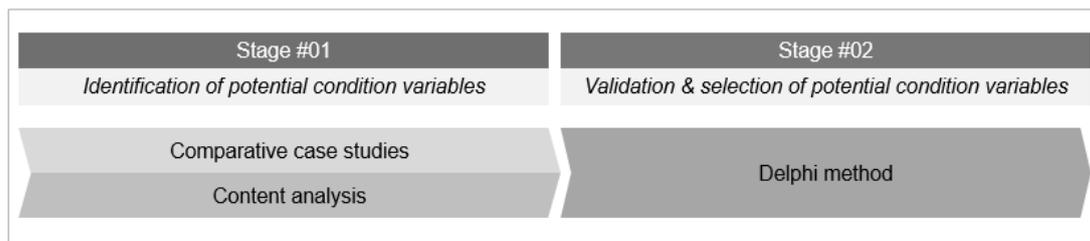


Figure 3: Research structure

APPLIED METHODOLOGICAL PROCEDURE

To simplify the research process for clarity purposes, the multi-method procedure has been split into its constituent elements. The methodological application of each of the methods will be explained in more detail in the following. Despite the sequential progression of the individual steps, the authors feel obliged to emphasize the parallel conduction of the comparative case study and content analysis methods (e.g., ‘stage #01’) during the research endeavor.

Comparative case studies

The comparative case study approach which was utilized in this research study is primarily informed by the seminal works of Eisenhardt (1989), Eisenhardt & Graebner, (2007), Yin (2014), Stake (2005), among others. The highly iterative research process consists thereby of three separate phases (‘research question and case selection’, ‘data collection & analysis’, ‘theory building’) which may be further split into eight ‘activity’ subcategories (according to Eisenhardt (1989)): ‘define questions’, ‘select cases’, ‘draft protocols’, ‘collect data’, ‘analyze data’, ‘shape hypotheses’, ‘compare with literature’ and ‘reach closure’. In the following, the three main phases will be outlined.

Firstly, the comparative case study procedure starts with the determination of the research question (incl. tentative a priori constructs or variables (Ridder 2017; Yin 2014), the selection of the case studies (using non-random theoretical sampling (Eisenhardt and Graebner 2007; Flyvbjerg 2006)), and the drafting of data collection protocols (Eisenhardt 1989). In a second step, data will be collected (employing data triangulation strategies (Burns 1997; Yin et al. 1985)) from multiple cases (as highlighted by Eisenhardt (1991)) and analyzed utilizing within-case analysis and cross-case pattern search (Eisenhardt 1989). Thirdly, in a last step, the developing categories or building blocks of the emerging construct (e.g., conceptual framework) will be accurately delimited from other concepts using conflicting and similar literature (Eisenhardt 1989) until ‘theoretical saturation’ is reached (Glaser and Strauss 1967).

In this study, the criteria for selecting the initial set of cases (‘city’ case studies) were as follows: location/ geographical distribution (cities that are geographically distributed within the United States of America), population size (population threshold of 75 thousand and above), and access (pragmatically cities were included that allowed the authors the opportunity to conduct several interviews with city representatives and/ or other important stakeholders within the city). 22 semi-structured interviews were conducted, across 10 cities, with experts in the field of (smart) cities and ‘data and analytics’ (namely Chief Data/ Analytics/ Information/ Technology Officers) and other key stakeholders from public, private and civic organizations to compile key and relevant insights for the identification of the conditions and variables included in this study.

Content analysis

The iterative content analysis approach is predominantly based on a variety of several seminal works (Berelson 1952; Crowley and Delfico 1996; Holsti 1969; Krippendorff

1980). Specifically, the authors chose to follow a ‘summative content analysis’ approach, as explained by Hsieh & Shannon (2005), that will be described briefly in the following.

Firstly, the appropriate body of literature (in this case journal articles as well as ‘grey’ literature (e.g., manuals, reports, etc.)) is identified by using keywords and a ‘backward and forward’ tracing process. Secondly, with the extant body of literature the textual data are coded, categorized (e.g., in major and minor themes) and accordingly sorted. In a third step, the emerging themes and categories are compared, contrasted with each other and (where appropriate) grouped to reduce the overall complexity of the research subject. Fourthly, in a last step, a reconsideration of the ‘source’ data is conducted to ensure completeness and accuracy of the generated insights.

Delphi method

To perform the second stage of this research study, a multi-tier survey to a panel of experts will be conducted. The methodological procedure is thereby primarily based on Hallowell & Gambatese (2010) (among others, e.g., Linstone & Turoff (1975)) and will be described in the following.

Firstly, the Delphi method process starts with the identification of potential experts for the selected research question(s). Thereby, the authors aim to select exclusively experts with a considerable wealth of experience in the field of (smart) cities and ‘data and analytics’. Therefore, the expert recruitment process will be guided by the subsequent selection criteria: (1) at least three years of relevant work experience (e.g., Chief Data Officer) in the field of (smart) cities and ‘data and analytics’ (or a closely related subject area), (2) at least one tertiary educational degree completed (e.g., Bachelor, Master or Ph.D.) in a related subject to (smart) cities and ‘data and analytics’, (3) authored articles, proceedings, publications or blog posts about the research topic and/ or participated in conferences (e.g., ‘Summit on Data-Smart Government’ (Harvard), ‘Digital Cities Summit’ (Stanford), etc.) focused on this subject and/ or holds an active membership in an association or a society (e.g., ‘Civic Analytics Network’) related to (smart) cities and ‘data and analytics’. Secondly, once sufficient candidates will have been identified the selection process can take place. Thereby, the authors will attach great importance to selecting a panel with the widest possible discipline-specific viewpoints. Thirdly, when developing the questionnaire, a variety of methods will be used to minimize bias (e.g., ‘collective unconscious’, ‘contrast effect’). The fourth process step represents the actual analytical phase of the Delphi method in which the answers are collected and analyzed as well as the consensus evaluated. It also includes the development of the appropriate feedback (e.g., consensus results, comments from other participants) for subsequent rounds. Consequently, this specific process step has to be repeated several times, depending on either how fast consensus among the participants can be reached or on the general number of feedback rounds envisioned by the researchers (probably three in this case).

RESULTS AND IMPLICATIONS

RESULTS

The preliminary results of the current state of this research indicate the existence of several potential causal condition variables of cities' utilization of 'data and analytics'. In the following, the classification of the potential drivers from the comparative case study and content analysis are presented.

Research stage #01: Comparative case study and content analysis results

The potential drivers of cities' utilization of 'data and analytics' were derived from various city case studies (through the comparative case study approach) and several categories of literature (through the content analysis approach). Therefore, each classification of the different drivers (and their corresponding themes) is briefly described and defined either through quotes from the semi-structured interviews (comparative case studies) (cf. Table 1) or from the literature (content analysis) (cf. Table 2) or both.

Condition variables	Relevant quotes from the interviews
'Stakeholders' [STA]	<ul style="list-style-type: none"> • "So I'm a huge proponent of cross sector collaboration [...]. [...] Involve different types of people, different types of skillsets, different types of organizations and different ways of working and thinking." • "And then we also have a position [...], which focuses on engaging external partnership, so we know that a lot of the work that we want to do can only be done when we leverage partnerships. We partner quite a bit with universities and with industries [...]."
'Structures' [STU]	<ul style="list-style-type: none"> • "I think hybrid [organizational structure] is probably best [...]. If you have data scientists in every department, but no one coordinating all that work, you are probably just going to reinforce the silos." • "I think a hybrid approach is probably optimal, but for medium to small cities with limited budgets, [...] where a lot of places start is just a single person, centrally, or hopefully a small team of people centrally."
'Processes' [PRO]	<ul style="list-style-type: none"> • "[...] you need some process in place in order to scale. Otherwise, you are only doing one-offs [...]." • Yeah, that was kind of like the crowning piece [highly formalized presentation] about requirements for data analytics project for departments of a whole lot of experimentation beforehand. [...]. It was a worthwhile effort to put together that framework."
'Leadership' [LEA]	<ul style="list-style-type: none"> • "[...] in my view, the most critical is leadership. I want to say leadership capacity but leadership by end or somebody really owning and driving a prioritization of this work, it is critical for success. [...] I think having a leader [...] that's like pretty high up the chain [...]." • "[...] it takes people who are able to negotiate, and influence, and manipulate people. [...] Yeah, so leadership is really important, obviously."
'Strategy' [STR]	<ul style="list-style-type: none"> • "It should be part of the whole city's strategy. So, I think, hang it all together and wrap it [having a 'data and analytics' strategy] is a good way to go." • "We do have the strategic initiatives every year, [...] so I would say that our strategy is more implicit because it supports the strategic initiatives at the city manager level [...]. We don't have anything published but we do have internal dialogs [...] and I can see that eventually, that's going to be more formalized."

'Culture' [CUL]	<ul style="list-style-type: none"> • "The other thing, I would say is more of a culture item. [...] One of the challenges we faced [...], starting with data analytics was really tricky, because there was not a culture of data appreciation in city hall at all." • "Because when it comes down to using data analytics [...], that requires changing an organization, and that work is really hard [...]"
'Types, sources & currency' [TYP]	<ul style="list-style-type: none"> • "We need more data. We have a lot of data, but it doesn't tell me a lot." • "All of them." [Response to a question on what types of data (sensory, crowd-sourced, geospatial, etc.) are needed for 'data and analytics' activities]
'Data infrastructure' [INF]	<ul style="list-style-type: none"> • "If you have those [data warehouse or some sort of internal data-sharing platform], it's just much easier for analysts to get their hands on data." • "You really need the new technology, because only this new technology will provide you with enough flexibility to develop the applications and the algorithms that you need."
'Data governance' [GOV]	<ul style="list-style-type: none"> • "I think thinking about data standards is really important. Because that empowers or enables the agencies to be more effective at sharing information and conducting data analytics projects across departments, which again is really critical." • "[...] you need a clear policy and clear software components that enable you to manage authorization and identification of users, and applications that want to use it, because otherwise you lose control of security and privacy."
'Skills' [SKI]	<ul style="list-style-type: none"> • "The other thing I think that is critical for success [...] is having the right skillsets in city hall. [...] The technology is there, there's no shortage of great technology that a city can leverage, [but] it's finding people who are skilled or knowledgeable enough to actually know how to leverage it in a powerful way." • "[...] there's a relative dearth of skilled talent with government that can really derive actual insights from it."
'Training' [TRA]	<ul style="list-style-type: none"> • "I think training is really important and a lot of city staff members are interesting as the nature of public sector jobs. They have been there a long time, there are skills can easily be outdated right? And so, trying to sort of level up those skills or build upon those skills. I think it's important both from actually building skills perspective, but also from a culture perspective." • "Different departments have increased the number of analysts and we make sure that part of our budget is providing training up communities and resources, [...]."
'Budgets' [BUD]	<ul style="list-style-type: none"> • "Obviously, more money and dedicated money is best. [...] the cities definitely need to invest in a core group of in-house staff and you can't outsource of all of it." • "I mean, more resources is way better right? So, if you have your own budget, I think that's great. As long as it's like a budget that's efficient to hire the talent that you need and to do the work that you need to do."
'Capacities' [CAP]	<ul style="list-style-type: none"> • "I think it's absolutely critical. [Our] city of couldn't have done the work we did without outside partners." (City & Industry Expert) • "Given the small amount of resources that are in-house, [...] there are creative ways to stretch those resources, like developing partnerships [...]"

Table 1: Selection of relevant quotes from the comparative case studies

Condition variables	Selected quotes from the literature
'Stakeholders' [STA]	<ul style="list-style-type: none"> • "This gap is created by a number of barriers to using data in city government, including: [...] challenges communicating the importance of this work to stakeholders." (Bloomberg Philanthropies 2016) • "Once companies' data-and-analytics foundations are in place, they may still find that the most innovative solutions can best be sourced externally, by partnering with others in the data ecosystem. Such partners include analytics companies that can supplement the organization's existing capabilities, platform providers that host tools or solutions, and data providers that can help the organization gain access to unique data sets." (McKinsey 2017)
'Structures' [STU]	<ul style="list-style-type: none"> • "In the private sector, where CDOs [Chief Data Officer] have been in place for longer than in the public sector, experts have studied the engagement of CDOs and have described two basic models - centralized vs decentralized. [...] While the centralized and decentralized models present opposite ends of a spectrum, some organizations employ a blended or hybrid model that uses the best elements of the two basic models. The hybrid models have been found to be the most effective in the private sector. In government, most CDOs follow the hybrid model." (Wiseman 2017) • "Rather, the results suggest that the biggest hurdles to an effective analytics program are [...], ill-fitting organizational structures, [...]. [...] low [enterprise] performers say their biggest challenge is designing the right organizational structure for analytics activities." (McKinsey 2016)
'Processes' [PRO]	<ul style="list-style-type: none"> • "A sound data governance program includes: a set of standards, policies, and processes that manage the quality, consistency, usability, security, and availability of information across the enterprise [...]" (PwC 2015)
'Leadership' [LEA]	<ul style="list-style-type: none"> • "Participants in our study recognized the importance of strong, proactive analytics leadership, which is central to embedding analytics within an organization's culture, governance and management." (Messatfa et al. 2011) • "A passionate sponsor who can clearly articulate the value of [...] analytics and can make that value concrete for both municipal employees and the public is an essential advocate for data-driven government efforts." (Wiseman 2017)
'Strategy' [STR]	<ul style="list-style-type: none"> • "[...] responses from the organizations that are seeing the most impact from their data-and-analytics programs offer lessons to others striving to make the most of their data. Those companies have [...] established a strong foundation for analytics in a few ways: clear data-and-analytics strategies [...]. [...] analytics leaders are nearly twice as likely as others to report enacting a long-term strategy [for analytics]." (McKinsey, 2017) • "Each leading data-driven city has taken a unique path. What is common at the highest level of data-driven government is a culture that values data and uses it to set priorities and allocate resources via stat programs, performance management, and advanced analytics." (Wiseman 2016)
'Culture' [CUL]	<ul style="list-style-type: none"> • "At the highest level of data-driven government maturity, [...] the city culture not only accepts but embraces the use of data." (Wiseman 2016) • "[CDOs] have the power to foster a culture of data use across government and create distributed capacity." (Wiseman 2017)
'Types, sources & currency' [TYP]	<ul style="list-style-type: none"> • "Data analytics projects rely on large volumes of quality data." (Wiseman 2016) • "Publishing a large volume and variety of data can also fuel curiosity and enable analytics and data-driven decision making, and can inspire a data culture in government." (Wiseman 2016)

'Data infrastructure' [INF]	<ul style="list-style-type: none"> • "A data analytics capability relies on a foundation of data infrastructure [...]. [...], data infrastructure provides the mechanism for data to be collected and shared with the public on open data portals, as well as with other departments of government." (Wiseman 2017) • "And they [high enterprise performers with regard to data and analytics] are nearly twice as likely to say they make data accessible across their organization." (McKinsey, 2016)
'Data governance' [GOV]	<ul style="list-style-type: none"> • "A data analytics capability relies on a foundation of [...] data governance [...]. A foundation is laid with data governance, establishing the policies and standards by which government data is collected and managed, as well as the strategy for data collection and sharing." (Wiseman 2017) • "A sound data governance program includes: (1) a set of standards, policies, and processes that manage the quality, consistency, usability, security, and availability of information across the enterprise [...]." (PwC 2015)
'Skills' [SKI]	<ul style="list-style-type: none"> • "It remains difficult, if not impossible, to find all of the skills required for analytics success within any one individual. Many mature companies, therefore, are establishing [...] teams, which have a mix of roles, including data scientist, analytics modeler, visualization expert, data engineer, business analyst and business domain expert." (Accenture 2015) • "[...], the high performers [enterprises] report significantly more advanced capabilities across the board. They are, for example, nearly five times likelier than their low-performing peers to say they have tools and expertise to work with unstructured and real-time data." (McKinsey 2016)
'Training' [TRA]	<ul style="list-style-type: none"> • "One of the best examples of [...] building capacity across government comes from San Francisco, where the CDO's office [...] offers training to city and county staff on a variety of data skills through the SF Data Academy." (Wiseman 2017) • "[...], governments at this stage [highest level of data maturity] view analysts and data scientists as valued assets and therefore provide commensurate investment in training and skills development." (Wiseman 2016)
'Budgets' [BUD]	<ul style="list-style-type: none"> • "Setting up the CDO office requires funding. The associated costs can seem high for companies that view the goal primarily as a means to comply with regulatory issues, rather than as a means to drive business value." (PwC 2015) • "[...] the more advanced the organization is in terms of analytics maturity, the more prevalent is an enterprise-wide funding and resourcing model." (Accenture 2013)
'Capacities' [CAP]	<ul style="list-style-type: none"> • "For most cities, the complex mathematical modeling and computing power required for this task is challenging, and many cities have developed

Table 2: Selection of relevant quotes from the content analysis

Research stage #02: Delphi method

The Delphi method is currently being conducted (research still in progress).

Calibration results

Number	Acronym	Outcome attribute	Short description
01.	[INT]	'Intention of data collection'	'City's intention of data collection with regard to 'data and analytics' projects, activities and/ or procedures within the city (or within the city's organization(s))'
02.	[COM]	'Combination'	'Combinatorial treatment of various data types and sources with regard to 'data and analytics' projects, activities and/ or procedures within the city (or within the city's organization(s))'
03.	[FRE]	'Frequency'	'Frequency of 'data and analytics' projects or activities and/ or procedures within the city (or within the city's organization(s))'
04.	[TEC]	'Technologies & methods'	'Types of technologies and methods utilized for 'data and analytics' projects, activities and/ or procedures within the city (or within the city's organization(s))'
05.	[PUR]	'Purpose'	'Types of different purposes of 'data and analytics' projects, activities and/ or procedures within the city (or within the city's organization(s))'

Table 3: Overview of preliminary attributes for outcome variable

The preliminary definition of the outcome variable is defined as the “level of utilization of ‘data and analytics’ within the city”. Thereby, the authors classify the potential outcome variable by the means of five attributes (displayed in Table 3): ‘Intention of data collection’, ‘Combination’, ‘Frequency’, ‘Technologies & methods’ and ‘Purpose’.

The specific calibration of the potential causal conditions variables and the outcome variable (as indicated in sub-research question #02 and #03) is currently being conducted (research still in progress).

IMPLICATIONS

The merged conceptual overview, displayed in Table 4, classifies the potential drivers of cities’ utilization of ‘data and analytics’ into five broad (‘superordinate’) categories: ‘organization’, ‘direction’, ‘data’, ‘competencies’, and ‘resources’. The superordinate categories and the accompanying factors are drawn from the preliminary results of the first stage (incl. comparative case study and content analysis) of the multi-method approach.

Superordinate structure	Number & acronym	Condition variables	Short description
Organization	01. [STA]	'Stakeholders'	'Level of engage- & involvement as well as collaboration among certain types of stakeholders and the city (or (the) organization(s) within the city)'
	02. [STU]	'Structures'	'Organizational structures (e.g. units, positions or roles) that are directly or indirectly associated with the collection, management and analytics of data and their organizational distance as well as clear interfaces to relevant stakeholders and decision-makers'
	03. [PRO]	'Processes'	'Procedures and process steps (e.g., collection, management (among others), analytics to action generation) related to 'data and analytics' among staff and important stakeholders'

Direction	04. [LEA]	'Leadership'	'All efforts, behaviors and activities of the leadership team of the city (or the organization(s) within the city) related to 'data and analytics''
	05. [STR]	'Strategy'	'Strategy or strategies with regard to the collection, mgmt. and analytics of data within cities (potentially describing ambition/ goals, priorities, set of actions, resource allocations, performance metrics, etc.)'
	06. [CUL]	'Culture'	'Cultural norms, values and rituals within the city or across city organizations that are directly or indirectly related to 'data and analytics' projects, activities, or procedures'
Data	07. [TYP]	'Types, sources & currency'	'Types, sources and the currency of data collected within the city (or within the city's organization(s))'
	08. [INF]	'Data infrastructure'	'Deployed infrastructure in the city (or in the organization(s) within the city) related to 'data and analytics''
	09. [GOV]	'Data governance'	'Level of proficiency and execution in the following 'data governance' areas: standards, regulation & licenses, security'
Competencies	10. [SKI]	'Skills'	'Level of data knowledge and expertise (with regard to collection, management and analytics of data) among staff of the city (or among organization(s) within the city) and important stakeholders'
	11. [TRA]	'Training'	'Online/ offline training courses, developmental exercises or other educational chances as well as existing plans and aspirations that provide staff and important stakeholders the opportunity to gain or improve their respective 'data and analytics' skill set'
Resources	12. [BUD]	'Budgets'	'Budgets or financial allocations for 'data and analytics' – related activities and expenditures'
	13. [CAP]	'Capacities'	'Any external capacities used to extend the city's 'data and analytics' capacity through the collaboration or cooperation with various types of stakeholders'

Table 4: Overview of preliminary condition variables of interest

The preliminary study should be seen, more broadly, only as a first step that delivers initial insights as to which conditions may cause the outcome of interest. As such, this study provides the basis for exploring the possibility that several causal pathways may lead to (smart) cities' utilization of 'data and analytics'.

CONTRIBUTIONS

CONTRIBUTIONS TO THEORY

Identification of drivers of cities' utilization of 'data and analytics'

This study identified a preliminary set of drivers that appear to be essential to cities' utilization of 'data and analytics' and, thereby, form a part of a new theory around this topic. The set of drivers also enables scholars to conduct a systematic analysis of 'data and analytics' utilization across (smart) cities. The authors expect that future studies may be able to utilize certain tools and findings from this study in order to generate additional insights to the area of (smart) cities, 'data and analytics' or related

fields. For example, further research could utilize the building blocks from this study (e.g., condition variables) to examine various other phenomena (e.g., to test other conceivable outcome variables of interest).

Description of factors to indicate the presence or absence of the outcome variable

While the previous literature has tangentially (if at all) mentioned (smart) cities' utilization of 'data and analytics', a clear operationalization of this construct (or parts thereof) had yet to be developed. Therefore, this study contributed a first attempt not only to define "a city's utilization of 'data and analytics'", but also to provide clear guidelines or indicators on how to operationalize this construct. As the significance of 'data and analytics' within and for (smart) cities has been meaningfully increasing (and will likely continue), establishing a set of indicators to measure a city's utilization of 'data and analytics' appears to be crucial for further research. For example, in order to carry out a cross-case comparison of several (smart) cities, clear evaluation metrics are needed and are crucial for measuring the presence or absence of cities' utilization of 'data and analytics' in a comprehensible manner.

CONTRIBUTIONS TO PRACTICE

Increased attentiveness towards variety of potential 'data and analytics' factors

As a result of this study, the authors were able to illustrate the existence of a wide range of potential drivers ('condition variables') that may influence or have an impact on cities' utilization of 'data and analytics'. This, in turn, can make city officials, in general, aware of the diversity of factors that need to be taken into consideration if 'data and analytics' utilization is to be substantially changed or affected. Although the preliminary results achieved so far do not indicate to city officials which factors (or combination of factors) to prioritize (a subsequent study will address this question), the sheer demonstration of the set of possible factors can already assist city officials and help frame the causal drivers. More specifically, city officials can step up their efforts on existing drivers or can initiate first attempts at engaging drivers that have been ignored or neglected so far.

Standardization tool for assessing cities' 'data and analytics' utilization

Although the literature (e.g., Goldsmith & Crawford (2014)) and semi-structured interviews with city experts explicitly highlighted the significance of cities' utilization of 'data and analytics', little research has been conducted to date to measure the presence or absence of such a construct. Therefore, this study offers a preliminary list of indicators in order to assess and depict a city's status quo with regard to 'data and analytics'. At present, the majority of cities do not measure either the absence or presence of their 'data and analytics' utilization or measure only subsections in different and extremely diverse approaches. Consequently, this study's preliminary indicators may be used as a standardization tool and evaluation support for overseeing and assessing cities' 'data and analytics' utilization in a consistent manner.

LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

LIMITATIONS

Issues with regard to sourcing of the data

Despite the diversity and depth of the various data sources used within this research (e.g. semi-structured interviews, etc.), there are certain limitations that need to be addressed. For example, critics may argue that the data variety and magnitude used in this research study may not be sufficient to provide reasonable support for the results and findings. Due to the relatively small number of case studies utilized in the comparative case study analysis phase, the authors' ability to detect and incorporate all conceivable and applicable conditions that might influence a city's utilization of 'data and analytics' was to some extent limited.

Nevertheless, for the purpose of theory building, the relatively small number of cases were deliberately selected by the authors to explore the outcome of interest. Furthermore, several precautionary measures have been taken throughout the research in order to alleviate the discussed concerns. For example, this study based its findings on several data sources (e.g. semi-structured interviews (comparative case study analysis), other published literature (content analysis)) which differ widely in terms of the type information provided, level of detail, and insights provided. Moreover, recurrent assessments of the collection methods were enforced to safeguard the internal validity of the collected data.

Concerns related to the analyzing of the data

The study often identifies and describes certain potential condition variables with the help of stakeholder assessments (or actions). However, by treating and evaluating certain stakeholder individuals or groups (from different case study types (e.g., in terms of their population size, economic strength, type of municipality, or geographical origin)) as a coherent homogenous set (with similar characteristics), this study forcefully harmonizes different stakeholder (and case study) types into an 'average' one. As a result, a more differentiated approach (e.g., a more sophisticated level of detail with different stakeholder or case study groups precisely defined at a sub-level) could potentially lead to a slightly adapted or considerably different list of potential causal condition variables. For example, the definition chosen of the 'leadership' condition variable can be seen as an aggregate of several distinct strands. With a more sophisticated sub-level of details, this condition variable could have potentially been split up into 'authority' (being in charge or command of 'data and analytics' activities) and 'sponsorship' (being supportive of 'data and analytics' activities).

However, to, at least, mitigate, if not to avoid, the debated limitations related to the analyzing of the data, precautionary measures have been taken. Recurrent reviews and sporadic stakeholder 'deep dives' were conducted to assure that the necessary depth of detail for the purpose of such an analysis were met. Moreover, the classifications of potential condition variables were employed from the literature, wherever possible.

SUGGESTIONS FOR FUTURE RESEARCH

Utilizing additional sources and supplementary case studies for analytical purposes

As pointed out earlier, the authors have tried to utilize a variety of data sources (e.g. semi-structured interviews, literature from various academic fields, etc.) as well as distinct types of (smart) city cases. The selected case studies had certain varying characteristics, notably with respect to population size (e.g., ‘small’, ‘medium’, ‘large’), economic strength, type of municipal government (e.g., ‘council-manager’, ‘major-council’), and geographical origin within the US (e.g., ‘East’, ‘Mid’, ‘West’). However, the authors were faced with certain limitations (e.g. timeframe of the investigation, available resources (e.g. labor) for conducting interviews, difficult or denied access to certain data sets, etc.) with regard to the data collection that subsequent research projects are not necessarily subject to. Therefore, the authors argue that the preliminary results of this study can, for example, be extended (e.g. by taking more condition variables into consideration) or validated (e.g. by studying a more diverse and larger amount of (smart) city case studies). This would enable scholars to assess whether the preliminary findings generated within this study apply to other circumstances and are therefore (to a certain extent) more generalizable.

Employing QCA in the context of (smart) cities and ‘data and analytics’

As research into (smart) cities and ‘data and analytics’ progresses and departs from purely qualitative analyses (e.g., single-case studies), the authors call attention to the added value that more comparative studies could bring to the field. Applying set-based analysis methods like Qualitative Comparative Analysis (QCA) (Ragin 1987; Rihoux and Ragin 2009; Schneider and Wagemann 2012) may offer a promising chance to move the field forward. The identified research gap calls for a more focused research approach not only to identify the set of condition variables (the focus of this study), but also to review the link between potential drivers and the cities’ utilization of ‘data and analytics’ (the focus of a subsequent QCA study to be conducted). Therefore, this preliminary study, in particular, has already generated an enhanced understanding of the potential set of drivers that provides the prerequisites to analyze their mutual dependencies. As a result, the authors argue that the application of QCA, a technique that permits the investigation of causal pathways that generate an outcome of interest (e.g., cities’ utilization of ‘data and analytics’), could create further relevant and applicable insights.

CONCLUDING REMARKS

The significance of ‘data and analytics’ as a facilitator and value driver for (smart) cities will only grow and, in all likelihood, be amplified by new technological developments (e.g., Internet of Things (IoT) and machine learning) in both the short- and long-term. Therefore, research on ‘data and analytics’ within (smart) cities appears indispensable — particularly at this juncture in time — where the ‘smart city’ concept, and thus cities’ utilization of ‘data and analytics’, is being confronted with heightened expectations. Therefore, of all the instruments at the cities’ disposal, analyzing and modifying cities’ drivers or enablers of ‘data and analytics’ utilization

seems to be among of the most relevant and beneficial. The identification of these potential drivers (as discussed in this study) could be of great value.

However, research on cities' utilization of 'data and analytics' has been comparatively limited and vague if set side by side with investigations of particular data-related topics (e.g., urban informatics). Thus, this preliminary study has investigated the research subfield in detail. To accomplish the widest systematic and holistic overview of potential drivers possible, the authors employed a multi-method research approach (incl. comparative case studies, content analysis, and a Delphi method (research still in process)).

The preliminary findings of the study reveal a conceptual overview that classifies the potential drivers' of cities' utilization of 'data and analytics' into five broad ('superordinate') categories: 'organization', 'direction', 'data', 'competencies', and 'resources'. Furthermore, five preliminary attributes have been identified that may serve as indicators of the specified outcome variable (cities' utilization of 'data and analytics'). In general, the results of this study reinforce the initial position with respect to the suspected variety of potential causal condition variables.

Nevertheless, specific findings are necessarily incomplete (e.g., with regard to the identification of all potential drivers) or have not been the focus of this research study (e.g., with regard to the multifaceted linkage between the potential drivers and the respective outcome) and would, therefore, benefit from additional research. Several proposals are suggested in order to investigate certain gaps and shortcomings further (e.g., employing QCA). Although this study presents only a preliminary base for further study, the authors recognize several limitations. Critics may focus on several issues with regard to sourcing and analyzing of the data that may trigger discussions about inaccuracy, arbitrariness, and preconceptions. In order to counteract the potential accusations, several preventive measures (e.g. usage of several data sources, recurrent assessments of data collection methods) have been taken throughout the research.

Overall, the authors recognize the tentative nature of this study's preliminary findings. However, the authors expect that the stated insights may (at least) inspire new momentum and trigger multifaceted discussions around (smart) cities and 'data and analytics'. Furthermore, the authors argue that, for practitioners, the results of this preliminary study could help inform the way in which cities can structure, enable, and manage to achieve increased utilization of 'data and analytics'.

To sum up, this study may offer much-needed insights on 'data and analytics' to take full advantage of the opportunities offered by (smart) cities. The authors hope that this study is thereby a step towards developing an appropriate response to the considerable urbanization problems and impediments that cities are currently confronted with and, more importantly, that still lie ahead.

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BUILDING PROJECT MANAGEMENT SKILLS IN UNIVERSITY PROGRAMS IN CONDITIONS OF UNCERTAINTY

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ABSTRACT

Decision-making in disaster scenarios in the built environment takes place both chaotically and rationally, sometimes systematically and sometimes serendipitously and relies on solutions that emerge as professionals, volunteers, communities, government agencies and bureaucrats respond. If engineering and construction professionals can better understand how these stakeholders interact and make decisions in the context of disaster scenarios it will assist the profession's ability to contribute towards developing resilience in project management in the built environment. Whilst there are systems available to support decision-making in disaster scenarios as they occur, there is a paucity of tools developed to assist in training new professionals, communities, volunteers and scholars to learn how to operate, react and make relevant and effective decisions. The paper highlights skills areas research has identified as necessary in conditions of uncertainty in the built environment. The outcomes identify an additional set of skills which university programs can incorporate to enhance the learning of flexible responses for project management in disaster scenarios in the built environment under conditions of uncertainty.

KEYWORDS

Uncertainty, construction management, project management, university program graduate attributes, policy

INTRODUCTION

Project management skills are considered an essential graduate attribute in Engineering and Construction (Takey & de Carvalho 2015; Walker 2015) In Higher Education, Construction Management, like Engineering and Medicine and other professions, is subject to the prescriptive determinations of professional associations. Policy prescriptions about essential graduate attributes from accrediting professional associations invariably are constituted within a framework of certainty in much the same way as policy studies analysts address policy generally. Policy studies are most often set within a rationalist context (Moran et al. 2006; Rein 2017; Sabatier & Mazmanian 1983). Policy is seen as rational, staged, or more simply, linear decision-

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making, and seen as an expression of general purpose or as formal authorization (Hogwood & Gunn 1984). Policy is also described as continuous and interactive (Rein 2017; Sabatier & Mazmanian 1983). However, another perspective sees policy as complex and messy (Ball 2012; Corbitt 1997). Ball (1994, p. 177) argues that ‘policies are not totalising, they do not address every eventuality, they do not specify every act, they do not speak meaningfully to all settings.’ This research asks, how do these prescriptions apply when projects in the built environment are subject to conditions of uncertainty such as with disasters?

Disasters are themselves complex and uncertain. In a disaster context, knowledge is characteristically unstructured and held in communities as either collective knowledge and sometimes as individual knowledge. The professional knowledge of communities of practice (Snowden 2002) in a disaster management context is knowledge held by formal organisations such as police, disaster battle agencies such as State Emergency Service (SES), the Metropolitan and Rural Fire Authorities, the Red Cross etc.,. However, there are also informal communities of practice in the form of social networks within, for example, towns, villages and cities that have relevant unstructured knowledge, and whose actions can simultaneously interact with formal professional organizations dealing with disaster. These interactions can be informal or formal, and interdependent or independent. Again, Snowden argues, others involved can be innovative and disruptive in contrast to formalized coherent groupings of bureaucrats and response organizing committees. Snowden argues that whilst there is knowledge and assigned actions to each group, knowledge is incomplete and not fully shared so there is no straight relationship between those involved in sharing and using knowledge to solve problems. There is in effect, an amorphous space where these elements of sense making of a situation, using and sharing knowledge, interact. It is muddled, often disorganized and rarely coherent. This situation has been recognized in existing studies of disasters (Jinks et al. 2011; Simonovic 2011).

The history of learning from disasters globally have been shown to create new knowledge and improve both the nature and effectiveness of responses and provides a strong basis of new or better resilience in the areas affected. These include, earthquakes in Haiti (Patrick 2011) and China (Li & Rao 2010), or the effects of tsunami in Indonesia, Sri Lanka and Thailand (Adger et al. 2005; Srinivas & Nakagawa 2008), bushfires and floods in Australia (McLennan & Birch 2005; Parker et al. 2009) or extreme weather events in the USA or Australia or the UK (Linnenluecke et al. 2012; Pielke Jr et al. 2008).

There is a gap in the education and training of disaster responders, just as there is a lack of understanding of whole-of-system dynamics (Simonovic 2011) and a lack of an integrated conceptual model that can assist project management (Haigh, Richard & Amaratunga 2010). When disasters inevitably destabilise systems and subsystems, an understanding of the relationships between components, their value and their external influences can provide a basis for sound judgement in decision-making. Current graduates emerging from university study are not doing so with the ability to make sense of complex systems (Wilensky & Stroup 2013) or operate efficiently in a trans-disciplinary environment (Remington-Doucette et al. 2013). Similarly, public and

private organisations face challenges in keeping the skill-base of their employees and volunteers up-to-date in the context of disaster scenarios (Haddow et al. 2013), citing reasons of finance, time, complexity, potential danger, communications. Risk reduction and hazard identification.

Disaster response relies on action by government, private and volunteer stakeholders. Different stakeholders have their own roles and responsibilities; they also have to coordinate with other agencies within an acceptable disaster response timeframe, which is often narrow and chaotic, and often under- resourced, and becomes a challenge to attainment of resilience. Understanding the complexity of the interactions between formal and informal communities of practice is important if engineering practitioners are to maximize their contribution to building resilience throughout the preparedness, response and recovery stages (Norman 2006; Wilkins & McCarthy 2011) of disaster management, although arguably engineers have the greatest role to play during pre and post-disaster stages (Haigh, Richard & Amarunga 2010). Engineers have an important role to play in disaster preparedness through, for example, designing disaster resistant structures in disaster prone areas, planning infrastructure repair responses, enabling engineering works timetables to support timely recovery and developing appropriate project management scenarios. During response, engineering practitioners need to navigate complex supply chains (Natarajathinam et al. 2009). In recovery, engineers need to learn which designs are best adopted to minimize impact of future disasters (Peterson & Perry 1999). These contributions require engineering practitioners to navigate and cross complex relationships with a wide range of business and community stakeholders (Miller 2015).

In addition, disaster events are never the same. Each disaster is unique, floods, for example, can happen in the same location but at different times can produce totally different damage outcomes (Collenteur et al. 2015). This is because there are complex interactions of variables involved. Therefore, for disaster response, stakeholders require a high level of preparedness and flexibility in their responses. These agencies have to be well equipped in terms of practice to face situations whenever they happen. They cannot rely on trial and error solutions or project management of those solutions. Unlike ordinary engineering, manufacturing or construction projects, disaster response projects are considered as high risk as they involve life and death. The stakeholders have to be able to accurately respond in a way that minimizes further damage and facilitates resilience. Currently, stakeholders predominantly rely on on-the-job training which is insufficient for the narrow window of time to respond (Whybark 2015).

Haigh, R et al. (2006) has indicated that there is a need for creativity, improvisation and adaptation knowledge for construction professionals on top of their day-to-day operations knowledge to help them see through complex and confused pictures and to prepare them to anticipate and respond to unexpected events. Reconstruction projects also require more than just a “business as usual” mind set, there is a need for additional skills and knowledge from construction stakeholders such as intangible contractual relationships and value of satisfaction (Aliakbarlou et

al. 2017). Each stakeholder professional has specific roles which they ‘learn’ their training from. However, in a context where events happen very quickly, and responses are directly affected by chaos, uncertainty, lack of communication and a sometimes a lack of certainty about who is where, about where resources are located, these stakeholders have to take on multiple tasks as situations eventuate (McEntire 2002; Riley & Meadows 1997).

There is an extant research literature which addresses uncertainty in project management in the Built Environment (Ballard & Howell 1994; Davies & Mackenzie 2014; Saunders et al. 2015). Mok et al. (2015) looked at uncertainties that occurred in mega-project. However, their focus is on uncertainty created by stakeholders and their interest in the project, rather than uncertainty created from disaster events. However, the attribution of these principles of uncertainty are not explicitly stated in accreditation processes. This paper emerges from an existing research project which captured critical dimensions in emergency management in higher education programs (Cooper et al. 2017). This paper extends the value of those critical dimensions and maps directives from within a policy of a Construction Management Professional Association in Australia (Australian Institute of Builders) onto learning attributes within a university program and compares those to the elements of uncertainty captured in the (Cooper et al. 2017) research. The policy document, *Standard for the Accreditation of Building & Construction Management Program* (AIB 2017), forms the basis for all accreditation of university programs in construction in Australia. The paper highlights skills areas that research has identified as necessary in conditions of uncertainty which the professional association did not focus on. The outcomes identify an additional set of skills for Project and Construction Management which university programs in the Built Environment can incorporate to enhance the learning of flexible responses for project management in disaster scenarios in the built environment under conditions of uncertainty.

Knowledge has structure and organizations have structure, and knowledge can therefore be classified and stored in a systematic way (Grant 2015; Nonaka 1994). In a scenario or specific context or event, this knowledge and the structures are stable over time (Evans et al. 2015). In a product development and/or engineering context this knowledge is ordered, ontologically sound and stable (Eken et al. 2015; Monticolo et al. 2015). However, in a disaster context the knowledge often becomes unstable and chaotic. The knowledge is unstructured, due to the existence of many stakeholders coming together (Palomares et al. 2015). Because of the natural chaos in the immediacy of a disaster event, it is difficult to build order and make the decision-making processes subject to ontological thinking. It is essentially chaotic. This knowledge then exists in a multiplicity of stakeholder actions. Structure and knowledge become blurred. This is relevant to engineering because in disaster when it starts until it ends, engineering must be involved in fighting, rebuilding etc. or in providing infrastructures for community recovery and engagement.

THE RESEARCH PROCESS

Scenario and problem-based learning environments are widely used to facilitate the consolidation of knowledge from previous lessons and encourage learners to critically and synthetically apply knowledge to solve problems (Zoakou et al. 2007). In addition, such tools enable learners to interact with each other and with the scenario context (Taylor, J & Evans 2005; Trillaud et al. 2012) in achieving learning outcomes (Jinks et al. 2011). The adoption of this concept has been applied in a pedagogical context in a variety of domains such as health (Schultz et al. 2012), business (Buytendijk et al. 2010), aviation (Schwaitzberg et al. 2009) and disaster management (Jinks et al. 2011). Online or e-learning is becoming more universally adopted in educational contexts around the world as a means of generating lifelong learning (Longworth 2003), more efficiently (Fish & Wickersham 2009). In many disciplines, blended or fully online modes of learning are increasingly popular and high-quality delivery is a necessity (Owston et al. 2013; Swan et al. 2012). As educators engage with learners in a different space, using new interfaces and technologies, it is essential to strategize effectively about how to maximise efficiency while achieving learning outcomes and creating a deeply satisfying learning experience for learners (Swan et al. 2012). The system being developing for this purpose harnesses the potential of learning tools that deliver both ‘event-based’ learning outcomes and experience in disaster contexts, as well as a holistic understanding of complex systems, in a virtual environment.

The initial phase of this research adopted a qualitative methodology using interviews (Taylor, SJ et al. 2015) and focus group techniques (Breen 2006; Onwuegbuzie et al. 2009; Stewart & Shamdasani 2014) to capture the elements necessary to support the building of the conceptual framework for scenario building as the basis of an IT-based learning system. For the interviews there were 2 participant groups targeted. The first group is composed of 10 higher education academics. The rationale for interviewing this group is to gain understanding about scenarios and game-based training; and about the advantages, disadvantages and common challenges encountered by educators who have experience using such teaching strategies. The second participant group was composed of 10 practitioners who are key stakeholders from disaster event response agencies who have provided data in a disaster events response specific context. The two sets of interview transcripts (from educators and practitioners) were analysed through concept mapping to identify common themes to inform the structure of the conceptual framework of the scenario-based learning system (Henly-Shepard et al. 2015). Concept mapping is a technique used to visualise relationship between emerged concepts and themes to construct new knowledge as the map reveal how individual concept connect to other concept to form holistic structure of a system (Cañas & Novak 2008). Data collected was analysed and through evaluation reduced from 96 elements identified to a proposed set of 10 more generalized elements.

Five focus groups were then conducted with stakeholders including DataLink Group (a company involved in development of disaster response software for the industry), the State Emergency Service, the Hunter Research Foundation, the Red Cross, and the Habitat for Humanity group. The focus groups were conducted to

validate the initial conceptual framework listed above and develop examples of disaster event scenarios. Groups of both educators/academics and disaster response practitioners participated in focus groups again to refine the themes, identify and further refine the key nodes of knowledge and action (elements of the proposed system), and capture the processes in the disaster events they had experience in. This was then analysed and the elements in the system reduced, or summarized further.

Finally, 3 workshops were conducted in three different large cities in Australia with multiple stakeholders in each workshop incorporating educators, volunteers, disaster professional, disaster battle agencies, and insurance companies and from non-government and from government agencies. The purpose of the workshops was to test and validate the revised conceptual framework structure which emerged from the interviews and reviewed in the focus groups. All stakeholders were asked to map their knowledge about disaster events to the researcher's reduction of the elements of knowledge reduced to 6 elements. This deliberative collection of knowledge has produced a significant accumulation of knowledge about disasters as it affects all stakeholders across the disaster spectrum. Our task now is enabling that data to inform the basis of a conceptual framework on which to build an IT-based training platform for training students across multiple disciplines and to train professionals.

In the final phase we have mapped and analysed the outcomes of those focus groups and workshops against one university's Construction program. This was done to ascertain the degree of match and propose where additional skills can be added to the outcomes of the programs and deal with the essential uncertainties inherent in the effects of disasters affecting construction management in practice.

FINDINGS AND DISCUSSION

The framework elements for the training systems that emerged from analysis of the first round of research using interview data were 96 nodes of knowledge which were then reduced initially to the following key elements for learning attributes in the uncertain conditions that correspond with disasters in the built environment:

- organisation structures [OS]: disaster response agencies organizational structures are different in the nature of who responds to what type of disaster; teams within these organisations form under event circumstances and change from event to event.
- decision-making processes [DMP] and time: different stakeholders decision making processes are organizationally and hierarchically dependent, sometimes making decision-making time consuming and adding complications to the disaster response time;
- protocols [Prot]: disaster response process and protocols (process and procedure) impact on how inter and intra-stakeholders make decisions to respond during disaster events;
- information needs [InfoN]: data management and communication (infrastructure and tools) affect 'battle agencies' as they require large amount of data and

information to help them make decisions. This information often comes in various formats and from various sources;

- types of Disaster events [Typ], physical hazards and environments: different types of disaster events create various physical hazards that impact how battle agencies response to the events;
- economic constraints (resources) [Eco]; economic constraints that have impact on how stakeholders make decisions during the disaster events; and
- social or community impact [SI]: impacts on disaster events and how ‘battle’ agencies responses affect communities in their social context.

The research (Cooper et al. 2017) then applied those knowledge nodes above to the Hayes (2015) simulations framework and identified a set of critical dimensions in addressing emergency management skills needed in uncertain built environment contexts. In this paper we extend the analysis and map those initial knowledge nodes, and the specified dimensions against an exemplar prescribed set of attributes by the Australian Institute of Builders for construction management students in the Australian Higher Education context. The intent here is to examine which of those required attributes of dealing with conditions of uncertainty are included and identify as a result what could/should be added to the learning outcomes about Project Management in Higher Education programs in the Built environment.

The following discussion compares the mapping of each of the AIB Knowledge and Skills and program objectives against the Key Identified Elements of Knowledge needed for learning about uncertainty in a Built Environment context (Cooper et al. 2017)

AIB Knowledge and Skills and program objectives map against courses	Key Identified Elements of Knowledge needed for learning about uncertainty in a Built Environment context (Cooper et al. 2017)
1) Project management theory and principles	types of disaster events [Typ] social or community impact [SI]

Types of disaster are never homogeneous or uniform in their expression. Rather, disaster event can vary in intensity, duration, location and impact. Various studies also mention that disaster is a compound event, even the same type of disaster event and at a similar scale can reoccur in the same area but at a different time can produce totally different levels of damage (Mechler & Bouwer 2015; Zobel & Khansa 2014). This means that construction practitioners have to apply project management principles and adapt it to suits condition in each event as they go along. This often relies on application of project management principles on a trial and error basis which takes time. Each of these elements represents a degree of uncertainty that creates conditions where actions are required based on pre-planning and where possible

action can be rehearsed in scenarios in situations where disaster events are real possibilities. However, in other events such as the 1989 Newcastle, Australia (Crompton & McAneney 2008; Edwards et al. 2004; Kenardy et al. 1996) and 2011 Christchurch earthquakes (Bruns & Burgess 2012; Reyners 2011), there was no expectation of those events. In those circumstances reaction was affected by the immediate uncertainty each created, and the agencies involved in the immediate vicinities had no planning in place or training in the types of disaster that happened Christchurch 2011 Newcastle earthquake 1989. It can be argued that scenario planning in dealing with this uncertainty was lacking. Scenario learning for those involved could have solved the problem of slow response and unexpected change that occurred. This was important not only for better understanding the physical damage to the built environment, but also to understanding the responses of agencies and the impact on communities. In the professional association accreditation prescription in column 1 there is no explicit mention or attribution of such learning in the Australian Higher Education context. We would argue that treatment about conditions of uncertainty be included, explicitly based on the data collected from practitioners in this study.

AIB Knowledge and Skills and program objectives map against courses	Key Identified Elements of Knowledge needed for learning about uncertainty in a Built Environment context (Cooper et al. 2017)
2) Managing project teams	organisation structure [OS] decision-making processes [DMP] protocols [Prot]

A similar argument to the one above can be made for scenario learning using a framework like in Cooper et al (2017) to better resource students/professional learners with a more complete inventory of skills about the uncertainty of the impact of various organisational structures, organisational decision-making process and varieties of protocols in uncertain disaster contexts in the built environment (McGuire & Silvia 2010; Perry & Lindell 2003; Staw et al. 1981). Decision-making in teams or groups is often described as fuzzy and consensus seeking based on individual preferences (Pérez et al. 2014). In the immediacy and uncertainty of a disaster, the fuzzy nature of consensus seeking in developing responses has the potential to affect the ability to determine best management practices and increases the potential complexity of making decisions. The structure of managing project team in the accreditation standard is concerned fundamentally with a traditional construction project organizational structure of construction stakeholders, whereas project organization structure in disaster scenarios are different to traditional ones because the traditional certainties of expected professionals is supplemented in all sorts of ways by non-traditional professionals such as local authorities, response agencies, sometimes charity agencies, police and defence forces. These additional personnel

create greater uncertainty and the ability of project managers to undertake their work in these situations, we argue, require additional skills and different modes of thinking.

AIB Knowledge and Skills and program objectives map against courses	Key Identified Elements of Knowledge needed for learning about uncertainty in a Built Environment context (Cooper et al. 2017)
3) Project programming techniques	information needs [InfoN]

Information uncertainty in disasters has been shown to affect the management of communities (Sheu 2010), community coping mechanisms (Afifi et al. 2012) and be affected by the complexities in typical multi-organisational disaster response contexts (Bharosa et al. 2010). Again, the complexities created by uncertainties are not explicit in the accreditation documentation for higher education programs in Australia, yet their impact is considerable and we argued should be added.

AIB Knowledge and Skills and program objectives map against courses	Key Identified Elements of Knowledge needed for learning about uncertainty in a Built Environment context (Cooper et al. 2017)
4) Constructability	Not identified

For construction project management students, constructability is one of the fundamental skills they require. However, constructability under normal construction project circumstances and during and post disaster events (reconstruction) they are different. There are various constraints that need to be taken into account and need to be taught to students such as how disasters affect site clean-up, preparation, material demand and supply, site access, and material handling (Fayazi et al. 2017; Yi & Yang 2014). These constraints have direct effect on constructability and operation. In a recent bushfire disaster in Australia (Tathra, NSW March 2018), any notion of revisiting homes or reacting as soon as possible to the disaster by residents affected, was affected by the possibilities of asbestos contamination. This is an example of an uncertainty derived from the disaster event. This creates implications about the roles and responsibilities of each stakeholder. We do not expect stakeholders such as the State Emergency Service (SES) to have a thorough knowledge of constructability about buildings. However, there is a need for the disaster response team to consider getting construction practitioners involved in the team when the issue is related to buildings.

AIB Knowledge and Skills and	Key Identified Elements of Knowledge
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program objectives map against courses	needed for learning about uncertainty in a Built Environment context (Cooper et al. 2017)
5) Value Management	economic constraints (resources) [Eco]

Okuyama (2003) argued that there are a set of issues that impact on the economics of disaster responses in the built environment. These include problems of information and communication, and problems affecting supply and demand for good noting explicitly that “in a chaotic situation, many will behave somewhat differently as usual, creating further complicated economic activities after a disaster”. This affects people’s behaviour differentially, a point that was mentioned many times during interviews and focus groups in this research. Okuyama (2003) also noted the impact on local economic production planning and ultimately on long-term economic growth. Learning how to deal with these issues in the built environment was found to be significant in the interviews and focus groups conducted for this research, yet expectations about knowledge of their impact for programs such as construction management, and the specific implications for Project Management, are not explicit in the accreditation documentation for the Australian Higher Education context.

AIB Knowledge and Skills and program objectives map against courses	Key Identified Elements of Knowledge needed for learning about uncertainty in a Built Environment context (Cooper et al. 2017)
Quality management	Not identified

Uncertainty emerges in the immediacy of projects in responding to disaster events. Responders have training about process and how to deal with the disaster, derived from their expertise. That expertise is most often accredited and built on principles of quality. However, the serendipitous nature of events creating issues of immediate response often men decisions are made on a ‘hunch’, backed up by expertise and training. Quality becomes an issue in dealing with impact in the long term and informs the training and development needed to enable event responders to take the actions they need to.

At a very detailed level, these same “Key Identified Elements of Knowledge needed for learning about uncertainty in a Built Environment context” (Cooper et al. 2017) were mapped against a complete Construction Management program. The outcome was that the accreditation document, whilst seemingly complete and covering all elements need by construction practitioners, “*Standard for the Accreditation of Building & Construction Management Program* (AIB 2017)”, the policy lacks sufficient attention to disaster events and the conditions of uncertainty that emerge in

that context, notably when applied to project management. The accepted proscriptions of a rationalist policy are challenged by the uncertainties and complexity created in management projects dealing with disasters, supporting Ball's statement that 'policies are not totalising, they do not address every eventuality, they do not specify every act, they do not speak meaningfully to all settings.' The implications for training project managements required to deal with disaster scenarios is to assume the key knowledge elements listed above and then operationalise their project management accepting that they too don't specify every act and must be recontextualised to the differences inherent in the disasters context.

CONCLUSION

The research reported in Cooper et al. (2017) and extended here examining the relationship between the demands of professional accreditation and the "Key Identified Elements of Knowledge needed for learning about uncertainty in a Built Environment context", has shown a somewhat disconnect when applied to skills demanded for project management. The paper highlights the disconnect at both a broad degree/program level and at a micro-level across all of the courses within an exemplar Construction Management program in the Australian higher education context. Both levels of analysis demonstrate that the real needs demanded in the uncertainty contexts of disasters in the built environment are not explicitly included. Previous research about the development of expertise in construction professionals (Kanjanaootra 2017; Kanjanaootra & Corbitt 2016) highlights the importance of basic skills foundation for the professional to build on in the workplace. Expertise was shown to be not limited to formal, normal practice, but to the development and acquisition of additional skills sets to deal with uncertain contexts. With this in mind and the disconnect evident in the analysis in this paper, it becomes very important that those elements of uncertainty pertinent to the built environment be contextualised and included in the project management elements of those courses. However, there is a paradox here. On the one hand as academics we know the importance of both theory and practice, learning to think and learning to do; on the other hand, accreditation bodies focus on skill sets and practice and have expectations that all of these skills will be learnt. Our tasks in university is to resolve that paradox as best we can using both traditional and newly emerging methods of learning using technologies, both in real time and non-real time contexts. This is a complex conversation we continually have to have.

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DECISION MAKING AT THE MEGA PROJECT BOARDROOM

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DECISION MAKING AT THE MEGA PROJECT BOARDROOM

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ABSTRACT

The governance arrangements of an Australian mega rail project that was delivered under budget and ahead of schedule was studied in detail.

The relationship between project success and the project governance is not strong, however an increasing body of literature suggests that when a mega project fails, ‘poor project governance’ is one of the main reasons. This paper explores the concept of project board performance and the changing institutional governance required to manage a megaproject over a lifecycle. A qualitative methods approach was adopted to analyse the case. The Board and its sub-committee’s minutes were analysed which spanned the project’s six year life.

Findings from the study identified that the form of project governance may sensibly change over the project life; and that a novel governance structure was used to deliver the project. Structurally, the governance was designed with a single point of accountability, and the project governance arrangements were far more dynamic than previous literature suggests, as it necessarily changed over the project’s life in order to effectively manage risk.

KEYWORDS

Project governance, corporate governance, mega project

INTRODUCTION

Is there an optimal governance structure for a mega project? Many suggest one of the primary causes of project failure is the systematic failure of organizational governance (Too & Weaver, 2014), while other literature suggests that the lack of operationalization of governance is a major cause (Muller & Lecoivre, 2014). Project failure is marked by an inability to deliver to the project management concepts of time, cost, and quality and over the longer term to deliver business benefits. Questions continue to be raised as to why high rates of project failure continue to occur (Breese, Jenner, Serra, & Thorp, 2015).

Project governance board arrangements have previously been considered as a one-sized, one-dimension and stable structure arrangements. However, within the structure the board must govern the project and make decisions (Pelham & Duffield, 2013). There are multi-dimensional factors and dynamic decisions that are made, and

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this aspect of project governance has not been widely researched. Disappointingly, the literature continues to demonstrate that there are no commonly agreed definitions of ‘project governance’ (Bekker, 2014), and similarly, a shortage of research on the impact project governance has on a megaproject. To address this gap, the approach used in this research focussed on a case study of a Mega Transport Project (MTP), and it was investigated in detail.

This paper is structured as follows:

- Section two discusses the literature on mega project and project governance
- Section three discusses the methods used in the case study
- Section four provides a brief background on the case
- Section five presents key findings; and
- Section six concludes.

LITERATURE REVIEW OF MEGA PROJECTS AND PROJECT GOVERNANCE

THE DIMENSIONS AND DEFINITIONS OF MEGA PROJECTS

While the term ‘*mega project*’ is not new it has seen a number of definitions applied over time. The term often uses cost as the basis of a definition. Altshuler and Luberoff (2003) trace the term ‘mega project’ to late 1970s where the Canadian Government and Bechtel both used it. For both organisations the definition referred to project size and scale; quantified as a project with a value greater than \$US250m. But what now makes these projects so distinctive is their exceptionally large budgets, which require significant economic and political involvement (Lehtonen, 2014).

Pollack et al (2017) identified that, although the field of mega project research is relatively small, it is rapidly expanding and has primarily drawn upon concepts from the field of project management. In understanding the maturity of mega project research, they undertook a study that considered if there were any substantive and influential works on mega projects. Three key works were proposed as the first potential ‘*classics of mega projects*’³. While their evaluation concluded that only one of the three works (*Mega Projects and Risk*) could potentially be a classic, the research serves as a reminder of the relatively small body of research on the subject.

Since the early 2000s, the definition of a mega project has been better represented as those project types with multibillion dollar budgets, characterised by uncertainty, multiple network actors and political involvement (van Marrewijk, Clegg, Pitsis, & Veenswijk, 2008). One common trait with mega project definitions, however, is the overwhelming recognition that such projects had, and continue to deliver ‘*strikingly poor performance records in terms of economy, environment and public support*’ (Flyvbjerg, Bruzelius, & Rothengatter, 2013).

³, The three potential classics are ‘Megaprojects and Risk: An Anatomy of Ambition’ by Flyvbjerg et al (2003), ‘The Anatomy of Major Projects’ by Morris & Hough (1987); and ‘Industrial Megaprojects’ by Merrow (2011)

DIFFERENT TYPES OF MEGA PROJECTS AND CHARACTERISTICS

Regardless of definition, mega project are usually found in Major Transport Projects (MTPs), Large Engineering Projects (LEP)⁴, ICT Systems (IS) and Complex Real Estate Projects⁵ (CREP) (Priemus, van Wee, & Flyvbjerg, 2008). The sheer size of such projects, and their impact has attracted much attention in the media and literature, especially when they fail. Lehtonen (2014) suggests that much of that focus has been on the mega project ‘pathologies’, whereby the mega project is characterised by chronic cost overruns, time delays and not delivering the expected social and economic benefits.

This research is nested within MTPs, and in that domain Frick (2008) uses the “six Cs” to characterise a mega project. She argues that the characteristics are illustrative of the many facets of a mega project, and the six Cs provide a framework for evaluating specific case studies. The six Cs that characterise mega project are:

- Colossal – in size and scope
- Captivating – because of the size, engineering achievements and aesthetic design
- Costly – costs often underestimated and increase over the life of the project
- Controversial – participants negotiate funding and mitigation packages, engineering and aesthetic design plans and pursue construction
- Complex – which breeds risk and uncertainty
- (laden with) Control issues – who the key decision makers are, who manages and operates the project, and who are the main project funders and what restrictions they put in place.

While definitions of each of the 6Cs are open to interpretation, the characteristics are useful as a mechanism to further to differentiate between what constitutes a mega project, and one that is not. After this differentiation is made, the mega project governance arrangements can also be separately analysed. The ‘fifth C’ is noteworthy, as it differentiates mega projects as ‘complex’ and not as ‘complicated’. The International Centre of Complex Project Management (ICCPM) authoritatively addressed project complexity in their 2010 report on Complex Project Management. The position was that while *‘complicated projects comprise a plethora of distinct and linear elements essential to the project as a whole’*, complex projects have multiple mutual independencies (ICCPM, 2010, p. 18). With a complex project, the position was that when one variable changes, the impact may create new realities and paradigms of which traditional (project management) methods and practices are not adequate. In particular, complex systems (‘projects’) also display attributes of emergence and self-organisation (Lichtenstein & Plowman, 2009), which current project management literature struggles to consider.

In contrast, Lundrigan et al (2015) evaluated the underperformance of mega projects through the lens of a meta-organisation. Instead of differentiating and observing characteristics of a mega project, the position was that common to all explanations of mega projects, is the assumption that all mega projects are controlled by a unitary actor, characterised from being outright incompetent through to

⁴ Such as nuclear facilities, water treatment and military weapon systems

⁵ Such as hospitals and shopping malls

Machiavellian. A meta organisation is considered as a '*network of legally autonomous actors collaborating under an identifiable system-level goal*' (Lundrigan et al., 2015, p. 3) and this implies that a mega project is created through a central founding actor (an "entrepreneurial architect") who during the early stages of the project implements an archetypal structure and ideology.

MEGA TRANSPORT PROJECT (MTP) SUCCESSES

Success and failure of a project is often defined in terms of time, cost, scope and quality considerations. By the late 1990s, Bruzelius (et al) (1998, p. 424) were suggesting that processes used for developing and appraising mega projects required change. This position was based on their initial work that focussed on the tenet that good decision making should be about institutional arrangements promoting improved accountability, and the processes being used did not promote economic viability and environment soundness. This was further reinforced with the view that the 'conventional approach' to project development between government and private sector involvement was unclear. The main lessons from their work at that time was that for transport projects:

1. Cost overruns (of mega projects) of 50-100 percent were common,
2. Traffic forecasts were out by 20-70 percent compared with actual development results, and
3. Forecasts of project viability for major transport infrastructure projects are often over-optimistic.

By 2005, Flyvbjerg, Holm and Buhl had systematically demonstrated that project performance, as forecasted in terms of cost, had a poor track record with 9 out of 10 transport projects being delivered over cost (2005, p. 140). More recently, there are emerging debates on the importance of not just the project metrics, but on the longer term benefits that are delivered after the project is completed. Fahri et al suggest that project benefits can be recognised in both financial and non-financing forms, and while tactical benefits may be realised through the completion of the project, the strategic benefits need to be considered more comprehensively (Fahri, Biesenthal, Pollack, & Sankaran, 2015, p. 52). With these considerations there is a contrasting view of traditional project 'success', which is demonstrated through the work at the Omega Centre (University College of London) who specifically reviewed 30 MTPs from 10 different countries over a 5 year period (2006 to 2011). The research focussed on gathering generic and context specific conclusions on how and why MTPs were judged 'successful'. Their findings showed that the view of success can be misplaced due to excessive focus on the project management criteria, and according to specifications. The findings identified two significant, holistic and long term perspectives on 'project achievement': emerging objectives (which occurred during the project) and the second around decision making in regard to risk, uncertainty and complexity decision making (Dimitriou, 2014, p. 391).

Mega project governance arrangements tend to be hybrids of meta organisations, which blend both open pluralistic systems and closed hierarchical systems (Lundrigan et al., 2015, p. 23) which is comprised a core and periphery. The core hold resources critical to deliver the system-level goals, whereby the periphery hold resources acquired through market transactions. With competing demands, differing preferences over priorities (concerning efficiency and effectiveness), and rivalry in high level choices can occur. These factors result in competing performance narratives which

cannot be reconciled. As a result, the ability to evaluate the overall performance of the mega project is surrounded in ambiguity. This at least provides one reason as to why MTPs have received such poor performance evaluations!

MEGA PROJECT FAILURE

In the context of mega project failure, the financial consequences alone can have wide impacts beyond the project. In response to such financial impacts, many countries have implemented improved governance controls to better understand and articulate project governance risk. Examples include Sarbanes-Oxley disclosure (USA) for internal project control risks (Dinsmore & Rocha, 2012) and governance guidance for Arm's Length Bodies (ALBs) in Northern Ireland (Ireland, 2007).

Hindsight provides clear and over-simplified reasons why mega projects fail. From the perspective of management consultant firm McKinsey, there are three reasons why mega project 'go bad'; and KPMG produced a three-dot point summary of lessons learnt for mega project success. The recommendations are summarised in Table 1, and while the recommendations are both valid and identify some distinct issues, the wider literature identifies far more issues than just these six.

Mega project failure is not a new area of research as outlined by Miller et al (2000), who undertook a detailed study of large engineering projects (LEPs) failures from the 1970s up to the late 1990s. The research identified the primary reasons why each project did not succeed, and argued that the stable mode of delivery that had been used over the past 70 years or so (through using techniques of project shaping and delivery, and through expert design and competitive bidding) were being challenged as activists assert new rights, regulators promote competition and the methods of assessing risks were being reassessed (2000, p. 3). As the sponsorship models of delivery of mega project also shifts from large public and private firms to alliance groups (comprising developers, engineering firms and/or entrepreneurs), Miller et al identified that the gap between the realities of project performance and the theories for managing them, was widening.

Table 1: Failure and Success for Mega Projects based on McKinsey (2015) and KPMG (2016)

Reasons for Mega Project Failure	Blueprint for Mega Project Success
<ol style="list-style-type: none"> 1. over optimism and overcomplexity 2. poor execution 3. weakness in organizational design and capabilities 	<ol style="list-style-type: none"> 1. Integrating the sponsors and stakeholders, 2. Forming a capable independent delivery body and 3. Creating a governance that gives the delivery body freedom and accountability

PROJECT GOVERNANCE

Mega Project Governance defined

While Merrow suggests that the \$US1 billion criterion for defining a mega project is completely arbitrary and misses considering complexity and project environmental

aspects of the project, he states that the cost is less arbitrary than it seems: ‘*in the neighbourhood of a billion dollars is where we see project outcomes begin to sharply deteriorate*’ (Morrow, 2011, p. 15). As was previously discussed, definitions around project governance are varied. This is highlighted by Too and Weaver (2014) who state that there are generally held misconceptions that governance is focussed on due process and control. Ansell (2016) suggests that definitions of governance are popular, but often very slippery terms. Definitions are either too narrow or are too open to contextual interpretation. In order to better define governance, the term often has a conjunction with a particular qualifying prefix – ‘*good*’ governance, ‘*corporate*’ governance and ‘*multilevel*’ governance, just to name a few. Unfortunately, adding the prefix does not necessarily assist in defining governance any clearer. For the purposes of this research, the broad definition of project governance is used. Apart from the scale, complexity and implied risks of a mega project, there is no compelling argument to see why this definition could not be used for mega projects too.

“it comprises the value system, responsibilities, processes and policies that allow projects to achieve organizational objectives and foster implementation that is in the best interests of all the stakeholders, internal and external, and the corporation itself” (Müller, 2010).

Corporate arrangements and mega project governance arrangements

Due to there being limited consensus on mega project governance definitions, the same applies to mega project governance structures. In order to compare the governance structure used on this case study, a sample of three commonly used project governance structures are presented (see Annex A). The first structure (Fig 1) describes a commonly used Private Finance Initiative (PFI) delivery model. It shows a simple reporting structure, allowing for clear accountability and decision making (Patel & Robinson, 2010). This model focusses on the importance of the project governance function being shared between the senior user, a (project) executive and a senior supplier. The second structure (Fig 2) from the Association of Project Management describes the relationship between corporate governance and project activities. The Venn diagram shows the relationship between the board, major project stakeholders and alignment of projects as the key to structuring project governance (APM, 2004). The third structure (Fig 3) is from a best practice project governance guide that describes a Public Private Partnership (PPP) structure. It focuses on the relationship between a department, steering committee and the relevant authority. In this structure, the complexity of the governance relationships relating to functional roles within the structure.

In each of the structures, a hierarchical construct exists where a higher level group oversee the work of a subordinate. In each, the organisational structure is oversimplified to show the key relationship of how work is compartmentalised and divided up. There is one view that complex [mega] projects are being used for strategic transformations, yet they exist in the context of uncertainty which makes governing the project difficult to deliver detailed objectives. In such circumstances, there is a requirement for skills in technical matters and the ability to function in turbulent operating environments (Pitsis, Sankaran, Gudergan, & Clegg, 2014). This suggests that the outcomes required (of the mega project) could actually be more important than concentrating on the project governance structure to deliver the project. This position is reinforced by Too and Weaver (2014), who suggest that ‘good

governance’ is about achieving an optimal balance between the four elements of portfolio management, project sponsorship, project management offices; and projects and programs.

While Frick (2008) and Lundrigan et al (2015) identified characteristics of mega projects, Miller and Hobbs (2005) argued there was little in the project governance literature that addresses the dynamic nature of governance structures of mega projects. Their position was that the literature suggested that governance was primarily an oversight function; with that oversight function being quite stable despite changing activities and priorities within a project. From a project management methodology point of view, as advocated by many project management methodologies (such as in PRINCE2) also considers a project board as being static. Miller and Hobbs argued that ‘*governance regimes that are themselves dynamic – that can change themselves to adapt to the emerging context*’ (Miller & Hobbs, 2005).

The need for adaptability is further reinforced by Too and Weaver (2014) who argue there must be a link between the outputs of a project and the business strategy for projects to be able to deliver value. Wilson et al (2010) argued that the complexity of a project necessitates a variety of governance structures, ranging from corporate governance and reporting obligations, to internal governance accountability. Within each stream, corporate and project governance is conceptualised as an oversight function, however, there is recognition that complex projects require governance structures that adapt to the context [of the project].

METHODS

USING A SINGLE CASE STUDY

The method used in this research was to investigate the project governance arrangements of a successfully delivered Mega Transport Project (MTP). A case study “*allows investigators to focus on a ‘case’ and retain a holistic and real world perspective*” (Yin, 2014). To refine the research, the case explored the detailed project board minutes, reports and agenda items over the 6-year life of the project. This allowed for a detailed longitudinal view of the issues the project board spent its time governing, and the changes that occurred to the structure of the board.

The methodology selected utilised Categorical Content Analysis. Content analysis examines social artefacts that are usually written documents, and uses coding as ‘the process of transforming raw data in to a standardised form’ (Babbie, 2015). For a qualitatively oriented procedure for interpretation of text, Kohlbacher (2006) identifies ‘structuring’ as a distinct analytical procedure that is the most crucial technique of content analysis. The goal is to filter out particular structures and it requires the development and use of the ‘coding agenda’ as part of the category application.

The study of a Case can involve single or multiple cases; can use qualitative, quantitative (or both) forms of evidence; and can be used to achieve various aims from providing a description, to testing a theory or generating theory (Eisenhardt, 1989). In this instance the research was used to provide a description of a Case. The data sets analysed were the monthly project board meeting minutes, its subcommittee minutes and interviews with the board members. This data was triangulated to provide detailed insights in to the key functioning of the project’s governance body.

DESCRIPTION OF TECHNIQUE

In the fields of business administration and management, there is an understanding that cases and case-based teaching can be more important than rules (B Flyvbjerg, 2004). This view is reinforced by Harrison (2013) when using mixed methods research in business. Harrison suggests that mixed methods research, where qualitative and quantitative components are used in a single study, is linked to pragmatism as a philosophy and pragmatic inquiry includes induction, deduction and abduction. One of the design types, triangulation, is described as a convergent design type where the components are combined to triangulate findings to be mutually corroborated. Content analysis is a research method used to systematically evaluate the symbolic content of all forms of communication (Kolbe & Burnett, 1991, p. 243). In this case, the board minutes were collected and were analysed in an unobtrusive manner, free from any bias other than that created through the coding process.

Any direct method of enquiry can have yielded biased responses. As the minutes of the board meetings were time bound, the method deployed allowed for the case to be considered within a distinct environment and timeframe. The evidence was wholly based on documented evidence throughout the project's life. Along with the data collected and analysed through the board interviews, the rich data sources were able to be contextualised and interpreted in order to test findings against theory.

SELECTING SUITABLE CASES

Gaining access to a detailed source of data on one mega project, over its whole lifecycle was a key consideration for the case study investigation. Many studies have retrospectively focused on 'why projects fail' (Frese & Saunter, 2003; Williams & Samset, 2012), with a series of recommendations of what (future) projects should change or improve. One of the limitations is an understanding of the governance arrangements used. With that gap, there is opportunity to research what a mega project board sets out to do and consider if it effective in doing so.

The selection of the case to study was an important consideration in order provide a deep understanding of the governance function of a successful mega project. The following criteria were developed: identification of mega projects that were either successful (or not); had a sufficient body of knowledge and data sources available in order to undertake research; and be of significant interest so the case/s studied would have broader significance to the overall sector. Fulfilling these criteria was significantly harder than expected, as getting access to detailed data sources, especially for mega projects, was difficult. While there are large bodies of publicly available data sources on failed projects, through media, audit reports, cases and so on, for successful projects there is little.

CRAFTING INSTRUMENTS AND SHORTCOMINGS

A suitable case study was identified, and its details will be discussed in the next section. Using a qualitative approach, the board and subcommittee reports were analysed using the content analysis technique to make inferences about the board's functioning by systematically and objectively identifying special characteristics of messages (Berg, 2001). Eisenhardt (1989) suggests that, as for hypothesis testing research, triangulation from multiple data collection methods provides stronger

substantiation of constructs and hypothesis. This research involved one investigator who used a sequential three phase data analysis process. The first phase was to visit the project case study's office site over a number of months, and after being provided full access to all project files, identified a primary data source. The focus was to analyse the written documentation, namely the project board meeting minutes and the board subcommittee reports to understand from the minutes, what decisions and activities the board focussed on.

Selecting content analysis as the method to research the case has its own limitations. For qualitative analysis, it firstly extracts the relevant parts of the text (or material) and then analyses them. Because of this process, the method can only be used if the text itself is not the subject of examination (Kohlbacher, 2006, p. 20). The subjective nature of the coding process, which required classification of the content of the board minutes, using a 'master' coding book was recognised. The interpretation of codes and their application could be strengthened through having multiple researchers coding the same documentation and then comparing the coding similarity.

Qualitative research can be more appropriate for answering questions that address the why and how; and when qualitative analysis examines a few, the ability to generalise the results can be lost (Harrison III, 2013, p. 2160). This research focussed on a rare type of mega project – one that was successful! A limitation of content analysis is that it is often limited to reporting specific elements of communication (Kolbe & Burnett, 1991, p. 244). In this case, the actual board meetings were recorded in the minutes, which was the primary document for analysis. Content analysis often results in categorical data, rich in descriptive and identification, but less sensitive to the subtleties in communication from other research methods. To address this weakness, an additional validation step, using a delphi study, was introduced to strengthen the potential limitations and bias.

VALIDATION OF RESULTS – DELPHI STUDY

The use of Delphi analysis has been traced back to the 1950s but although it has a long history, the knowledge about the use of Delphi is divided. Mullen argues that some hail it as a well-established technique while others imply it was not widely known (Mullen, 2003, p. 37). At its core, delphi studies involve a questionnaire being sent to participants whereby the responses are collated and recirculated, and participants are asked to confirm or revise their responses based on new information. Keeney et al (2010) identified that there are hundreds, if not thousands of studies in the literature using on the different Delphi methods. Variations to the classical Delphi from a method and procedural perspective are often called modified Delphi, and these differ in the administration procedures, the number of survey rounds, and the data collection techniques. A commonly seen design includes three rounds whose aims can be quite different (Quyên, 2014).

While Loo (2002) identified that other group decision making methods have been developed, he identifies several advantages of Delphi over others. The first is that the Delphi is individual, anonymous and independent. A second is that it avoids interpersonal conflict and communication issues as there is no interaction between the members. A final benefit is that due to the successive rounds, the moderator can build upon earlier results and sharpen the focus the study.

The Delphi was a structured communication activity that used a panel of experts to develop a systematic, interactive consensus method. The participants were the Project Board members. All the board members participated. Board members were provided with a list of initial findings across 12 governance dimensions and 100 potential indicators and asked to rank the most important indicators.

BRIEF BACKGROUND ON THE CASE

The case was the \$AUD 4.1 billion Regional Rail Link (RRL) project which was delivered in Victoria, Australia (2008-2014)⁶. The project was initiated following a Government sponsored report, ‘Investing in Transport, the East West Link Needs Assessment’ (Eddington, 2008). The report made two recommendations for a metro [rail system], which included a new rail connection to improve regional rail service to the city. In total, the 90 kilometres of new rail infrastructure was laid, to connect the regional city of Geelong to the centre of Melbourne. By implementing the project, the economic value of the investments were projected to be 1.2⁷, meaning the project would have a positive economic impact on the State (Meyrick, 2008).

The project was delivered below its original budget and ahead of time over a seven year period. In 2014 it was recognised as the Infrastructure Project of the Year, delivering ‘a step change for commuters travelling on one of the state’s busiest corridors’ (IPA, 2014). The case is an example of a mega-project that was widely heralded as a success. With a project of this size, there will always be some element of opposing views (see for example ‘More tracks, slow trains’, Nestor (2011)), however opposing views to the benefits and success of this project were few and far between.

PROJECT GOVERNANCE STRUCTURE

Project governance practitioners consider that implementing a project governance structure is one of the key project management activities, however the literature currently does not extend past the project board being in place. In non-complex and non-mega projects, project governance arrangements can be administered using conventional project governance techniques, including procurement and scope management to transfer risk to parties most capable of managing it.

The governance structure of the Case developed over time, with the evolving governance structures implemented over the lifecycle, as outlined in Figure 1. The procurement and construction delivery phase constituted the bulk of the project, and as a result a rich source of documentation was available. The evolving governance structures are labelled as Stage 1, 2 and 3. The first stage addressed the early development of the project, where strategic alignment, development and planning was undertaken. Stage 2 was the translation of the strategy and planning stage, from business case to the procurement and delivery. Stage 3 was the physical completion of the project and hand over to the operations and maintenance stage lifecycle stage. Stages 1 and 2 project governance documentation was included in the analysis; while the Stage 3 governance structure is shown for completeness.

⁶ further details of the specifics of the case can be found at ‘Mega-project governance – a case study in to the governance of a successfully delivered project’ (Pelham & Duffield, 2016)

⁷ including Wider Economic Benefits (WEB)

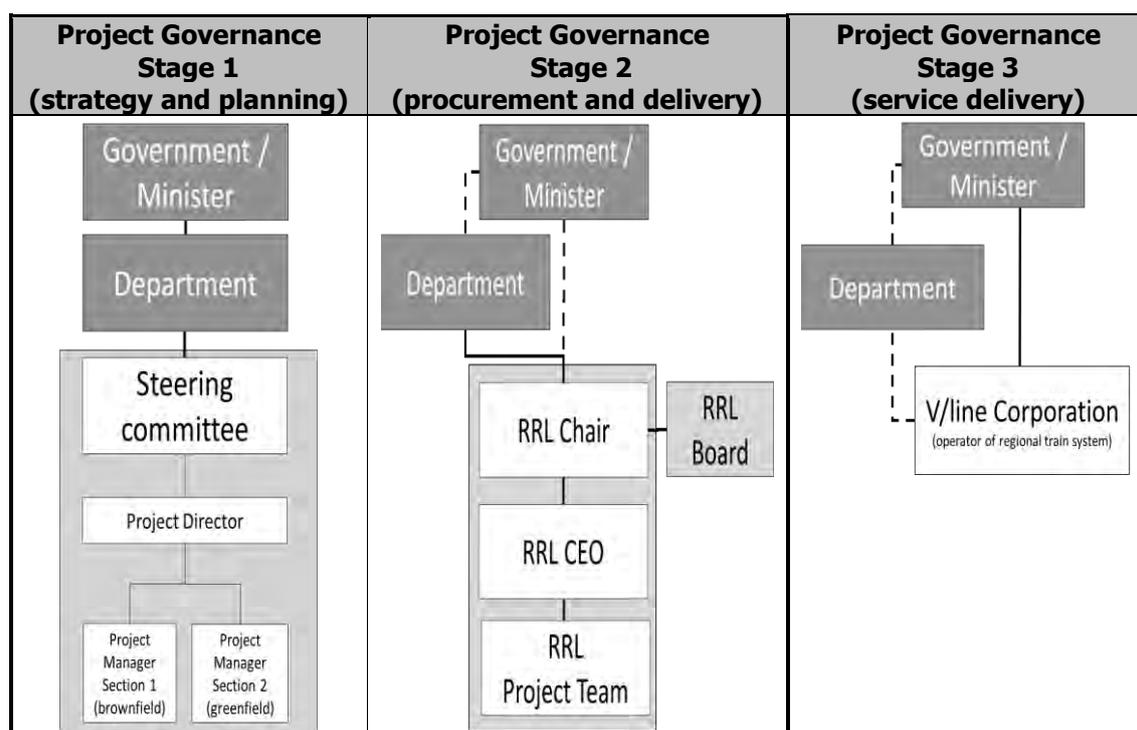


Figure 1: project governance structures for the case

The composition of the Project Board saw two different board structures implemented during the lifecycle – the Project Steering Committee (PSC) during the Stage 1, and the Regional Rail Link Authority (RRLA) Board during Stage 2. The first saw the project originally as part of a government department. This governance arrangement saw the project governance as part of a project planning process, where a department would develop a proposal (over a number of years) for consideration for funding. Only five formal project governance meetings were held during this stage.

The Stage 2 arrangement saw the creation of a new entity, the Regional Rail Link Authority as a separate Administrative Office. It had the sole purpose of delivering the project through the procurement and delivery phase. The stage 2 project governance was in place for the longest of all the stages (5+years). The stage 3 governance arrangement occurred when the project was physically completed and was handed over. The stage 2 arrangement had a core team who remained on staff to close out the project, attending to defect rectification and to close the Authority.

The Stage 2 project governance was novel on two structural issues. Firstly, the board was appointed as to act as an advisory board only. Traditionally a project board would be accountable for the project, but in this instance the board was advisory. Special legislation was required for the RRLA which did not provide for the project board to operate as ‘Directors’, only recognising the ‘Head’ of the organisation. The Chair (the ‘Head’ of the organisation) therefore was the responsible officer for the project, and Board members were technically advisors to the Chair.

The second structural difference was the *somewhat* unique sub-committee structure, which was given delegation to resolve project integration risks before being escalated to the Board for resolution. Corporate governance board structuring is well

documented, understood and implemented. Corporate governance frameworks generally suggest the use of sub committees, and best practices are regularly updated and reported against in annual reports, with significant guidance, such as the Financial Aspects of Corporate Governance (Cadbury, 1992), the OECD Principles of Corporate Governance (OECD, 1999), and the ASX Principles of Good Governance and Best Practice Recommendations (ASX, 2003)

Within the field of project management, such frameworks and practices focus primarily only on the need for a governance structure and process. Too and Weaver identify that focussing only on the mechanism needed to achieve governance does not represent good governance; and current project governance models have shortcomings that can result in fundamental conflicts of interest (Too & Weaver, 2014, p. 1386).

KEY FINDINGS

TRIANGULATION - THE THREE PERSPECTIVES OF ANALYSIS

Three perspectives of the project governance were investigated: the first involved the content of the Project board minutes; the second involved the monthly reports prepared by the project board sub-committee. Collectively the two provided a grounding for the development of a set of board member interview questions to enable perspective three to be executed. The third perspective involved individually interviewing each of the board members, and through use of a semi-structured questionnaire, gain an understanding on their perspectives of the decision making and insights they experienced from governing the mega project.

First perspective – project board minutes

The first perspective provided some compelling insights in to the decision making and actions of the project governance boards. In total, 233 different individual codes were created to capture the subjects discussed, and the specific issue within each subject. To enable an understanding of the project governance decision making, the results were separated in to the Stage 1 and Stage 2 project governance results (see Figure 1), with results classified by the ‘subject area’ and the ‘issue’ addressed.

The stage 1 governance was in operation for 5 meetings, compared to the Stage 2 governance which was in place for 46 meetings over 4 years. Table 1 summarises the most frequently occurring codes, showing the focus of each governance arrangement. During stage 1, the results for ‘subject area’ shows that the most frequent issues were risks and procurement, while the issues discussed focused on the board members noting a number of issues, with a specific focus on the issues concerning the stakeholder, the project schedule and risks. Stage 2 results, showed a shift in focus to the ‘subject area’ being far more administrative, with a focus on recording who was at the meeting, the status of actions and the timing of the next meeting. Safety was the only non-administrative subject. This suggests that for this mega project, the board was very focussed interested in safety as a high priority topic. The ‘issues’ in stage 2 indicate that the board spent the bulk of its time on being updated and receiving reports on the status of various actions, specific project issues and due diligence, especially around safety obligations.

Table 1: core codes by stage and subject/issue

Steering committee (Stage 1)		Project Board (Stage 2)	
Subject area	Issue	Subject area	Issue
Risk	Note	Attendees	Reporting
Procurement	Stakeholder	Action items	Open action
	Schedule	Other business	Monthly status report
	Risk	Apologies	Specific work package issue
		Next meeting	Closed actions
		Safety	Due diligence/ safety
			Overview update

Second perspective – subcommittee reports

The board subcommittee implemented a proactive approach to reporting to the project board. The subcommittee reports were collated and analysed, and actions summarised in to two categories of ‘*issue of concern*’ and ‘*issue requiring action*’. The sub committee held 31 meetings which was only in place during the construction phase of the project. During that time a total of 364 issues and potential risks were escalated (see Table 2). Of those 364 risks, 27.2% required action to be taken either by the subcommittee or by the Board.

The escalation of risk highlights the importance of pro-active risk management for the mega project board. The results provide a detailed insight in to the areas of concern for each of the work packages and provide a basis to make some statements about the impact of project governance on a project. Risk management was identified as a core issue that required consistent and ongoing attention. For a successful project, as in this case, the risks required active risk monitoring, but less direct intervention by the board. This demonstrates that risks were ever present throughout the life of the megaproject, but in this case they were able to be effectively managed.

Table 2: total occurrences

Occurrence	Subcommittee escalations (count)	
	Of concern	Requiring action
Count	265	99
%	72.8%	27.2%

Third perspective – board member interviews

The third perspective involved individually interviewing the board members, and through use of a semi-structured questionnaire, gain an understanding from each on their perspectives of the decision making and insights they experienced from governing the successful mega project. The board interviews sought to validate earlier findings (from the two earlier perspectives) and confirm the collective decision making of the project board. This perspective triangulates the two perspectives. Responses (referred to as ‘indicators’) to 12 governance dimension questions were coded, with 100 different responses provided by board members. The responses will be discussed as part of the Delphi validation section.

The board survey responses were first analysed to understand the levels of ‘case similarity’ responses between each of board member. A cosine similarity index analysis was undertaken, which indicated the relative strength of responses against

each of the board members, using a dendrogram plot as seen in Figure 2. The dendrogram provided the strength of relationship between the responses and shows that there were four strong groupings between individual board member responses, those being:

- Group 1 (Board members A, J, G)
- Group 2 (Board members D, H, E and K)
- Group 3 (Board member I)
- Group 4 (Board member C)

Each of the four groupings were mapped using an agglomeration to compare the nodes. The higher the number, the higher the similarity index is. The dendrogram result identifies that on the project board, there are members who responded similarly (ie Groups 1 and 2), while Groups 3 and 4 provided lower similarities.

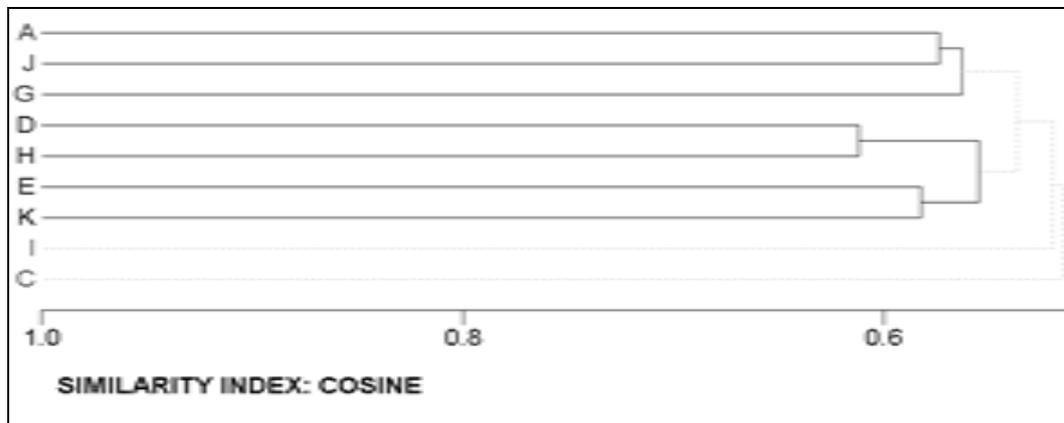


Figure 2: dendrogram of similarity index between board member responses

Next, a number of simulations were run to further understand the relationships using a 2-d conceptual plot approach. The model plots differentiates the strongest relationships from weaker relationships. The results are shown in Figure 3. The result of the conceptual plot provided a stress value of 0.31894 and an R² value of 0.5249. The regression result (0.5249) indicates that the overall data set neither has a high nor a low correlation. Regression scores that involve human interactions do not normally provide high regression scores, which could explain the result, to an extent. This model analysis therefore didn't provide any additional significant conclusions about the results in aggregate. It did however indicate that there was a divergence of results between each of the board members, which provided a new avenue for exploration.

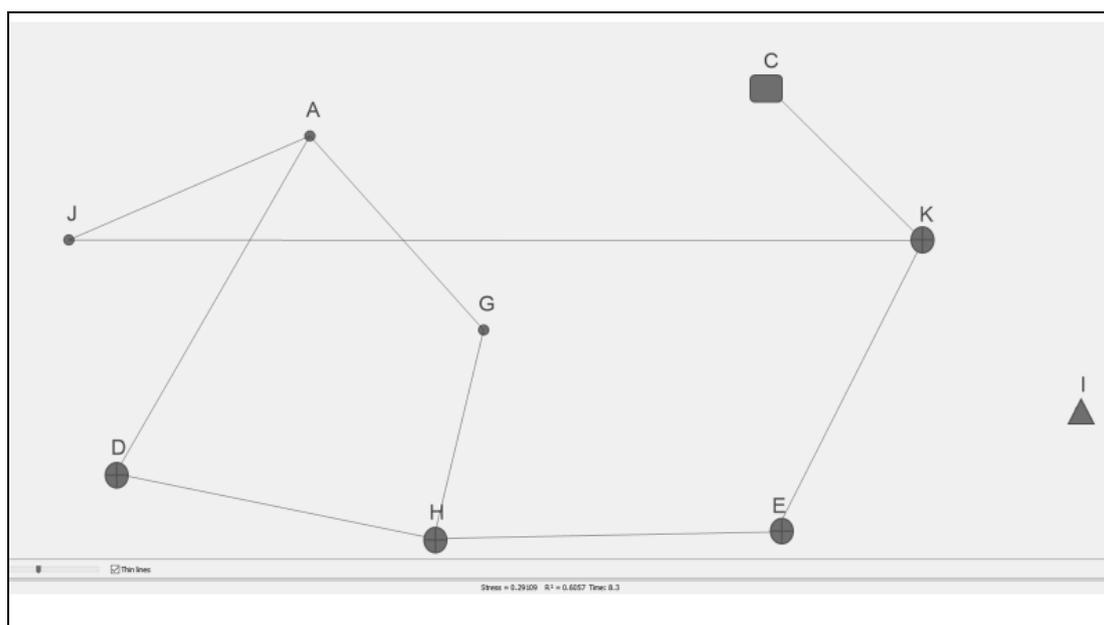


Figure 3- clustering of responses (interpretation based on strength of relationship)

DELPHI STUDY AS A VALIDATION

Board members were presented with the questionnaire that outlined the 12 dimensions and 100 potential indicators that had been created in the individual board member interviews. The Delphi required the board members were to identify which of the indicators in each dimension were the most important to them.

Each indicator within the 12 dimensions that received a response was then weighted to differentiate those indicators that were rated as being more important by a majority of the subject matter experts, from those indicators that did not receive a rating or were rated by a small number of the candidates. All but one of the 100 indicators were confirmed by the board as being relevant (to differing levels). Individual indicators within each dimension were analysed and compared against the overall mean score. In order to identify the most important indicators, those that scored above the mean were ranked (in priority order against each other). The results are found at Table 3, which ranks the relative importance of each indicator relevant to each dimension.

Table 3: Indicators above mean by dimension

Dimension	# indicators	% above median	Indicators above median (ranked by importance)
1. Primary role	5	100%	3. performance of the project 2. (previous) project experience 1. outcomes 5. drove positive culture 4. governance
2. Accountability	3	33.3%	3. both the board and the project
3. Board member contributions	11	36.4%	3. safety 8. leadership 6. believed in the project 2. stakeholder management

4. Governance type	2	50%	1. template
5. Governance effectiveness	2	50%	1. yes
6. Governance improvements	13	23%	1. introduce the board earlier 9. been closer to rail operators and end clients 4. end user/customer impact
7. Governance structure differences	8	50%	1. inclusive board 3. external board members 5. good team 8. single purpose
8. Key decisions	7	57.1%	1. packaging the work 4. outcomes focus 6. safety 5. risk management
9. Measuring governance success	9	44.4%	1. time/cost/quality 3. benefits realisation 2. stakeholder feedback 8. whole of life outcomes
10. Project governance need	6	50%	3. when a high degree of risk 2. large/mega project 4. need accountability and discipline
11. Relevant governance improvements	20	90%	9. front end planning 1. selecting boards 4. risk vs cost 8. CEO-Chair relationship 2. project ownership 15. right people 3. Project delivery/ structure 16. business case 17. risk transfer 12. construction vs operations 5. independent 7. skills review (of board) 10. long term planning 11. collaborative outcome 20. board structure
12. success criteria	12	33.3%	1. planning 2. control of time, cost, quality 7. good team 3. scope management
Total	100	n/a	

Finally, the Delphi results considered participation rates and mean standard distribution. The participants were asked to rank the indicators in priority relating to the level to which they believe is the most important (i.e. 1 through to 5, with 1 being the most important). The analysis of the data followed the methodology used by Quyên (2014) which considered the importance of the dimensions by consensus amongst the ratings of participants. The Coefficient of Quartile Variation (CQV) was used to reflect the level of convergence in experts' opinions and the level of importance of each indicator. CVQ is measured as:

$$CVQ = \frac{Q3 - Q1}{(Q3 + Q1)}$$

, whereby Q1 is the 25th percentile of the population and Q3 is the 75th percentile. CVQ is a descriptive measure of relative dispersion, and the use of CVQ can be preferred method of measuring relative dispersion in distributions that are moderately non-normal. In this case, it can be used to provide an approximate confidence measure of relative dispersion (Bonett, 2006).

Consensus provided an insight into the level of convergence of the experts' responses from the Delphi. The analysis provides a numerical result falling between 0 and 1. The lower the CVQ, the higher the level of consensus. As the Delphi limited the participants to rank their 'top 5' indicators within each of the 12 dimensions, not all of the indicators necessarily received a ranking, therefore understanding the more important dimensions, versus those considered to be the less important indicators, was quite relevant in confirming the findings from earlier findings. The overall average across the entire dataset was $CQV = 0.3$, demonstrating that there was a high degree of consensus with the overall Delphi study by dimension. This validates that the 12 dimensions were confirmed to be relevant by the board members, and each of the dimensions are individually mapped in Figure 4.

The results provided some strong correlations between 'similarity of responses' and 'clustering of responses', but also presented a number of divergent views. In particular differing responses between the board members highlighted the importance of having different perspectives (and skill sets) on a mega project board. While there was strong consensus and importance on the primary role, the need for project governance there was divergence in responses from the board on governance improvements and the board member contributions. While the board was selected using a skills matrix, the analysis demonstrated that there was divergence within the board members' responses. This is consistent with corporate governance practices of having board members being independent of managers, which can bring acumen and knowledge to decisions that consider shareholder needs (Baker & Anderson, 2010). For the mega project governance context, that would be to deliver the project within its constraints.

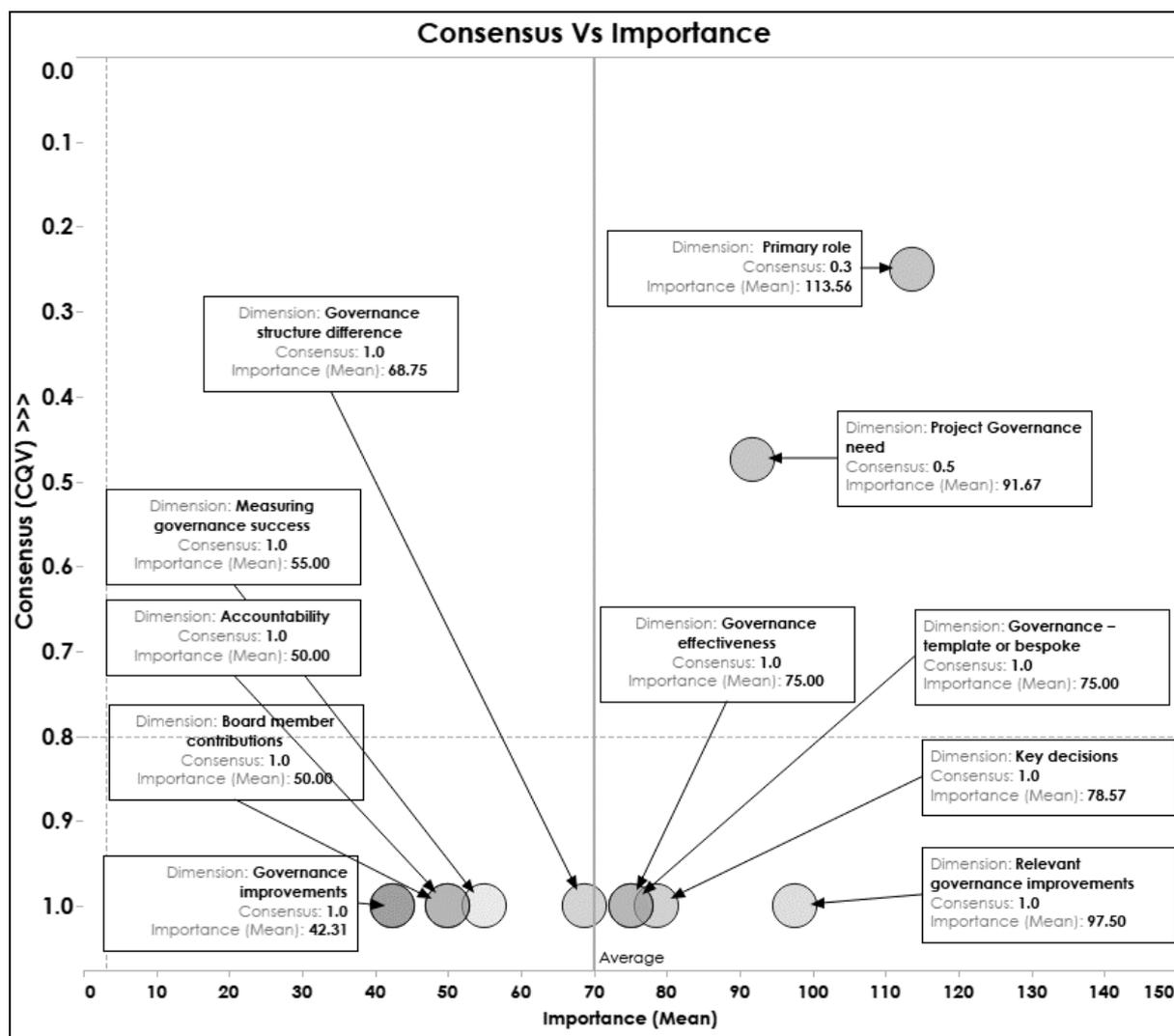


Figure 4: consensus and importance of Dimensions

CONCLUSION

The current literature demonstrates that there is an increasing number of insights in to governance arrangements of projects. While the recommendations generally provide structural improvements or orientation, many of the recommendations are taken from an external view of the project; the outside-looking-in perspective, and make suggest improvements. This gap is reinforced by Chang (2013) in his case review of a major UK transport privately financed projects that required significant restructuring. While the issues could be empirically explained by theory, ‘*without looking into this opaque box*’, essential aspects of the problems may not be being addressed (Chang, 2013, p. 629).

Carpenter (2008) suggests that (corporate governance) Boards spend up to four-fifths of their time dealing with the ‘*trivial many*’, whereas if the Board focused on the vital few issues (20%), the board’s value could create upwards of 60% greater value of their output than their input. Within the context of project management, one

dominant position is of the importance of front end governance, as a mechanism to improve the analysis and decision making at the start of a project, in order to reduce implementation costs (Samset, Berg, & Klakegg, 2006, p. 4).

The project governance structure studied was not static and was far more dynamic than previously understood. The project governance structure changed over the life of the project and the volume of issues and risks managed by the project board was significant. The analysis of the project board minutes showed that during the early stage of the project governance, there was a focus on risk management and procurement, which then changed focus towards safety and being updated and holding detailed briefings on the progress of the project. The stage 2 governance included a shift in focus to having more administrative structure, with a focus on recording meeting detail, the status of actions and the timing of the next meeting. The issues analysed in stage 2 indicate that the board spent the bulk of its time on being updated and receiving reports on the status of various actions, specific project issues and due diligence, especially around safety obligations.

The project governance structure was novel, in that it did not function as an accountable board, but as an advisory board to the head of the organisation. While it is impossible to determine if there is a relationship between this structure and project success, the project governance was effective and resulted in the project meeting its project management metrics. The use of a sub committee to actively manage risk is also noteworthy. The effective use of this sub committee provides evidence of the continuing need for more flexible project governance frameworks and it provides project governance practitioners with new insight in to what issues mega project governance needs to consider when governing a mega project.

More importantly, the Delphi study supported the position that the project governance structure for this case study mega project was novel, and far more dynamic than the literature has previously suggested. While the governance arrangement changed over time, quite necessarily over the project's life, the focus of the project board remained on delivering the project management concepts of time, cost and quality, as well ensuring the performance of the project. Without adequate project governance structures being in place, it seems quite necessary that such an omission would be a core governance failing. When adequate governance is in place, it is difficult to specifically state if that structure was the core reason for the project being successful or if it is just an essential part of the project to be successful. For this reason, without governance, it is a core failing, and with governance in place it is a key enabler for project success.

As this research has focussed on one case in detail, there is still the consideration as to the applicability of the learnings from this case, and whether it could be used to govern other mega projects. An ideal way to pursue further types of investigations in to project governance studies would be observe multiple mega projects, in both the similar and different sectors, with some that were successful, and others that were deemed failures. Having this comparison would broaden the application of testing theory on a larger set of mega projects.

ANNEX A - SAMPLE OF THREE PROJECT GOVERNANCE STRUCTURES

	<p>Figure 1:- typical PPP governance structure (DTF, 2012)</p>
	<p>Figure 2: –the Governance of Project Management (APM, 2004)</p>
	<p>Figure 3:- typical project governance structure (Patel and Robinson, 2010)</p>

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BALLASTING, LOADING, DE-BALLASTING, AND SAILING SHIPS: AN EXPLANATION OF HOW WORK PRACTICES EMERGE IN GLOBAL PROJECTS

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BALLASTING, LOADING, DE-BALLASTING, AND SAILING SHIPS: AN EXPLANATION OF HOW WORK PRACTICES EMERGE IN GLOBAL PROJECTS

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ABSTRACT

Governance practices are ‘rules of the game’ which articulate (i) the objectives guiding the work (ii) the means of achieving those objectives in a predictable manner (iii) the means of monitoring performance and (iv) the frameworks for efficient & effective decision-making in a project. In the light of rapid globalization and increasing number of complex, pluralistic and heterogeneous megaprojects, the need for project organizing approaches which depart from the assumptions of isomorphism in these practices is emphasized in the related scholarship. Nevertheless, inadequate attention has been paid to study how these governance practices are actually set up on contemporary projects. We use a combination of institutions-based and practice-based lens to develop arguments on how governance practices are initially selected and replicated or revised, thereby leading to the emergence of order in the governance structure. We gather empirical evidence by qualitatively studying how practices are set up to govern the development of the Chennai Metro. The observations show how the promoter drew from the Delhi Metro's practices pertaining to design, procurement, construction, and other organizational aspects and sustained or changed them within the project field through situated interactions. Consequently, we identify twelve mechanisms of sustenance and change of governance practices on projects. By bridging both generic and contextual perspectives of governance, the study underlines the role of field-specific ‘governing’ in (re)creating governance.

KEYWORDS

Work practices, Project governance, Institutions-based view of governance, Practice-based view of governance, Project shaping.

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1 INTRODUCTION

While technical knowledge and skills form the shell and core of engineering projects, the conduct and management of these activities, involving resources and information held by the various stakeholders, are organized through coordination processes collectively termed as 'project governance' (Sanderson, 2012). These 'rules of the game' embody formal rules and non-codified practices which articulate (i) the objectives guiding the work (ii) the means of achieving those objectives in a predictable manner (iii) the means of monitoring performance and (iv) the frameworks for efficient & effective decision-making (Muller et al., 2014) in a project. Operationally, project governance encompasses 'rules' in design, procurement and execution of projects. Of these, the non-codified practices, which form the normative and cultural-cognitive components of governance, have predominantly been the locus of the extant research on project organizing. Ray Levitt has continually emphasized the importance of norms and work practices on projects in determining outcomes and how challenges often arise due to differences in these work practices among actors in the project community. In the light of rapid globalization and increasing number of complex, pluralistic and heterogeneous megaprojects, the need for project organizing approaches which depart from the assumptions of isomorphism in these non-codified practices is emphasized in the related scholarship (Levitt, 1984, 2007; Ainamo et al., 2010). Nevertheless, inadequate attention has been paid to study how these governance practices are actually set up on contemporary projects.

In the extant work on project governance, there have been two dominant conceptions of the subject. First, by virtue of the flexibility to deal with the end demands and objectives, projects are characterized to be unique, temporary, fluid, time-bound, disconnected and discontinuous in nature (Lowendahl, 1995; Shenhar, 2001). As a result, there is a tendency to theoretically treat projects in isolation from their embeddedness in the wider environments (Engwall, 2003; Manning, 2008). The project governance discourse in this stream draws on contingency theory and illuminates the project-specific and unique nature of governance mechanisms to meet the heterogeneous end demands and objectives. Alternatively, a complementary set of literature on projects implicitly vests project actors with 'interpretative flexibility' to draw upon preexisting sets of rules and resources, make sense of the encountered challenges, and come up with rational responses (Mahalingam & Levitt, 2005; Ahern et al., 2014). The project governance discourse here embeds instrumental rationality and reflects governance as a 'future perfect' framework, which is prospectively constructed to deal with the anticipated risks and uncertainties in a project.

However, neither of these conceptions acknowledge or provide much attention to the emergent and institutionally embedded practices that lead to the creation of governance systems on projects (Cicmil et al., 2006). On the one hand, while contingency-based approaches can account for some of the design decisions made in a project, the actualities of the bottom-up construction of project governance are under-played in such accounts (Hallgren & Wilson, 2007). On the other hand, though pre-designed reflections of governance have shed their rigid and stable notions and moved towards agile and flexible formulations, such as hierarchical-contract-based (Stinchcombe & Heimer, 1985) and organization-culture-based (Clegg et al., 2002) systems, 'best practice' adoptions are often studied ex-ante, can often lead to inefficiencies if employed as a 'cookie-cutter' approach (Ahern et al., 2014), and do not reflect the actualities of adaptations enacted in the projects (Sanderson, 2012). As stressed by Westney (1987), designs that have proven their

effectiveness in one context need to be creatively adapted to be suitable to other, different situations.

These deficiencies consequently lead us to question how governance mechanisms take shape and evolve on projects. Investigators have attempted to address this agenda using, in general, one of two types of approaches: *institutions-based* and *practice-based* views on project governance. We provide a brief overview of these.

2 INSTITUTIONS-BASED VIEW OF GOVERNANCE

Disapproving the notion that 'every project is an island', scholars adopting an institutional-field based view on project governance have observed that all projects within a field operate in a broader set of contextual affiliations drawn from norms, bodies of knowledge, best practices, socio-cultural values, and informal impositions that provide both resources for and constraints in project governance (Kadefors, 1995; Engwall, 2003; Mahalingam & Levitt, 2005). Even though each individual project may be unique and cannot be reduced to being routine, arguments are placed in favor of understanding the employed governance mechanisms which are (i) constrained by the project's organizational, historical, industry level, country level affiliations and (ii) embedded in the long-term institutions of a project's surroundings (Engwall, 2003; Manning, 2008). More specifically, Levitt et al. (2010), Henisz et al. (2012), and Scott (2012) identified normative, and cognitive-cultural elements of a field as institutional pillars, supporting non-codified governance mechanisms embedded in projects.

Consequently, there is an increasing focus on the initial selection of governance mechanisms based on the institutional affiliations inculcated by the field-level context. Scholars observed that 'institutional conflicts' (Bresnen et al., 2004, 2005; Mahalingam & Levitt, 2007) and 'institutional exceptions' (Orr & Scott, 2008) often arise as projects governance frameworks clash. Innovative approaches to resolving such conflicts in a particular institutional environment are critical to steering projects through the quagmire of available governance mechanism choices (Chi & Javernick-Will, 2011; Hellstrom et al., 2013).

However, Mahalingam et al. (2011) note that it is often impossible to initially select the perfect set of governance mechanisms on a rational basis. Consequently, the ensuing institutional conflicts or exceptions lead to contested process that may result in a stable governance regime. Mahalingam & Delhi (2012) for instance show how episodes of contestation created new governance norms for PPPs in three different Indian states. Jooste et al. (2011) describes the emergence of governance in PPP regimes in a variety of commonwealth countries as a process of institutionalization and structuration of wider norms drawn from the United Kingdom.

3 PRACTICE-BASED VIEW OF GOVERNANCE

Scholars adopting a practice-based view of project governance first observed that the generic conception of project governance only partially explains the practices enacted to govern projects in reality (Dubois & Gadde, 2002). Subsequently, Bredillet (2004) explained the above anomaly by articulating the differences between (i) governance strategies which are drawn from the existing frameworks and implemented as a rational process at the generic level and (ii) situated practices enacted by the project participants in a 'para-rational' manner

at the contextual level. Soderlund (2005) emphasized the need to pay attention to the practices enacted by the project participants in their everyday life to understand the bottom-up construction of governance. Thereby, the 'project-as-practice' treatment specifically articulates the 'lived experience of projects' reflecting the competencies and skills of the project participants in gathering knowledge about the context and enacting situated practices (Cicmil et al., 2006).

With 'the practice turn' (Schatzki et al., 2001) influencing the literature on projects, scholars used the 'project-as-practice' approach extensively to study the mitigation of uncertainties and deviations in projects. For example, Engwall & Svensson (2004) and Pavlak (2004) highlighted the situated practices of temporarily mobilizing 'cheetah teams' and 'tiger teams' respectively during emergencies in project governance. Extensive accounts of Hallgren & associates (e.g. Hallgren & Wilson, 2007) showed how contingencies are resolved, as acts of 'mini-muddling' through one-off practices like meetings, follow-up calls, enhanced communication, contingency teams, supervision, and training—practices that resolve roadblocks emergently through 'satisficing' solutions. Subsequently, scholars called for, not the rejection of the project management instruments but, the deeper understanding of contextual practices which form a larger part of the project governance process in the lived reality (Chan & Raisanen, 2009).

Practice-based studies by Alderman et al. (2005), Laybourne & Sadler-Smith (2006), and Boyd (2013) focus on the underlying praxis involving these situated practices and the practitioners who enact them. These scholars observed contingent governance construction as a sense-making process where practitioners link their existing knowledge and capabilities with the objectives at hand to enact situated practices. Building on the sense-making perspective, Ivory & Vaughan (2008) and Maaninen-Olsson & Mullern (2009) suggest that contingencies are addressed during the course of evolution of generic practices into contextual practices in a project. Consequently, Sanderson (2012) and Ahern et al. (2014) propose to replace the term 'governance' with 'governing' which envisages 'learning the project over (its) life cycle' by enacting practices which evolve as events unfold in actuality. Thereby, the practice-based scholarship invites attention to the realm of action where 'governing' reflects the ongoing activities of the project participants steering the projects through encountered uncertainties.

4 COMBINING THE INSTITUTIONS-BASED AND PRACTICE-BASED VIEWS ON GOVERNANCE

In contrast to the traditional conception in which institutions subsumed practices by default, recent work helps combine institutions and practices in interesting ways. Giddens (1984) stimulated a mutually constitutive grounding by underlining the duality of structure and action. Following DiMaggio's (1988) ideation of influential agents being able to defy or manipulate institutions, Holm (1995) questioned the *modus operandi* of such embedded agents whose practices are conditioned by the very institution they are trying to change. In response, Barley & Tolbert (1997) developed on Giddens' theory and conceived a recursive model of institutionalization/structuration wherein practices are drawn/encoded from the institutional realm as 'scripts' within a field and then replicated or revised in the field as a result of human action during the course of multiple iterations. Emirbayer & Mische (1998) underlined the role of (i) habitual agency in encoding the practices from institutional realm, (ii) practical-evaluative agency in assessing the presently evolving situations in the realm of

action, and (iii) projective agency in replicating or revising the practices for the forthcoming iterations. In such a recursive process, Pierson (2000, 2004) notes that the initially selected practices have an increasing-returns effect on the subsequent iterations of encoding, replication and revision, thereby inducing path dependence in the process of institutionalization/structuration. Given the path dependent nature of the institutionalization/structuration process described by Barley & Tolbert, Seo & Creed (2002) invited subsequent attention on the actual praxis of replication or revision of the practices to explain the sustenance or disruption of institutional order.

In this milieu, institutional scholars exerted efforts to study the unfolding of institutionalization and structuration. For example, Zilber (2002) examined the micro-processes of institutional change by adopting an actor-action-meaning framework and casted attention on the contestation of existing meanings and diffusion of new meanings in a field through the practices carried by the challenging actors. Subsequently, Hinings et al. (2004), Lawrence et al. (2004), and Thornton et al. (2005) reflected on the (i) path dependent intricacies of meanings and practices, (ii) systemic and episodic power embedded in the actors' practices, and (iii) pluralism accruing from competing practices to develop explanations on how the agents' practices induce institutional change.

While these conceptions proposed under different banners help us to superficially understand the underlying role of enacted practices in theorizing-legitimizing-diffusing institutional change, constructivist insights on how practices evolve in the course of emergence of institutional order remain 'black-boxed' (Lounsbury and Crumley, 2007). Subsequently, these authors called for the development of an integrated institutions-practice based ontology to account for the creation and changes in 'broader cultural frameworks' in consideration with the shaping of 'lower-level activities' of actors who 'articulate with those frameworks'. While the recent scholarship on micro-institutional origins (e.g. Powell & Colyvas, 2008) also iterated these arguments on the combinatory ontology, practice scholars' articles (e.g. Jarzabkowski et al., 2009, 2013) in institutions-based publications reinforced this ontology by (i) construing institutional logics as 'constructed' rather than given and (ii) situating institutional sustenance and change in the everyday practices of actors who inhabit the institutions. Vaara & Whittington (2012) called for the development of a joint institutions-practice approach to broaden the consideration on the societal structures while analyzing the patterns of situated action which both constitute and are constituted by these structures. As a cross-validation, Ventresca & Kaghan (2008) and Smets, Greenwood, & Lounsbury (2015), in their articles in practice-based publications, also share this combinatory notion in view of the need for 'stronger contextualization in the broader social orders' (Smets et al., 2015), which embed the situated practices and form the 'key locus of variation, selection, and retention (selection, retention, and variation)..'. of these practices (Ventresca & Kaghan, 2008).

This nexus of institutions and practices has also generated interesting views on the creation of institutions, structures and norms. Tsoukas & Chia (2002) held that both stasis and change of structure are emergently produced by the ongoing form of the practices enacted by the actors. Feldman & Pentland (2003) explicated this ongoing form of the practices as a resultant of performative dispositions of the actors who constantly strive to make sense of the unfolding events and then enact decisions to replicate or revise their practices. In an article that addresses an agenda similar to ours, Rerup & Feldman (2011) conceptualized the co-

constitutive nature of schemas and routine practices through an iterative process of first espousing initial ‘schemas’ and then enacting interpretive ‘schemas’.

While the hybrid underpinnings have helped scholars explain the transformation of money management practices (Lounsbury & Crumley, 2007), structuration of organizational strategy (Jarzabkowski, 2008), environmental practice shifts (Zietsma & Lawrence, 2010), and hybridization of law firm practices (Smets et al., 2012), in the context of project governance, the institutions-practice lens facilitates the conception of governance mechanisms as a set of governance practices which are first selected based on the institutional affiliations and then situatedly stabilized or changed in multiple iterations of the ongoing process of ‘governing’ by the project actors, thereby leading to the emergence of order in the governance structure. As Lounsbury & Crumley (2007) and Smets et al. (2015) point out, bringing together the institutional and practice-based perspectives, leverages their complementary strengths in connecting the evolution of governance practices with the emergence of a governance structure in a project field. This conception bridges ‘becoming’ with ‘being’, ‘organizing’ with ‘organization’ (Tsoukas & Chia, 2002; Hallgren & Soderholm, 2011), and ‘coordinating with coordination’ (Jarzabkowski & Feldman, 2012) in reference to the ‘activities of ‘governing’ (which) might (re)create the forms of governance’ (Sanderson, 2012). Consequently, while pushing Ray Levitt's agenda (Levitt, 2007; Ainamo et al., 2010; Jooste et al., 2011) on understanding the determinants of governance structures, we emphasize the need to combine institutions and practices to understand the mechanisms of normative construction of governance practices in the context of global, heterogeneous, pluralistic and temporal projects. To this end, this paper attempts to answer the following research questions:

How are the initial set of governance practices in a project field chosen? How are the practices sustained or contested & changed? How does order, stable or otherwise, evolve with regards to project governance?

5 RESEARCH METHODS

5.1 RESEARCH SETTING AND DATA COLLECTION

To answer these research questions, we adopt an in-depth, qualitative, single case-based methodology driven by an induction-based approach. We chose to study the development of a metro-rail in the city of Chennai, India – a megaproject that was budgeted at USD 2.7 Billion. The project was developed by a Special Purpose Vehicle called Chennai Metro Rail Limited (hereafter referred as CMRL). The development activities undertaken by the project organization envisage a large scope of infrastructure construction, operations and maintenance, involving plural public and private stakeholders, and numerous contract packages/projects, which are spread over multiple phases and span a long tenure. At the time of this study, (i) the first phase of the development of the transit infrastructure was nearing completion (ii) major portions of the Phase 1 network were opened to the public (iii) an extended network of Phase 1 was under construction (iv) CMRL was waiting for the final approval for Phase 2 from the Central Government. We studied various stages of development: conceptualization, pre-developmental clearances, detailed engineering, pre-developmental activities, construction, commissioning, operations, and maintenance.

Primary case evidences were collected through semi-structured interviews with the personnel of promoters, consultants and contractors of the Chennai Metro. The duration of each interview lasted between a minimum of one hour to a maximum of three and half hours. A total of 30 interviews were conducted with 27 participants accounting for over 42 hours of interviews. Hand-held notebooks were used to record field notes during the site visits and interviews. The collected data was transcribed on the same day of the interview using the field notes. In addition, along the lines of engaged scholarship approach, two brainstorming sessions were organized with the participants in the project to assimilate their collective learnings from Phase 1 and deliberate upon governance strategies for Phase 2. Newspaper reports, online pages/forums, and officially published reports were also valuable sources of secondary data on project governance. Bias or factual errors were removed through (i) internal triangulation of the data collected among the various interviewees and (ii) external triangulation of the data collected from the primary and secondary sources. A detailed case report was prepared based on the insights obtained from the triangulated data.

Governance practices in design, procurement and execution constituted our key units of analysis. We observed how CMRL borrowed governance practices from the Delhi Metro - promoted by the Delhi Metro Rail Corporation (hereafter referred as DMRC), and sustained or adapted these practices based on situated interactions.

5.2 DATA ANALYSIS

The detailed case report was analyzed through open coding and axial coding techniques (Corbin & Strauss, 1990). The pattern of analysis was been adapted from the interpretive sensemaking method employed by Welch et al. (2011) for building theory through an inductive methodology. The original technique involves (i) identification of labels using open-coding (ii) cross-relating the labels using axial-coding (iii) theory-building through iterations between the tentative assertions and raw data.

In the present research, open coding techniques were used to identify key themes surrounding governance. As a foremost step, the rationale for selection of the initial set of governance practices were tagged based on the descriptive content of the case report. Subsequently, various governance aspects were identified through typology-based open coding (Corbin & Strauss, 1990). For each governance aspect, the initial form of the governance practice drawn from the Delhi Metro and the replicated or revised forms of the same practice enacted along the cycles of governance were identified and mapped as a vignette. In the next step, all the other data associated with the governance aspect, which influenced the replication or revision of the governance practice was annexed into the respective vignette. Thereby, each vignette tracked the history of the related governance aspect and the evolution of the corresponding governance practice. Through axial coding, the mechanisms of replication and revision were compared between the vignettes of the case to understand how practices remained stable or changed. Finally, we compared governance practices between various junctures: T0 (initial Project Sanction), Ti (Project Organizing), T1 (Phase 1 development), T2 (Phase 1 extension), and T3 (Phase 2) through axial coding to reflect on the emergence of institutional order in project governance.

We borrowed Barley & Tolbert's (1997) recursive model of institutions and actions to study the normative construction of governance practices. This model enables us to theoretically articulate the observed data in a recursive process where (i) governance patterns

are first *encoded* from the wider *institutional realm* of project governance to generate governance practices which act as overarching *scripts* (ii) the encoded scripts are *enacted* by the project actors and subsequently *replicated or revised* based on the *realm of actions* unfolding during the course of the development (iii) the replicated or revised scripts are then *objectified* for the subsequent cycle of governance. Correspondingly, (i) the encoding sub-process help us to understand the dynamics of the selection of initial set of governance practices, (ii) the patterns of revision or replication help us to extract the situated mechanisms that changed or sustained the governance practices, and (iii) analysis of the form of the governance practices objectified at the end of each governance cycle yielded insights on the emergence of institutional order.

6 OBSERVATIONS

India faces a huge demand-supply deficit in urban transportation infrastructure. India's 10th Five Year Plan recommended rail-based transit systems to be implemented in the cities with populations greater than 2 million. The Kolkata Metro was the first urban rapid transit system to be built in India (between 1970-1992). However, the Kolkata Metro set a bad precedent to rapid transit development in India owing to the delays (upto 4 times the initial duration) and cost overruns (up to 14 times). Consequently, the Kolkata Metro failed to fuel motivations to pursue urban rail transit projects in India for a brief period of time.

In 1998, the Delhi Metro Rail Corporation (DMRC) was formed as a Special Purpose Vehicle to develop, operate and maintain a metro rail system in New Delhi. With respect to the modalities for implementation of the Delhi Metro, Mr.Sreedharan, the managing director of DMRC from 1998 to 2011, noted,

"After the bad experience of the Kolkata Metro, it was decided that the Delhi Metro would be built in a different style."

As a result, the Delhi Metro evolved to be distinctly different from the Kolkata Metro in major technical and implementation aspects. The Delhi Metro attained its break-even point in a short-span of three years and remains one of eight profitable transit systems in the world. The Chennai Metro became the fourth urban rail transit system in India, after the Kolkata, Delhi and Bangalore Metros.

6.1 THE CHENNAI METRO

Phase 1 of the Chennai Metro, costing US\$ 2.7 billion over 6 years, was approved by the Tamil Nadu State Cabinet in 2007. With an aim to reduce pollution and a vision of 'moving people, sustaining growth', the Chennai Metro Rail Limited (CMRL), a Special Purpose Vehicle responsible for developing and operating the metro, was incorporated in 2007 on a 50-50 ownership pattern between the Central and Tamil Nadu State Governments. The consultants and contractors were subsequently appointed in 2008-09 and construction began in 2009.

6.2 SELECTION OF INITIAL PROJECT NORMS

Immediately after the incorporation of CMRL in 2007, a critical task was to formulate strategies to govern the development of the Chennai Metro⁴. With DMRC being the only domestic agency to possess the expertise to develop metro transit systems with a proven track record, they were engaged in preparing the feasibility study and detailed project report for the Chennai Metro which borrowed heavily from the similar reports for the Delhi Metro⁵. Also, the Delhi Metro Railway General Rules (2002) and the Delhi Metro Railway Operations & Maintenance Act (2002), which bind the Delhi Metro, were the only available resources that could provide frameworks for transit service delivery in 2007. Thereby, the CMRL personnel wanted to align their practices with these. Technical specifications on the Delhi Metro also had a bearing on the execution of the Chennai metro. For instance, the tunnel boring machines imported to India for the execution of Phase I of the Delhi Metro were resold or retained by the contractors for the development of other metro transit systems in the country (after refurbishment). Consequently, the bids committee of CMRL observed that the adoption of a tunnel diameter different from that of the Delhi Metro only increased the cost of tunneling by 30%. Furthermore, in response to the thrust exerted by DMRC towards interoperability and standardization, CMRL emulated the Delhi Metro's designs and specifications with respect to tunnels, viaducts, tracks, traction, signaling & telecommunication, and rolling stocks through voluntary governance decisions. Also, both the Delhi Metro and Chennai Metro were funded by a common financier. Consequently, the common pre-requisites for obtaining the loans influenced CMRL to imitate the Delhi Metro's contracting practices.

In terms of executing the project, motivations to (i) mimic the Delhi Metro and build a similar transit system in Chennai⁶, (ii) alleviate the stature of the transit development (iii) and capitalize on existing expertise, triggered the recruitment of DMRC and other active/retired

⁴ Speaking about the setting up challenges encountered by CMRL, a former advisor who was first on-board noted, "The Kolkata Metro, Delhi Metro, and Bangalore Metro were ahead of us and had established their systems of governance. Similarly, we had to quickly establish ours and start the projects."

⁵ A senior advisor who worked with CMRL during the kick-start stages cited an example to substantiate how DMRC employed a cookie-cutter approach to prepare the detailed project report: "We had to go through the report word-by-word and check for copy-paste mistakes. While terms such as 'Delhi' and 'Delhi Metro Rail Corporations' were replaced as 'Chennai' and 'Chennai Metro Rail Limited' respectively, the DMRC officials forgot to replace the word 'NCR' (which expands as National Capital Region) with 'Chennai Metropolitan Region'."

⁶ During the award of the contract for principal consultancy, the Deputy Chief Minister requested Mr.Sreedharan, the visionary advisor of DMRC, to 'plan and model the Chennai Metro in the same manner as Delhi Metro Rail was built.'

DMRC personnel onto the Chennai Metro. Such engagements were established through the appointment of the DMRC personnel in managerial positions in CMRL, the appointment of DMRC as the principal consultant and the MD of DMRC as the principal advisor to the project, and the nomination of senior personnel of DMRC to the honorary directorial board of CMRL. Consequently, several practices from the Delhi Metro diffused on to the Chennai Metro. CMRL therefore started its journey by relying upon the tried and tested coordination and governance strategies that were utilized in DMRC⁷ to draft templates, policies, standard operating procedures and manuals.

6.3 EVOLUTION OF GOVERNANCE PRACTICES

6.3.1 Practices pertaining to leadership, hierarchy, human resources, organizational functions

The practices pertaining to leadership, hierarchy, human resources, and organizational functions were one of the first to be negotiated as soon as CMRL was incorporated. DMRC adopted a model of organizational leadership and hierarchy which was driven by the intent to make the transit authority independent and insulated from political influences. As a result, powers were often vested with the Indian Railways. However, the political climate in Tamil Nadu is marked by a Dravidian welfare culture in which the State Government provides services to the people. To this end, the State Government preferred to rely more on the bureaucracy than on the technocracy and wanted powers to be vested in personnel from the State's Administrative Service, Chennai Metropolitan Development Authority (CMDA - town planning authority) and the State Highways Department (SHD).

The resultant of the collision of these two views was the creation of a hybrid model: A State Administrative Service official was deputed to serve as the Managing Director; the State Highways Department's employees were inducted, in addition to the experienced personnel from other transit systems, for the project control functions; and employees of the Indian Railways were inducted into the directorial and managerial board. However, as Phase 1 of the development began, the State Government cited a lack of liaising with the state as an issue. To this end, more personnel from the state's Public Relations department, Finance Ministry, Personnel & Administration department & Planning Commission were deputed to work with CMRL. Soon after, citing the negligible value addition to viaduct and tunnel construction, the contracts of Indian Railways personnel, apart from those with the tracks & power traction team, were not renewed. Personnel with overseas experience filled the shoes of the exiting Indian Railways contingent.

The Delhi Metro's human resources practices embedded considerations for a fully staffed project control team and operations & maintenance team, each trained in their respective functions. The project control team was required to handle a variety of functions such as

⁷ A site manager working with CMRL admitted about the rationale of adopting the Delhi Metro's practices, "We felt safe by adopting DMRC's practices. When there are no standards, you are under risk. If you take a wrong decision, you will be questioned."

contract management, cost and procurement consultation, planning, execution supervision, quality and safety control and commissioning supervision. Nevertheless, the team was only appointed on a short term contractual basis and the contracts were extended/terminated based on the requirements. However, the second managing director of the Chennai Metro had prior first-hand experiences of labor revolts in the State for conversion of temporary positions to permanent positions in the mining industry. Consequently, the managing director formulated an ‘one-asset policy’ where the interested members of the project team take over the operations & maintenance functions, instead of being terminated, after the construction contracts are closed out. Moreover, due to a perception that the General Consultants on the project were underperforming, the role assumed by the project control team went from a supervisory nature to comprehensive project management. Further, based on DMRCs recommendation, 45 permanent personnel were employed per route per km for the operations & maintenance functions. However, CMRL could not decipher the rationale and assumptions behind these norms. Fresh benchmarks were derived through bottom-up formulations and at present, the corresponding number for CMRL stands at 23.

Similarly, DMRC's practices envisaged formal and conventional coordination mechanisms with the revenue department for the land acquisition functions. In the Chennai Metro, the finance department of CMRL directly assumed the land acquisition responsibilities and acquired land through hefty compensations so as to avoid delays accruing from litigations. However, devoid of the task-related experience, the finance personnel encountered difficulties in identifying and handling fraudulent land ownership issues during Phase 1. Consequently, adhering to the conventional model, these responsibilities were moved to the revenue department of the State Government. A revenue department official was deputed to CMRL for offering assistance in verifying the authenticity of land ownership and CMRL resumed the practice of directly acquiring land.

6.3.2 Contractor management practices

The practices pertaining to contracting modality, prequalification criteria, key dates, and contract packaging, were one of the most actively negotiated ones on the Chennai Metro. First, based on the Delhi Metro experience, Design-Build/lump sum contracts were deemed as the proven modality of contracting for metro rail construction⁸. Apart from the contracting modalities, prequalification requirements for the Chennai Metro projects were also copied from the Delhi Metro. In the case of formulating key contractual dates, though the general consultants objected to the adoption of the Delhi Metro's milestone scheduling practices on the grounds that they were too optimistic, the principal consultants who were erstwhile employees of the Delhi Metro were able reinforce their templated practices by virtue of their hierarchical position in the Chennai Metro.

⁸ A former Indian Railways official with the CMRL's team expressed about the unhabituated nature of design-build contracts in India, "In Indian Railways, we were not used to executing Design-Build contracts. However, Design-Build contracts were successful in the Delhi Metro. Thereby, we decided to imitate the same."

However, CMRL deviated from the Delhi Metro's contract packaging practices right from the start in two ways. While DMRC bundled the specialized/allied services such as ventilation, air conditioning and overhead electrical lines within the scope of the main contractors, CMRL segregated the allied services from the viaduct and tunnel packages and aggregated the scope of work pertaining to these services as specialized contract packages. This upfront change was driven by the need to standardize the product selection and obtain competitive bid values⁹. As a second differentiating aspect, CMRL awarded the elevated stations and viaducts as segregated packages. This decision was made in order to open the bids for station construction to the building contractors (who would not prequalify to construct the viaducts) and thereby increase bid competition. However, as in the Delhi Metro projects, in view of the interfaces between tunnel and underground station structures, tunnels and stations were bundled together. CMRL personnel believed that they had the right strategies in place¹⁰. Nevertheless, in course of time, these practices failed owing to a variety of dynamics which are described below.

6.3.2.1 Failure of the adopted practices

As a first misfit, design-build contracts turned out to be a wrong strategy in the Chennai Metro. CMRL personnel observed that the contractors exhibited poor capabilities to execute the design activities in-house or manage design sub-contracts efficiently. As a result, the benefits accruing from the design build contracts in the form of reduction in project duration, single point of design-construction interface, and construction-driven design optimization did not materialize in practice. Furthermore, changes were prevalent during the execution of geotechnical works, finishes, utility diversions, and MEP works due to differing site conditions, preferences, uncertainties and technological obsolescence respectively. Thereby, disputes ensued. Resolution of these disputes was a long-drawn out process. A Russian contractor even abandoned the project and exited the country as their additional claims were not resolved for a long period of time¹¹. Also, the contractors were unable to cope with the

⁹ A key contract management official informed about the rationale for adopting a modified contract packaging practice, "We did not want to approach 5 different manufacturers for maintenance and repairs. We wanted to optimize O&M and this required fewer coordination interfaces with the manufacturers. We also wanted to capitalize on the economies of scale created by bundling the specialized/allied services separately."

¹⁰ The former senior advisor initially believed that the selected contractor management practices were right and commented, "We were very happy with how things worked out. We got very competitive bids which were much lower than DMRC's benchmarks. All the tunneling and track contract packages were bagged by JVs of reputed firms. The viaducts and station packages were bagged by firms of high repute."

¹¹ A resident engineer working with the general consultant remarked on the Russian contractor's termination, "The Russian contractor demanded Rs.130 Crore as an additional claim on account of differing soil and utility conditions. It was a very huge amount. If one had to authorize the additional claim, it was literally going to cost him a lifetime of enquiry and litigation. However, by terminating the contracts after a long procedure and awarding

irregular, milestone-linked cash flows generated by the design-build contracts and stalled their performance on the grounds of unavailability of complete work fronts.

As a second misfit, the key dates drawn from the Delhi Metro did not work as a cookie cutter in the Chennai Metro owing to unforeseen geological, hydrological and utility-related conditions. Moreover, the Delhi Metro's practices prescribed only 2 or 3 key dates in each contractual package. Fewer milestones led to fewer cash flow generating opportunities and fewer assessment points as a result of which CMRL had to wait until the key dates elapsed to initiate contractual proceedings against the poorly performing contractors.

As a third misfit, the prequalification criteria did not lead to the employment of the right contractors in the Chennai Metro. Some contractors who met the prequalification criteria in terms of annual turnover and technical experience, had internal financial problems and were amidst financial restructuring. Several contractors had also submitted over-optimistic bids. To this end, three contractors who were executing 30% of the total scope of works in Phase 1 were behind schedule, buckled under the financial stress and were terminated. In the case of consortium arrangements, CMRL ended up maintaining separate interfaces with the consortium partners, thereby defeating the purpose of the arrangement. Furthermore, while a foreign contractor executing two contract packages exited the country during the course of the execution, another foreign contractor exhibited only a ceremonious presence in a contract package¹².

While the strategy of segregating elevated stations and viaducts worked in the Chennai Metro, the imitated strategy of bundling underground stations and tunnel work packages did not. Construction was planned by each tunneling contractor so as to lower the tunnel boring machines through one terminal station of a contract package and de-erect the tunnel boring machine after breakthrough at the other terminal station of the same contract package. In this methodology, delays in the construction of the stations, and repairs and hard rock stoppages of the tunnel boring machines drastically affected the progress of tunneling packages.

fresh contracts, CMRL incurred an additional cost of Rs.270 Crore. Rs.140 Crore would have been saved if a change order could have been issued. This is people's money. After facing plenty of cases, the vigilance department should at least understand about uncertainties and the need for flexibility. If that is not possible, the CMRL officials should at least be brave to enact bold decisions. Both are not happening."

¹² The Managing Director, during a separate meeting, vented about the foreign contractors not having sufficient baggage to remain aground in the Indian market, "No Indian contractor would abandon a project. They would worry about their reputation. In the worst scenario, the contractor would demobilize their personnel and consequently progress would take a hit. They would go the courts to resolve serious problems. Foreign contractors are not like that. Suddenly, on May 1st, the Russian contractor personnel were found missing."

6.3.2.2 CMRL's response to these failures

A hybrid version of lump-sum (for sub-surface works – tunneling& excavation, and bridges), item-rate (for super structure works - piers, viaducts and stations), and cost reimbursable (for uncharted utility diversion works) contracts were adopted by the CMRL personnel for the Phase 1 extension phase. To this end, a design consultant was appointed for providing semi-detailed design drawings to the contractors, who had to validate these and in turn prepare the shop drawings. To evaluate contractual changes easily, the present managing director made the following revisions: (i) the cost of each lump-sum item was separately identified, and (ii) remarks were made against each lump-sum item to enable proportional payment in case of any addition/deletion in the scope of work. Further, standard reference books for determining the costs of escalation and all the possible additional scope of works were established in the contracts. Similarly, to minimize the contractual changes, preliminary geotechnical investigations were carried out at 50m lateral intervals for Phase 1 extension and plans are in place to conduct them at every 25m intervals for Phase 2(as compared to every 100 m in phase 1). Also, few retired employees of CMRL, through the support of the present managing director, entrepreneurially donned the role of dispute resolution chairpersons. As these experienced personnel understood the practicalities of metro rail construction and were in favor of infusing flexibility, the contractors began to trust this dispute resolution forum¹³. In addition to these changes, risk matrices and bonus clauses were incorporated in the contract.

CMRL altered the milestone durations in the Phase 1 extension and more time was allocated for sub-surface works to account for the incidence of non-uniform soil profiles and high ground water table levels. A provision for liquidated damages-free one-year time extension, which the contractors could exercise in the event of unforeseen sub-surface conditions and utility diversions, was also incorporated. Further, based on the instructions of the managing director, the contracts of Phase 1 extension stipulated 80 key dates for the elevated packages and 50 key dates for the underground packages.

With reference to contract packaging, the current managing director decided to segregate the underground stations and tunnels as separate packages and specify the employment of two tunnel boring machines for each tunnel in a contract package. Also, the revised methodology of erection and de-erection of the tunnel boring machines without drive-throughs worked effectively in Phase 1 extension. The prequalifying benchmark to execute these tunneling packages was decreased from 10 km to 2 km in Phase 1 extension. To this end, bid provisions were made so that Indian contractors meeting the prequalification criteria,

¹³ A contracts manager deputed from SHD added on the changes in the dispute resolution practices, "We realized that additional claims had to be granted quickly without any disputes with the finance team. We informally discuss with the contractors and ask them to not stop work on the projects We sit on additional claims for 6 months so that the claims would be directed to the dispute resolution board. In the dispute resolution board, after scrutinizing the issue, the decision is awarded in favor of the contractor if he deserves a contractual change. In comparison with litigations which take years for resolution, a 6-month resolution period seems workable for us and the contractors."

by virtue of their pro-rata participation in integrated joint ventures, could prequalify single handedly for the tunneling works¹⁴. While the annual turnover prescriptions for the underground station construction packages were relaxed to attract competitive bids, the prescription was increased for the remaining packages in Phase 1 extension. Further, the prescriptions on performance bank guarantee were also increased for all the packages.

In order to enhance inter-contractor cooperation, an interface sheet, which contained a scope matrix of the work responsibilities of various contractors, was incorporated as a contractual document. As per the provisions of the contracts, interface meetings were held every fortnight and as many as eight contractors including the main contractor and specialized contractors attended the meetings along with the CMRL officials. A chief interface coordinator nominated by the main contractor was in-charge of the conduct of the interface meetings.

6.3.3 Engagement with the general consultants

The rationale for imitating the Delhi Metro's practice of employing a general consultant was not just to obtain loans from the financier, but also to cope with the lack of expertise and staffing constraints. The General Consultants were given great responsibility in the Delhi Metro to enact stringent safety & quality norms, and play a boundary spanning role in client-contractor interactions. They were the de-facto clients representatives on the project. While the same structure was adopted on the Chennai Metro, no provisions were made for the general consultants to veto the decisions of CMRL or make decisions on behalf of CMRL. A faction within CMRL were at loggerheads with the general consultant's personnel for favoring the additional claims of the contractors, and not adding value to design optimization and project management¹⁵. The current managing director also espoused the need to be self-dependent with respect to project management and technical supervision functions. Subsequent to these misfits, CMRL decided to curtail the role of the general consultants only to overall supervisory functions a far cry to the role that they played in Delhi.

¹⁴ The Managing Director questioned the need for joint ventures, "Why should we mandate the formation of JVs? Internally, the Indian and foreign contractors are anyway working as separate contractors. The Indian contractors can hire the foreign partners as sub-contractors also. An Indian contractor who prequalifies to execute 2km of tunnels will be able to execute a 10km tunnel also. Why are we bringing joint ventures into the equation by asking for 10km tunneling experience?"

¹⁵ A former principal consultant added, "The top management wanted to just have a skeletal structure and leave all the field work the consultants. The consultants can only facilitate. Accordingly, their contract is on a man-month basis. They are meant to stay as long as the projects are complete. How can you expect them to get your work done on time? There is a conflict of interest."

6.3.4 Design practices

While a majority of the design practices enacted in the Chennai Metro were simply drawn from the Delhi Metro, CMRL also tried to change them in a few cases. For instance, contesting the principal consultant's recommendation of standard-gauge track standards (1.4m), the Indian Railways personnel initially tried to adopt the national broad-gauge (1.6m) track standards, in attempts to link the Chennai Metro with the conventional suburban railways. However, the principal consultant personnel cited the higher initial and replacement costs of the rolling stocks which are designed for the broad-gauge standards and the need to standardize the design and specifications of the rolling stocks amongst the various metro transit systems. Consequently, CMRL discarded the intervention. Similarly, when the suppliers of CMRL pushed the proposal for rolling stocks with a driverless operation technology, DMRC inhibited this on the grounds that the Delhi Metro, being the pioneer of metro rail transit, should be the first to implement the same.

In the case of signaling & telecommunication systems, the newer transit systems adopted a wireless/communication-based train control system, which allows a headway of 90 seconds between two trains. Having made the decision to adopt a conventional rail-based train control system based on Delhi Metro's experience and with the construction works for the same in progress, CMRL could not adopt the newer practice. Along the same lines, CMRL adopted coin-based & card-based ticketing systems from the Delhi Metro and is now encountering difficulties in enabling a more efficient QR code-based ticketing system.

There were also cases where significant departures were observed from the Delhi Metro's design practices. In an endeavor to save air conditioning costs by 25% and make the Chennai Metro safer, platform screen doors were incorporated in all the underground stations. A former advisor spoke about the success of this new initiative,

"After seeing the effectiveness of platform screen doors, now DMRC is trying to incorporate the same in their stations."

In a similar instance, imitating the Delhi Metro's designs, the track sections in the premises of the elevated stations of the Chennai Metro were designed to be open-to-the-sky (with 6m wide openings). Unlike Delhi which received scant rainfall throughout the year, Chennai receives considerable rainfall in the months of October-November. Such wide openings would have led to flooding of the railway tracks and water logging on the platforms (due to coastal winds) in Chennai. Only after the former Indian Railway employees were on-board, the shortfall of the imitated station design could be identified and addressed. Another instance pertains to the length of the stations and the dimensions of the entry sections, various rooms, and stairwells of the stations. After a short stretch of the Chennai Metro became operational, the present managing director began to contest the imitated geometries for their non-essential redundancies. Though the principal consultants accused CMRL of being short-sighted, the managing director cited the significant cost benefits accruing from these interventions and went ahead to enact them in Phase 1 extension. As a result, the length of the platform has been remarkably reduced from 220m to 140m.

6.3.5 Engagement with the principal consultants

Though the Delhi Metro's practices acted as a foundation for shaping the Chennai Metro, these practices did not work as a cookie cutter and several changes were enacted during the course of development. Consequently, DMRC's involvement and their value addition to the project was debated by the managing director. Though the contract period with DMRC ended only in May 2015, the contract was terminated by CMRL in September 2014 on the grounds that "DMRC's services were no longer required for CMRL". The general manager (design) added,

“The new managing director has a vision that we should create a unique mark not blindly be inspired from DMRC.”

In the light of the above events, the contract for the preparation of detailed project report for Phase 2 was outsourced to an alternative agency. Table 1 summarizes this case discussion and describes 18 arenas where we observed the formation and contestation of norms, as well as the evolution of these scripts over the projects timeline.

7 DISCUSSION

In this case study, we empirically described the episodes of CMRL setting up a governance structure – containing norms for design, procurement and coordination - to develop the Chennai Metro. Initially CMRL borrowed governance practices from the Delhi Metro. However, during the course of development, only a few of the borrowed practices were sustained by CMRL and the remaining were altered from their initial forms. Similarly, while some norms are now stable, others are still evolving. To this end, we use an institutions-practice lens to explain the selection of the initial set of governance practices, sustenance or change of the selected governance practices, and emergence of order in the governance structure.

7.1 THE SELECTION OF THE INITIAL SET OF GOVERNANCE PRACTICES

Our observations show that the initial selection of governance practices in a project field is constrained and enabled by institutional affiliations which provide normative and cultural-cognitive supports for governance in the various stages of development such as conceptualization, core network assembly & implementation, and service delivery. In line with the views outlined by Jarzabkowski (2004), we argue that these institutional affiliations operate at three levels. First, at the individual level, affiliations with model projects reinforce frames of reference and ontological securities which channel the actions of the project actors along familiar, institutionally rational, and recently successful paths (Pierson, 2004). In our case, the mental models of the project actors were bounded mimetically as they drew conceptual benchmarks and legitimacy filters from the Delhi Metro. Consequently, the project actors exhibited alignment with the Delhi Metro's practices and selected them to begin development of the Chennai Metro.

Second, we argue that affiliations with external entities and institutional brokers (Pierson, 2004) induce path dependencies in the selection of practices by different groups (tunneling team, tracks team, rolling stocks team and so on) in the project field. As observed in the case, the external entities such as the suppliers, contractors, financiers, and institutional brokers

such as the principal consultants drew heavily from the Delhi Metro's practices which permeated across project groups thereby leading to collective rationalities (DiMaggio & Powell, 1983). In the light of such path dependencies and legitimacy demands induced by external actors and institutional brokers, the initial set of governance practices selected by various groups were identical to that of the Delhi Metro.

Third, at the organizational level, we note that project pioneers – early project evangelists - and service regulations embed conceptual and service delivery logics which cascade downstream and transcend upstream in the project organization, thereby constraining the initial selection of governance practices by the project organization (Pentland et al., 2010). Correspondingly, we observed that the project pioneers and service regulations embedded the Delhi Metro's logics in the detailed project report and service requirements of the Chennai Metro. Following DiMaggio & Powell's (1983) argument that organizations drawing from similar structures resemble each other, we observed that CMRL was thus constrained to emulate the Delhi Metro's practices.

Thereby, we argue that path dependencies taking roots in the habitual agency (Emirbayer & Mische, 1998) of individuals, group, and organization can explain the sub-process of primary encoding. At the end of this sub-process, the initial set of governance practices are drawn from the institutional realm as scripts at time T0.

7.2 SUSTENANCE & CHANGE OF THE SELECTED GOVERNANCE PRACTICES

During the initiation of actual development, the scripts at 'T0' were enacted by CMRL to generate governance prototypes at 'Ti' by virtue of the practical-evaluative tendencies of the agency. In this process of prototype generation, the scripts at T0 acted as a frame of reference for the CMRL personnel to make sense and incorporate innovations or changes, if required for the implementation phases. These replicated/revised scripts were objectified for the actual implementation. Based on our analysis of Table 1, twelve mechanisms for sustenance and change of practices were identified as depicted in Table 2. Figure 1 maps these mechanisms on to the recursive model of institutions and actions.

7.2.1 Triggers that sustained the governance practices

Legitimacy requirements imposed by the various institutional affiliations, which were identified earlier, sustained the borrowed practices at Ti in 11 of the 18 vignettes identified in the study. Similarly, along the arguments of Pierson (2004) that revision of institutionalized practices involves significant costs, it was noted that *reduction of immediate costs* triggered the replication of borrowed governance practices at Ti in 3 vignettes. Furthermore, out of these 13 vignettes (both the triggers together sustained the track gauge standards of the Delhi Metro) which reflect the sustenance of borrowed practices at Ti, the practices enacted in 6 vignettes were immune to revision in the subsequent iterations owing to irreversible path dependencies. In these cases, order evolved as soon as immediate costs were reduced and legitimacy was established at Ti. For instance, the selection of rail-based train control at Ti locked all the subsequent phases from adopting the modern communication-based train control. An interesting governance contest could also be cited to further appreciate the bearing of these triggers on project governance. Though 5.5m tunnels were functionally more efficient and would have been more beneficial from a transaction costs perspective, the decision to sustain the 6.2m diameter tunnel prescription of the Delhi Metro was solely

triggered by the reduction of immediate costs. Similarly, marred by prospects of immediate/short term cost benefits, the episodes pertaining to the track gauge and power traction also show that contests triggered to reduce the transaction costs at Ti failed to change the governance practices. Thereby, offering empirical support to Sanderson (2012), we observe that bounded rationality constrains project actors in project governance upfront during development.

7.2.2 Triggers that changed the governance practices

We observed two categories of triggers that changed the governance practices. The first category of triggers changed the governance practices right from Ti to T2, throughout the course of development. For example, power contests began during the proposition stage itself as the State Government contested the borrowed practice which stipulated a dominant role for the Indian Railways. Through situated adaptations, the empirical data shows how the *distribution and subsequent quasi-centralization of power* created adaptive practices at Ti and T1. Another significant instance pertains to the human resources and public relations practices. As the meanings embedded in the scripts were lost during encoding or could not be encoded, *generation of lost/tacit meanings* over the course of development created adaptive practices. Though human resources practices were also changed to also *inculcate flexibility* in organizational capacity at Ti, the adaptations made in the contracting modalities at T1 and T2 show that inculcating flexibilities is entirely not an ex-ante phenomenon and ex-post adaptations are required to determine the manner in which flexibilities are administered. In exceptional cases, as observed in the contract packaging and inter-agency coordination, when *reduction in transaction costs* also led to the reduction in immediate costs, adaptive practices were enacted even at Ti. Similarly, by virtue of path dependence, contests to *enhance functional efficiency* were successful at Ti only when the resultant adaptations led to reduction in immediate costs. However, as noted in the previous section, contests to reduce transaction costs and enhance functional efficiency were more prevalent and successful in T1 & T2.

On the other hand, the second category of triggers changed the governance practices only during the implementation phases. For instance, *role gaps* which triggered the public relations personnel and project control team to assume marketing and comprehensive project management functions respectively surfaced emergently only when the implementation phase began. Similarly, the *absence of desired actor-sets and organization-sets* was required to be countered by revised practices for creating the desired set or coping with the available set of actors and organizations (Westney, 1987) during implementation. The termination of the institutional brokers on *attaining self-efficacy* is also an instantiation of how project-based learning leads to normative changes.

7.2.3 Ballasting, loading, de-ballasting and sailing ships

We draw from a maritime analogy of sailing ships to reflect on the setting up of a governance structure through an institutions-practice lens. The analogy begins with a new ship which is built and docked at a port A. The ship is destined to sail to a port B. The locations of both port A and port B regulate the route taken by the ship. However, without a load, the empty ship is unstable and can't leave the port. To this end, the ship is ballasted with water. When the ship is ready to leave, the anchors are heaved up and tug boats guide the ship into sea. In the sea, as the ship begins to encounter fierce winds, the sail position set in port A ceases to

work and sails are constantly maneuvered to move amidst the winds. Nevertheless, the ship does not remain empty and keeps picking up cargo at intermediate ports on the way to port B. With the cargo load building up, the ballast becomes redundant and pulls down the progress, thereby triggering the de-ballasting of water. However, the ship is never fully loaded with cargo and some ballast water always persists in the ballast tanks. Subject to these constraints, the ship reaches B at the end of the journey.

Drawing from this analogy, we reflect that governance practices enacted by the actors in a project field are (i) constrained by the conceptual start points enabled by the early project evangelists and end service points enabled by the service regulators and (ii) tugged by the various network externalities and institutional brokers along this development, thereby inducing resource deepening behavior in the project organization (Pierson, 2004). By virtue of habitual agency (Emirbayer & Mische, 1998), the project field is ballasted with the initial set of governance practices to get the ball rolling on the development, in accordance with the normative and mimetic sanctions. Also, functional/aesthetic requirements of the infrastructure are embedded within the habitual frames of reference. To meet the legitimacy requirements and reduce the immediate costs, these selected practices tend to sustain in the initial phases of the development. Further, as outlined by Gil (2015), the actor network in the initial phases of the development tends to be small, thereby is vulnerable to power imbalances. Also, under conditions of novelty and uncertainty, the projects actors exhibit risk-averse behavior (Kahneman & Tversky, 1979) and look for ontological securities which legitimize their actions (Giddens, 1984). Consequently, the cognition and rationality of the actors are bounded so as to weigh immediate cost savings more than the transaction cost savings and legitimacy requirements more than the functional efficiencies.

However, when the development begins, the project network expands rapidly and the project field becomes more pluralistic (Gil, 2015). As the designers and innovators come on-board, they draw from their habitual frames of reference and alter these frames through a sensemaking process. At the same time, adaptive practices are enacted by resourceful entrants to bridge the plural logics and disrupt the power imbalances in the project field. Further, practices are also modified by these entrants so as to create a desired set of actors and organizations in the project network or alternatively cope with the existing set or finally cope with the role gaps if the former attempts fail. Moreover, entrants such as the State Government personnel and the current and former managing directors inducted into the expanded network may not draw the same scripts which condition the project field (Zilber, 2002) and instead develop their own dispositions to meet the governance tasks as 'institutional entrepreneurs' (DiMaggio, 1988). These dispositions sublimate the notions of legitimacy and short-sighted benefits by virtue of practical-evaluative agency or performativity (Feldman & Pentland, 2003). Consequently, similar to the sails being dynamically operated to mitigate the emergent winds, ongoing patterns of actions enacted by the actors reduce transaction costs, increase contextual and functional efficiencies, enhance flexibilities, and regenerate tacit/lost meanings. Thereby, these ongoing patterns of actions de-ballast the initial set of generic practices and substitute them with localized practices which are objectified projectively for the subsequent cycles of governance. However, not all the practices can be localized performatively as the initial set of practices also tend to induce path dependencies. Consequently, order evolves in the structure of governance as legitimacy and resilience are established; transaction costs are reduced; contextual and financial efficiencies are enhanced; meanings & roles are stabilized; power contests subside; and resiliency & self-efficacy emerge.

8 CONCLUSION

In this paper, we use the analogy of a sailing ship to provide an explanation of how Chennai Metro Rail Limited borrowed governance practices from the Delhi Metro to develop the Chennai Metro. To this end, the adoption of an institutions-projects lens helped us to explain the emergence of a governance structure in consideration with the situated activities of 'governing' which sustained or adapted the borrowed practices of governance. On the contrary to the conventional approaches which articulate governance as an ex-ante designed framework or attribute project shaping to a front-end activity (Morris, 2009), the institutions-practice perspective reflected governance and shaping as an ongoing process which is situated in all the phases of governance such as conceptualization, core network assembly & implementation, and service delivery. In this sense, we first showed how the initial set of governance practices are selected in a project field. Subsequently, we identified and appraised the role of triggers, which sustain or change the governance practices in various phases of development. We then showed how order emerged in the governance structure. Thereby, we develop an understanding of bottom-up construction of governance practices in the context of heterogeneous, pluralistic context, and temporal projects.

As an implication for the practitioners, we sensitize the role of institutional context in governing similar projects. By virtue of the institutional context surrounding two similar projects, while one case may not need any deviation from the widely institutionalized practices, such departures may be inevitable in another case. Correspondingly, the paper sheds insight on how project promoters, particularly Special Purpose Vehicles, can imitate and innovate the practices of governance. As a corollary, the study attempts to explicate the institutional efforts which need to be exerted even to develop projects through a cookie cutter approach. The arguments made in the paper also raise an alarm on the careful selection of the initial set of governance practices, which by virtue of path dependence can constrain the project towards a limited set of subsequent options available during development.

Our work also has limitations. First, by examining only few initial cycles of governance, the adopted empirical approach suffers from a theoretical limitation in comprehensively explaining institutionalization and structuration. Consequently, no claim is being made that the evolution of project governance has been studied throughout the course of development of the Chennai Metro. Second, the single case-based methodology suffers from empirical limitations in generalizing the findings across multiple contexts. Nevertheless, the theoretical insights synthesized from the in-depth qualitative study allows to capture and generalize the mechanisms of sustenance and change of governance practices within the bounds of the current research.

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Table 1 Evolution of governance practices in the Chennai Metro

Vignette No.	Governance aspect	Initial selection (T0)	Proposition (Ti)	Phase 1 (T1)	Phase 1 extension (T2)	Phase 2 (T3)
1	Technical/ design practices - track gauge	-Standard gauge track standards	- Broad gauge track standards -Standard gauge track standards	-Standard gauge track standards	-Standard gauge track standards	-Standard gauge track standards
2	Technical/ design practices - train operation	-Manned train operations	- Driverless train operations -Manned train operations	-Manned train operations	-Manned train operations	-Manned train operations
3	Technical/ design practices - signalling & telecom	Rail based train control	Rail based train control	Communication-based train control Rail based train control	Rail based train control	Rail based train control
4	Technical/ design practices - power traction	Alternating Current-based overhead traction	Direct Current- based third rail traction Alternating Current-based overhead traction	Alternating Current-based overhead traction	Alternating Current-based overhead traction	Alternating Current-based overhead traction
5	Technical/ design practices - station	-Wide stairwells -220m long platforms -Open-to-tunnel underground stations -Open-to-sky elevated stations -Coin-based ticketing system	-Wide stairwells -220m long platforms - Underground stations with platform screen doors -Open-to-sky elevated stations -Coin-based ticketing system	-Wide stairwells -220m long platforms - Underground stations with platform screen doors - Covered elevated stations - QR-based ticketing	- Narrow stairwells - 140m long platforms, - Underground stations with platform screen doors - Covered elevated stations - QR-based ticketing	- Narrow stairwells - 140m long platforms, - Underground stations with platform screen doors - Covered elevated stations - QR-based ticketing*
6	Technical/ design practices - tunnel	-6.2m diameter tunnel	- 5.5m diameter tunnel -6.2m diameter tunnel	-6.2m diameter tunnel	-6.2m diameter tunnel	-6.2m diameter tunnel
7	Overarching arrangements	-Participation of Japanese contractors/suppliers -Adoption of FIDIC standard contracts -JV between Central & State Governments	-Participation of Japanese contractors/suppliers -Adoption of FIDIC standard contracts -JV between Central & State Governments	-Participation of Japanese contractors/suppliers -Adoption of FIDIC standard contracts -JV between Central & State Governments	-Participation of Japanese contractors/suppliers -Adoption of FIDIC standard contracts -JV between Central & State Governments	-Participation of Japanese contractors/suppliers -Adoption of FIDIC standard contracts -JV between Central & State Governments

Vignette No.	Governance aspect	Initial selection (T0)	Proposition (T1)	Phase 1 (T1)	Phase 1 extension (T2)	Phase 2 (T3)
8	Contractor prequalification requirements	-Delhi Metro's norms - Annual turnover, performance bond, contractor experience & JV	-Delhi Metro's norms - Turnover, performance bond, contractor experience, JV	-Delhi Metro's norms - Turnover, performance bond, contractor experience, JV	-Turnover requisites - relaxed for stations & enhanced for other works -Contractor experience & JV requisites - relaxed -Performance bond -enhanced	-Turnover requisites - relaxed for stations & enhanced for other works -Contractor experience & JV requisites - relaxed -Performance bond - enhanced*
9	Contracting modality	-Design-build/lump sum contracts -Unified lump-sum items -Sharing of risks and value engineering benefits not addressed -No bonus for early completion - Neutral persons are appointed as chairpersons of dispute resolution boards	-Design-build/lump sum contracts -Unified lump-sum items -Sharing of risks and value engineering benefits not addressed -No bonus for early completion -Neutral persons are appointed as chairpersons of dispute resolution boards	-Design-build/lump sum contracts -Unified lump-sum items -Sharing of risks and value engineering benefits not addressed -No bonus for early completion -Neutral persons are appointed as chairpersons of dispute resolution boards	-Lump sum-item rate-cost reimbursable hybrid contracts -Segregated lump-sum items with remarks for change -Incorporation of risk matrices -Sharing of value engineering benefits not addressed -Incorporation of bonus clauses - Retired CMRL employees are appointed as chairpersons of dispute resolution boards	-Lump sum-item rate-cost reimbursable hybrid contracts -Segregated lump-sum items with remarks for change -Incorporation of risk matrices -50-50% sharing of value engineering benefits -Incorporation of bonus clauses - Retired CMRL employees to be appointed as chairpersons of dispute resolution boards*
10	Contract packaging	-Integrated stations-viaducts and stations tunnels packages -Integrated primary-specialized works packages -No stipulations on interface matrices, periodic coordination meetings & penalty practices -No stipulations on number of TBMs to be employed	-Split stations-viaducts and integrated stations-tunnels packages -Split primary-specialized works packages -Synchronous award of all contracts -No stipulations on interface matrices, periodic coordination meetings & penalty practices -No stipulations on number of TBMs to be employed	-Split stations-viaducts &integrated stations-tunnels packages -Split primary-specialized works packages -Synchronous award of all contracts -Adoption of interface matrices, periodic coordination meetings & penalty practices -No stipulations on number of TBMs to be employed	-Split stations-viaducts & stations-tunnels packages -Split primary-specialized works packages -Deferment of award of contracts for MEP & finishes -Adoption of interface matrices, periodic coordination meetings & penalty practices -Stipulation of 2 TBMs per tunnel	-Split stations-viaducts & stations-tunnels packages -Split primary-specialized works packages -Deferment of award of contracts for MEP & finishes -Adoption of interface matrices, periodic coordination meetings & penalty practices -Stipulation of 2 TBMs per tunnel -Package size is being contemplated*

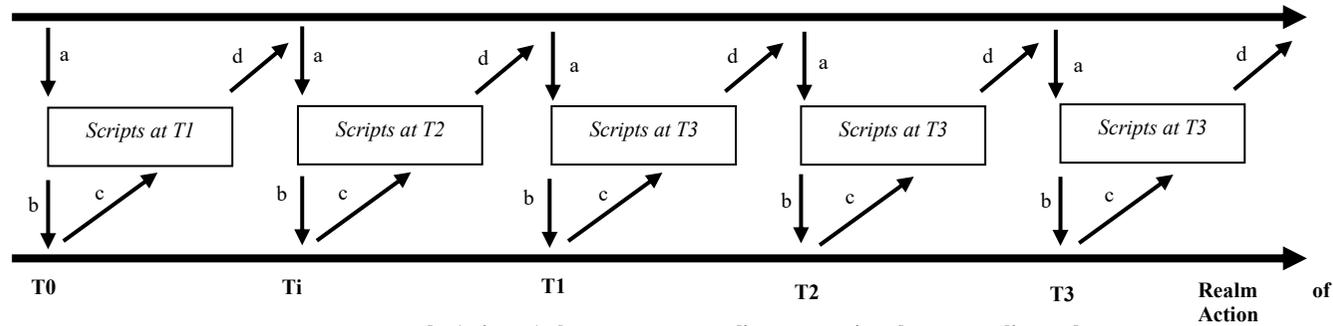
Vignette No.	Governance aspect	Initial selection (T0)	Proposition (T1)	Phase 1 (T1)	Phase 1 extension (T2)	Phase 2 (T3)
11	Scheduling practices	-2/3 milestones - fixed duration contracts	-2/3 milestones - fixed duration contracts	-2/3 milestones - fixed duration contracts	-50/80 milestones - optionally extendable duration contracts	-30 milestones - optionally extendable duration contracts*
12	Geotechnical investigation	-Conducted at 500m lateral intervals	-Conducted at 500m lateral intervals	-Conducted at 500m lateral intervals	-Conducted at 50m lateral intervals	-To be conducted at 25m lateral intervals*
13	Organizational leadership	-Deputation of the Indian Railways personnel for the following positions: managing director, functional directors, and general managerial board; Employment of experienced personnel for the project control functions.	-Deputation of the State Administrative Service and CMDA personnel to the chair and SHD personnel to the project control team -Deputation of the State Administrative Service personnel as the managing director; Deputation of Indian Railways personnel to the directorial and general managerial board; Employment/deputation of experienced/SHD personnel for the project control functions	-Deputation of the State Administrative Service personnel as the managing director; Deputation of Indian Railways personnel to the directorial and general managerial board; Employment/deputation of experienced/SHD personnel for the project control functions -Deputation of more State Government personnel from the departments such as public relations, human resources, liaison, finance, planning, SHD; Employment of more personnel with overseas experience in the directorial and managerial board; Termination of DMRC, near termination of the general consultants, exit of the Indian Railways personnel from the directorial and managerial board.	-Deputation of the State Administrative Service personnel as the managing director; Experienced personnel from the other metros employed in the directorial and managerial board; Few Indian Railways personnel in the managerial board; Employment/ deputation of experienced/SHD personnel for the core project control functions; Deputation of more State Government personnel for the allied project control functions.	-Deputation of the State Administrative Service personnel as the managing director; Experienced personnel from the other metros employed in the directorial and managerial board; Few Indian Railways personnel in the managerial board; Employment/ deputation of experienced/SHD personnel for the core project control functions; Deputation of more State Government personnel for the allied project control functions.
14	Organizational functions - Inter-agency coordination	-Conventional coordination with land acquisition department & utility agencies	-In-house land acquisition & conventional coordination with utility agencies	-In-house land acquisition & utility diversion -Deputation of the land acquisition and utility personnel	-Deputation of the land acquisition department and utility agency personnel	-Deputation of the land acquisition department and utility agency personnel*

Vignette No.	Governance aspect	Initial selection (T0)	Proposition (T1) EPOC 2018 (Re)Organizing in an Uncertain Climate	Phase 1 (T1)	Phase 1 extension (T2)	Phase 2 (T3)
15	Organizational capacity & functions	-45 O&M personnel per route per km -Specialized projects & O&M teams -Projects team assumed comprehensive project management functions	-23 O&M personnel per route per km -Multi-faceted projects team taking over O&M operations -Projects team assumed only supervisory project management responsibilities	-23 O&M personnel per route per km -Multi-faceted projects team taking over O&M operations -Projects team assumed only supervisory project management responsibilities Projects team assumed comprehensive project management functions	-23 O&M personnel per route per km -Multi-faceted projects team taking over O&M operations -Projects team assumed comprehensive project management functions	-23 O&M personnel per route per km* -Multi-faceted projects team taking over O&M operations* -Projects team assumed comprehensive project management functions
16	Public relations practices	-Relatively less extensive press management and marketing responsibilities	-Relatively less extensive press management and marketing responsibilities	-Relatively less extensive press management and marketing responsibilities More extensive press management and marketing responsibilities	-More extensive press management and marketing responsibilities	-More extensive press management and marketing responsibilities*
17	Engagement of the general consultant	-General consultants assumed comprehensive functions	-General consultants assumed comprehensive functions	-General consultants assumed comprehensive functions -General consultants assumed only supervisory functions	-General consultants assumed only supervisory functions	-General consultants assumed only supervisory functions*
18	Engagement of DMRC	-Engagement of DMRC for Phase 1 DPR preparation and principal consultancy	-Engagement of DMRC for Phase 1 DPR preparation and principal consultancy	-Engagement of DMRC for Phase 1 extension DPR preparation and principal consultancy -Principal consultancy agreement was terminated	-No engagements with DMRC during implementation	-Appointment of RITES for DPR preparation -No engagements with DMRC during implementation*

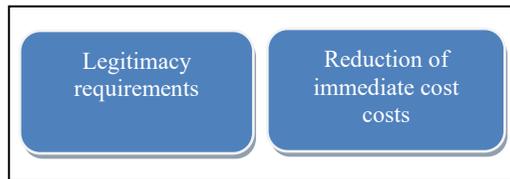
Remarks on Table 2: Conventional governance practices are marked by green colored texts, contesting or intermediate practices are marked by orange colored texts, adaptive governance practices are marked by red coloured texts. *Asterisk mark denotes that the observation reflects the vision and views of the Chennai Metro personnel on how Phase 2 would be most probably governed. Absence of *Asterisk mark in the Phase 2 column denotes that (i) the governance decision is locked-in owing to the preceding decisions (ii) the governance decision has been made already.

Table 2. Mechanisms of sustenance and change of practices

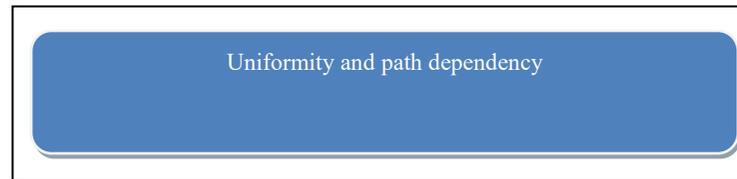
S. No.	Triggers	Proposition (Ti)	Phase 1 (T1)	Phase 1 extension (T2)
Mechanisms that sustained governance practices				
1	Legitimacy requirements (leading to uniformity & path dependency)	11	4	4
2	Reduction of immediate costs (leading to uniformity & path dependency)	3	3	3
Mechanisms that changed governance practices				
3	Increase in functional/aesthetic efficiency (instances in which contests to increase functional efficiency actually led to change)	3 (1)	2 (1)	0
4	Alteration of power structures	1	1	0
3	Generation of tacit/lost meanings	1	1	0
4	Inculcation of flexibility/durability	1	3	1
5	Emergent gaps in roles	0	2	1
6	Absence of desired actor-sets	0	2	0
7	Absence of desired organization-sets/ removal of undesired organization-sets	0	4	2
8	Reduction of transaction costs (instances in which contests to reduce the transaction costs failed)	5(3)	2	1
9	Attainment of self-efficacy	0	2	0
10	Increase in contextual efficiency	0	3	1



Key: a = encode (primary), b = enact, c = replicate or revise, d = externalize and objectify



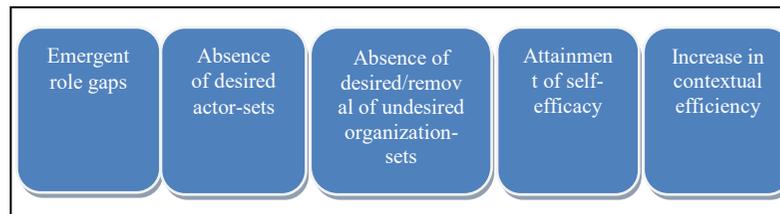
Triggers that sustain the governance practices prior to implementation



Triggers that sustain the governance practices during & after implementation



Triggers that change the governance practices throughout the course of development



Triggers that change the governance practices during implementation

Figure 1 Mapping of triggers along the recursive model of institutions & actions



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