FORUM ARTICLE: REFLECTIONS ON MODELLING APPLICATIONS AND 'BLACK BOXES' IN CONSTRUCTION MANAGEMENT RESEARCH - AN OPINION PIECE.

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ABSTRACT

Black Box models are a common method of investigations across many knowledge domains including Construction Management. Grounded in Systems Theory the 'black box is an indeterminate part of a process of identified inputs creating a set of outputs without necessarily understanding the process of inputs getting to outputs. Some researchers argue that it is better to understand what is going on inside the black box, others are less concerned. However, research is showing that investigating what is inside the black box can incrementally enable better understanding of process, albeit that such understanding is somewhat limited. This paper reviews a recent model developed by the author researching the capabilities needed in construction firms to take climate action in their projects. The analysis of that proposed model highlights the understandable set of limitations of the 3 'black boxes' within the model and offers a rationale to investigate what is 'inside' those boxes, accepting the difficulties arising. These limitations to knowledge are discussed and their effect as barriers to more complete understanding is investigated. As researchers we constantly need to question what we do and how effective it is.

KEYWORDS

Climate action, capabilities, black box, system theory, limitation to knowledge

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INTRODUCTION

Recently I have been researching the capabilities needed for successful/effective adoption of climate action, and of Big Data applications, in the Construction industry. This research has been grounded in Dynamic Capability Theory and resulted in two models which are now being applied empirically. At the recent EPOC in Berlin (2023), I presented a paper on climate action capability research and the application of DCT (Burt et al. 2023) which raised some interesting questions which I think are useful to reflect on in this opinion piece.

Kaminsky (2021) has argued that "a stable climate is an absolutely essential assumption in our existing and past design and construction practices; it is absolutely essential to things we all care about, like for example the continued existence of our species. Even climate mitigation work is not enough; I have come to believe we must all turn our attention to preventing climate change, not by becoming climate scientists, but by harnessing our existing expertise and the incredible, collective power of the built environment." That immediately poses the question: what competencies do those in the construction industry need to achieve this?

DISCUSSION

To begin our reflection let us look at the proposed model of capabilities for taking climate action in construction presented at EPOC (Fig 1).

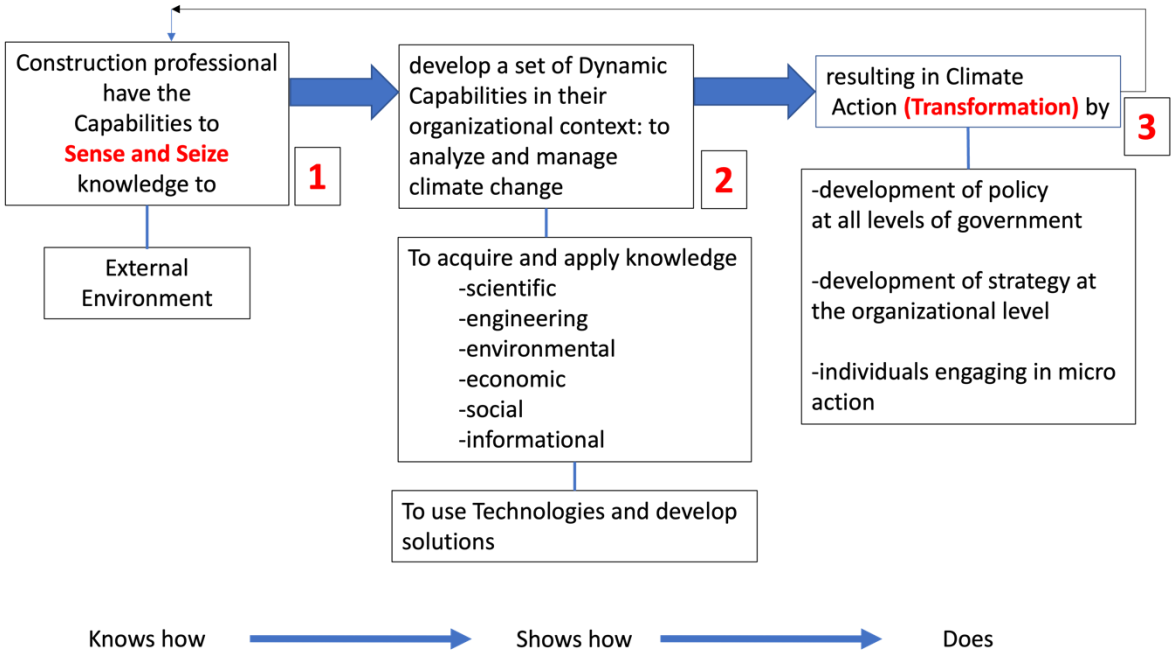

Figure 1: Proposed model of climate action capabilities for construction (Burt et al. 2023)

The model, built on and developed from a Structured Literature Review of existing relevant research, proposes, through a series of 'black boxes' [1,2,3 in Fig 1], that if construction companies have the capabilities to sense and seize knowledge to dynamically analyse and manage climate change and use technologies to develop solutions, then a transformation (climate action) will result. We argued that our proposed model is all inclusive. Without one element of sense, seize, transform, the chance of real change and real action is, it can be argued, significantly reduced. The advantage of adopting DCT in the model is

that it identifies contextual/organisational capabilities, to sense and then seize knowledge, to develop capabilities and skills as competencies, and to produce transformation through action at all levels. This proposed model (Fig 1) builds on the models of Teese et al (1997), Ruittenen et al (2021), Weik (2009), Espallagas and Moron-Monge (2020), to identify what Teece argues is the requirement to 'know how' and the requirements to 'show how and do'. Riuttanen et al (2021) argues that there are certain dynamic elements needed in the process of 'sense, seize and transform' for any real action to happen. These elements are having capabilities of systems thinking, problem solving, ability to collect, analyse and evaluate data and information for sustainability issues, adoption of strategy for transformation, and leadership through participation and collaboration. These capabilities exist within individuals in organisations. These capabilities also exist within what each of the modellers describe as 'context'. In our model this 'context' represents organisational conditions. The sum of the individual capabilities in that organisation are considered in much of the literature as organisational capabilities. However, understanding these elements and the associated capabilities assumed in the model results in their representation as 'black boxes' as there is little research to either describe and/or explain the processes happening to 'sense, seize and transform' to enable climate action in construction organisations.

"The black box" is a concept used to describe a system or process that is observed or analyzed based on its inputs and outputs without knowledge of its internal workings or mechanisms. It is used across knowledge domains including science, engineering, psychology, and information technology. Ashby's (1956) theory of the black box derives from his argument that total understanding is not possible in every case and is inclusive of elements which he describes as uncrossable limits. There are henceforth things that are "fundamentally not discoverable (Von Hilgers, 2011)."

The term 'black box' is used as a metaphor to represent a situation where the internal details are either unknown or intentionally abstracted for simplicity, especially in complex situations and for apparently complex or intricate or very large systems. Systems theory treats a system as a whole, focusing on its inputs and outputs, without delving into the internal interactions and components, focusing on observing inputs, external behaviors and outcomes. In some situations systems theory using a 'black box' is used when detailed knowledge of the internal mechanisms is not necessary for the intended purpose, for example in studies of organisational competencies it is used to understand, manage, and optimize various aspects of an organization's functioning without delving deeply into the internal processes. Von Hilgers (2011) argues that the 'black box' manifests a thoroughly scientific practice because it allows an equally operative and symbolic plane to become the sole scene of inquiry (Von Hilgers, 2011 p43). He argued further that 'the black box as a concept stands a central concern for contemporary society. This is a result of the concept's ability to address the complexities of communication technology. The call for transparency in our society is for this reason just one side of the coin, as no other society produces to such an extent the same sort of opacities of sheer technological complexity that the black box renders manageable' (Von Hilgers 2011 p54). In essence it goes someway to address what we know and what we don't.

'We don't know what we don't know' is an often-quoted statement developed from the Johari Window model of interpersonal awareness (Luft and Ingham 1955) which has been applied in numerous contexts, for

example, strategy development in organisations (Welch 2023). The black box becomes assumptive about what we know and don't know; we just accept that a process occurred, and that it had outcomes. However, if we don't know what happened how can we properly explain those outcomes and reduce the need to repeat the same process with the next innovation? This is highlighted by Black and William (2010, p81) who, in the context of understanding learning, said: "in terms of systems engineering, present policies in the U.S. and in many other countries seem to treat the classroom as a black box. Certain inputs from the outside pupils, teachers, other resources, management rules and requirements, parental anxieties, standards, tests with high stakes, and so on are fed into the box. Some outputs are supposed to follow: pupils who are more knowledgeable and competent, better test results, teachers who are reasonably satisfied, and so on. But what is happening inside the box? How can anyone be sure that a particular set of new inputs will produce better outputs if we don't at least study what happens inside?"

What the black box does is create a scenario or set of scenarios that are probabilistic in the first instance and through continued research become more and more evident (hopefully!). In trying to understand behaviors or decisions we use extant knowledge, previous research conclusions, and hypotheses grounded in those research outcomes, to make a set of assumptions about 'if' and 'then' and begin the process of evaluation. In quantitative studies the researchers develop a set of hypotheses into a causality model using collected data to measure relationships between various elements of the model (Regression, Factor Analysis) or use the whole model to measure the extent to which the model as a whole (the black box) can explain variance (Structured Equation Modeling). There is a substantial literature of attempts to understand what is happening in the 'black box' across many disciplines. Some examples include Goldstein et al. (2015) use plots of individual conditional expectations to better understand how learning capabilities can be explained. Jing et al (2018) used regression analysis to better understand the quantitative relationships of the three thermal adaptation processes in building resulting in significant additions to knowledge about thermal adaptation. Others like Kadefors (2004) have tried to investigate elements within the black box to make better sense of existing observations and used a general theory of trust to better understand trust issues in project management in construction. Howard-Grenville (2006) used ethnography in a longitudinal study to better understand how companies respond to environmental issues.

The outcomes from these and many other research papers are inevitably incomplete, invariably highlight strong causal relations and reject many, enabling researchers to modify models, try new hypotheses and continue the process of improving the reliability of their model (black box). In our model (Burt et al 2023) of the capabilities needed for adoption of climate action in construction companies, that same process of determination of probabilities for the requited capabilities constitute the framework for advancing our knowledge of what capabilities are specifically needed and which capabilities need modification or even rejection. This gives us some clue about what is. These papers invariably enable incremental insights into what is in the 'black box'. Universally, they offer incomplete understanding of the processes assumed in the 'black box'. However, extending knowledge incrementally is an expectation we as researchers should not be dissuaded from. It makes us know more with each increment added. The hope is eventually to complete the model and enable full understanding.

Therefore, we can ask the following questions about the proposed model of climate action capabilities for construction (Fig 1): 'How do we really know for certain that those are the right/correct capabilities, if the firm itself also doesn't know? Is that thing we are looking for even in the 'black box' that we are looking into?' This question mirrors Skinner's (1985) argument that there is an inherent dilemma about inventing explanatory systems which are notable for their depth of meaning but which, he claims, are more properly termed inaccessibility. Others have extended this argument. Kadefors (2004) argues that there needs to be a deeper analysis of what goes on inside the 'black box' of projects to gain a better/fuller understanding of the effects of the various project management measures. Ika (2015 following Hirschman 1967) argues that Economists largely ignore the project management process, accepting it as a black box. The economists' models are concerned with how inputs are translated into outputs, invariably giving no explanation of what goes on in between. They argue that exploring inside the black box can enable a deeper understanding of process. Some methods to examine this process, hidden in the black box, include using a common frame of reference, or a collective memory, and of a subjective commitment (Retour & Krohmer, 2006; Melkonian and Picq 2010). These, they argue, are observable events at a group level but which cannot be related specifically to individuals. The model proposed in this research is attempting a similar method to identify the apparent components in the 'black boxes', identified in the model (Fig 1).

Lehtinen and Aaltonen (2020) and Aubry et al (2021) argue further that organizing external stakeholder engagement in projects remains a "black box," and that opening this black box may help to better understand and explain the solutions that create value-adding external stakeholder engagement, 'contributing to existing research by enhancing our understanding of novel organizing solutions and organizational practices that facilitate and underpin the implementation of management-for-stakeholders approach in inter-organizational projects. Our findings here provide nascent evidence about a fundamental change in how external stakeholder engagement is approached and how to engage external stakeholders on an extended level' (Lehtinen and Aaltonen 2020: 95). What these researchers highlight is that identification of what is going on in a 'black box' is limited by various factors.
Recognition of the limitations of the 'hidden' in the black box are, as the literature shows, important to recognise. Sometimes there are accepted limitations to knowledge which themselves make the articulation of knowledge therein very difficult. Lawton and Beall (2023) have listed 5 keys obstacles that limit our ongoing pursuit of knowledge. These limits include: 1) when measurement is impossible; 2) when things are outrageously complicated, 3) when our best tool to describe the universe may be unreliable; 4) when we can't directly experience something; and 5) when logic itself might be fatally flawed. The context Beall discussed might be in the area of hard sciences, but all of these lImits are applicable to organizational or social science studies. However, these limits are also inherent in the use of the 'black box' in modelling and these generate difficulty because, as Bunge (1963:357) argues, 'black box' theory is one with a high degree of generality and superficiality because the theory is unconcerned with the basic structure of the box itself and is unstable.

In applying the limitations to the pursuit of knowledge identified by Lawton and Beall (2023), we can begin to address those questions relating to 'what is in the black box'? To analyse this apparent conundrum, it is useful to re-examine the model (Fig 1)

in detail. The extant literature and the SLR undertaken in this research (Burt et al. 2023) following (Tranfield et al 2003) were used to frame the model with 3 black boxes: i) sense and siege knowledge for climate action, ii) develop climate action capabilities, and iii) transforming the organization, each grounded in DCT. To facilitate a more detailed analysis, the limitations discussed by Lawton and Beall (2023) are used to frame the following discussion, beginning with the 'black box' of sense and seize knowledge.

The knowledge assumed to exist in any construction organisation is both complex and complicated and would include profession knowledge, knowledge from the PMBOK; knowledge of construction processes; knowledge developed from experience and practice etc. However, using Lawton and Beall, this is obviously complicated by the multiple stakeholders structure of construction and the phased development of construction projects where task vary from phase to phase and where personnel involved will invariably change. The tasks are both individual and undertaken in groups. This diversity could lead to lesser levels of reliability through different sets of knowledge and variation in experience in being able to use and apply that knowledge. Some elements of that reliability are also challenged by the political realm of knowledge use: does everyone involved actually believe that we are experiencing climate change and that there is a real need for action? Does any reference to climate affect conventional project financing? This scenario can emerge when any action adopted begs the question: is there any evidence that taking action on climate now is something we are actually experiencing?

Consider this notion of 'experience'. When a human is stung by a wasp, the experience is both intense and immediate. The human learns that wasps are to be avoided so real behavior changes (Winchester, 2023). With climate action, that experience, I would argue, is neither immediate nor intense. What climate change that we are experiencing now probably results from the effects of the Industrial Revolution, high intensity, mass manufacturing, agricultural intensification, new chamical advances and population growth that emerged in the Twentieth Century (Hardy 2003; Chin and Hart 2023). So, will knowing about climate action actually enable change by itself or does it need more. The Lithium-ion battery is often seen as a 'hope' to reduce carbon emissions from automobile engines. Tests on individual cars show the output of greenhouse gases emission from those cars is reduced. However, others argue that the power needed to charge the lithium-ion battery in the first place was probably generated in many instances from highly creating greenhouse gas emission sources. There is still a hope. Electric vehicles have seemingly reached a tipping point (Gladwell 2000) and there is a realistic hope that each incremental purchase will have some effect. There is no evidence of such a tipping point in the construction process framework. Yet there is some hope in their endeavors of many companies to design and build 'green buildings' (Hwang et al 2017, Sangmesh et al 2023). Does this endeavor translate any experience that will enable construction process workers to adopt processes that are also green? What capabilities then are needed to translate the hope of 'green buildings' into the adoption of green construction processes?

The second box in the model contains an acceptance of the capabilities needed to enable climate action. Development of climate action capabilities is not a 'done deal' process. There is a need to validate the competencies. How do we know that these sets of competencies actually work and help organizations achieve climate action goals? There are many "green buildings" certification programs e.g. LEED

(Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), Green Star (by the Green Building Council of Australia (GBCA), WELL Building Standard, GreenMark (Singapore Green Building Council), Estidama, Pearl Rating System (Developed in the United Arab Emirates (UAE). These programs have some differences and some similarities. They also categorize outcomes into "green buildings" designed or "green buildings" built. One might argue that these tools are measurable and reliable during the design stage. However, the construction stage is complicated because it involves many stakeholders. Is there a tool that can help us measure inputs and outputs of this process? Is the tool reliable? If a tool is reliable, why do we have to have so many certification programs? Those programs, even though they are not specifically built on climate action competencies, do provide technical domain knowledge that construction organizations need to at least address climate change problems (integral to the first box in the model).

The third box assumes there is the capacity and willingness through these capabilities to take action on climate in construction processes. That capacity and willingness are fundamental for the decision-making processes involved. The construction industry is still operating in an overly fragmented market (Martek et al 2019). All stakeholders are profit-seeking organizations which makes the problems even more pronounced because the decision-making process to convert capabilities to act to address climate change is significantly influenced by economic factors and is profit driven. Each decision is made under the bounded rationality (Simon, 1990) of capital cost and/or return of investment. The tool that can help us make decisions is also not reliable, and many times is influenced by the challenge of logic. Most importantly, the lack of experience because of the outcomes of the decisions are not immediate. In other words, it is hard to experience the change. Without experience how will behavior be modified initially? Does this come from a legalistic domain of compliance, as many have tried with implementation of BIM (Dainty et al 2015; Dainty et al 2017; Shirowzhan et al 2020), and/or does it emerge from organisations accepting their corporate responsibilities (Zhang et al 2019) to social development? There is also a rich literature about innovation being driven by 'champions' (Azzouz and Papadonikolaki 2020; Loosemore et al 2021) and that research demonstrates these champions do make a difference, albeit a top-down process. If there is a demonstrated case that adoption of climate change action will foster a better project 'bottom line', or that such action might lead to taxation benefits through compliance then the decision and support of champions should enable action to be taken to develop and build the capabilities needed to achieve these goals. Similarly, it can be argued that if a company's market positioning and reputation is enhanced by adoption of new technology, then a champion can build organisational skills to achieve that. For example, Emaminejad and Akhavian (2023) argued that the use of AI-powered cobots in construction projects is akin to a black box and incorporates unknown technical and psychological aspects of those to job sites. These aspects, they argue, are precursors to trust challenges in the use of this new technology. Their study found that while the key trust factors already identified from existing research was noted by construction experts and end users interviewed, other factors such as financial considerations and the uncertainty associated with change were also barriers against trusting AI-powered cobots in construction. Their argument is essence is to improve trust investigation of what is inside the black box becomes important.

There is one other element to having capabilities to create change and that is argued in the 21st century to rely on 'influence'. Gladwell (2000) has demonstrated the dramatic effects of innovation acceptance, not through capabilities, as they can be learned, but by momentum building and reaching a 'tipping point' where there is a psychological pressure to change and adopt. I would argue then that the model discussed here seeks to identify the capabilities that will be needed to enable the adoption to occur in an industry where reaching tipping points are traditionally slow. In a review paper McNamara and Sepasgozar (2021) highlight the reluctance for innovation adoption in construction; specifically, Yang et al (2019) have addressed the various arguments put for this, noting the significant challenges existing in the construction industry and then offering a solution of co-evolution through interaction in adoption of digital technologies in construction. In essence these reviews by McNamara and Sepasgozar (2021) and Yang et al (2019) confirm both the challenges of adoption of new technologies and ideas and argue that the reasons are very complex. How they interact as causes of this slow adoption is essentially a 'black box', but one where some incremental solutions are offered. Like almost all of the adoption literature (Regona et al 2022; Wuni and Shen 2020) there is little attention paid to the capabilities at the organisational and individual levels needed to create environments where adoption by edict, or by co-adoption or by trial and error happens. So again, what innovation capabilities are needed to enable adoption of climate action? Does the model (Fig 1) really represent those capabilities?

CONCLUSION

Kaminsky argued that in dealing with climate change issues, construction professionals do not need to become climate scientists, rather they should harness their existing expertise. This will involve additions to knowledge. However, as challenges to these additions of new knowledge, Lawton and Beall (2023) have noted, there are limitations. In this paper I have argued that models using black boxes are commonly adopted in research and that processes and actions in these black boxes are most often not understood. There is also recognition that many researchers have tried to add knowledge, incrementally, to the understanding of what is in those black boxes, often adding additional understanding, albeit incomplete.

Existing researchers believe that the expected outcomes of adopting green construction processes will be a) limiting global warming to well below 2 degrees Celsius, b) reduce the emissions of greenhouse gases (GHGs) such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), c) Net-zero emissions, d) Renewable Energy and Energy Transition etc. Is it measurable – Yes, but was it the process that did this or something else? The model proposed at the start of this paper (Fig 1) draws on a rich, existing literature but raises more questions about how the inputs added to the model actually enable knowledge to be sensed, seized and transformed. Dewulf (2021) and Levitt (2011) have analysed the elements of Project Management 2.0 showing that it "requires other project planning tools and different competencies based on relational contracting that exploits psychological and sociological mechanisms, such as developing a shared identity for all stakeholders involved in the project" (Levitt 2011 in Dewulf 2021). Their argument is that change means a change of mindset which is a process within a black box. They offer a solution to what is in the black box stating that change is required from a 'predict and control' paradigm to a 'monitor and adapt' one. These are behavioural changes and ones independent

of inputs into the systems of project management. Yet they, as both authors argue, do affect the outputs.

So I ask, wither the modelling process in construction research? What I have tried to engage the reader with is a sense that black box models have been and are useful in research and offer a framework in which to add to knowledge. However, these models also raise many more questions and they do not offer a real or rational explanation of what happens between the inputs to and outputs from a model. Incrementalism offers researchers a pathway to add to knowledge, building a better and more complete understanding of what is happening, knowing there are limitations. Each addition can then help to answer the questions I asked earlier. But what is happening inside the box? How can anyone be sure that a particular set of new inputs will produce better outputs if we don't at least study what happens inside?"

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