Project Team Collaborations During Time of Disruptions: Transaction Costs, Knowledge Flows, and Social Network Theory Perspective

Hasan Gokberk Bayhan,[1] Sinem Mollaoglu,[2] Hanzhe Zhang,[3] and Kenneth A. Frank[4]

[1]Graduate Research Assistant, School of Planning, Design, and Construction, Michigan State University, East Lansing, MI 48824, United States. Email: bayhanha@msu.edu

[2]Professor, School of Planning, Design, and Construction, Michigan State University, East Lansing, MI 48824, United States. Email: sinemm@msu.edu

[3]Assistant Professor, Department of Economics, Michigan State University, East Lansing, MI 48824, United States. Email: hanzhe@msu.edu

[4]Professor, Department of Counseling, Educational Psychology and Special Education, Michigan State University, East Lansing, MI 48824, United States. E-mail: kenfrank@msu.edu

ABSTRACT

The project-based nature of the construction industry requires organizations to establish temporary alliances to complete projects within required limitations. Knowledge transfers (KT) and transaction costs (TC) are often studied in economics as two separate theories. In the construction industry, the relationship between KT and TC has not been evaluated in the context of inter-organizational project teams. To fill this gap and better understand the links between TC and KT in project teams, the researchers conducted and analyzed interviews with core members of a complex healthcare project team involving over 20 organizations. The results provide insights to common communication problems in complex project teams leading to suboptimal team and project performance outcomes and potential remedies to reduce TC during time of disruptions (ToD). The insights include unique contributions to team functioning under abrupt changes to meeting modality (i.e., from in-person to virtual and then to hybrid modality during the pandemic). The results provide a foundation for future work in exploring TC in project networks for improved efficiency in KT.

INTRODUCTION

The project-based nature of the construction industry requires temporary bonds between organizations to complete the work within constraints. Economic crises, climate change, and epidemics are project risks. The industry's rising complexity and risks are partially tackled by different parties undertaking different parts of a given work. For example, different project delivery methods and team dynamics help cope with changing environments to maximize the value of work (Whittington 2008). Systematic and individual remedies are researched to understand the risks and successes (Akintoye and Macleod 1997). The Iron Triangle (Time-Cost-Quality) is linked with the project management success for over 70 years (Atkinson 1999), but firms tend to associate the total project cost with only production costs. Recent developments in the industry attribute success to interactions between parties in a project network.

This study investigates the links between ***transaction cost*** (TC) and ***knowledge transfer*** (KT) in project teams using interviews of core members of a complex healthcare project. Researchers identify and evaluate constraints affecting TC and KT in time of disruptions (ToD), considering the perspectives of owner, designer, and general contractor. This study provides a foundation to explore KT-based TC, which have become prominent in more complex projects (Li et al. 2012, 2015). In an intractably polarized and uncertain world, authors aim to understand the ways to minimize TC to better govern projects (Teece 1986, Jobin 2008).

TRANSACTION COSTS

A transaction occurs when good, service, or knowledge is transferred across a technologically separable interface (Williamson 1987). Coase (1937) poses fundamental questions regarding TC:

If markets are so effective at allocating resources for production, then why do firms exist? If firms exist because they are better than the market at allocating resources, then why isn't the economy organized as one huge firm? He proposed that firms and markets differ in their ability to manage economic exchange and that those activities for which firms provide less costly management will be organized within firms. Coase/Williamson TC theory of the firm explains the existence of firms as they can avoid the costs associated with market transactions. Williamson (1985) identifies TC as drafting, negotiating, enforcing an agreement, governance, and bonding costs to secure commitments. Other researchers add acquiring and processing information, breaches of contractual promises, costs associated with inefficient pricing, legal costs, organizational costs, and production behavior to this definition (Joskow 1985, 1988, Winch 1989, 2001). There is no unity in the construction literature; procurement or contract costs as well as soft costs are used to define TC. The knowledge-based view focuses on the costs associated with a specific type of knowledge (Grant 1996). The terms of transportation, inventory, motion, waiting, overprocessing, overproduction and defects (TIMWOOD) concepts in the literature are compatible with the TC literature (Helmold 2020). Table 1 summarizes the categories of TC relevant to project teams.

Table 1. Categories of transaction costs relevant to knowledge transfers in networks

Appropriability (AP): Proprietary knowledge leakage risk from the interaction between or within firms.
Asset specificity (AS): The degree to which an asset is valuable only in a specific use and with a specific exchange partner. Assets are specific to transactions, not to firms. The difference between the best use of the asset and its second best gets bigger, the more specific is the asset.
Bounded rationality: Adaption limit of people to complex environments (Simon 1991). The rationality is affected by the inability to process all available information (Grover and Malhotra 2003). If economic actors could anticipate every future contingency, they could write complete contracts covering any potential outcome.
(In)Frequency: Repeatability of transactions between two partners positively related to hierarchical structure. Frequency could be categorized as one time, occasional, and recurrent (Williamson 1979).
Opportunism: People have a propensity to seek their own self-interest (cheating, withholding information, etc.). In a world without any opportunistic people, actors could simply agree to work things out as future events unfold.
Small Number of Participants: The limit of the potential other firms to develop alliance. Geographical and environmental factors highly influence this characteristic.
Uncertainty: The unfolding events relevant to contracts. Higher uncertainty increases the difficulty of managing the arrangement.

The construction industry is prone to risks because of the complexity of organizational and project related structure. Uncertainty might cause parties increase bids, file claims, work inefficiently, and develop antagonistic relationships, conflicts, and litigation. The TCs in the construction phase are much higher than in the procurement phase due to unforeseen events and incomplete contracts (Li et al. 2013). In the post-contractual phase, direct and indirect costs arising from disputes and litigation could cause additional TCs (Li et al. 2015). Li et al. (2013) categorized TCs based on the contract signature date and used latent variables of (1) predictability of the owner's behavior, (2) predictability of the contractor's behavior, (3) project management efficiency, and (4) uncertainty in the transaction environment scale. Uncertainty in the transaction environment appears to be the core construct of their model. Defining the rights and responsibilities of each party clearly due to different perception of risk allocations is crucial.

Efficient project management reduces TC and predictable behaviors enhance project management efficiency. Effective leadership, speedy decision making, efficient communication, fair conflict management, and high technical competency are the major factors to reduce TC (Li et al. 2012). Owner's behavior affects transaction environment, which determines contractor's behavior. The in-situ process adds additional TC to the construction industry as costs become dynamic. Each project demands a new design, execution program, different teams and heterogenous activity types. Therefore, construction project teams tend to establish longer-term alliances. The construction alliances are referred to establish quasi-firms (Eccles 1981, Winch 1989). The unique challenges of the industry lead firms to operate in networks with longer-term relationships. In the Finnish project networks, the relations are not solely based on the "lowest price" mentality, which supports the statement of total cost includes not only production cost (Taylor and Levitt 2007). Social relations and exchanges carry additional costs in the project life cycle (Granovetter 1985). Any deviation from the contract, bidding, estimating, and preparation creates additional TC. Knowledge flows in the vertical project management settings are crucial (Macher and Richman 2008) and TCs arise from various discrepancies.

KNOWLEDGE TRANSFER AND SOCIAL NETWORK THEORY

KT refer to sending or receiving knowledge (Foss et al. 2010), where organizational features and needs define the optimal frequency, media and participants involved (Garcia and Mollaoglu 2020). Construction alliances can be regarded as a network of information flows with material and information as main elements (Pryke 2004). Combining partner technologies or capabilities presents unique coordination challenges because of how diverse (or dissimilar) partner specialties/technologies and priorities are. The more a firm's technological expertise differs from its partner(s), the more difficult it will be for the firms to share its expertise and for the firm to benefit from partner expertise. Communication and coordination are costly. The additional intermediaries increase the chances of distortion and passing of less precise information (Borgatti and Cross 2003). Instead of influencing governance choice directly, a transaction's knowledge attributes influence the choice of knowledge management practices, which economize on the cognitive limitations of actors. At higher levels of diversity, the lack of absorptive capacity reduces the risk of leakage and, therefore, the need for increased monitoring and control mechanisms of the equity joint venture decrease (Sampson 2004). Not only the control process but also KT, creation, assimilation, storage, organization, protection, application, validation, verification, and identification steps are expected to be affected by various characteristics (Landaeta and Kotnour 2005). Allying firms have similar knowledge bases or technology portfolios, so there is less knowledge to transfer and control. But misunderstandings due to lack of specialized knowledge, forgetting details, failing to mention everything, filtering or deliberately withholding certain aspects could be experienced (Hansen 2002). Firm or internal organization means to increase productive knowledge flow (Kogut and Zander 1992). More hierarchical organization is a stock of knowledge and principles, so the equity joint-venture enhance more efficient transfer (Sampson 2004). Difficulties in KT imply greater opportunities in between firms than internal organizations.

Social network analysis is effective in analyzing KT (Muller-Prothmann 2007), as it helps map the flow in construction projects (Schröpfer et al. 2017). Nodes (units in a network such as individuals), dyads (pairs of nodes), and structural elements (e.g., density, centrality, and subgroups) shape social networks (Borgatti and Ofem 2010). For example, it is crucial for someone in the network to have valuable expertise and to be easily accessible (Borgatti and Cross 2003). The temporary nature of multidisciplinary project alliances impediments stronger bounds (Schöpfer et al. 2017), and projects consist of a combination of smaller sub-project goals.

Unpredictable events make the application of cognitive processes a critical factor for convenient and quick response to the complex characteristics of project teams (Yeung et al. 1999). These sudden and ambiguous parts of the project offer opportunities for researchers to improve the organization's performance through knowledge (Kotnour 2000). Project teams consist of people from different specialties, so their learning curves impact project effectiveness. KT can positively influence the capabilities and project performance. Articulation capacity and receiver's absorptive capacity determine the receiver's ability to apply KT, although there is not a high common knowledge share (Garcia and Mollaoglu 2020). However, the projects exerting a large effort transferring knowledge across projects were to a limited extent likely to influence their body of knowledge. Knowledge broker individuals suggested to possess relevant experience, the capacity to understand other project's knowledge and a social character. KT-related conditions provide a more powerful tools to explain governance choices than either KT or TC alone (Sampson 2004).

METHODOLOGY

Figure 1 depicts the network structure of a construction project team where team members can be put into three tiers: (i) Tier 1: main roles and lead representatives from owner, designer, and general contractor roles; (ii) Tier 2: organization members of Tier 1 representatives; and (iii) Tier 3: subcontractors, vendors, consultants, and other stakeholders. Lines of privity and knowledge flows are indicated for the project interactions. We conducted interviews with five team members from a healthcare project addressing the challenges in ToD, where in this case, COVID-19 era. Interviewee-1 (I1) and I2 are from the design team, I3 is one of the owner's representatives and I4 and I5 are from the general contractor team. I1, I3, I4 and I5 are in Tier 1, and I2 is in Tier 2. Interview transcripts were analyzed qualitatively and categorized in terms of TC and KT characteristics.

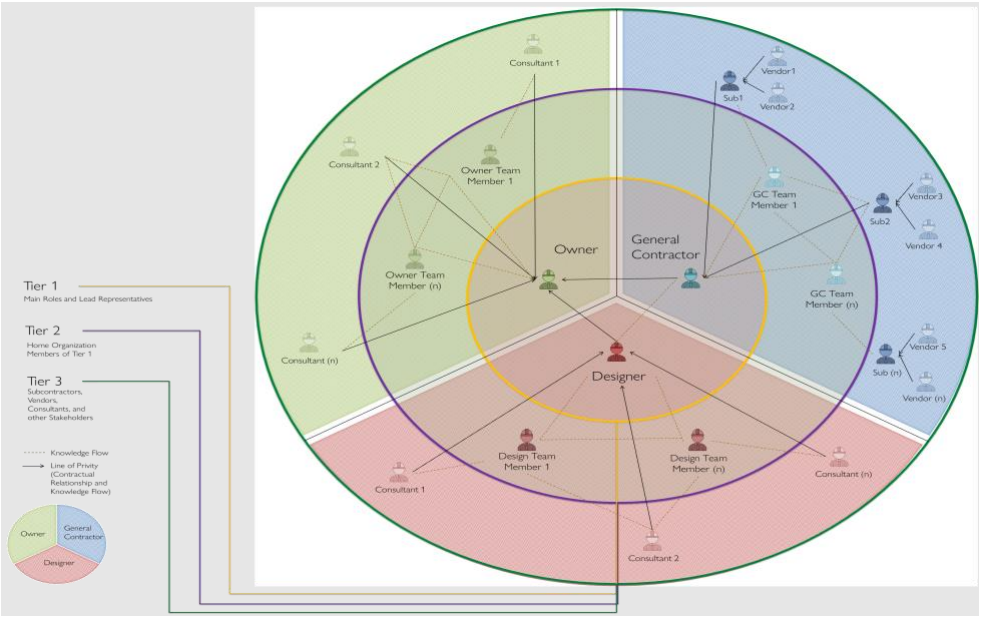

Figure 1. Construction project team network structure (Mollaoglu-Korkmaz et al. 2014)

RESULTS

Table 2 categorizes challenges and remedies during ToD, in terms of parties affected, TC, and network unit for KT. In terms of TC, uncertainty and bounded rationality are two of the most important TC constraints on effective communication and production. In terms of KT and network units, dyadic issues are mostly communication issues, node-related issues affect both the owner (in how they consider interventions to realign team members around project goals and priority

issues) and individual participants (e.g., loss of motivation in isolation, and lack of manpower). There are also issues that can be categorized as both node-related and dyad-related: Impediment planning and pull planning fall in both categories, as they involve both personnel and communication among the personnel.

Table 2. Transaction cost and social network categorization

Challenges	**Party**	**TC**	**Node/dyad**
Communication Frequency (Load)	O/D/GC	BR, F, U	Dyad
Communication Mediums	O/D/GC	BR, F, U	Dyad
Communication Medium Preferences	O/D/GC	BR, U	Dyad
Lack of Material and Manpower	D/GC	O, SN, U	Node
Loss of Motivation in Isolation	O/D/GC	BR, U	Node
Remedies			
Impediment Planning (Contingency Meetings)	O/D/GC	BR, F, O, U	Node & dyad
Interventions	O	BR, U	Node
Pull Planning Meetings	O/D/GC	BR, F, O, U	Node & dyad
Flexible Use of Communication Mediums	O/D/GC	BR, U	Node

** O=Owner's Representative, D=Designer, GC=General contractor*

** BR=Bounded rationality, F=Frequency, O=Opportunism, SN=Small number of participants, U=Uncertainty*

Below, we provide quotes from interviews in details to delineate the problems in Table 3. We then suggest remedies for each of these challenges. We then provide discussions.

DISCUSSIONS

It is especially challenging to switch communication medium in ToD. The pandemic has affected the project during the design, bidding, and construction phases. Experienced parties with common work history provided an easy adaption to the virtual communication with less issues in KT and TC (Landaeta 2008). Important challenges for markets, such as asset specificity and appropriability, are not of primary concern in project teams. This could be due to the repeated nature of interactions: asset specificity could be enhanced with repeated transactions with a small set of suppliers/members (Yousuf 2017). Bayhan and Demirkesen's (2019) work put forward the importance of cognition and system-based trust measures in the construction industry. Communication-based challenges affected all parties. These changes increase uncertainty by hindering informal communication channels. Adaption to this unpracticed, new, and complex environment of virtual meetings with different teams increase bounded rationality. The number and frequency of emails have surged in number. This caused team members to communicate with others mainly via email, but it was inefficient. Interviewees complained about the lack of time based on the number of emails from different members. Instead of tedious emails, phone calls expedite the issue resolution process with quicker responses and the opportunity to learn from informal interactions. The loss of motivation in isolation can be alleviated by personal phone calls with teammates or managers, not necessarily about tasks. These personal relationships increase feelings of belonging and embracement of the project. Parties may have different communication preferences changing by the unique characteristics of the members too. However, a standard code in ToD and communication strategies according to individual preferences can alleviate TCs in knowledge flows. These codes will decrease the uncertainty and ease knowledge flows.

Table 3. Problems, interview quotes describing the problems, and suggested remedies

Problem	Quote	Remedy
Communication Frequency	*"We found other good communication platforms ... to not burdening an email because that was really tough due to the quantity."* **[I1]** *"The volume and email has gone up three or four times since COVID started and it's got to the point where it's unmanageable ... I hear that from a lot of people try to prioritize what is important to get answered ... the rest just must fall by the wayside, that's just the way it is ... I defined email is the curse of our generation but it's a tool that we must use however just the volume is so just unmanageable because of COVID"* **[I2]** *"Probably the biggest challenge in the last three months would be the increased amount of email and virtual correspondents ... So, it is ten e-mail streams to get a small issue all the way through full resolution. In the past it was probably simpler phone call but now everyone is overburdened in so many emails they just take so long to finally return to that one subject ... I find myself spending more time early in the morning and late in the evening going just through the emails. 5 to 7pm is just reading and replying to e-mails and 4 to 9 pm is just reading and building the mental list of kind of to-do tomorrow or the e-mail returns ... I find myself having to start the emails and stop them to either change the tone of the email or to redirect how I am approaching to a subject depending on which one of those groups I am talking to ... I will get 15 emails drafted and must go back to them later in the day to finish them ... I cannot talk to Owner's rep like I am going to talk to a subcontractor on e-mail."* **[I5]**	Select the right communication medium (CM); always sending and waiting for an answer via email is not ideal. Parties should spare time to focus on unexpected issues with other parties. This collaborative effort can increase the issue resolution speed. Convenient communication platforms and messaging could solve a particular problem needing bilateral input instead of emails. Written communication might miss important information or alter different emotions according to the receivers' situation. E-mails are mostly thorough so; other platforms could be more efficient and show the interaction flexibility.
Communication Medium (CM): Virtual Meetings	*"We've had really productive meetings with the [other parties] ... face to face meetings - we were in the same room with everybody for eight hours a day - multiple days in a row. We were successful to transfer to the virtual world ... but you can't see ... the body language on the other side of the table ... there's nobody on video so I can't read any bodies expressions ... somebody could interrupt that thinking process and then that sort of disrupts the whole conversation"* **[I1]** *"In pre-COVID, we were face to face communicating in a large room on a regular basis. Sitting down collectively and getting through of the issues as we progress further into the project. Then COVID changed everything ... but all the tools were there so we have things like Zoom and Webex and [Microsoft] Teams ... we are well down to communicating that way. ... we had the designer and one architect via camera ... the contractor, the supplier, me. We looked at the mockup and we were able to have the approved sample side by side to the mockup looking at the two. We determined that one of the colors was not correct and we were able to discuss and get new material fabricated as quickly as possible ... that was somewhat of a major hurdle and we were able to effectively deal with technology."* **[I2]** *"I guess whether it's via just straight email or only web-based meeting - lack of in person communication. I think a lot of expression and what you pick up from vibes from the people in the room has been virtually erased on this project ... You lose that seeing the person seeing the reaction on their face understanding their body language type communication [going back to in-person can solve this]."* **[I5]**	Meet in the same room for longer hours to enhance team identity. Though technology transfer was successful, informal knowledge exchange of in-person communication could be dissolved. All team members using their cameras for video-conferencing option can help alleviate some of the constraints relating to understanding of body language. This way, participants could understand the reason for cutoffs and problems that interrupting thinking process.
CM: Phone Calls	*Fortunately, the phones still worked through COVID, which is my most important tool ... so if I missed something important, I tell everybody to call me; that's the best way to get ahold of me or text me ... so text messaging is a good secondary form of communication. The team in this project does a good job communicating with each other and the phone is really the primary source to improve the communication ... [You use your phone for e-mail and text too] but making a phone call you can talk to a person, that's an important thing."* **[I2]**	Consider various CMs and preferences of different generations. Communication preferences and efficiency differ according to the work complexity and involved parties. Suitable CM should be evaluated for specific tasks to reduce TC.
CM: Other Channels	*"We found other good communication platforms like Microsoft Teams and messaging. We did talk a lot with each other and ... we just understand the push and pull that we have with each other ... we had one subject so we could set up a Teams channel that hit that subject and everybody would work on it ... I can't say I've had that success on other projects so, I feel like it's just the comfort level of all the team members and how willing they are ... sometimes it just overwhelms everybody the amount of digital communication"* **[I1]** *"[The Contractor] added more photograph correspondence, I guess. Photographs ... trying to tell the story a little more."* **[I5]**	Set up a different channel (Teams) for topics within project groups to reduce TC. Caution it is about the comfort level, willingness, and convenience; in previous projects, the experience was not very good with these channels to the project team.
CM:	*"It's just the age difference is what I see [not about project roles]. There is not much organizational difference, it is not that one company requires everything written in writing. It seems to be more of a major generational difference of I would*	Communication preferences changes with experience and age. Project managers can focus

Preferences	*like to just email.in making my answer and save it on the screen. Or I would like to have in-person meetings ... 0 to 5 years of experience, it's much more of an e-mail driven discussion ... 5 to 15 years of experience, they would rather pick up the phone and call and discuss an issue, each person goes over things together."* **[I5]**	on their team characteristics according to their communication preferences in ToD.
CM: Hybrid	*"We would probably suffer a little if we were all remote. We benefit from us being here ... Informal verbal conversation is preferred, and we would probably struggle and take longer if we had to be remote and coordinate conversations for phone calls only."* **[I4]**	Understand technology systems and their strengths to resolve potential issues quickly.
Contingency Meeting: Impediment Planning	*"If we could eliminate [COVID] it would get better ... the impediments in the future that that would need to be worked through ... think about the worst-case scenario ... to create chaos and be prepared for ... we sat around a couple tables late February and March and figured what's working and what's not. What can we do with what we've got and that's the way to work through it ... if we had a cataclysmic weather event ... create a lot of havoc ...so we were at the excavation back late winter last year and we had rains coming in so we were able to plan ahead and protect the banks from eroding, rolling down into the hole. We recovered the excavation slopes with plastic so, we effectively headed off an issue of runoff coming into the excavation, into the foundation area ... [our contractor] did great job of planning and allowed that work to continue through the early portions of the project so we get ductwork into cavities up to the roof and they were able to set the rooftop in these units. Stones were set once they arrived at the site. When we set those immediately once they got there rather than waiting for ductwork to be installed."* **[I2]**	A couple of planning sessions on the emergency issues might happen on a regular basis quarterly or biannually. Teaming up with [other parties] to determine when to have contingency meetings is important. Contingency plans should involve inputs from different parties and scenario analysis should be prepared. "Play-books" for ToD should be compiled to manage teams. The priorities are to be determined for the worst-case scenario.
Pull Planning	*"We need a roof by this date ... and we did have pull-planning in person meetings before the pandemic hit, so it was good ... maybe it should have been continued after documentation was complete ... that would address this submittal issue about when [information is needed] to release to ... subcontractors and so on."* **[I1]** *"[The contractor] does pull planning right now as a construction team, with the trade partners. I find it very useful as a communication tool for reaching subcontractors. I personally don't use it as a tracking metric for percent complete. I am not as worried about that as I am about the being honest with one another on projected work in location and timely finish or the dialogue that takes place at that meeting of why they're going this direction or why they're working on this or why this can't be done. That seems to be a very worked-well processes and it's just shepherded by the pull planning process."* **[I5]**	Pull planning meetings could be continued virtually on office programs after the documentation phase to enhance the communication between the Owner, designer, and contractor. These meetings are planned according to the phases and the need of the project.
Material, Manpower	*"I think what holds us up is when either subcontractor needs to go get material information. So, we can know OK this material might not be in the right fix because it is six weeks to get it versus this other material. So, some of that information being more handy would be probably the only way we could go faster."* **[I4]**	Local materials and manpower can be utilized in ToD.
Motivation in Isolation	*"We got isolated, and a lot of our staff are working from home. There is a lot of anxiety being generated because they were home alone working isolated. So, I kind of started hearing that in their voices ... the longer [isolation] goes on the more anxiety ... and especially the younger folks; they need to be talked to on a regular basis voice to voice."* **[I2]**	Managers should increase the communication frequency with their staff in person. Make sure their staff is feeling fine in an isolated time. If possible, sitting with the staff face to face or giving them calls to check on well-being and improve ties would help to relieve their anxiety and decrease transaction time and costs. Disseminate accolades to teams. Posting successful reviews motivates project teams. Drone videos showing the progress of the construction inspire teams and improve belonging.
Interventions	*"There was a long delay. A longer turnaround time than two weeks for return of submittals. RFIs were coming back, responded to but not answered. Coordination of changes were not really coordinated by all disciplines. So, with the RFI, where we had the red, yellow, green, on behalf of [the Contractor], they send their RFI log every week [to the Owner's responsible person] before meeting with [the Designer] and [the Owner's responsible person] prioritize the RFIs with [the Design team] directly. Same with the submittals: [the Owner's responsible person] asked for [the Designer's] top 5 submittals or their party submittals [...] might have something red out there [according to the submittal coloring scheme] that's not an issue. But a hot party, the roof recently, that might be a hotter issue that was packaging up today"* **[I3]**	The authority giving direction to all parties for submittal and RFIs can intervene and prioritize necessary items for project goals in ToD. Track the progress of the project: A color-coded submittal tracking system helps track the submittals and expedites different parties. Project managers evaluate these in conjunction with the schedule and progress of works on the field. Performance reports according to submittal features can help the authority assess the submittal process effectiveness.

Contingency meetings are advised to reduce uncertainty and determine playbooks for the worst scenario. Pull planning meetings are crucial to determine upcoming issues and avoid risks in advance by meeting in a common area to evaluate activities from different parties' perspectives, including subcontractors. Beginning from the final product and progressing towards the start, these meetings collect members as a team with the same values to finish the project within the schedule. Therefore, these meetings decrease bounded rationality and uncertainty by reviewing tasks from different parties' perspectives and sharing information. Opportunism also decreases with these meetings by team building activities. Though it might not be possible in ToD to meet in person for pull planning, simple office software can be utilized to sequence and discuss activities in a virtual meeting with an effective de facto party that holds the authority.

Lack of manpower is common in ToD, increasing the overall transaction time and communication efforts. The time-cost tradeoff in materials can be challenging, especially for small firms. The soaring inflation, the lack of materials, or swift drops in manpower increase TCs and overall time to accomplish tasks. ToD limits alliances and increases the TC for the small number of participants. Local sources can be utilized to survive disruptions with minimal damage. Intervention from the authority is needed because other members do not have the proper information. This intervention reduces bounded rationality and uncertainty and balances the workload between parties to align the expectations according to the project goals.

Teams need ways to communicate and solve issues more efficiently. Important remedies include: (1) prepare and implement the project plan; (2) control team integration; schedule team building event(s) to get the team working toward the same end goal; and (3) establish BIM process early and set up the expectations of the team.

CONCLUSIONS

This study aims to establish a framework regarding TC in the construction industry. Interviews are held to better understand the links between TC and KT networks in project teams. The authors identified and evaluated challenges in ToD in the construction industry to establish the foundation of TCs in project network knowledge flows especially considering different communication mediums. KT-related TCs are detected and will be measured according to the activity productivity in future research. The remedies suggested in this paper aims to guide project parties in the ToD. Note that our suggested remedies for problems during the pandemic often involve dyadic changes, even for problems involving nodes. For example, a problem involving nodes is loss of motivation due to isolation. Our suggested remedy involves increased interactions among project network members. Limitations that can be improved upon in both depth and breadth by additional studies include (i) limited number of teams interviewed, (ii) limited number of project participants interviewed, and (iii) potential confounding effects of individual demographics.

ACKNOWLEDGEMENTS

This research was supported by the National Science Foundation through Grant No. 1928278. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the researchers and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

Atkinson, R. (1999). Project management: cost, time, and quality, two best guesses and a phenomenon, it's time to accept other success criteria. International journal of project management, 17(6), 337-342.

Akintoye, A. S., & MacLeod, M. J. (1997). Risk analysis and management in construction. International journal of project management, 15(1), 31-38.

Bayhan, H. G., & Demirkesen, S. (2019). Impact of trust on partnership selection in the construction industry. Trust in major and mega projects, 49.
Borgatti, S. P., & Cross, R. (2003). A relational view of information seeking and learning in social networks. Management science, 49(4), 432-445.
Borgatti, S. P., and Ofem, B. (2010). Social network theory and analysis. Social network theory and educational change, 17-29.
Coase, R. (1937). "The nature of the firm." Economica, 4(16), 386–405.
David, R. J., & Han, S. K. (2004). A systematic assessment of the empirical support for transaction cost economics. Strategic management journal, 25(1), 39-58.
Eccles, R. G. (1981). The quasifirm in the construction industry. Journal of economic behavior & organization, 2(4), 335-357.
Eisenhardt, K. M. (1989). Agency theory: An assessment and review. Academy of management review, 14(1), 57-74.
Foss, N. J., Husted, K., & Michailova, S. (2010). Governing knowledge sharing in organizations: Levels of analysis, governance mechanisms, and research directions. Journal of management studies, 47(3), 455-482.
Garcia, A., & Mollaoglu, S. (2020). Individuals' capacities to apply transferred knowledge in AEC project teams. Journal of construction engineering and management, 146(4), 04020016.
Granovetter, M. (1985). Economic action and social structure: the problem of embeddedness. American journal of sociology, 91(3), 481-510.
Grant, R. M. (1996). Toward a knowledge-based theory of the firm. Strategic management journal, 17(S2), 109-122.
Grover, V., & Malhotra, M. K. (2003). Transaction cost framework in operations and supply chain management research: theory and measurement. Journal of operations management, 21(4), 457-473.
Hansen, M. T. (2002). Knowledge networks: Explaining effective knowledge sharing in multiunit companies. Organization science, 13(3), 232-248.
Helmold, M. (2020). Lean Management and Kaizen. Springer international publishing.
Jobin, D. (2008). A Transaction cost-based approach to partnership performance evaluation. Evaluation, 14(4), 437-465.
Joskow, P. L. (1985). Vertical integration and long-term contracts: The case of coal-burning electric generating plants. Journal of law, economics, & organization, 1(1), 33-80.
Joskow, P. L. (1988). Asset specificity and the structure of vertical relationships: empirical evidence. Journal of law, economics, & organization, 4(1), 95-117.
Kogut, B., and Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. Organization science, 3(3), 383-397.
Kotnour, T. (2000). Organizational learning practices in the project management environment. International Journal of quality & reliability management.
Landaeta, R. E. (2008). Evaluating benefits and challenges of knowledge transfer across projects. Engineering management journal, 20(1), 29-38.
Landaeta, R., & Kotnour, T. (2005, October). Knowledge systems. Proceedings of the American society for engineering management national conference (pp. 194-199).
Li, H., Arditi, D., & Wang, Z. (2012). Transaction-related issues and construction project performance. Construction management and economics, 30(2), 151-164.
Li, H., Arditi, D., & Wang, Z. (2013). Factors that affect transaction costs in construction projects. Journal of construction engineering and management, 139(1), 60-68.

Li, H., Arditi, D., & Wang, Z. (2015). Determinants of transaction costs in construction projects. Journal of civil engineering and management, 21(5), 548-558.
Macher, J. T., & Richman, B. D. (2008). Transaction cost economics: An assessment of empirical research in the social sciences. Business and politics, 10(1), 1-63.
March, J. G. (1978). Bounded rationality, ambiguity, and the engineering of choice. Bell journal of economics, 587-608.
Mollaoglu-Korkmaz, S., Miller, V. D., & Sun, W. (2014). Assessing key dimensions to effective innovation implementation in interorganizational project teams: an Integrated Project Delivery case. Engineering Project Organization Journal, 4(1), 17-30.
Müller-Prothmann, T. (2007). Social network analysis: a practical method to improve knowledge sharing. Hands-on knowledge co-creation and sharing, 219-233.
Pryke, S. D. (2004). Analyzing construction project coalitions: exploring the application of social network analysis. Construction management and economics, 22(8), 787-797.
Sampson, R. C. (2004). Organizational choice in R&D alliances: Knowledge-based and Transaction cost perspectives. Managerial and Decision Economics, 25(6-7), 421-436.
Schröpfer, V., Tah, J., & Kurul, E. (2017). Mapping the knowledge flow in sustainable construction project teams using social network analysis. Engineering, construction and architectural management.
Simon, H. A. (1991). Bounded rationality and organizational learning. Organization science, 2(1), 125-134.
Taylor, J. E., & Levitt, R. (2007). Innovation alignment and project network dynamics: An integrative model for change. Project management journal, 38(3), 22-35.
Teece, D. J. (1986). Transactions cost economics and the multinational enterprise: An Assessment. Journal of economic behavior & organization, 7(1), 21-45.
Whittington, J. M. (2008). The transaction cost economics of highway project delivery: design-build contracting in three states. University of California, Berkeley.
Williamson, O. (1979). Transaction-cost economics: the governance of contractual relations. Journal of law and economics, 22(2), 233-261.
Williamson, O. (1993). Opportunism and its critics. Managerial and decision economics, 97-107.
Winch, G. (1989). The construction firm and the construction project: a transaction cost approach. Construction management and economics, 7(4), 331-345.
Winch, G. (2001). Governing the project process: a conceptual framework. Construction management and economics, 19(8), 799-808.
Yeung, A. K., Yeung, E. D. A. K., Ulrich, D. O., Nason, S. W., & Von Glinow, M. A. (1999). Organizational learning capability. Oxford University Press on Demand.
Yousuf, A. (2017). Transaction costs: a conceptual framework. International journal of engineering and management sciences, 2(3), 131-139.