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KNOWLEDGE APPLICATION IN IPD TEAMS: THE ROLE OF ABSORPTIVE AND ARTICULATING CAPACITIES, AND COMMON KNOWLEDGE

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KNOWLEDGE APPLICATION IN IPD TEAMS: THE ROLE OF ABSORPTIVE AND ARTICULATING CAPACITIES, AND COMMON KNOWLEDGE

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ABSTRACT

Architecture, Engineering, and Construction (AEC) project teams following the integrated project delivery (IPD) method allow unconstrained knowledge transfer interactions under shared goals, risks, benefits, and decision-making power among owners, designers, contractors, and key trades starting early on in the project delivery process. IPD can generate unprecedented knowledge transfer networks significantly increasing interactions across disciplinary and organizational boundaries. Although these interactions might benefit AEC projects' performance, an uncontrolled proliferation might have a negative effect. Individuals might spend excessive time reconciling diverse knowledge, be unable to efficiently handle such interactions, and/or lack common knowledge necessary to collaborate with others from different disciplines. This paper examines the underlying factors (i.e., articulating and absorptive capacities, and common knowledge) driving knowledge application at individual level in IPD teams. Via online surveys, data was collected from an IPD by contract project team including around 160 members from distinct AEC organizations. Data was analyzed via structural equation modeling. Results show that in IPD project teams: (1) Team members occupy network positions where their absorptive capacities enable application of transferred knowledge; and (2) Individuals can apply knowledge from their peers without sharing large portions of common knowledge. The study main contribution to the body of knowledge states that individuals' absorptive capacities and free interactions constitute two key factors to shape knowledge transfer networks facilitating knowledge application in AEC project teams. This expands our understanding about AEC project team integration which involves not only an increase of knowledge transfer interactions across disciplines and organizations, but also the degree to which team members can freely move in a knowledge transfer network to take positions where their absorptive capacities enable knowledge application.

KEYWORDS

Interorganizational project teams, integrated project delivery, knowledge application.

INTRODUCTION

AEC project teams gather members from diverse organizations and disciplines to develop a common project. They are expected to collaborate to deliver a product meeting targeted cost, time, quality, and sustainability requirements. Recurrently, poor knowledge transfer between these team members results in team fragmentation and deficient project outcomes (i.e., time, cost, and quality) (Korkmaz and Singh, 2012). To overcome team fragmentation via enhanced

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knowledge transfer, the AEC industry recently started looking at project teams as social networks needing increased quantity and quality (e.g., degree of trust) of interactions between team members (Chinowsky, Diekman and Galotti, 2008; Chinowsky, Diekmann and O'Brien, 2010). Therefore, AEC project teams recently started implementing relational contracting approaches to project deliver to promote knowledge transfer interactions based on trust among team members, such as IPD.

IPD method imposes free knowledge transfer interactions among key parties (i.e., owners, designers, contractors, and multi-disciplinary subcontractors) since early on during project delivery (AIA, 2007; AGC, 2010). Currently, it is not known how knowledge transfer networks in IPD teams are shaped so they favor effective application of multi-disciplinary and multi-organizational knowledge to deliver a product meeting targeted project outcomes. The research goal is to examine key factors influencing the development of knowledge transfer networks facilitating individuals' knowledge application including: articulating and absorptive capacities (i.e., ability to codify knowledge and make it comprehensible, and ability to identify and understand valuable knowledge, respectively), and common knowledge. To achieve the study goal, data was collected from an IPD by contract project team with more than 160 team members from multiple organizations and disciplines. Data analysis was performed via structural equation modeling which allows examining causal models with latent variables determined via other observed variables (i.e., key factors examined herein are latent variables inferred from survey indicators).

BACKGROUND

During the last two decades, knowledge management has attracted many researchers due to its drastic impact on organizational performance. This has resulted in a general shared perception that processes involving knowledge transfer, diffusion, creation, retention, and combination are critical to optimize organizational efficiency, and gain and sustain competitive advantage (Grant, 1996; Webb, 1998; Argote and Ingram, 2000; Earl, 2001; Argote et al., 2000, 2003; Frank et al., 2011; Foss et al., 2010).

The AEC literature embraces research under all key factors affecting knowledge management outcomes. AEC project teams' difficulties to integrate diverse knowledge, due to involving individuals with different backgrounds that typically do not know each other before project start, has strongly attracted researchers. Thus, recent research has greatly focused on knowledge transfer across disciplines (e.g., Iorio et al., 2012, 2014; Alin et al., 2011, 2013), motivations for knowledge sharing (e.g., Chinowsky et al., 2008; Javernick, 2012), adoption of collaborative project delivery methods (PDMs) as an innovation (e.g., Unsal and Taylor, 2011; Sun et al., 2015), or effects of PDMs on team integration and performance (e.g., Baiden et al. 2006, 2011; Mollaoglu et al., 2013, Franz et al., 2016).

Poor knowledge transfer within AEC project teams might result in team members holding asymmetric knowledge or inversely understanding the same knowledge, thus hindering effective collaboration across disciplinary and organizational boundaries (Adler, 1995; Poole, 2011). AEC teams can ensure an appropriate quantity and quality of knowledge transfer via engaging in key communication behaviors such as monitoring, managing, and negotiating (Paik, Miller, and Mollaoglu, 2017). They involve, respectively, detecting key knowledge impacting project performance, sharing key portions of knowledge across disciplinary and organizational boundaries, and devising combined solutions via open communication (Sun, Mollaoglu, Miller, and Manata, 2015). These behaviors might improve AEC teams' performance via enhanced team integration promoted by higher levels of knowledge transfer (Mollaoglu et al., 2014; Mihic et al., 2014). Nevertheless, increased knowledge transfer might be useless if it does not enable knowledge application, that is, exploitation of transferred knowledge.

Knowledge application refers to individuals' exploitation of acquired knowledge (Alavi and Tiwana, 2002) due to replication (Zander and Kogut, 1995), or assimilation for later modification and adaptation to specific needs (Szulanski, 1996). Application of transferred knowledge across AEC project teams' disciplinary boundaries might be problematic if knowledge receivers lack common knowledge with senders (Alavi and Leidner, 2001). In such case, integrated teams increasing knowledge transfer interactions might not outperform non-integrated teams (Baiden et al., 2006, 2011).

POINT OF DEPARTURE AND STUDY HYPOTHESIS

This section first discusses knowledge transfer and application in the context of AEC project delivery methods leading to the study focus as the unit of analysis: ***IPD project teams***. Second, ***key factors influencing individuals' knowledge application*** are examined including: articulating and absorptive capacities, and common knowledge. And third, in the light of these discussions, ***study hypothesis, model, and mathematical model*** are developed.

Knowledge Transfer and Application under AEC Project Delivery Methods: Knowledge transfer might merely refer to sending or receiving knowledge, or assimilation and/or utilization of acquired knowledge (Foss et al., 2010). This study considers that knowledge transfer refers to either sending or receiving knowledge without the need to understand or use it. Knowledge application refers to individuals' exploitation of acquired knowledge (Alavi and Tiwana, 2002) due to replication (Zander and Kogut, 1995), or assimilation for later modification and adaptation to specific needs (Szulanski, 1996). Since replicating knowledge without fully understanding its details might be a valid strategy to benefit AEC project outcomes, this study considers knowledge application as the act of exploiting received knowledge without the need to fully comprehend it.

The most common project delivery methods (PDMs) in the AEC industry under which project teams transfer knowledge include: Design-Bid-Build (60%), Construction Management at Risk (25%), Design-Build (15%), and Integrated Project Delivery (IPD) (1%) (CMAA, 2012). These project delivery methods present two main differences affecting knowledge management in AEC project teams, especially regarding knowledge transfer outcomes. First, regarding features of knowledge transfer networks, they propose different timing of involvement of key parties (i.e., owners, designers, contractors, and multi-disciplinary subcontractors), and degree to which they can freely interact. And second, regarding features of relationships between units, they implement distinct motivational factors to promote collaboration between key parties. Therefore, the influence on knowledge transfer on different project delivery methods in the AEC industry may create knowledge transfer networks constraining many team members' interactions to reduce costs associated with knowledge transfer. Different from the others, an innovative and fairly recent project delivery method, Integrated Project Delivery (IPD), aims to create knowledge transfer networks via free interactions involving all key parties to detect and exploit any key valuable knowledge. Despite increasing knowledge transfer costs, IPD might ultimately generate a greater payoff due to improved project outcomes. IPD project teams are suitable to examine what factors, other than imposed hierarchical structures, shape knowledge transfer networks; thus, is selected as the focus for the unit of analysis in this study.

***Absorptive Capacity*:** Individuals possess certain level of absorptive capacity, a concept including three dimensions: The ability to identify, assimilate, and apply valuable knowledge (Cohen and Levinthal, 1990; Mowery and Oxley, 1995; Da Silva and Davis, 2011). The third dimension coincides with the concept of knowledge application previously presented. Nonetheless, in this study, absorptive capacity is defined as the ability to only identify and understand knowledge. The reason is the need to separately consider the concept of knowledge application which, unlike absorptive capacity, allows exploitation of valuable knowledge without the need to previously understand it.

A knowledge receiver's absorptive capacity depends on his/her network position, and stored knowledge in his/her brain related to transferred knowledge (Cohen and Levinthal, 1990). First, the network position determines a receiver's accessible knowledge and, therefore, what valuable knowledge he/she can identify. And second, a receiver assimilates new knowledge easier if he/she has some related knowledge (Grant, 1996; Alavi and Leidner, 2001). By "associative learning," he/she manipulates and combines portions of this related knowledge to understand transferred knowledge (Reagans and McEvily, 2003). For instance, someone describing a room may use the concepts of height, width, and length, and combine them to articulate a description. If the receiver of this description also commands the same geometric concepts, he/she will make associations with them to depict the room in his/her mind.

Therefore, despite possessing large amounts of knowledge, a receiver's absorptive capacity might be low if he/she occupies network positions supplying knowledge with which he/she lacks related knowledge (Lane and Lubatkin, 1998). In IPD project teams, a receiver might tend to avoid these network positions due to being unable to apply acquired knowledge, and his/her willingness to collaborate because of sharing goals, risks and benefits (Tjosvold, 1999).

Thus, ***in IPD project teams, a receiver with high absorptive capacity indicates that he/she is placed in a network position capturing knowledge with which he/she shares some related knowledge, thus easing knowledge application.***

Articulating Capacity*:** Individuals possess articulating capacity to codify knowledge and make it comprehensible to others (Reagans and McEvily, 2003). In IPD teams, knowledge senders with high articulating capacity possess common knowledge with receivers (Burt, 2002). This allows senders to codify knowledge considering a receiver's perspectives or assumptions to understand knowledge, thus facilitating the receiver's assimilation of transferred knowledge without being distorted (Thomas, DeScioli, Haque and Pinker, 2014). For example, an individual in an IPD team might send a project schedule to a peer. If the peer receiving the schedule possesses differing assumptions regarding resources' productivities to calculate durations of activities, then he/she will not be able to understand the schedule. ***Therefore, senders with high articulating capacity make it easier for a receiver to apply transferred knowledge in IPD project teams.

***Common Knowledge*:** As argued above, a key component constituting individuals' absorptive and articulating capacities is their stored common knowledge with transferred knowledge. Nevertheless, how much of this common knowledge do individuals' absorptive and articulating capacities need to favor application of transferred knowledge?

Common knowledge is necessary to ease assimilation of transferred knowledge via "associative learning" (Reagans and McEvily, 2003). A receiver may just need small portions of common knowledge with transferred knowledge to identify and understand the valuable pieces. Moreover, too much common knowledge might impede the receiver to test novel combinations of diverse knowledge and devise innovative solutions (Nooteboom et al., 2007). For instance, a mechanical engineer may know that key 10% of the electrical system that is important for him/her to develop and connect a compatible mechanical system. Thus, his/her absorptive capacity (i.e., ability to identify and understand valuable knowledge from the electrical system) might be high while sharing low common knowledge (i.e., 10%) with the engineer developing the electrical system.

Therefore, individuals' knowledge application might not be dependent on sharing large amounts of common knowledge but key pieces. ***Herein it is tested whether high common knowledge between a receiver and his/her senders enhances his/her knowledge application.*** If the test fails, it would suggest that key shared pieces of knowledge, even though small, might suffice to enhance knowledge application.

Considering all the above, the following study hypothesis is developed:

Study Hypothesis: In IPD project teams, the higher a receiver's absorptive capacity, senders' articulating capacities, and common knowledge between the receiver and senders, then the higher the receiver's knowledge application.

The study model reflecting the hypothesis above is displayed in Figure 1.

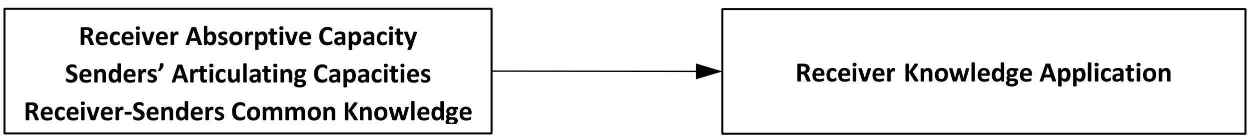

Figure 1: Study Model

The mathematical equation below represents the study hypothesis, where:

A_i: Ability of receiver (i) to apply transferred knowledge;
α_0: Intercept;
Θ_1: Effect of factor;
b_i: Absorptive capacity of receiver (i);
$\Sigma a_{i'}/N$: Average articulating capacity of (N) senders (i') transferring knowledge to receiver (i);
$\Sigma K_{ii'}/N$: Average common knowledge between receiver (i) and (N) senders (i') transferring knowledge to receiver (i); and
e:: Errors are assumed iid normal, with mean zero and variance (σ^2).

$$A_i = \alpha_0 + \theta_1 b_i + \theta_2 (\Sigma a_{i'}/N) + \theta_3 (\Sigma K_{ii'}/N) + e$$

Equation 1: Mathematical Model for the Study Hypothesis

The equation will help develop the statistical model to test the study hypothesis.

METHODS

To test the study hypothesis, data was collected from project team members of an IPD project. The IPD project selected for the case study is the delivery of a four story higher institution building project sized at 100,000 square feet. The project is valued approximately at $60 million and was designed in about 13 months. The project team during design involved more than 160 team members. All key parties in the project including owner, designers, constructors, and mechanical, electrical, structural, glazing, and plumbing subcontractors signed a multi-party IPD contract by which they shared goals, benefits, risks, and power in decision-making. Owners' representatives and designers kicked of the project with the validation phase; general constructors came on board at the beginning of the conceptual design; electrical and mechanical subcontractors got involved at the end of the conceptual design phase; steel, structural, and glazing subcontractors came into the project at the beginning of design development phase; and other subcontractors, who did not necessarily sign the multi-party IPD contract, were added later during design development when required (e.g., landscaping).

IPD method aims to foster intense knowledge transfer interactions early on in project delivery and maximize the impacts of key team members' knowledge on design outcomes; thus, eliminating or minimizing design changes during construction. As most key knowledge transfer interactions tend to occur during the design phase in IPD projects, this study collected data during the design phase in project delivery at about 50% design completion mark, 4 months into the project.

To collect data from this project, owner representatives were reached and recruited via personal rapports. Upon their agreement and following the Institutional Review Board guidelines, all project team members were called to participate in the data collection. Using the team roster supplied by the owner representatives, a web-based survey link was emailed to all project team members asking for their voluntary participation in this study. Reminders via email were sent every two days for ten days to achieve the highest possible response rate. The survey aimed to:

1. Capture individuals' top 5 most valuable knowledge transfer interactions.
   Knowledge transfer interactions is defined as the act of receiving or sending knowledge (Chinowsky et al., 2008). To map out these interactions, individuals report those team members who provided them with valuable knowledge (Chinowsky et al., 2011). In this study survey, participants were asked to list, in order of importance, the top 5 individuals from the case study project team (within/outside their home organization) who provided them with the most valuable knowledge during the last month. Capturing interactions providing most valuable knowledge instead of interactions providing knowledge more frequently is appropriate for this research. Highly frequent interactions might exclude lowly frequent interactions supplying key valuable knowledge and exerting a greater impact on AEC projects' outcomes. In addition, this approach allows examining whether individuals have the appropriate capacities to exploit knowledge that is valuable rather than frequently transferred.

2. Collect data on the study variables as presented in Table 1 below.
   The participants were asked to report on the characteristics in Table 1 for each of the 5 individuals they listed above at the first section of the survey. They were asked to consider their interactions within the last month in making those evaluations. Their answers were reported in in a five-level Likert scale.

Table 1: Description and Operationalization of Study Variables

Variables	**Description**	**Latent Variables & Indicators**	
Independent Variables:	Individuals' capacity to make knowledge comprehensible to others (Reagans and McEvily, 2003)	**Articulating Capacity**	
Sender's Articulating Capacity		***Art1***	***Art2***
		This person articulated his/her knowledge in such a manner that it was easy to understand	This person made complex knowledge look simple
Receiver's Absorptive Capacity	Individuals' capacity to identify and understand valuable knowledge (Cohen and Levinthal, 1990)	**Identify**	
		Iden1	***Iden2***
		This person was able to identify within the team the knowledge that would be most valuable to improve project performance	This person was able to determine what knowledge within the team was credible and trustworthy
		Understand	
		Und1	***Und2***
		This person's expertise in design-construction projects made it easy for him/her to understand the knowledge conveyed to	This person was able to easily connect to his/her knowledge in design-construction projects the knowledge conveyed to him/her
Receiver and Sender's Common Knowledge	Shared knowledge or overlapping areas of expertise between two individuals (Reagans and McEviliy, 2003).	**Common Knowledge**	
		CK1	***CK2***
		This person's expertise in design-construction projects overlapped with mine	This person and I had similar knowledge that helped us communicate easier
Dependent Variable:	Individuals' ability to exploit received knowledge to develop her tasks (Alavi and Tiwana, 2002; Gold, Malhotra, Segars, 2001).	**Knowledge Application**	
Receiver's Knowledge Application		***Kapp1***	***Kapp2***
		This person easily adapted his/her work to make use of the knowledge conveyed to him/her	This person quickly applied the knowledge conveyed to him/her *improving project performance*

The data collected was analyzed via structural equation modeling (SEM). SEM was performed via Rstudio software with the Lavaan package. SEM is a general framework utilizing path analysis techniques and general linear models such as multiple linear regression while allowing to model latent variables. All study variables in this research are latent variables, that is, unobserved variables that must be inferred from observed variables (e.g., survey indicators). SEM is an adequate method to evaluate both the established correlations among the latent variables in the study hypotheses, and internal validity of latent variables' indicators, that is, whether the survey indicators are truly measuring the study variables (Rosseel, 2013). Since the dependent variable's sampling data was left-skewed, the function testing the model's fit used the MLR estimator (i.e., maximum likelihood estimation with Huber-White standard errors). This estimator ensures robustness when dependent variables' sampling data is not normally distributed (Rosseel, 2013).

RESULTS

Of the 164 project team members, 32.3% (n=53) responded. After missing data points were eliminated sample size of 48 was reached for data analysis. The sample included mostly male (75%) and white (98%) individuals. Participating team members belonged to more than 10 different organizations. Their roles included: owner's representatives (21%); architects (11%); contractors (11%); mechanical subcontractors (11%); electrical subcontractors (4%); structural subcontractors (2%); and others (40%) including steel fabricators, data communication and information technology engineers, sustainability consultants, glazing contractors, plumbing and fire protection engineers, mechanical and electrical consultants, project managers, lightning and controls engineers, building information modeling (BIM) coordinators, landscape architects, archeology experts, soil erosion engineers, interns, and advisor on needs. Most of team members involved had an experience working in the AEC industry between 20 and 35 years. Most of them had participated in less than 5 AEC projects implementing IPD by contract before getting involved in this case study project.

Frequent methods used to transfer knowledge across disciplines and/or organizations included core team meetings to evaluate work performed and plan future work, pull planning meetings to coordinate team members' tasks, cluster groups using BIM to simultaneously design multiple building systems, and reconciliation meetings to adjust design according to cost estimate.

Most of the knowledge transfer interactions between team members occurred weekly (45%) or monthly (37%). Daily interactions were the least frequent (18%). Team members primarily transferred knowledge via face-to-face conversations (63%), video-conferences (15%), phone calls (13%), and shared software (e.g., Revit) (6%).

Descriptive statistics for the collected data are shown in Tables 2, 3, and 4.

Table 2: Sampling Data Distribution and Correlations among Latent Variables

Lat. Var.	**Min.**	**1st Qu.**	**Median**	**Mean**	**3rd Qu.**	**Max.**	**Kapp**	**Abs**	**Art**	**Ck**
Kapp	2.00	4.00	4.43	4.25	4.77	5.00	-	-	-	-
Abs	2.50	4.00	4.38	4.27	4.69	5.00	0.79	-	-	-
Art	3.70	4.14	4.29	4.31	4.43	5.00	-0.36	-0.32	-	-
Ck	2.17	3.75	4.24	4.04	4.50	5.00	0.34	0.50	-0.18	-

Sample Size: 48. Kapp: *Receiver Knowledge Application*; Abs: *Receiver Absorptive Capacity*; Art: *Senders' Articulating Capacities*; Ck: *Receiver-Senders Common Knowledge.*

Table 3: Sampling Data Distribution of Latent Variables' Indicators

Value	Kapp1	Kapp2	Iden1	Iden2	Und1	Und2	Art1	Art2	Ck1	Ck2
Min.	2.00	2.00	2.00	2.00	2.80	3.00	3.82	3.00	1.0	1.00
1st Qu.	4.00	4.00	4.00	4.00	4.03	4.00	4.32	4.05	3.87	4.00
Median	4.50	4.67	4.39	4.71	4.71	4.50	4.53	4.22	4.25	4.25
Mean	4.44	4.42	4.24	4.42	4.49	4.44	4.50	4.19	4.15	4.19
3rd Qu.	5.00	5.00	5.00	5.00	5.00	5.00	4.66	4.36	5.00	5.00
Max.	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

Sample Size: 48 Kapp: *Receiver Knowledge Application*; Abs: *Receiver Absorptive Capacity*; Art: *Senders' Articulating Capacities*; Ck: *Receiver-Senders Common Knowledge. For indicators, see Table 1.*

Table 4: Correlations Among Indicators of Latent Variables

Indicator	Kapp1	Kapp2	Iden1	Iden2	Und1	Und2	Art1	Art2	Ck1	Ck2
Kapp1T1	-	-	-	-	-	-	-	-	-	-
Kapp2T1	0.85	-	-	-	-	-	-	-	-	-
Iden1T1	0.73	0.72	-	-	-	-	-	-	-	-
Iden2T1	0.48	0.43	0.69	-	-	-	-	-	-	-
Und1T1	0.69	0.66	0.57	0.35	-	-	-	-	-	-
Und2T1	0.68	0.59	0.46	0.34	0.88	-	-	-	-	-
Art1T1	-0.36	-0.39	-0.36	-0.21	-0.29	-0.15	-	-	-	-
Art2T1	-0.16	-0.23	-0.05	0.20	-0.52	-0.38	0.20	-	-	-
Ck1T1	0.50	0.39	0.34	0.29	0.66	0.64	-0.03	-0.30	-	-
Ck2T1	0.37	0.30	0.29	0.40	0.48	0.42	-0.09	-0.05	0.75	-

Sample Size: 48 Kapp: *Receiver Knowledge Application*; Abs: *Receiver Absorptive Capacity*; Art: *Senders' Articulating Capacities*; Ck: *Receiver-Senders Common Knowledge. For indicators, see Table 1.*

The sample (n=48) contained individuals for which values for all latent variables could be collected. There were 53 additional individuals for which there were missing values for one or two latent variables. When performing SEM, the missing values were estimated via full information maximum likelihood (FIML) which calculates "unbiased parameter estimates and standard errors" (Newsom, 2017). Therefore, SEM was performed over 101 (i.e., 48 + 53) observations.

After a first attempt running SEM, several actions were performed to improve the model fit. The variances of Receiver Knowledge Application and Art1 were constrained to equal zero due to delivering negative values. In addition, based on variables' modification indices, a new path was added in the model between indicators Und1 and Art2. Modification indices can be used to select key additional links in the model to improve the fit (Rosseel, 2013).

SEM results show Minimum Function Test Statistic (Chi-Square) of 43.71 (p = 0.03), indicating that we do not reject the null hypothesis of perfect model fit. The Comparative Fit Index (CFI=0.96) is greater than 0.95 and close to 1.00, suggesting that the model fits the data well (Hu and Bentler 1999; Kline 2005; Hair et al. 2010). The Tucker-Lewis Index (TLI=0.94) is greater than 0.8 and close to 1.00, indicating a good fit as well (Hu and Bentler, 1999). The Root Mean Square Error of Approximation (RMSEA) is 0.08 (p = 0.15), that is, equal or lower than 0.8; and the lower bound of its 90% confidence interval (CI.lower=0.03) is close to 0.0, suggesting a reasonable fit (Browne and Cudeck, 1993). ***Overall, the fit indices suggest that the model in Figure 2 is plausible for the data***.

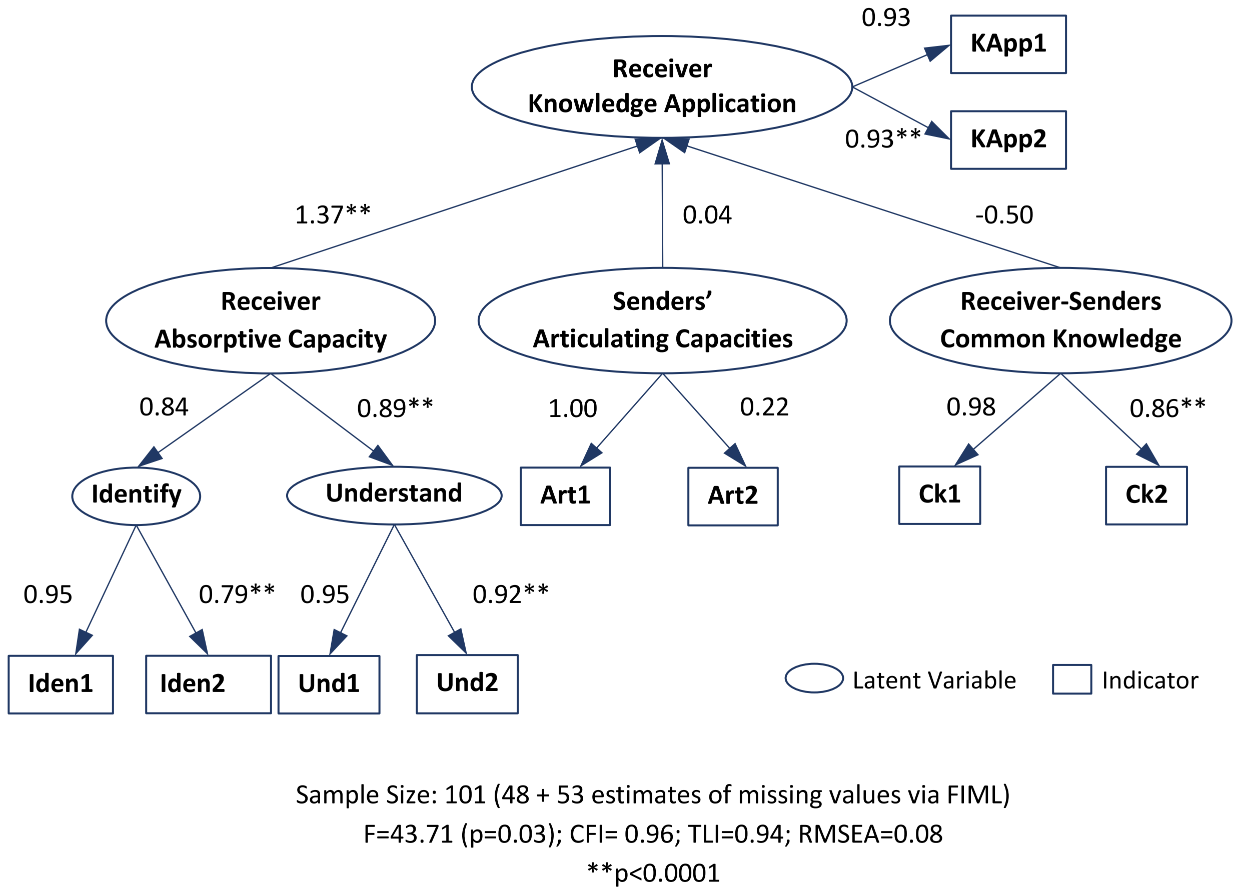

Figure 2: Model to Test the Study Hypothesis Including Path Coefficients, and Model Fit Indices

Factor loadings (i.e., path coefficients between latent variables and their respective indicators (Figure 2)) for indicators Kapp2, Iden2, Und2, and ComK2 are 0.93, 0.79, 0.92, and 0.86, respectively. In addition, they are statistically significant ($p<0.001$), and with confidence intervals (95%) with high lower and upper limits: (0.81, 1.23), (0.39, 1.12), (0.78, 1.18), and (0.61, 1.03) respectively. The factor loadings were calculated using the "marker indicator" method (Hoyle, 2012). This method initially fixes one factor loading to 1.00 between a latent variable and one of its indicators (i.e., between Kapp1, Iden1, Und1, and ComK1 and their respective latent variables in this case). This allows using the path coefficient between the latent variable and the indicator as a reference to calculate the variance of the latent variable.

Therefore, data suggests that, in the model in Figure 2, indicators used to measure Receiver Knowledge Application (i.e., Kapp1 and Kapp2); Identify (i.e., Iden1 and Iden2); Understand (i.e., Und1 and Und2); and Receiver-Senders Common Knowledge (Ck1 and Ck2) are valid. In addition, path coefficients between Receiver Absorptive Capacity's and its dimensions, i.e., Identify and Understand, are high, 0.84 and 0.89, respectively. Thus, data do not reject the multi-dimensionality of Receiver Absorptive Capacity. Finally, results suggest a weak and not statistically significant factor loading between Senders' Articulating Capacities and its second indicator (i.e., factor loading=0.22 with Art2T1). Therefore, data reject the validity of the indicators used to measure Senders' Articulating Capacities (i.e., Art1 and Art2).

Reliability of measurements was calculated via Cronbach's alpha. If this coefficient is greater than 0.7, then it can be assumed that indicators consistently measure the latent variable they intend to measure (Nunnally, 1978). ***Results showed that measurements are reliable for all latent variables except for the fourth (model in Figure 2):*** Receiver Knowledge Application ($\alpha=0.92$), Identify ($\alpha=0.82$), Understand ($\alpha=0.94$), Senders' Articulating Capacities ($\alpha=0.32$) and Receiver-Senders Common Knowledge ($\alpha=0.85$).

SEM yields that the only latent variable statistically significant is Receiver Absorptive Capacity with a path coefficient equal to 1.37 (p<0.0001). The confidence interval at the 95% significance level for this path coefficient includes high lower and upper boundaries (0.89, 1.98), thus suggesting a ***strong relation between Absorptive Capacity and Receiver Knowledge Application.*** However, data reject that Receiver Knowledge Application is significantly influenced by Senders' Articulating Capacities, and Receiver-Senders Common Knowledge. Nevertheless, Table 2 displays a high correlation between Receiver Absorptive Capacity and Receiver-Senders Common Knowledge ($r=0.50$). This can raise multi-collinearity issues hiding the real effect of Receiver-Senders Common Knowledge on the dependent variable. Therefore, the model in Figure 2 was re-tested dropping the variable Receiver Absorptive Capacity. Results showed that Receiver-Senders Common Knowledge was highly correlated with the dependent variable ($r=0.77$) and close to statistical significance at the 0.05 level.

DISCUSSIONS

Results suggest that, in IPD teams, individuals' absorptive capacities enhance their knowledge application. Team members' absorptive capacities are dependent on the common knowledge that they share with new knowledge that they receive (Cohen and Levinthal, 1990). This common knowledge allows receivers to assimilate acquired knowledge via "associative learning" (Reagans and McEvily, 2003). Thus, team members search network positions where they share common knowledge with new knowledge that they receive. Team members preferably occupy these positions because they enhance their absorptive capacities and, subsequently, knowledge application (Lane and Lubatkin, 1998). Thus, the study posits that ***team members occupy***

network positions where their absorptive capacities enable application of transferred knowledge in IPD teams.

This finding has important implications for AEC project team integration. This is frequently seen as an increment of knowledge transfer across disciplinary and/or organizational boundaries (Baiden et al., 2006; Troy et al., 2008; Mollaoglu et al., 2013; Franz et al., 2016). However, if transferred knowledge cannot be applied, project performance might be deficient. Therefore, effective AEC team integration also involves the degree to which team members can freely interact, and take network positions where their absorptive capacities allow them to apply transferred knowledge. Thus, owners in AEC projects aiming to improve team integration should not only bring in key parties early on during project delivery to increase knowledge transfer interactions. Moreover, owners should also evaluate key parties' absorptive capacities to enable application of transferred knowledge.

Additionally, results suggested that individuals' knowledge application is not dependent on sharing high levels of common knowledge in IPD teams. However, this relation was very close to statistical significance. Common knowledge is vital to understand new knowledge via "associative learning" (Alavi and Leidner, 2001; Reagans and McEvily, 2003). Moreover, individuals' absorptive capacities are built upon the common knowledge that they share with acquired knowledge (Cohen and Levinthal, 1990). Nevertheless, per results, receivers might only necessitate to share key small portions of common knowledge with senders so their absorptive capacities enable application of transferred knowledge (Nooteboom et al., 2007). Hence, the second study posits that ***individuals can apply knowledge from their peers without sharing large portions of common knowledge in IPD teams.*** This finding also has key implications for AEC project team integration. Increased inter-disciplinary interactions in integrated teams should involve team members sharing key, rather than large, pieces of common knowledge to make interactions fruitful.

CONCLUSION

AEC project teams are temporarily formed by experts belonging to different organizations and disciplines. Unfortunately, these project teams frequently struggle with fragmentation, that is, team members' inability to merge diverse knowledge resulting in the pursuit of personal interests at the expense of project performance. To overcome fragmentation, AEC project teams are progressively implementing relational contracting approaches to project delivery such as Integrated Project Delivery (IPD) method.

The IPD method allows unconstrained knowledge transfer interactions among key parties (i.e., owners, designers, contractors, and subcontractors) since early on during the design phase. IPD significantly increases knowledge transfer interactions across disciplinary and organizational boundaries, thus potentiating team integration and avoiding fragmentation. However, an uncontrolled proliferation of such interactions can negatively affect team performance: Team members might spend excessive time applying diverse knowledge, be unable to do so, and/or lack common knowledge to understand diverse knowledge.

This paper examined the underlying factors (i.e., articulating and absorptive capacities, and common knowledge) driving knowledge application at individual level in IPD teams. To test the study hypothesis, data from all team members of an IPD project was collected via a web-based survey at design development stage during project delivery.

The results showed that the higher a receiver's absorptive capacity, the higher his/her knowledge application. Indicators for senders' articulating capacities were not valid. There is no statistically significant correlation between common knowledge and knowledge application.

The study's main contribution to the body of knowledge states that individuals' absorptive capacities and free interactions constitute two key factors to shape knowledge transfer networks facilitating knowledge application in AEC project teams. This expands our understanding about AEC project team integration which is not a mere increase of knowledge transfer interactions across disciplinary and organizational boundaries. In addition, effective team integration involves the degree to which team members can freely move in the knowledge transfer network to take positions where their absorptive capacities enable knowledge application. Therefore, owners aiming to optimize AEC project outcomes should include early on during project delivery those key parties whose absorptive capacities in key network positions enable knowledge application.

Although the findings proposed herein focus on IPD project teams in the AEC industry, they are grounded on research findings and/or theories from diverse bodies of knowledge such as construction management, social networks, psychology, communication, knowledge management, or organizational science. Thus, it is expected that the study findings will be applicable to industries other than the AEC one where inter-organizational project teams similar to IPD teams are temporarily formed to achieve specific goals.

Main limitations of this research include AEC projects teams' size, complexity, and unit of analysis being limited to individuals working only in an IPD project. This research offered key findings after testing study hypotheses collected from one IPD project team relatively large developing a complex design (i.e., more than 160 team members, and $60 million budget approximately). Future research can benefit from comparisons with smaller teams, and project teams developing simpler designs, or implementing non-IPD methods.

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