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A bridge too far: examining the impact of facilitators on information transfer in global virtual project networks

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As the architecture, engineering and construction industry globalizes and the use of virtual environments to connect this workforce becomes more common, it becomes increasingly important to understand how to best support efficient systems of information transfer in technologically mediated workspaces. Previous research has demonstrated that global project networks face technological challenges that can interfere with collaboration, and it has been argued that facilitators are an effective means to help networks overcome these challenges. We conducted a study to determine how facilitators impact the transfer of information through a global project network in a modally robust virtual workspace by examining the centrality of facilitators and actors from different knowledge domains. We used task conflict duration as an outcome variable in comparing the performance of two facilitated and two non-facilitated networks of student teams engaged in complex design and planning projects. Our findings indicate that when facilitators occupied highly central positions during task interactions, conflict length was observed to increase. In non-facilitated networks, highly central actors emerged from a variety of knowledge domains and conflict length was observed to decrease. This evidence suggests that while facilitators are typically viewed as information bridges in global project networks, when they are central to task discussions, facilitators may impede the development of efficient network structures.

Keywords: Collaboration, computer-supported collaborative work, conflict, facilitation, globalization, project networks, virtual teams.

Introduction

Engineering firms are outsourcing complex design work to international vendors (Joseph, 2005; Messner, 2008), which increases project complexity, in part, because stakeholders are typically distributed across large geographical distances. Complex design activities may include consideration of alternative analyses, problem-solving sessions and decision-making between teams of architects or engineers that can lead to the discovery and subsequent management of unanticipated conflicts. In turn, these teams must collaborate with contractors to plan construction activities that adhere to cost, quality and scheduling requirements. This type of complex design and planning work is typically enacted by teams within a particular knowledge domain, composed of individual specialists and organized into a project network that is ultimately responsible for the development of the final product. In order to ensure the success of these types of collaborations, it is important to understand the ways that information is transferred between specialists from different knowledge domains.

To reduce the cost associated with physically bridging geographical boundaries by sending collaborators to a shared physical workspace, global project networks are increasingly composed of technologically mediated teams working in a variety of virtual spaces (cf. spaces studied in Mortensen and Hinds, 2001; Armstrong and Cole, 2002; Kiesler and Cummings, 2002). Because the interactions between stakeholders in these networks are mediated by technology, new challenges arise for our understanding of how to best support collaboration between virtual teams (Chinowsky and Rojas, 2003; Paul and Seetharaman, 2004; Ramalingam and Mahalingam, 2011). Many of the challenges faced

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by virtual networks arise from computer-mediated interaction, in part because network participants may not be provided with sufficient technological affordances to facilitate the transfer of different types of information.

Researchers have identified that facilitators enable information transfer in these types of distributed project networks. According to Paul and Seetharaman (2004), facilitators are more crucial to virtual team success compared with face-to-face team success because they are tasked with helping teams overcome technological challenges in addition to work process challenges. While research has examined the role of facilitators in managing information transfer in traditional offline networks and a growing body of research is investigating facilitation in virtual networks, this research is typically based on spaces with one or two modes of communication (e.g. email and video conferencing as in the case of Olson and Olson, 2000), which makes it difficult to account for the role that a lack of sufficient communicative modalities play on information transfer compared with the role played by facilitators.

The research reported in this paper investigates the impact of facilitators on information transfer in a modally robust virtual workspace. We compared the performance of facilitated and non-facilitated teams in reducing the length of task conflicts that are centred on the need for information transfer between teams in different knowledge domains.

Background

Existing literature on the facilitation of distributed networks has identified a number of ways that facilitators play important roles in project success. Bostrom *et al.* (1993) argue that the primary role of facilitators is to assist network participants to achieve an outcome more easily. They show that even in cases in which facilitators provide minimal guidance to project network participants, better project outcomes result. Facilitators provide a 'method to transform user demands into design quality' (Akao, 1994, p. 14) as they act as coordinators of diverse project demands (Sullivan, 1986). Sullivan argues that facilitators who are able to effectively address these demands are involved in specific aspects of the project, i.e. facilitators contribute to planning the meeting, guiding the collaborative process and motivating the team to develop quality outcomes. Each of these contributions is at a higher level than the task-specific work engaged in by the network. Thus, effective facilitators, while not necessarily content area specialists, help the teams to develop systems and norms for doing the work associated with the task. In other words, facilitators can help networked teams address many of the interactional challenges that may lead to conflict (Wood and Silver, 1995; Paul and Seetharaman, 2004).

Effectively addressing conflict plays an important role in successful collaboration regardless of whether the teams are distributed or co-located (Jehn, 1997; Hinds and Kiesler, 2002) because successful conflict management is critical to creating successful project outcomes. However, in geographically distributed teams, additional factors such as lack of a shared context and technological mediation serve to increase the potential for conflict among teams (Hinds and Mortensen, 2005). Without a shared interactional context, as is often the case with asynchronous, text-based distributed collaboration such as through email, team members find it difficult to establish interactional norms (Hinds and Bailey, 2003), which can lead to a lack of shared understanding (Fussell and Kreuz, 1992). *Shared understanding* refers to the 'collective way of organizing relevant information' (Hinds and Weisband, 2003, p. 21) that enables a group to collaborate more effectively, to anticipate the reactions of others and to coordinate actions implicitly within a predictable and coherent framework. A shared understanding by the networked teams is needed for successful collaboration around a complex and ambiguous task (Beamish and Biggart, 2006) such as construction project design and planning, and information technologies can stabilize meanings between teams within a distributed network (Dickey *et al.*, 2006).

The role of facilitators in successfully managing conflict is dependent on strategic input by facilitators during specific phases of a meeting (Dubs and Hayne, 1992; Miranda and Bostrom, 1999). Research by Macaulay (1999) indicates that facilitators enhance interactive cohesion by managing the flow of information between network participants, and Hayne (1999) demonstrates that facilitators provide structure to tasks and contribute to the design of work processes, which implies a relationship between effective facilitation and management of information transfer.

The relationship between conflict and network performance has been studied by a number of researchers, with contradictory findings (cf. Wall and Callister, 1995; Hollenbeck *et al.*, 1998). The research can be divided into two broad categories: conflict as a barrier to information processing and conflict as a means of discovery. The former views conflict as detrimental to network performance, as it serves to 'reduce satisfaction because it produces tension, antagonism, and distracts team members from performing the task' (De Dreu and Weingart, 2003, p. 741). The latter views conflict as a positive outcome of interaction that leads to the discovery of new ideas as people confront issues and learn to take different perspectives (Tjosvold, 1997). Since our

aim in this study is to explore how facilitators impact information transfer, we view conflict as potentially interfering with the efficient transfer of information, although we acknowledge that positive outcomes can emerge when collaborators are confronted with conflict.

Paul and Seetharaman (2004) show that conflict between networked global teams may be aggravated in virtual contexts due to cross-cultural, geographical and organizational boundaries. Because of the facilitator's specialization in managing work processes and aiding in the transfer of information across organizational boundaries, they argue that facilitators are more essential to the success of global project networks compared with networks where teams meet face-to-face. Thus, by closely analysing cases of conflict in the interactions of teams collaborating in global virtual networks, we gain insight into factors that may impede information transfer. The inability of teams to successfully address conflict can, at best, lead to inefficient dissemination of specialized information through the network and, at worst, lead to project failure.

Methodology

Research questions

Our goal is to develop an understanding of how a facilitator in a virtual project network working on a complex design and planning task impacts information transfer pathways. In order to determine the impact, we compared the network structures of facilitated and non-facilitated networks and looked for patterns between the structure and the network's ability to decrease time spent in conflicts that require information to be transferred between the knowledge domains of the distributed teams.

In order to determine whether facilitated teams are more effective than non-facilitated teams in transferring task-specific information between knowledge domains, we first needed to determine: (1) whether facilitators were central to information transfer during network interactions focused on the task and (2) how the position of the facilitator in the network corresponded to how quickly conflicts were resolved. To this end, we posited two research questions that form the basis for our study.

RQ1: *From which knowledge domains do information brokers emerge in facilitated and non-facilitated global virtual project networks engaged in a construction design and planning task?*

We are interested in determining whether facilitators emerge as information brokers, i.e. whether facilitators are centrally located within information transfer pathways, when the network is engaged in work focused on a construction design and planning task as opposed to other types of interactions that occur during the course of a project network meeting (e.g. during rapport-building, role setting and/or meeting scheduling). If the facilitators are not engaged with the network during these discussions or are not centrally engaged, then there will be little evidence to support a contention that facilitators impact the transfer of information across knowledge domains, as facilitators will not be engaged in network interactions where project-critical information has a need to be transferred. In these cases, facilitators may be helping the network to transfer social or relational information, for instance, during an ice-breaker exercise. While this information is certainly important in building group cohesion, it is not of the type we are concerned with in this paper. Our concern is with the exchange of information related directly to the design and planning task.

If we are able to determine that facilitators are information brokers in the network, then we will proceed with the investigation of our second research question:

RQ2: *How do information brokers in facilitated and non-facilitated global virtual project networks impact task conflict duration?*

Our second research question is aimed at exploring patterns between the structural positions of the facilitators as determined in RQ1 and a measure of network performance. To measure network performance, we identified cases of conflicts faced by the network and measured how long it took the network to resolve the conflict. In each case, the conflicts involved a need for information to be transferred across knowledge domain boundaries inhabited by the distributed teams.

Experimental design

In order to investigate how facilitators impact information transfer in global virtual project networks, we designed an experiment to capture the interactions between facilitators and other actors engaged in the hypothetical planning and design of a real construction project. Interactions between the networked teams occurred in the CyberGRID (Iorio *et al.*, 2011), a virtual workspace developed by researchers in the Project Network Dynamics Lab at Columbia University and in Simlab at the Helsinki University of Technology (Figure 1). The CyberGRID is a relatively novel research context when compared with previous studies on facilitation, information transfer and conflict in AEC. The CyberGRID is a *modally robust* working environment, in that it provides network actors with a variety of communicative modes, including

Figure 1 Screenshot of the CyberGRID virtual workspace

synchronous text (i.e. chat), asynchronous text (i.e. message board and email), voice (via VOIP), gesture and access to document storage and version tracking. Previous research has studied interactions through these modes in isolation (e.g. conflict during video conferencing as in the case of Olson and Olson, 2000), with very little research focused on, in Mark *et al.*'s (1999) terms, 'virtually collocated teams'.

We examined recordings of meetings between actors in four networks that held hour-long meetings once per week over the course of an academic semester (approximately nine weeks). The networks were composed of graduate and undergraduate students enrolled at five universities in four countries: (1) Columbia University and the University of Washington in the USA, (2) the University of Twente in the Netherlands, (3) the Indian Institute of Technology—Madras and (4) the Helsinki University of Technology in Finland. Students opted in to courses within a particular architecture, engineering or construction knowledge domain and, as a component of the class, were required to participate in a virtual collaborative design and planning project with students at partner universities. A portion of the students' grades was based on the project and differed by university. Student teams selected ongoing construction projects in their respective cities, including, for example, a renovation of a section of Madison Square Garden in New York City and a married student housing complex in Chennai, India. Students were provided with information from the real project manager and were then tasked with hypothetically designing a construction estimate and plan for the project based on that information.

The participating students at each university were organized into teams based on their respective knowledge domains, which corresponded to the classes in which they enrolled. Each team of 1–2 students per knowledge domain was then combined into a project network with 7–10 participants per network that was collectively responsible for a finalized construction plan. Individual teams were responsible for a single component of a complex construction project (i.e. with both team *independent* tasks and team *interdependent* tasks), including the creation of a construction schedule, the development of a 3D computer-aided design (CAD) model, the mapping of the schedule to the 3D model to create a 4D model and the estimation of construction costs. In the participating courses, there was very little overlap in knowledge domain specialization between the teams, as many students were learning concepts for the first time. In other words, teams learning 3D modelling did not receive training in cost estimation and vice versa. However, overlap existed, as some of the students had varying levels of experience in industry or were taking other courses in their respective programmes.

Two of the project networks we studied included trained facilitators. A second set of two non-facilitated networks served as the control group to test the effect of the facilitator on information transfer. Facilitators were enrolled in a virtual world facilitation course and learned general facilitation techniques, including

problem solving, process management and conflict resolution strategies. Crucially, facilitators received no training in any aspect of AEC and therefore interacted with teams outside of their domain expertise. We chose to employ facilitators without training in AEC knowledge domains because research has indicated that facilitator involvement during meetings should be limited to non-task interactions (Dubs and Hayne, 1992; Miranda and Bostrom, 1999). By using facilitators with training outside of AEC, we increased the chances that facilitators would help to structure work processes, yet not become involved in decision-making centred on the task. In other words, we did not expect the facilitators to be central actors when the network was engaged in the task. In this experiment, the facilitators' location outside of the AEC domain distinguishes them from project managers and clarifies that their role in the project network was one of facilitation.

In the previous work, we found that the transfer of different types of information is better suited to particular technological tools (Iorio *et al*., 2011), whereas technological challenges can be antecedents to conflict and can potentially compound the effects of task-based conflicts. Technological challenges can be associated with: (1) a lack of technological resources provided to the network and/or (2) a lack of training in use of the technological resources. By interacting in the CyberGRID and with the inclusion of facilitators familiar with the CyberGRID functionalities, our research design combined with the research context serves to minimize the impact of both of these challenges on the network interactions, as described by Chinowsky and Rojas (2003). The purpose of providing the network with a modally robust working environment is to help control for the impact of the technology on the interactions, so that we are able to focus more specifically on how the position of the facilitators within a network impacts information transfer.

Analytical techniques

The recorded interactions between networked team members were imported into an analysis software program called ELAN (Wittenberg *et al*., 2006). ELAN is a multi-modal annotation software package that allows researchers to map annotations onto the timeline of a recorded video. Annotations can be arranged hierarchically, allowing for the analysis of relationships between annotations. For our study, we are interested in the relationship between status as a facilitator and position within the network as well as task conflicts involving a need for information transfer between teams. Thus, at one level of the analytical hierarchy, we noted speaker and addressee in order to determine how facilitators were positioned along information transfer pathways in the network, and on another level, we noted any cases of task conflict that were caused by a need to transfer information across knowledge domains.

Interactions were annotated based on a modification to the distributed work topic typology developed by Anderson *et al*. (2007), which allowed task interactions to be distinguished from non-task interactions. Two researchers annotated 3319 interactions for the meetings, achieving a 79.08% inter-annotator reliability rating. A third researcher identified the 694 cases where there was disagreement about a particular annotation and then the annotation team attempted to resolve the disagreement. In the 35 cases where a resolution was not achieved, the interaction in question was excluded from the data set. Therefore, agreement was achieved, or inter-rater disagreements resolved in 98.97% of the annotations.

In order to determine whether a series of interactions were considered a conflict, we operationalized conflict as *a disagreement between two courses of action, two perspectives or two interpretations that must be resolved in order for the continuation of task work*. For this analysis, only those conflicts that were resolved were noted. However, in some cases, actors decided to table a conflict until more information could be acquired and proceeded to develop a plan enabling the network to move forward in the absence of a firm resolution to the conflict. For instance, during a meeting where the construction schedule and 4D model teams were trying to determine whether it was possible to format the output of the scheduling software such that it could be imported into the software used to create the 4D model, the network decided to table the conflict and to seek additional information outside of the network. We considered these cases as resolved conflicts and included them in our annotations.

Once all of the meetings were annotation in this way, a spreadsheet containing the speaker, addressee, interactional topic type and any identified conflicts was exported from ELAN for network analysis. The network analysis was composed of calculating *betweenness centrality* values for all actors in the four networks using UCINet (Borgatti *et al*., 2002) to determine the structural position of facilitators within the networks. Centrality as a network measure has been used in a number of research efforts in the AEC field (Loosemore, 1997; Chinowsky *et al*., 2008; Di Marco *et al*., 2010). Actors with high betweenness values can be considered *information brokers* (Hanneman and Riddle, 2005), as they serve as central connecting points between all members of the network and are thus well positioned within the network to facilitate the transfer of information. For instance, if interactions between network actors are focused on rapport-building, a high betweenness value for facilitators is desirable because it indicates

that they are ensuring that actors are engaged in relationship work and becoming comfortable in networked interactions. Since rapport-building lies outside of an AEC knowledge domain, facilitators are well positioned to be social information brokers as they relate their own experiences to the experiences of the specialists during rapport-building interactions. However, for task interactions, we expect the facilitators to have relatively low betweenness values because they lack the understanding of how the knowledge domains inhabited by the networked teams relate to one another, and perhaps more fundamentally, they lack familiarity with information and information types that constitute the domain.

Next, we examined more closely how the centrality of the facilitators impacted task conflict duration during single team meetings with three conflicts each. We selected these meetings specifically because they were analogous in terms of meeting length, position of the meeting in terms of the overall project and in the number of conflicts that occurred during the meeting. Because the real construction projects were different in scope and level of complexity, the number of analogous conflicts was limited to those where the networks were engaged in similar phases of the design and planning process.

In summary, we analysed four student networks—two facilitated and two non-facilitated—that each contained 3D and 4D modellers, construction schedulers and cost estimators. For the two facilitated networks, we combined an analysis of the facilitators' structural positions during the task interactions with an account of how quickly the facilitated networks resolved task-based conflicts. We contrasted this analysis of facilitated networks with an analysis of the two non-facilitated networks. In doing so, the analysis is well positioned to inform our understanding of how facilitators impact information transfer in global virtual project networks.

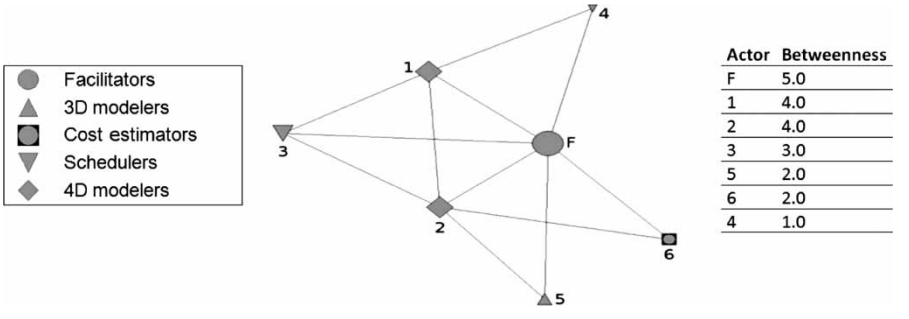
Findings

The discussion that follows provides a structural description of where the facilitators were positioned along information transfer pathways when the networks were enacting task work. To this end, we compared the two facilitated networks with the two non-facilitated networks to develop a sense of how facilitators impact information flow through a global virtual network.

Identifying information brokers in facilitated and non-facilitated networks

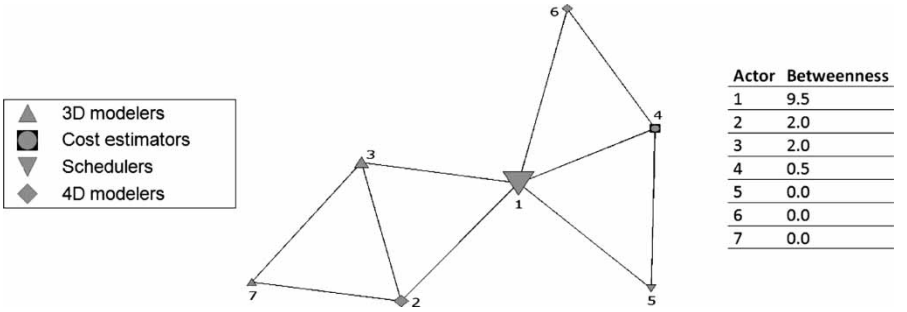
The first step in our analysis of how facilitators impact information transfer was to determine whether facilitators were central to network interactions focused on task work that require information to be transferred between specialists. If facilitators are not central to the interactions, then it will be difficult to determine what effect they have on information transfer, since they do not directly participate in task work. However, we found that in both of the facilitated networks observed, facilitators had the highest betweenness centrality values compared with the other actors in the network, which indicates that facilitators played critical roles as information brokers when the network was engaged in task work.

Because the facilitators are not specialists in any aspect of the task (i.e. they have no specialized knowledge of construction scheduling, 3D and 4D modelling or cost estimation), the high betweenness centrality value associated with the facilitator is problematic because it suggests that information associated with the task work is not flowing efficiently through the network from one specialist to another. Rather, information is being routed through and perhaps interpreted by the facilitator. For example, in Figure 2, the network identified that items in the 3D model (i.e. glazing, doors and sprinklers) were not included in the construction schedule. The network decided that either the 3D model or the construction schedule needed to be modified in order to resolve the conflict. In this example, information must be exchanged between actors in the 3D modelling and construction scheduling knowledge domains. The network diagram, combined with our observations, shows that the facilitator (Actor F)



Actor	Betweenness
F	5.0
1	4.0
2	4.0
3	3.0
5	2.0
6	2.0
4	1.0

Figure 2 Sociogram for Network 1 (facilitated) based on betweenness centrality



Actor	Betweenness
1	9.5
2	2.0
3	2.0
4	0.5
5	0.0
6	0.0
7	0.0

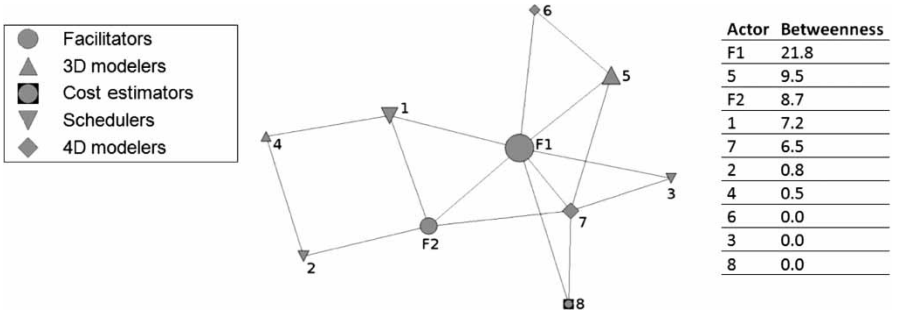
Figure 3 Sociogram for Network 2 (non-facilitated) based on betweenness centrality

brokers the transfer of this information between the construction scheduler (Actor 4) and the 3D modeller (Actor 5), thus intervening in the shortest path between the two specialists.

This configuration is problematic because nothing theoretically prevents Actors 4 and 5 from interacting directly, i.e. both 3D modellers and construction schedulers are well suited to occupy highly central roles in the network. Thus, if the facilitator was not active during this discussion of the task, we assume that Actor 4 would interact directly with Actor 5 and that either of the actors would assume a more central position in the network. Moreover, the betweenness values for the actors in Network 1 are all relatively close to that of the facilitator, which also suggests that other actors are well suited to take more central roles.

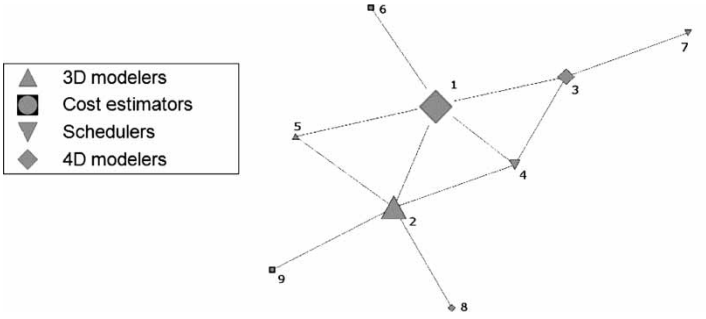
To test whether information specific to the 3D modelling and scheduling domains prohibits centrality of the associated actors, we turn next to findings developed through analysis of a non-facilitated network. When we examine the sociogram based on betweenness centrality for non-facilitated Network 2 (Figure 3), we see a scheduler (Actor 1) in the position of highest betweenness, nearly five times more central than the next most central actor. This configuration is theoretically preferable to the configuration in Network 1 because task interactions between specialists are direct. Thus, we are able to confirm that the nature of the information within the knowledge domain of the construction schedulers is well suited to position the actor as an information broker in the network. However, unlike in Network 1 where all of the actors had relatively similar centrality values, in Network 2, the most central actor (Actor 1) is clearly the most central information broker in the network. While this may suggest that actors in the scheduling domain are somehow best suited to become information brokers, we will return to this analytical thrust below, when we discuss Network 4, the other non-facilitated network.

Both of the networks that we have discussed to this point contain seven actors. The last two networks we will discuss are larger (9–10 actors). To account for the larger size, two facilitators were included in the larger facilitated network. By examining networks of different sizes and with different numbers of facilitators, we are able to explore whether the centrality of the facilitators observed in Network 1 is compounded when another facilitator is added to the network. In facilitated Network 3 (Figure 4), the two facilitators (Actors F1 and F2) rank 1 and 3 in terms of highest betweenness values. The betweenness value for F1 is more than twice the value for Actor 5, the actor with the second highest betweenness value. So, the relationship between the centrality of the facilitators compared with the other actors is situated somewhere between Network 1 (where all actors had relatively similar



Actor	Betweenness
F1	21.8
5	9.5
F2	8.7
1	7.2
7	6.5
2	0.8
4	0.5
6	0.0
3	0.0
8	0.0

Figure 4 Sociogram for Network 3 (facilitated) based on betweenness centrality



Actor	Betweenness
1	13.5
2	12.5
3	7.0
4	3.0
5	0.0
6	0.0
7	0.0
8	0.0
9	0.0

Figure 5 Sociogram for Network 4 (non-facilitated) based on betweenness centrality

betweenness values) and Network 2 (where the most central actor was five times more central than the other actors).

Given the configuration of Network 3, a 4D modeller (Actor 7) is ideally positioned to take a more central role in negotiation of the task as Actor 7 shares direct ties with a 3D modeller (Actor 5), cost estimator (Actor 8) and construction scheduler (Actor 3). Since development of the 4D models requires scheduling information and the 3D model, the 4D modellers, by the nature of their knowledge domain, were well situated to become information brokers for the other specialists since network paths exist between the 3D modellers, 4D modellers, schedulers and cost estimators that do not pass directly through the facilitators.

When we examine the larger non-facilitated Network 4 (Figure 5), we observe that two actors emerge in highly central positions, i.e. 4D (Actor 1) and 3D modellers (Actor 2). Thus, there may be some relationship between network size and number of central actors that emerge in the interactions. We have observed that in networks of size 7, a single central actor emerges. However, in networks of size 9 and size 10, we observed two actors to emerge in central positions. This pattern was observed for both facilitated and non-facilitated networks, which implies that the emergence of central actors is not necessarily contingent on their membership in a given project-specific knowledge domain, but actors outside of knowledge domains (i.e. facilitators) can also emerge in positions of high centrality. Combined with our findings for Network 2, the emergence of 3D and 4D modellers as information brokers confirms that most of the knowledge domains, with the exception of cost estimation, are well suited to have actors in highly central roles. Because the cost estimators only require information from the 3D modellers and schedulers and none of the other tasks depends on their work, their small centrality values are in line with the type of information that they require and that the network requires from them in order to accomplish the project.

Our findings to this point demonstrate that, although they lie outside of the knowledge domains central to accomplishing the task, facilitators in both of the networks we studied were highly central actors when the network focused on task work. We have observed that in facilitated networks, facilitators are central to the interactions. In non-facilitated networks, other actors fill this central role. Thus, we have determined that in the absence of facilitators, specialists can occupy central nodes along critical information transfer pathways in global virtual project networks focused on task work. Our next step is to determine how the position of facilitators impacts network performance in terms of the network's ability to resolve conflicts rooted in a need to efficiently transfer information across knowledge domain boundaries.

The impact of facilitators on information transfer

The final step in our analysis was to determine how facilitators impacted information transfer in distributed project networks. As an indicator of efficiency of information transfer, we closely examined participation by facilitators and other highly central actors during task conflicts where information had to be transferred across knowledge domain boundaries. For example, one case of observed task conflict occurred when a 4D modeller was unable to interpret the relationship between a particular geometry in the 3D model and an activity assignment in the schedule.

It may be the case that the participation by facilitators in task conflicts helps the teams to operate more efficiently, thus reducing conflict length over time. It also may be the case that facilitators are modelling effective conflict management strategies during the first instance of a conflict, which becomes adopted by the network as a strategy to help resolve subsequent conflicts. If either of these scenarios are observed in the data, then, in contrast to Dubs and Hayne (1992) and Miranda and

Bostrom (1999), the participation by facilitators during task interactions could be viewed as beneficial.

For this analysis, we focused on a single (approximately hour-long) meeting for each of the networks. These meetings were analogous in terms of meeting length and in the number of conflicts that required information transfer across knowledge domains in order to be resolved. The meetings occurred in the middle, between weeks 3 and 6 of the nine-week project, which suggests that all of the networks had at least some time working together in order to develop or to begin to develop interactional norms.

In-degrees (i.e. cases where information is directed *towards* a particular actor) for those actors with the highest betweenness centrality values (i.e. the information brokers) for the four networks were extracted from the ELAN output to a spreadsheet for analysis. Each in-degree represents an utterance directed by one network participant to another related to the task. In most cases, full sentences (e.g. 'The backlog is too high'.) or a series of sentences (e.g. 'The backlog is too high. We need to reduce it'.) were considered utterances. In some cases when speakers were interrupted by other speakers, sentence fragments were considered utterances. Crucially, the boundary between utterances was typically signalled by a shift in speaker, although in cases where the semantic content of the utterance shifted, two or more utterances were noted (e.g. 'We've resolved the backlog issue. The next issue we must consider is reducing the cost of the project because it is over budget', would be coded as two utterances). To determine the extent to which facilitators and other highly central actors were involved in the discussion of the task, we calculated the number of in-degrees (or utterances directed towards a facilitator) per minute over the course of the meetings.

In both of the facilitated networks, facilitators emerged as the information brokers. In the non-facilitated networks, a 4D modeller and a construction scheduler emerged as the information brokers. Our decision to analyse in-degrees allows us to exclude cases where facilitators were initiating interactions (e.g. performing comprehension checks) because these cases may not have necessarily involved a need to transfer information. By examining in-degrees, we are able to capture only those cases when actors are receiving information.

When we compare the number of in-degrees for the information brokers over the three conflict segments observed in the four networks, we find that in each case, but to different degrees, the in-degrees for the information brokers increase during subsequent conflicts (Figure 6). This means that over time, the amount of information transferred towards the information brokers increased as the meetings progressed.

The final stage of our analysis required that we calculate the amount of time spent by the networks in information transfer conflict. We may expect that because information brokers are becoming more involved in conflicts over time, that conflicts would be resolved more quickly as they become more comfortable addressing and working through conflict with the other actors. Given the similar structural positioning of the facilitators vis-à-vis the other actors with high betweenness centrality values, we also might expect that the facilitators would impact conflict duration in the same way.

When we examine the results of the analysis of conflict length (Figure 7), we find a surprising inversion of the relationship that we have observed between facilitators and other information brokers in Figure 6. Specifically, while conflict length *increases* in the facilitated networks, conflict length *decreases* in the non-facilitated networks. This implies that, in terms of efficiency of information transfer, the facilitated networks are under-performing the non-facilitated networks. Combined with the findings in Figure 6, a more

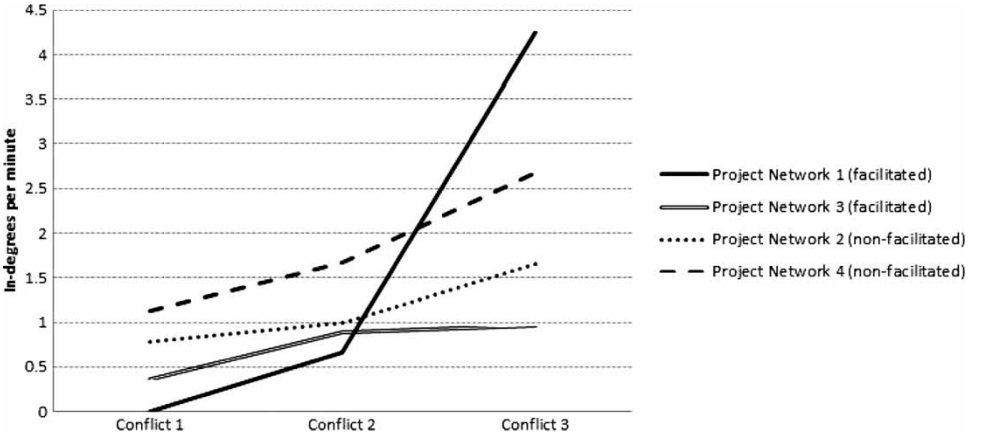


Figure 6 Comparison of normalized in-degrees for information brokers by network over time

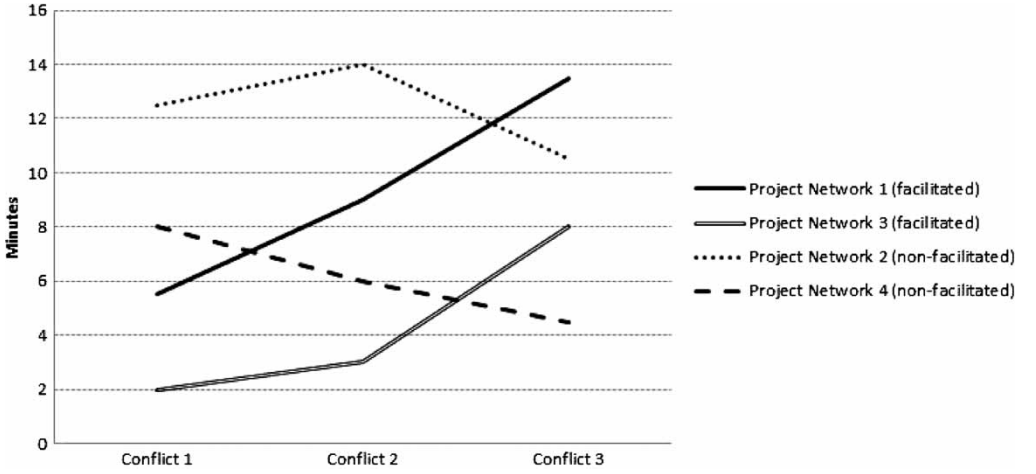


Figure 7 Comparison of conflict length in task interactions over time between facilitated and non-facilitated networks

concrete account emerges of the role that facilitators play in information transfer during instances of task conflict. As facilitator in-degrees increase, task conflict length increases.

To illustrate this finding more concretely, we return to an interaction that occurred between facilitators and specialists in Network 3 and between specialists without the presence of a facilitator in Network 4. In both networks, a conflict occurred between the schedulers and 4D modellers (Figure 7, cf. Networks 3 and 4, Conflict 3), where they were required to determine whether it was possible to format the output of the construction scheduling software such that it could be imported into the software used to create the 4D model. In both cases, the actors struggled to identify the problem and to develop strategies for finding solutions. In the facilitated network, one of the facilitators (Actor F1, Figure 4) engaged the scheduling and 4D modelling specialists and discovered that, through an internet search, it was indeed possible to export in the necessary format. This triggered additional questions by both the schedulers and 4D modellers directed towards the facilitator that he/she was unable to answer because he/she had no knowledge of either software package aside from his/her brief and focused internet search. In this case, the network eventually determined that the information they required was not held by any actor in the network and decided to table the conflict until the information could be retrieved from the faculty. The non-facilitated team adopted a similar process (i.e. a search through the scheduling software manual by the scheduler) before they decided to table the conflict until information could be retrieved from the faculty, but the non-facilitated team came to this resolution nearly twice as fast as the facilitated team. While the facilitator effectively answered the 4D modellers' initial question, they simultaneously shifted the focus of the interactions away from the specialists and onto the non-specialist (i.e. the facilitator). The effect of this shift was further confusion within the network, and with the facilitator now at the centre of the interactions, questions that should have been directed to the specialists were being inefficiently redirected through the facilitator. As subsequent conflicts emerged, the facilitator had already established his/her central role in the interactions, and thus it was difficult to become less central after already establishing such a precedent.

Although our findings suggest a potentially causal relationship between facilitator in-degree and task conflict length, due to the relatively small size of the data set and the limited number of analogous conflicts considered in this analysis, a causal relationship cannot be determined at this time. However, the results from this analysis suggest that there is some quantitative relationship between facilitator involvement in task conflict and inefficiencies in information transfer.

Discussion

Research has demonstrated that global project networks face cultural and technological challenges that can interfere with collaboration (Chinowsky and Rojas, 2003). Researchers have argued that facilitators can be an effective means to help distributed networks overcome many of these challenges (Paul and Seetharaman, 2004), including the resolution of conflicts through the transfer of information across knowledge domains. Our overall goal in this study was to determine how facilitators can impact the transfer of information through a global virtual project network in an effort to better understand how to employ facilitators effectively to help networks achieve project success. To pursue this

line of inquiry, we posited two research questions, which will now guide our summative discussion.

RQ1: *From which knowledge domains do information brokers emerge in facilitated and non-facilitated global virtual project networks engaged in a construction design and planning task?*

In both facilitated networks, the facilitators emerged as the information brokers. In the non-facilitated networks, information brokers emerged from the 3D modelling, 4D modelling and construction scheduling domains. Because we observed emergence from most of the project-specific domains and the non-project-specific domains (i.e. facilitation), it is clear that, with the exception of cost estimation, actors are not restricted by their knowledge domain from emerging as information brokers in a global virtual project network engaged in the design and planning tasks we studied. Because research has demonstrated that facilitators can detrimentally affect interactions focused on the task (Dubs and Hayne, 1992; Miranda and Bostrom, 1999), it is perhaps surprising that the facilitators emerged as information brokers for the task work.

However, given the evidence presented in Figure 6 indicating that facilitator involvement in task conflict increased over time, we can infer that the network became more dependent on the participation of the facilitator over time, even though the participation did not positively affect the network's ability to resolve conflicts efficiently. It follows then that facilitators may have established themselves as 'problem solvers' for technological, relational or work process challenges and then had difficulty in shifting to less central positions for task-related challenges. It is this type of normalization of roles that can be responsible for the over-reliance of teams on the opinion and decisions of facilitators described in Miranda and Bostrom (1993).

Research has demonstrated that facilitators who limit their involvement to specific phases of the meeting process serve as information bridges (e.g. Dubs and Hayne, 1992), effectively connecting the distributed domain knowledge held by individual project network teams and ensuring that information transfer is appropriately directed and flows unimpeded. In the two facilitated networks examined as part of this study, information tended to be transferred through the facilitator to the target specialists, which increased the number of information pathways through which the information travelled, thus creating a suboptimal network configuration. The centrality of the facilitator in Networks 1 and 3 contrasted with the centrality of the AEC knowledge domain specialists in Networks 2 and 4 suggests that the facilitator may be impeding the development of direct information transfer pathways between specialists in the network. In this sense, the facilitator is serving to weaken the ties between participants in the network because the facilitator, as an active participant in information transfer related to the task, interferes with potentially direct ties specialists.

By addressing RQ1, we have established that the facilitators were highly involved in network interactions that focused on the task. By addressing RQ2, we developed a description of the impact that highly central facilitators had on the duration of information transfer conflicts.

RQ2: *How do information brokers in facilitated and non-facilitated global virtual project networks impact task conflict duration?*

Our research suggests a relationship between the number of facilitator in-degrees and conflict length, although because of the small sample size, we are unable to prove a causal relationship. Our research has demonstrated that in-degrees for information brokers, regardless of whether they are facilitators or other network actors, increased for subsequent conflicts. However, an inverse relationship lies between the facilitators and other information brokers in terms of the duration of conflict. More specifically, task conflicts were observed to decrease in duration for non-facilitated teams, whereas they increased for facilitated teams. This finding supports the research by Dubs and Hayne (1992) and Miranda and Bostrom (1999), who argue that facilitators must refrain from being engaged in work focused on the task. It also supports the conclusions drawn by De Dreu and Weingart (2003) who show that conflicts can interfere with information transfer as evidenced in a decrease in collaborator satisfaction, because our findings demonstrate that in addition to decreasing satisfaction, conflict length increases when facilitators intervene in information transfer pathways between specialists. We extend these authors' arguments by demonstrating how, from a structural perspective, facilitators can interfere with the formation of direct ties between network actors, which were observed in the non-facilitated networks.

While our findings demonstrate that facilitators, when engaged in task discussion, can negatively impact global project network performance in terms of the network's ability to reduce conflict length, the study has a number of limitations that decrease its generalizability to other contexts. Dobbins *et al.*'s (1988) work shows that findings about human behavioural conducted in laboratory settings can lead to valuable applications in industrial contexts. However, because we employed students for the study, a number of concessions had to be made in the research design, so that the exercise was valuable from a pedagogical standpoint for the students. For instance, it would have been ideal

to measure network performance in terms of project quality in addition to conflict duration, but we allowed students to select their own projects, which turned out to be dissimilar in scope and complexity. It would be difficult to develop a general project quality evaluation rubric to address the various projects such as the renovation of an arena in New York City and a married student housing complex in India. We allowed the students to select their own projects in order to increase their ownership of the project and to lend a sense of authenticity to their work. In addition, although the projects were realistic, the student networks were composed of novices in their respective knowledge domains, which limits the direct generalizability of the study to an industrial context. For instance, the conflict described at the end of the previous section was resolved when the teams sought additional information from the faculty. While this specific situation would not occur in an industrial context, it is plausible that in an industrial context, network actors may seek information to resolve a conflict from a source outside of the project network, e.g. from a client's representative. Also, student teams were selected from four countries, which we believe accurately reflect the cultural heterogeneity of global project networks in the AEC industry. So, on the one hand, student teams accurately reflect the industrial global virtual project networks, but, on the other hand, they are quite different. Future research might productively replicate studies like ours with industrial participants to explore whether or how significant the differences are between findings from student networks and professional networks.

The study was also limited by the size of the data set and the number of conflicts that occurred during the observed meetings. While some teams had a large number of information transfer-based conflicts, other teams had only three. In part, some of this discrepancy is related to the complexity of the projects chosen by the student teams. In order to compare the two ranges of conflict, we decided to limit our analysis to three cases of task conflict experienced by the teams in a single meeting. Had the teams worked on projects similar in scope and complexity, it would have been possible to explore the role that facilitators play in reducing the total number of conflicts, not just the duration of analogous conflicts.

Given these limitations, this research contributes to the understanding of the relationship between facilitators and information transfer in global virtual project networks. We now know that information that must be transferred across knowledge domains should be done so through specialists within one of the knowledge domains in order to reduce conflict associated with the transfer. Moreover, we have determined that information brokers can emerge from any of the knowledge domains included in this study and that a given knowledge domain is not better suited for the emergence of information brokers compared with others. We have also learned that facilitators can have a negative impact on information transfer when they are engaged in task work, as evidenced in an increase in task-based conflict duration.

As this is in an educational setting, an important application of our research relates to the training of facilitators and their employment in global virtual project networks. The effectiveness of a facilitator in terms of optimizing information transfer between networked project teams is based on their structural position in a network and on the type of activity in which the network is engaged. Crucially, effective facilitators shift their structural position dynamically as the meeting progresses, based on the nature of the interactions between specialists. The challenge for facilitators is to develop the self-awareness to pull back from interactions focused on the task and work actively against the creation of interactional norms that position them at the centre of the network's task work. The development of these types of interactional norms is quite subtle as they occur over time. However, it is important to train facilitators to be aware of the power of these norms, as they may find that it is not easy to adopt facilitation practices where facilitators are highly involved during one phase of the meeting and then have a low involvement during other phases.

Conclusions

Our goal in this study was to explore how facilitators impact the transfer of information through a global project network in a modally robust virtual workspace by examining the centrality of actors from different knowledge domains. We used task conflict duration as an outcome variable in comparing the performance of two facilitated and two non-facilitated networks engaged in a complex design and planning project. Our findings indicate that when facilitators occupied highly central positions during task interactions, conflict length was observed to increase. In non-facilitated networks, highly central actors emerged from a variety of knowledge domains and conflict length was observed to decrease.

From an applied standpoint, the research presented in this paper supports a model of facilitator involvement in global virtual project network meetings that varies based on activity type. Thus, facilitator training programmes must ensure that facilitators develop an understanding that a *low level* of involvement during task interactions is critical to project success. If we can train facilitators to work actively to counter the interactional norms that draw them to the centre of task interactions, then facilitators will be better positioned to avoid bridging too far across knowledge domains and

impeding the critical flow of specialized information in global project networks.

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