Examining the Impact of Facilitation on the Performance of Global Project Networks Collaborating in Virtual Workspaces

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ABSTRACT

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Globalization impacts the Architecture, Engineering and Construction (AEC) industry; customers in the AEC industry are seeking lower costs, faster construction schedules and higher quality services. In order to keep up with the changing demand and to stay competitive in the global AEC industry, firms are forming joint ventures and outsourcing design and services work. As a result, these new trends in the AEC industry require the collaboration of widely dispersed and diverse project workers and companies. Accordingly, it becomes increasingly important to understand the impact of diversity on performance. In this sense, the initial aim of this study was to find empirical evidence on how differences in national culture and language may affect performance in Global Project Networks (GPNs). According to the results of the first experiment comparing the performance of multi-cultural versus mono-cultural simulated project networks over time, I found cultural and linguistic diversity to have a negative impact on initial performance. However, culturally and linguistically diverse project networks studied achieved better adaptation performance that has long term advantages. Even though GPNs have long term performance benefits, bringing the widely dispersed project participants together is costly. Therefore, firms are seeking ways to employ collaboration technologies to bring together the project participants. Little research exists to examine how to increase the efficiency of GPNs that collaborate using technologies such as virtual workspaces to perform design work. In order to examine collaboration in GPNs utilizing virtual workspaces, I conducted two experiments. In the first study, I investigated the formation and the maintenance of Transactive Memory System
(TMSs) and cohesive subgroups as a proxy for performance in two facilitated and two non-facilitated global virtual project networks. I found a negative impact on collaboration effectiveness when process facilitators engaged in content facilitation in virtual project networks, which restricts the establishment of TMSs. The findings of the first study revealed inappropriate ways of facilitating GPNs collaborating in virtual workspaces, which motivated the second study. In the second experiment, I observed two global and two domestic virtual project networks that were appropriately facilitated. I examined the interactions between network members in order to identify whether significant differences between the collaboration approaches of global and domestic virtual project networks exist. Facilitators were utilized more frequently in global networks, particularly in the early stages of collaboration. Boundary spanning visualization technologies within the virtual workspace were also utilized more frequently by the global network members; however, this was due more to the spatial richness of the task than the maturity of the collaboration. The overall findings have significant implications in improving the effectiveness of global project network collaborations in virtual workspaces.
Dedicated to my mom and sister.
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“What matters in life is not what happens to you but what you remember and how you remember it.”

-Gabriel García Márquez

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CHAPTER 1: INTRODUCTION

This is a very exciting time in the world of information. It's not just that the personal computer has come along as a great tool. The whole pace of business is moving faster. Globalization is forcing companies to do things in new ways.

-Bill Gates

The world is becoming more and more connected. Never before in human history has such diversity of relationships been possible between people and this connectivity is enabled by technology. The advancing information and communication technologies have been a major driving force for globalization. Technology is making our lives simpler and easier. The technological advancement of computers, communication systems, internet and transportation continues to have a huge impact on our lives and the barriers that hindered our ability to reach out to people across the world have diminished. According to an International Telecommunication Union 2012 report, total mobile-cellular subscriptions reached almost 6 billion by the end of 2011, corresponding to a global penetration of 86%. Similarly, the percentage of individuals using the internet continues to grow worldwide and at the end of 2011, 2.3 billion people were online. Considering that in 2005, the total number of mobile-cellular subscriptions was only 2.2 billion and only one billion people were online, this demonstrates the drastic increase of new technologies in our lives. The globalization of technologies and industries has changed our lives. Globalization has completely altered the way world operates; it has impacted politics, our social lives and the economy.
As the quotation at the start of this chapter by Bill Gates suggests, globalization forces companies to do things in new ways. This is also true in the construction industry. The expectation of the customers is changing in the global Architecture, Engineering and Construction (AEC) industry; they are looking for lower cost, faster construction schedules and higher quality services. In order to keep up with the changing demand and to stay competitive in the global industry, firms in the AEC industry are seeking ways to employ technology to improve cost, schedule and quality.

**Trends in the Architecture Engineering Construction Industry**

Opportunities for AEC firms outside of their domestic markets have increased over the past several decades, leading many firms to expand operations into other countries. Many developing countries have provided such opportunities as they need new infrastructure to accommodate population growth and the needs of a modernizing society. Through international construction companies, developing countries gain access to technology and products which could not be produced locally with efficiency (Raftery et al. 1998). However, current market conditions are not only beneficial for developing countries; the international construction companies also benefit. AEC firms from countries with advanced technology, sophisticated managerial systems and increased financing capabilities have taken advantage of these opportunities during this era of increasing global competition (Abdul-Aziz 1994). For example, over the years, U.S. construction companies have acquired experience in complex projects including the building of highways, industrial plants, and dams; and these capabilities provided a competitive advantage to many U.S. firms in the international market (Ngowi et al. 2005). Likewise, an increasing number of international firms have expanded their operations into other developed markets. Thus, while
global competition presents an opportunity to enter new markets, it also poses a domestic challenge when international firms compete in local markets.

A growing number of engineering firms are also outsourcing complex design work to international vendors (Messner et al. 2007). In the AEC industry, U.S. firms secure engineering services at a comparatively lower price from offshore service providers such as low cost engineering centers in China, India, Russia, Eastern Europe, Latin America, and Central Asia (Friedman 2005). According to Bryant (2006), the main reasons for global outsourcing in the AEC industry are cost reduction, customers and projects moving offshore; access to better service, increased quality at overseas engineering offices, and shortened design cycle times. Therefore, the need for cost competitiveness in global markets has led to hybrid business arrangements in which firms within the same specialization collaborate with similar firms in other markets seeking to achieve the optimal combination of cutting edge technology and cost competitiveness.

The increasing size and complexity of projects also increased the need for participation of engineers, contractors, and suppliers from multiple countries. The demand for complex, large-scale construction projects and the growth in the number of mega projects is increasing globally; however, small or medium sized local contractors can often not meet the requirements of such projects. This need has paved the way for growth in international construction (Ngowi et al. 2004). Highly specialized AEC firms consider global projects as an opportunity to capitalize on their experience and high level of technological skills (Han 2007). Moreover, some nationalities have developed specializations in certain specialty areas. For example, the U.S. has historically provided expertise in green buildings and high-rise steel structures, while Japan is often associated with tunnel construction and earthquake-resistant buildings. Therefore, in many large-
scale projects, it is strategically beneficial to collaborate with companies from certain countries to utilize their experience and specialized expertise. It is now common practice for large and highly complex projects to involve major AEC players from many different countries (for examples, see Mahalingam and Levitt 2007).

**Project Networks in the Global AEC Industry**

As a result, all these new trends in the AEC industry require the collaboration of widely dispersed project workers and companies. Yet, bringing the project participants together through a single hierarchical organizational structure is not feasible. Many researchers discuss that both single firm hierarchical structures and pure market-based approaches to assembling firms on projects can result in inefficiencies in a highly competitive and unstable global economy (Powell 1990, Miles and Snow 1992). To address these inefficiencies, a hybrid structure emerged that balances the flexibility of markets with the predictability of traditional hierarchies (Miles and Snow 1992, Powell 1990, Snow et al. 1992). This hybrid structure is defined by different terms in previous research such as "quasi-firms" (Eccles 1981), "network organization" (Miles and Snow 1986), and "network forms of organization" (Powell 1990).

Starting from early the 1980s, network forms of organizations became a popular description for organizations characterized by having continuous and flexible resource exchanges among network units that rely on trust and social relationships (Eccles 1981, Bradach and Eccles 1989; Powell 1990). Many industries increasingly prefer using network structures rather than hierarchical structures within firms in order to benefit from long term transactions and thereby reduce their costs. The AEC industry is one of the industries that has adopted the network form of organization. Forming network structures over the course of a construction project provides a great deal of flexibility. In network forms of organizations, individual units do not exist by
themselves, but rather in relation to other units (Powell 1990). Thus “with their emphasis on lateral forms of communication and mutual obligation, the network forms of organizations are particularly well-suited for such a high skilled labor force where participants possess fungible knowledge that is not limited to a specific task but applicable to a wide range of activities” (Powel 1990, pg:324). Knowing that construction projects require a large number of design and labor specialties, coordinating the work of these different specialties over the course of a project is an extremely complex task (Eccles 1981). Moreover, the transactional implications in the AEC industry are different from mass assembly and process technologies typically found in manufacturing (Eccles 1981). Therefore, hierarchical structures, while are well-suited for mass production and distribution (Powell 1990), are not an appropriate form for the AEC industry since a hierarchical structure with clear departmental boundaries, clean lines of authority, detailed reporting mechanisms and formal decision making processes (Powell 1990) are not flexible enough for construction projects. Therefore, because of the dependent and complex relationships in construction projects, using the network form of structure is efficient and beneficial in the AEC industry.

Considering the global nature of the current AEC industry, forming Global Project Networks (GPNs) has many organizational benefits. Yet, managing a culturally and linguistically diverse network of firms on a global construction project is extremely complex and challenging. In short, even though the globalization of the AEC industry brings business opportunities, it also has conveyed distinct challenges in terms of managerial issues and coordinating across time zones, different languages and different cultures (Nayak and Taylor 2009). In the globalizing AEC industry, building strong ties between widely dispersed project network participants is crucial to achieve project success. Cooperating on highly complex design
and construction projects across wide geographical distances and time zones is not straightforward. Researchers have shown that approximately 40% of global projects result in poor performance (Beamish and Delios 1997). However, to keep up with highly competitive global markets, it is necessary for companies to mitigate cost, complete projects faster and provide better services and creative solutions. Therefore, many researchers examine GPNs in order to understand and manage key dynamics and thereby achieve higher network performance (Horii et al. 2005, Chinowsky et al. 2011, Di Marco et al. 2011). Considering that the main characteristic of GPNs is cultural and linguistic diversity since project participants are from different countries, researchers have been particularly interested in the impact of diversity on global projects (Porter 1995, Horii et al. 2005, James 2008). Moreover, collaborating through various communication modes (e.g. email, teleconference, video conference, and virtual workspaces) is an inevitable consequence of forming GPNs. The role of technologies that enable communication and information transfer over physical boundaries in GPNs in increasing project performance is also another aspect of GPNs that has received extensive treatment in the literature (e.g. Mitropoulos and Tatum 2000, Taylor 2007).

**Impact of Cultural and Linguistic Diversity on Global Project Networks**

Given the fact that GPNs are composed of individuals from different countries with diverse cultural backgrounds, the diversity among project participants is an inherent characteristic of GPNs. In order to develop a deeper understanding of GPNs, researchers have put tremendous effort toward identifying the impact of diversity on project performance (e.g. Horii et al 2005).

Research has shown that diversity yields both advantages and disadvantages for the effective functioning of project networks. Global groups are more creative and more likely to reach high quality decisions (Distefano and Maznevski 2000). Participants from different
cultures bring a variety of perspectives to a task; thereby diversity may add a range of resources to a group (Adler and Gundersen 2008). Another positive impact of diversity is that it reduces the probability of groupthink (Janis 1982), a phenomenon that occurs when domestic participants do not explore alternative solutions; not considering all available solutions can lead to errors. Additionally, according to Adler and Gundersen, diverse groups have built-in protection against groupthink by bringing new approaches to solve the problem (2008).

While diversity among project participants has many benefits, researchers also call attention to the disadvantages of the diversity. According to Hofstede (1983), cultural diversity may have become one of the most crucial problems for modern management. Foremost, the communication problems due to different native languages and cultures are the main handicaps to achieve higher performance (Matveev and Nelson 2004) that also trigger other drawbacks such as weak trust development (Jarvenpaa et al. 1998, Jarvenpaa and Leidner 1999, Holton 2001). Difficulties in communication due to diversity may also affect knowledge transfer in diverse groups (Oshri et al. 2008).

Role of Technology in Global Project Networks

Developments in communication and information technology have made it easier to collaborate across geographical boundaries. Accordingly, physically dispersed project participants can utilize various virtual communication modes in order to collaborate, leading to the formation of Global Virtual Project Networks (GVPNs). Organizations benefit from utilizing virtual environments by responding faster to increased competition and gaining access to the individuals working from various locations which provide greater flexibility (Bell and Kozlowski 2002).

In addition to the development of communication systems in virtual environments, evolving project information formats such as virtual design practice also make it easier to
transfer explicit knowledge (Dossick and Neff 2011). The evolving project information format (e.g. from 2D paper-based design to 3D computer-based modeling) in the construction industry is a catalyst that supports virtual collaboration. Considering the vast amount of data produced during the lifecycle of a project, it would be nearly impossible to collaborate virtually without having advanced digital project information formats. Moreover, since using spatial design technology makes it easier to identify and visualize potential design problems, support brainstorming activities to investigate different design alternatives and support documentation of the meeting process (Golparvar-Fard et al. 2006), having visual models in a virtual setting enables effective communication.

Although the use of advanced communication and information technology has enabled geographically dispersed individuals to work together, collaborating through technology is adding some new challenges to the functioning of GVPNs. There are potentially serious disadvantages that should be considered before firms adopt the use of collaborative virtual workspaces. For instance, overcoming cultural issues and feelings of isolation and establishing trust among individuals (Cascio 2000) is typically more difficult in virtual workspaces than in face-to-face settings. Thus, virtual project networks must be supported in order to overcome these difficulties and perform effectively.

**Facilitating Global Virtual Project Networks**

As a means of supporting the relational, communication and knowledge-sharing challenges of working in virtual settings, some researchers have proposed the use of virtual team facilitators (Warkentin and Beranek 1999, Sarker et al. 2000, Pauleen and Young 2001b). They claim that facilitators may help virtual teams to perform better by establishing the stronger interpersonal links between team members that are associated with effective communication and which lead to
more effective task performance (Warkentin and Beranek 1999, Sarker et al. 2000). To achieve this, building relationships between virtual team members is a fundamental concern for virtual team facilitators (Pauleen and Yoong 2001b). Clawson and colleagues (1993) argue that the most crucial role of facilitators in projects is to help network participants achieve an outcome more easily, which is even more critical in virtual settings.

In the complex virtual collaboration context, an important role of facilitators is to provide support to improve the use of information and communication technologies, which is critically important for virtual collaboration success (Thomas and Bostrom 2005). Therefore, facilitators can help to build cooperative relationships between project network participants, mediate conflicts within the network, encourage participants to participate in the work activities, and, most importantly, facilitators may help participants overcome technological problems and develop appropriate norms of technological use. In short, the role of facilitators in GVPNs is an emerging and important research topic. Previous research has identified the role of facilitators collaborating in face-to-face and virtual settings; however, a nuanced understanding for GPNs performing design work in a virtual workspace is lacking in the literature.

**Research Questions and Format of Dissertation**

Previous research has investigated the impact of cultural and linguistic diversity on GPNs. While some researchers emphasize the drawbacks of diversity, some studies emphasize the advantages, such as inducing creativity and bringing different perspectives. We currently lack a robust understanding of the impact of cultural and linguistic diversity on GPNs. In GPNs, virtual communication to exchange project information is an inevitable consequence of having physically dispersed project network members, therefore changes in the communication and information technologies directly impact GPNs. In this sense, little research exists to examine
how to increase the efficiency of GPNs that collaborate in virtual workspaces to perform design work. Consequently, a key aim of this research is to illuminate ways to support GPNs utilizing virtual workspaces. This dissertation follows a three-paper format. The research questions investigated are:

1. How is the performance of simulated project networks affected by the cultural and linguistic diversity among participants?
2. How do process facilitators that engage in content discussions impact the performance of global project networks collaborating in virtual workspaces?
3. How do the collaboration approaches developed by global project networks differ from domestic project networks collaborating in a virtual workspace?

The structure of this dissertation and how the three aforementioned research questions are logically related is illustrated in Figure 1. Given the importance of the globalization in the AEC industry, the first research question aims to identify the impact of cultural and linguistic diversity on global project networks performance collaborating in a face-to-face setting and then explores the reasons behind the resulting differences in performance. Having identified that in the early stages of collaboration GPNs have difficulty collaborating but that such cross-cultural collaborations can possibly lead to better performance over time, in the next two research questions I begin to address the factor of technology in GPNs, that most GPNs inevitably have to face due to their wide geographic distribution. In addressing the next two research questions, I focus on GPNs collaborating in virtual workspaces. Advances in information and communication technology have enabled virtual collaboration among physically dispersed
participants. Because of the increasing and prevalent use of technology, all GPNs can be classified as virtual to some extent. Yet, there are serious practical disadvantages to virtual collaboration. To overcome these disadvantages and the potential drawbacks of diversity and to achieve the positive performance advantages of cross-cultural collaboration I identify in addressing the first research question, GVPNs must be supported. In the second research question, I discuss the impact of facilitators on GVPNs’ performance. More specifically I examined the consequences of process facilitators that engage in content discussion in a virtual setting. The contribution of this research effort helps to shape the third study. Examining the second research question I present appropriate versus inappropriate ways of facilitating GVPNs which I then investigated further in the third research question. The third research question aims to distinguish the collaboration approaches developed by participants in GVPNs as compared to those in DVPNs. In this final research study I am able to demonstrate more appropriate utilization of facilitators in GVPNs and, more importantly, demonstrate that when facilitators are utilized appropriately by GVPNs, the cross-cultural project workers investigated were able to make productive use of the technological affordances in the virtual workspace. The main goal of these three cumulative efforts is to work toward a more robust understanding of how GPNs function in virtual collaboration environments.
This dissertation is structured following a three-paper dissertation format. In Chapter 2, I introduce the dual impact of diversity and compare project performance of global and domestic networks collaborating in face to face environment. This article was published in the *Journal of Management in Engineering* in 2011 and was co-authored by myself, my PhD colleague Hakan Unsal, and Professor John E. Taylor. Then, in Chapter 3, I begin to investigate performance in a virtual collaboration workspace in order to examine appropriate ways of facilitating GVPNs to avoid the shortcomings and achieve the benefits of performance I identified in Chapter 2. In this chapter, I use advanced social network analysis methods in order to model the dependent network relations by which I could conclude the likelihood of observing hypothesized network structures within the collected data set. This chapter is current in press to be published in the *Journal of Construction Engineering and Management* and was co-authored by myself, Dr. Josh Iorio, Professor John E. Taylor and Professor Carrie Sturts Dossick. In Chapter 4, I identify
differences in the collaboration approaches of GVPNs and DVPNs by examining the use of facilitation and boundary spanning visualization technologies within the virtual workspace. In this study, I again take advantage of social network analysis in order to identify the dependent relations among network participants. The article presented in this chapter will be submitted to an academic journal for publication in the near future. It is co-authored by myself, Professor John E. Taylor and Professor Carrie Sturts Dossick. I end the dissertation with a discussion of the contributions of the research to our current understanding of GPNs in Chapter 5 and a discussion of limitations and potential avenues for future research in Chapter 6. Finally, a reference section is provided with a bibliographic list of the publications cited in the dissertation.
CHAPTER 2: THE DUAL IMPACT OF CULTURAL AND LINGUISTIC DIVERSITY ON PROJECT NETWORK PERFORMANCE¹

Abstract

As the design and construction industry globalizes, it becomes increasingly important to understand the impact of cultural and linguistic differences on performance. Researchers have recently begun examining issues associated with design and construction globalization. Yet there is little empirical evidence on how differences in national culture and language may affect performance in global project networks. This paper presents the results of an experiment comparing the performance of multi-cultural versus mono-cultural simulated project networks over time. We found cultural and linguistic diversity to have a dual impact. We observed such diversity to have a negative impact on initial performance; however, culturally and linguistically diverse project networks studied achieved better adaptation performance on average. The results suggest that, although there are initial performance liabilities, sustained interaction of culturally and linguistically diverse networks may ultimately result in multi-cultural networks outperforming mono-cultural networks. This finding has implications for the effective design and management of global projects. It also contributes a new theoretical perspective to on-going theoretical debates on cross-cultural performance.

Keywords: Culture, Globalization, Organizational Issues, Performance, Project Networks

Introduction

Increasing globalization of design and construction projects brings with it the challenge of dealing with cultural and linguistic differences. Design and construction firms that expand operations abroad attempt to mitigate these differences by changing the way they organize projects, by modifying the information technologies and systems they employ, and by thinking globally (Kini 2000). However, managing a culturally and linguistically diverse network of firms on a global project is extremely complex and challenging. Researchers have shown that approximately 40% of global projects result in poor performance (Beamish and Delios 1997). Researchers have argued that cultural differences may have become one of the most crucial problems for modern management due to the range in implications from political to psychological considerations (Hofstede 1983).

Despite the difficulties of working outside a firm’s domestic market, many firms operate in the global marketplace. Some firms expand abroad to mitigate the cyclic nature of their domestic market. Other highly specialized firms view expanding outside their domestic market as an opportunity to take advantage of their specialized expertise to lead in that same specialized niche in other geographic markets (Han et al. 2007). According to Delios and Beamish (2001), firms’ experience in interaction, acquisition of knowledge and establishment of communication contributes in two ways; experience generates new capabilities to offset the liability of foreignness and it also helps the adaptation of existing intangible assets to improve a foreign subsidiary’s host market competitiveness. The success of these firms depends in part on how effective they are at arranging the transfer of these activities both within the firm and through the inter-firm network (Antia et al. 2007). Cultural diversity among the parties can hinder the complex process of knowledge transfer (Javernick-Will and Levitt 2010; Miller et al. 2000), can
impact contractual relationships between firms (Chan and Tse 2003; Rahman and Kumaraswamy 2004), impacts trust development (Fong and Lung 2007), and therefore is an important risk factor in global design and construction projects (Bu-Qammaz et al. 2009).

However, one can also raise a compelling argument that the conflict which is created by diversity in a global project network might prove to be offset by the benefits; project networks can gain access to diverse approaches that derive from the various cultures participating on a project. One might expect a positive return in terms of cost, schedule, and/or quality when working in a multi-cultural environment. In the long-run the benefits of cultural diversity might be greater creativity, better problem solving ability, and a more comprehensive approach to problem solving (Miller et al. 2000). This may explain why some firms operating globally are highly successful notwithstanding challenges created by cultural and linguistic diversity in global projects. The aim of this paper is to empirically examine how performance in simulated project networks is affected by cultural and linguistic diversity among participants.

**Background**

A number of researchers have hypothesized that cultural diversity results in decreased performance (Barkema et al. 1997, Brouthers and Brouthers 2001). They argue that individuals and organizations in the project network will have different values, beliefs, and norms (Hofstede 2001, Kogut and Singh 1988). Institutional theorists argue that this will lead to increased transaction costs both in monetary and efficiency terms (Mahalingam and Levitt 2007). Many studies in the international business literature have sought to relate the performance of international ventures to the cultural distance between the countries involved (Barkema et al. 1997, Brouthers and Brouthers 2001, Beamish and Kachra 2004, Ozorhon et al. 2008, Park and Ungson 1997). However, taken as a whole, these studies have been inconclusive. Some
researchers have found a significant and positive relationship between cultural distance and performance (Park and Ungson 1997, Shenkar and Zeira 1992). Others have found a significant and negative relationship (Barkema et al. 1997). Complicating things further, still others have found no significant effect of cultural distance on performance (Beamish and Kachra 2004). The disagreement between these studies raises important questions about the nature of this problem and how best to approach investigating it.

The Cultural Distance Index (CDI) is a measure used to estimate the extent to which two cultures are different from each other (Kogut and Singh 1988). It gained broad acceptance in the international business literature and has been applied in many other disciplines (Shenkar 2001). CDI has been used to understand strategic decision making such as how firms adopt innovations (Straub et al. 1997), entry mode choices (Kogut and Singh 1988), and foreign investment decisions (Morosini et al. 1998; Slangen 2006), among others. The quantitative cultural distance measure defined by Kogut and Singh (1988) is used extensively by researchers and is based on the five cultural dimensions identified by Hofstede (1980). Hofstede’s framework defines five dimensions on which national cultures have been found to vary including; power distance, individualism versus collectivism, masculinity versus femininity, uncertainty avoidance, and long term orientation. Hofstede defines these dimensions as follows (Hofstede and Hofstede 2005);

- Power Distance Index (PDI) defines how much a culture does or does not value hierarchical relationships and respect for authority
- Individualism versus Collectivism Index (IDV) defines how much a culture emphasizes the rights of the individual versus those of the group,
• Masculinity versus Femininity Index (MAS) defines the degree to which 'masculine' values like competitiveness and the acquisition of wealth are valued over 'feminine' values such as relationship building and quality of life,

• Uncertainty Avoidance Index (UAI) measures a country’s or culture's preference for strict laws and regulations over ambiguity and risk, and

• Long Term Orientation Index (LTO) refers to how much society values long standing as opposed to short term traditions and values.

In addition to research on cultural diversity, researchers have examined the impact of linguistic diversity on effectiveness of task coordination. In skilled tasks, a team with a diverse skill set that is able to coordinate those skills will generally outperform teams that lack certain skills or are unable to coordinate them successfully (Chen et al. 2006). A key challenge faced by linguistically diverse multi-cultural networks is achieving sufficient communication to coordinate the diverse set of skills on a project. As the global village gets smaller, project network members around the world are expected to have good communication and cross-cultural language skills with at least a working ability to speak, write and understand in English, the international lingua franca (Gillear and Gillear 2002). In multi-cultural project networks where a specific language is selected for project communications, it is very often the English language (Crystal 1997). English might be the second or even third language for many project participants. Those individuals may communicate in English at a basic level and may not have sufficient knowledge of theoretical vocabulary or idiomatic expressions that are used by native speakers of the language (Miller et al. 2000). Moreover they may not be equally proficient in all
the modes of the language; they may have proficient writing, listening and reading skills but they may perform poorly in speaking.

Pronunciation might be another obstacle in communication even though non-native speakers have adequate knowledge of the language selected for the project. According to Chen and colleagues (2006), pronunciation differences impacts successful communication processes in global teams. Hofstede and Hofstede (2005) corroborate these findings and describe further that without a shared language one will miss a lot of the subtleties of a culture and be forced to remain a relative outsider. To be able to establish an authentic intercultural understanding in multi-cultural networks, participants must be competent in a shared language. Conflicts and misunderstandings from linguistic differences may make taking advantage of a diverse skill-set in a multi-cultural team difficult or even impossible.

**Research Methodology**

**Hypotheses**

One possible explanation for the disagreement in previous research on the impact of cultural diversity on performance may be related with the validation of the independent variable. In much of the earlier research the independent variable is the cultural distance index which is calculated using the cultural scores assigned to each country. Using generic cultural indices for countries to reach conclusions about specific individuals or firms may be problematic. If the objective is to relate the generic cultural distance index value to a dependent variable, then the relatively high variance that can exist among individuals in a population would be ignored. It is then impracticable to validate the accuracy of the dependent variable since people are assumed to carry exactly the same characteristics of their native cultures. In this research we compared the actual performance of multi-cultural and mono-cultural project networks adapting to a new
process. Researchers have considered various criteria for measuring project performance (Wuellner 1990, Songer and Molenaar 1997). Until the early 1990s, there were three main performance criteria—time, cost and quality—which have been referred to as the iron triangle by Atkinson (1999). Atkinson proposed that these three basic criteria be included in project performance measurement. Accordingly, we measured performance as the time required to execute multiple successive projects. We excluded the cost dimension since it would unnecessarily complicate the experiment for the participants. Quality was embedded into the experiment as project networks were not allowed to go to next project until the model met the design and specifications. If insufficient quality was achieved then rework had to be completed which was added to the total time it took to complete the project. We also collected data on each individual’s actual cultural assessment score, as opposed to using the cultural distance index from their home country. This was used to compare the mono-cultural networks versus the multi-cultural networks.

The existing literature on the impact of cross-cultural differences on performance is equivocal (Barkema et al. 1997; Beamish and Kachra 2004; Park and Ungson 1997). However, we know that many international projects fail (Beamish and Delios 1997). And yet cultural diversity has been shown to lead to greater creativity, better problem solving ability and a more comprehensive approach (Miller et al. 2000). Therefore we hypothesize that—with actual performance data from multiple projects and individually derived cultural index scores—we will observe an initial negative impact on initial performance due to cultural and linguistic differences. Conversely, we posit that sustained interaction over multiple successive projects will enable culturally and linguistically diverse project networks to adapt to the new process
more quickly. In other words, culturally and linguistically diverse project networks will achieve better adaptation performance. We formally state these first two hypotheses as follows:

**Hypothesis 1a:** Culturally and linguistically diverse project networks will result in worse initial performance than mono-cultural, mono-linguistic project networks.

**Hypothesis 1b:** Culturally and linguistically diverse project networks will result in better adaptation performance than mono-cultural, mono-linguistic project networks.

Utilizing the widely accepted method of calculating cultural distance (Kogut and Singh 1988), we hypothesize (H1a) that as cultural distance increases; the initial performance of the network worsens. This is in line with the findings of Barkema and colleagues (1997). However, we anticipate adaption performance to improve as cultural distance increases (H1b). This is in line with the findings of Park and Ungson (1997). We anticipate that collecting actual performance data and individually derived cultural distance scores will enable us to validate the findings of Barkema and colleagues (1997) as related to initial performance and the findings of Park and Ungson (1997) as related to adaptation performance. We will test the following hypotheses:

**Hypothesis 2a:** The effect of cultural distance indices on culturally and linguistically diverse project networks’ initial performance is significant.
Hypothesis 2b: The effect of cultural distance indices on culturally and linguistically diverse project networks’ adaptation performance is significant.

It is widely accepted that language and culture are intertwined with each other. Language is a way of expressing culture (Kramsch 2003). Jiang explains the inseparable nature of language and culture by referring the following metaphor; “Communication is like transportation: language is the vehicle and culture is traffic light. Language makes communication easier and faster; culture regulates, sometimes promotes and sometimes hinders communication” (2000: 329). Therefore we propose further that project networks must be able to communicate effectively for cultural distance to have an effect. This is in line with the findings of Hofstede and Hofstede (2005) and Chen and colleagues (2006) that for authentic intercultural understanding to occur a minimum ability to communicate must be present. Moreover, difficulties in communication may explain why some researchers have found no relationship between CDI and performance (Beamish and Kachra 2004). Since CDI doesn’t account for the linguistic component of culture, scores from a reliable language test can be used to measure linguistic diversity. The Test of English as a Foreign Language (TOEFL) evaluates the level of individuals’ understanding of English and many institutions such as universities, government agencies and businesses require this test from international applicants (ETS 2009). We collected and utilized TOEFL scores in the culturally and linguistically diverse project networks to test the following hypotheses:

Hypothesis 3a: The effect of TOEFL score on culturally and linguistically diverse project networks’ initial performance is significant.
Hypothesis 3b: The effect of TOEFL score on culturally and linguistically diverse project networks’ adaptation performance is significant.

Experimental Design and Methods

We conducted a series of experiments to examine the impact of cultural and linguistic diversity on performance in project networks. We developed a set of interdependent tasks modeled on the design and construction process that required the participation of three distinct roles: an architect, an engineer and a contractor. The goal of each project was to design, specify and build a small model of a building. All roles were given specific instructions to follow in order to perform the task assigned. Each assembled project network was comprised of one architect, one engineer and one contractor and they were asked to complete five successive projects. Each project could only be completed with the collaboration of every role through a set of independent and interdependent tasks. Having only one individual represent each role in the simulated project networks, there is a possibility the assembled networks would adopt a team structure. However, the following features of the simulated project networks were included in the formulation of the experimental tasks and the participant interactions to address this possibility:

- Each individual role had its own distinct and independent set of tasks which it necessarily completed separately from the other individuals in the network.
- Each role had a portion of its task dependent on the output of another role. For example, the engineer needed to get the design from architect to develop the specifications and the contractor needed both the design and specifications to assemble the model. In the rework phase, the architect depended on the contractor if there were insufficient materials to construct the original design.
• The participants conveyed only the necessary information (i.e., the graph paper with the design and specifications).

• The participants were spatially separated from each other at three different tables in the same room to ensure each role did not collaborate on the independent tasks but that they could still communicate.

• The time required to complete the five successive projects was a maximum of 90 minutes leaving insufficient time for a team to complete its formation or move on to other later stages of team formation (Tuckman 1965).

At the beginning of each project, the architect was given an envelope that included rough design requirements and a sheet of graph paper. The design requirements included, for example, how many exterior and interior walls were required, how many doors and windows, and the locations of the doors and windows. They were instructed to draft plan and elevation views of the building design that met the design requirements. When the design was complete, they passed the plans to the engineer who was given a set of building codes and tasked with specifying the specific types of material to be used and the dimensions of the building to meet the required codes. Once the structure was designed and specifications completed, the design and specifications were passed to the contractor who was tasked with building the structure according to the provided design and specification. The last step of the experiment was for the researcher to inspect the model. If errors were found, the design and specification were marked up and the project network had to resolve any punch list items. Completion times, inclusive of rework, were recorded for each project. We minimized external factors which may have impacted the performance by sustaining exactly the same experimental environment and by
recruiting participants of approximately the same age and educational level. All of the participants recruited were Columbia University students; studying at either the undergraduate or graduate level. All the U.S. citizens were native English speakers and international students recruited were required to have been in the United States for less than three years to be eligible to participate in the experiments. The backgrounds of the participants were not taken into account since the assigned tasks were sufficiently general that they did not require specialized knowledge.

In order to examine and compare mono-cultural and multi-cultural network performance, we recruited sixty participants to populate twenty project networks. Each project network was responsible for designing, specifying and building up to five models in a 90 minute period. Therefore, the experiment was developed around the design, specification and construction of 100 models. Of the twenty project networks recruited, half were mono-cultural and half were multi-cultural in composition. The first ten project networks were comprised entirely of U.S. citizens who all spoke English as their native language. These networks represented the control group by which we would compare multi-cultural project network performance. The remaining ten project networks were comprised of participants that originated from different countries. We did not include a U.S. citizen in the multi-cultural project networks nor did we recruit participants with English as their native language.

Multi-cultural project network participants were required to have lived in the United States for less than three years. Moreover, we required that none of the multi-cultural project network participants have a shared native language with another member of their network. These experimental design considerations were critical in order for both cultural and linguistic diversity to be present in the multi-cultural networks. Table 1 provides the national origin of
each member of the ten multi-cultural project networks in the experiment. All multi-cultural networks had some level of understanding of English as they were currently living in the United States. Both mono-cultural and multi-cultural networks spoke English during the experiment.

### Table 1: Multi-cultural Network Experimental Design

<table>
<thead>
<tr>
<th>Multi-cultural Network</th>
<th>Nationality</th>
<th>Multi-cultural Network</th>
<th>Nationality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network 1</td>
<td>Turkish</td>
<td>Network 16</td>
<td>Indian</td>
</tr>
<tr>
<td></td>
<td>Chinese</td>
<td>Network 11</td>
<td>Indian</td>
</tr>
<tr>
<td></td>
<td>Indian</td>
<td>Network 12</td>
<td>Greek</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chinese</td>
</tr>
<tr>
<td>Network 12</td>
<td>Greek</td>
<td>Network 13</td>
<td>Chinese</td>
</tr>
<tr>
<td></td>
<td>Colombian</td>
<td></td>
<td>Turkish</td>
</tr>
<tr>
<td></td>
<td>Turkish</td>
<td>Network 14</td>
<td>Vietnamese</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chinese</td>
</tr>
<tr>
<td>Network 13</td>
<td>Chinese</td>
<td>Network 15</td>
<td>Vietnamese</td>
</tr>
<tr>
<td></td>
<td>Israeli</td>
<td>Network 17</td>
<td>Thai</td>
</tr>
<tr>
<td></td>
<td>Nigerian</td>
<td></td>
<td>South Korean</td>
</tr>
<tr>
<td>Network 14</td>
<td>Vietnamese</td>
<td>Network 18</td>
<td>Chinese</td>
</tr>
<tr>
<td></td>
<td>Chinese</td>
<td></td>
<td>Indian</td>
</tr>
<tr>
<td></td>
<td>Indian</td>
<td>Network 19</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cypriot</td>
</tr>
<tr>
<td>Network 15</td>
<td>Turkish</td>
<td>Network 20</td>
<td>Russian</td>
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<td></td>
<td>Chinese</td>
<td></td>
<td>Indian</td>
</tr>
<tr>
<td></td>
<td>Kazakh</td>
<td></td>
<td>Chinese</td>
</tr>
</tbody>
</table>

After completing the five projects or reaching the end of the 90 minute period of the experiment, each participant from the multi-cultural networks was asked to complete a cultural assessment test. This is the same survey instrument used to derive the country cultural indices...
(Hofstede and Hofstede 2005). The survey has been used in a number of other research investigations and is described as the Values Survey Module 1994 (Hofstede 1994). We used the cultural assessment test results to measure the cultural distance among project participants. As many other researchers have done in the past, we utilized the cultural distance index (CDI) formula as a measure of cultural distance (Kogut and Singh 1988). The function is based on the Hofstede (1980) cultural indices described earlier. The CDI function is calculated as follows:

\[
CDI_{ij} = \frac{1}{5} \sum_{k=1}^{5} \frac{(I_{ik} - I_{jk})^2}{V_k}
\]

Where;

\[
CDI_{ij} = \text{Cultural Distance Index between countries } i \text{ and } j
\]

\[
I_{ik} = \text{The index of country } i \text{ on the } k^{th} \text{ cultural dimension}
\]

\[
V_k = \text{The variance of the index of the } k^{th} \text{ dimension}
\]

Additionally, each participant in the multi-cultural project networks was required to submit their TOEFL scores (ETS 2009). Not all of the multi-cultural network participants took the IBT (Internet-based Test) version of the TOEFL exam. We collected scores from participants who had taken three different types of TOEFL exams; paper based, computer based and internet based. Among these three types of TOEFL tests, only IBT has the speaking component included, therefore the contexts of the different scores are not identical. To compare the scores accurately we used the TOEFL Internet-based Test Score Comparison Tables (ETS 2005) that considers the contextual difficulty difference between the tests. We used the average
TOEFL score for each multi-cultural project network as the value for the independent variable in our regression analyses.

Findings

The performances of both mono-cultural and multi-cultural networks are presented in Table 2. Not all of the networks succeeded in completing all five projects hence there were missing data points. In order to be able to compare the data, we projected those missing data points in Table 2 utilizing regressions techniques. We predicted the missing performance values by fitting a learning curve to the existing data for each network. The straight-line model of Wright (1936) in equation 1.1 below was used to determine the learning curves. This model assumes that the pattern of improvement follows a straight line in a logarithmic scale as in equation 1.2. The $R^2$ values in the second column of Table 3 are obtained by fitting a line to the data which is converted to logarithmic scale.

$$y_a = xa^n \text{ or } (1.1)$$

$$\log(y_a) = n\log(a) + \log(x) \text{ (1.2)}$$

Where;

$y_a$ = the duration of the $a^{th}$ project

$x$ = the duration of the first project

$n = \log_2 LR$

$LR = $ learning rate
<table>
<thead>
<tr>
<th>Network Type</th>
<th>Network in Sample</th>
<th>Project 1</th>
<th>Project 2</th>
<th>Project 3</th>
<th>Project 4</th>
<th>Project 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mono-Cultural</strong></td>
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<td></td>
<td></td>
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<td>543</td>
<td>456</td>
<td>487</td>
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<td>Network 2</td>
<td>1346</td>
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<td>391</td>
<td>324</td>
<td>380</td>
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<tr>
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<td>1665</td>
<td>929</td>
<td>593</td>
<td>375</td>
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<tr>
<td>Network 4</td>
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<td>1104</td>
<td>911</td>
<td>1144</td>
<td>925*</td>
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<tr>
<td>Network 5</td>
<td>1981</td>
<td>987</td>
<td>657</td>
<td>614</td>
<td>458*</td>
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<td>Network 8</td>
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<td>408</td>
<td>323</td>
<td>293*</td>
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<tr>
<td>Network 9</td>
<td>1933</td>
<td>1077</td>
<td>712</td>
<td>913</td>
<td>644*</td>
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<tr>
<td>Network 10</td>
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<td>502</td>
<td>349</td>
<td>310</td>
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<tr>
<td><strong>Average</strong></td>
<td><strong>1424.3</strong></td>
<td><strong>890.7</strong></td>
<td><strong>538.0</strong></td>
<td><strong>524.6</strong></td>
<td><strong>452.4</strong></td>
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<td>407</td>
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<td>880*</td>
<td>776*</td>
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<td>770*</td>
<td>662*</td>
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<td>545</td>
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<td>Network 18</td>
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<td>1155</td>
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<td>454*</td>
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<td>Network 19</td>
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<td>530</td>
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<td>230*</td>
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<tr>
<td>Network 20</td>
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<td>754</td>
<td>542</td>
<td>392</td>
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<tr>
<td><strong>Average</strong></td>
<td><strong>2218.5</strong></td>
<td><strong>977.0</strong></td>
<td><strong>684.3</strong></td>
<td><strong>517.5</strong></td>
<td><strong>401.3</strong></td>
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*Projected Results*
<table>
<thead>
<tr>
<th>Network Type</th>
<th>Network in Sample</th>
<th>Adaptation Performance</th>
<th>R^2</th>
<th>Average Adaptation Performance</th>
<th>Average R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mono-Cultural Project Networks</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Network 1</td>
<td>0.59</td>
<td>0.94</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Network 2</td>
<td>0.57</td>
<td>0.82</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Network 3</td>
<td>0.48</td>
<td>0.98</td>
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</tr>
<tr>
<td>Network 4</td>
<td>0.83</td>
<td>0.58</td>
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<td>Network 5</td>
<td>0.54</td>
<td>0.98</td>
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<td>Network 6</td>
<td>0.49</td>
<td>0.92</td>
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<td>Network 7</td>
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<td>Network 8</td>
<td>0.45</td>
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<tr>
<td>Network 9</td>
<td>0.64</td>
<td>0.81</td>
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<tr>
<td>Network 10</td>
<td>0.54</td>
<td>0.97</td>
<td></td>
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</tr>
</tbody>
</table>

| **Multi-cultural Project Networks** |                   |                        |     |                               |             |
| Network 11                    | 0.36              | 0.97                   |     |                               |             |
| Network 12                    | 0.49              | 0.96                   |     |                               |             |
| Network 13                    | 0.68              | 0.95                   |     |                               |             |
| Network 14                    | 0.38              | 1.00                   |     |                               |             |
| Network 15                    | 0.55              | 0.82                   |     |                               |             |
| Network 16                    | 0.63              | 0.96                   |     |                               |             |
| Network 17                    | 0.44              | 0.98                   |     |                               |             |
| Network 18                    | 0.47              | 0.99                   |     |                               |             |
| Network 19                    | 0.34              | 1.00                   |     |                               |             |
| Network 20                    | 0.48              | 0.98                   |     |                               |             |

The reliability of the performance prediction is determined by the R^2 value. The high R^2 values signify that the learning curve can be used to predict the data and future outcomes reliably.
using the existing data points. A graph of the average adaptation performances of both mono-cultural and multi-cultural networks including the projected values is included in Figure 2.

![Graph showing average performance of mono-cultural and multi-cultural networks](image)

**Figure 2: Average Initial and Adaptation Performance of Multi-cultural and Mono-cultural Project Networks**

We hypothesized that mono-cultural networks would perform better in completing the first project. To examine this hypothesis we first applied a statistical t-test to confirm that the initial performance values of the mono-cultural and multi-cultural project networks were independent. When we compared the first task durations, the p value was 7.07E-05 which is significantly smaller than the acceptable error level of 0.05. Since the initial performance of the
multi-cultural and mono-cultural project networks was independent, we were able to compare the average initial performance for each group and found mono-cultural networks to perform better. Therefore Hypothesis 1a is supported. Table 2 shows the average duration of the initial projects of the multi-cultural networks was considerably higher than the average duration of the mono-cultural networks’ projects. It took the multi-cultural networks on average over 50% longer to complete the first project.

Adaptation performance, calculated by fitting a learning curve to the data available, is a very practical measure of performance since it gives a single comparable index. The results in the Table 3 indicate the adaptation performances and their coefficient of determination for each mono-cultural and multi-cultural network. The adaptation performance is a measure of the rate of improvement across successive project iterations (in logarithmic scale) in terms of duration. We again conducted a t-test to ascertain the independence of the adaptation performance mono-cultural versus multi-cultural data samples. We found the p value to be 0.068 which is slightly greater than 0.05 but significantly lower than 0.1 which is also commonly used as an acceptable error level. We therefore concluded that the adaptation performance scores of the mono-cultural and multi-cultural project networks were independent. The average adaptation performance of multi-cultural networks was calculated to be 0.48 while the average adaptation performance of mono-cultural networks was calculated to be 25% worse with a value of 0.60. Therefore Hypothesis 1b is supported.

We also executed a multivariate regression analysis in order to examine whether the cultural assessment data acquired from the Values Survey Module 94 questionnaire (Hofstede 1994) and TOEFL scores can predict the multi-cultural networks’ initial performance and their
adaptation performance. The survey results and average TOEFL scores of each network are presented in Table 4.

<table>
<thead>
<tr>
<th>Network Type</th>
<th>Network in Sample</th>
<th>Cultural Distance Indices</th>
<th>Average TOEFL Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PDI</td>
<td>IDV</td>
</tr>
<tr>
<td>Multi-Cultural Project Networks</td>
<td>Network 11</td>
<td>40550</td>
<td>28800</td>
</tr>
<tr>
<td></td>
<td>Network 12</td>
<td>22850</td>
<td>1800</td>
</tr>
<tr>
<td></td>
<td>Network 13</td>
<td>10550</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>Network 14</td>
<td>14600</td>
<td>15350</td>
</tr>
<tr>
<td></td>
<td>Network 15</td>
<td>6450</td>
<td>34550</td>
</tr>
<tr>
<td></td>
<td>Network 16</td>
<td>3150</td>
<td>31850</td>
</tr>
<tr>
<td></td>
<td>Network 17</td>
<td>1050</td>
<td>74400</td>
</tr>
<tr>
<td></td>
<td>Network 18</td>
<td>2850</td>
<td>9650</td>
</tr>
<tr>
<td></td>
<td>Network 19</td>
<td>2850</td>
<td>1250</td>
</tr>
<tr>
<td></td>
<td>Network 20</td>
<td>3650</td>
<td>1550</td>
</tr>
</tbody>
</table>

Initially, we conducted linear regression analyses for each cultural dimension and TOEFL score in order to examine the correlation with the multi-cultural network initial performance and adaptation performance. However, a significant correlation was not observed. Subsequently, a multivariate regression analysis was conducted between the cultural distance indices and initial performance. Cultural distance indices were assigned as the independent variables and the initial performance was assigned as the dependent variable. Then another independent variable, the TOEFL score, was included for the initial performance prediction of the multi-cultural
networks. The multivariate regression model that does not include TOEFL as one of the independent variables is presented in Table 5 and the model including TOEFL score is presented in Table 6. When Table 5 and Table 6 are compared, the significant impact of TOEFL score on the initial performance can be recognized by the statistically significant $p$ value of 0.0279. The $p$ values of the cultural distance indices are not significant in either of the regression models. We conclude that Hypothesis 2a is rejected, but that Hypothesis 3a is supported.

**Table 5: Multivariate Regression Model of Multi-cultural Project Networks’ Initial Performance Scores (Note: TOEFL Scores are not included in the model)**

<table>
<thead>
<tr>
<th></th>
<th>Coefficients</th>
<th>Standard Error</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2181.1914</td>
<td>481.4874</td>
<td>0.0106</td>
</tr>
<tr>
<td>PDI</td>
<td>0.0127</td>
<td>0.0171</td>
<td>0.4974</td>
</tr>
<tr>
<td>IDV</td>
<td>-0.0072</td>
<td>0.0149</td>
<td>0.6567</td>
</tr>
<tr>
<td>MAS</td>
<td>-0.0011</td>
<td>0.0093</td>
<td>0.9094</td>
</tr>
<tr>
<td>UAI</td>
<td>0.0168</td>
<td>0.0133</td>
<td>0.2771</td>
</tr>
<tr>
<td>LTO</td>
<td>-0.0930</td>
<td>0.1690</td>
<td>0.6116</td>
</tr>
</tbody>
</table>

**Table 6: Multivariate Regression Model of Multi-cultural Project Networks’ Initial Performance Scores (Note: TOEFL scores are included in the model)**

<table>
<thead>
<tr>
<th></th>
<th>Coefficients</th>
<th>Standard Error</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>13790.9003</td>
<td>2907.7075</td>
<td>0.0178</td>
</tr>
<tr>
<td>PDI</td>
<td>0.0170</td>
<td>0.0079</td>
<td>0.1213</td>
</tr>
<tr>
<td>IDV</td>
<td>-0.0064</td>
<td>0.0068</td>
<td>0.4219</td>
</tr>
<tr>
<td>MAS</td>
<td>-0.0039</td>
<td>0.0043</td>
<td>0.4291</td>
</tr>
<tr>
<td>UAI</td>
<td>0.0170</td>
<td>0.0061</td>
<td>0.0690</td>
</tr>
<tr>
<td>LTO</td>
<td>-0.0956</td>
<td>0.0775</td>
<td>0.3049</td>
</tr>
<tr>
<td>TOEFL</td>
<td>-105.7532</td>
<td>26.4100</td>
<td>0.0279*</td>
</tr>
</tbody>
</table>

* $p<0.05 = $ Strong Evidence Against the Null Hypothesis
The same multivariate regression analysis was conducted between the cultural distance indices and adaptation performance scores of the multi-cultural networks. Table 7 shows the multivariate regression model results that do not include TOEFL scores as one of the independent variables. The model presented in Table 8 includes the TOEFL scores in the regression. In both cases, the $p$ values of both cultural distance indices and TOEFL scores were found to be much higher than the acceptable $p$ value of 0.05. Consequently both Hypothesis 2b and Hypothesis 3b are rejected.

### Table 7: Multivariate Regression Model of Multi-cultural Project Networks’ Adaptation Performance Scores (Note: TOEFL Scores are not included in the model)

<table>
<thead>
<tr>
<th></th>
<th>Coefficients</th>
<th>Standard Error</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.6107</td>
<td>0.0988</td>
<td>0.0035</td>
</tr>
<tr>
<td>PDI</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.2739</td>
</tr>
<tr>
<td>IDV</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.5150</td>
</tr>
<tr>
<td>MAS</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.6465</td>
</tr>
<tr>
<td>UAI</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.1999</td>
</tr>
<tr>
<td>LTO</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.9636</td>
</tr>
</tbody>
</table>

### Table 8: Multivariate Regression Model of Multi-cultural Project Networks’ Adaptation Performance Scores (Note: TOEFL scores are included in the model)

<table>
<thead>
<tr>
<th></th>
<th>Coefficients</th>
<th>Standard Error</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.1342</td>
<td>1.1119</td>
<td>0.3828</td>
</tr>
<tr>
<td>PDI</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.1918</td>
</tr>
<tr>
<td>IDV</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.4881</td>
</tr>
<tr>
<td>MAS</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.7729</td>
</tr>
<tr>
<td>UAI</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.1681</td>
</tr>
<tr>
<td>LTO</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.9683</td>
</tr>
<tr>
<td>TOEFL</td>
<td>0.0159</td>
<td>0.0101</td>
<td>0.2136</td>
</tr>
</tbody>
</table>
Discussion

In this paper, we empirically examined the impact of cultural and linguistic diversity on the initial performance and adaptation performance of simulated project networks. From the statistical analyses of both initial performance and adaptation performance of multi-cultural and mono-cultural networks, we concluded that multi-cultural project networks performed worse initially but learned faster throughout the experiment. Once members of the multi-cultural networks identified ways to overcome cultural and linguistic difficulties, they made productive use of the diversity. In other words, the multi-cultural networks needed to invest additional time to overcome the initial cultural and linguistic difficulties but they were able to introduce new approaches and tactics that eventually led them to perform better. Researchers have shown that multi-cultural networks are able to draw from a wider experience base to introduce new approaches and tactics (Matveev and Nelson 2004; Miller et al. 2000; Nemeth 1986). Figure 2 demonstrates that despite the significant initial performance difference, the multi-cultural networks end up attaining the performance level of the mono-cultural networks. Figure 2 also shows that multi-cultural networks were even able to outperform the mono-cultural networks. Between the third and fourth projects in our study the multi-cultural networks began to outperform the mono-cultural networks on average in absolute performance. Therefore, in general there were positive returns to the new approaches and knowledge contributed by members of the network as a result of their different cultural backgrounds.

We subsequently examined correlations between cultural distance indices and initial network performance. Based on the multivariate regression analyses, we concluded that cultural distance indices did not predict the initial performance of multi-cultural networks. In other words, the effect of cultural distance indices on culturally and linguistically diverse project
networks’ initial performance was not significant. Similarly we did not find a correlation between the cultural distance indices and adaptation performance of culturally and linguistically diverse project networks. We then conducted the same analyses adding TOEFL as an independent variable. Although the model including the TOEFL score did not correlate with adaptation performance, we did find a statistically significant correlation between the TOEFL score and initial performance of culturally and linguistically diverse networks. In retrospect, this finding is not surprising. According to our anecdotal observations during the experiment, the multi-cultural networks spent a considerable amount of time in the first project addressing linguistic differences and agreeing on a common lexicon for the subsequent projects. Hence, lower average TOEFL scores would make this task considerably more difficult and have a more measurable effect on performance in the first project.

In this study, the multi-cultural project networks were intentionally comprised of members from different countries none of whom were native English speakers. Multi-cultural project networks with native English speakers involved may be able to more efficiently address linguistic barriers by having a stronger understanding of the specifications. For future research, examining the impact of having a native English speaker in the multi-cultural networks may also provide relevant and perhaps surprising results. Other configurations of multi-cultural project networks worthy of examination may also include cultural boundary spanners that bridge two culturally distinct groups in a project network (Di Marco et al. 2010) or include ‘cosmopolitan’ workers that have experience working in several countries and who speak several languages (Haas 2006). Future research could also study the impact of native speakers having different dialects of English, such as American English, British English, Indian English, Singaporean
English, or Kenyan English, thus researchers may emphasize the impact of different cultures with a common language.

An important limitation of this research relates to the type of tasks used in the experiment. Exploration and exploitation is a tradeoff between investing of new knowledge and utilizing current knowledge. The essence of exploitation is the refinement and extension of existing competences, technologies, and paradigms while exploration is experimentation with new alternatives (March 1991). In the construction industry both forms of learning are needed yet the experiment focuses narrowly on exploitation learning. We tested the participants’ performance at doing a series of complex tasks but that did not differ significantly from one project to the next. The results may differ if the nature of the projects were to require more exploration by the project network participants. Another important limitation of this research is that in actual project networks, each individual participant and their relevant network organization is influenced by different types of culture such as organizational culture, project culture, and national culture. This experiment is limited in its focus on the role of national culture only.

Conclusions and Implications

The findings of the experiment demonstrate that in the initial stages of global project collaboration, performance can suffer significantly when compared to domestic collaborations. This is validated by the regrettable fact that as many as 40% of international joint venture projects perform poorly (Beamish and Delios 1997). Therefore although partnering with a local firm in an overseas project has advantages due to access to the local knowledge, firms should take into account the potential performance loss in the initial projects that can occur when
establishing a global collaboration. To mitigate the initial performance loss, firms may consider cross-cultural communication training. Nevertheless, the findings also exposed that after only a few projects, as multi-cultural project network members get accustomed to collaborating and develop strategies to overcome the cultural and linguistic barriers, the global project network starts to benefit from the diversity and outperform mono-cultural project networks. Thus, researchers that have found a significant and positive relationship between cultural distance and performance (Park and Ungson 1997) and others that have found a significant and negative relationship (Barkema et al. 1997) may both be correct. The dual impact of cultural and linguistic diversity means that studies of initial cross-cultural interactions are likely to find performance liabilities while studies of longer-term, sustained interactions are likely to find performance benefits associated with cultural and linguistic diversity. What matters is at what point in the multi-cultural project network collaboration the performance data is considered.

This research has important practical implications for design and construction firms. In the United States there is a strong sentiment toward developing strong collaborative relationships on projects using partnering techniques. And yet the industry is still relatively relationally unstable compared to other countries (Taylor and Levitt 2007). Projects are still largely temporary organizational networks where the firms participating on one project are unlikely to be working with the same set of firms on the next project. This experimental research suggests that adopting a partnering strategy, a common collaborative process in global construction projects, is critically important. If a firm works with a different foreign partner firm on each project, they will invest time and resources to address cultural and linguistic differences with each partner without benefitting from the significant performance gains which may be possible with sustained collaboration in a global project network.
CHAPTER 3: QUANTIFYING THE IMPACT OF FACILITATION ON TRANSACTIVE MEMORY SYSTEM FORMATION IN GLOBAL VIRTUAL PROJECT NETWORKS²

Abstract

Building strong ties between geographically dispersed project participants is crucial to project success. In global project networks, many firms have adopted virtual collaboration tools to address the challenges imposed by temporal and geographic distance. Some researchers have examined the role of facilitators and found that process facilitation can improve collaboration. Research has also shown that facilitators can be drawn into content interactions, which may negatively impact collaboration effectiveness in virtual workspaces. Yet, research to date has not quantified this negative impact. In our study, we investigated the formation and the maintenance of Transactive Memory Systems (TMSs) in two facilitated and two non-facilitated global virtual project networks each executing a two-month project. Using TMS formation and cohesive subgroup formation as a proxy for performance, we found quantitative evidence that demonstrates a negative impact on collaboration effectiveness when facilitators engage in content facilitation in virtual project networks. We show that this negative impact restricts the establishment of TMSs. Our findings have important implications for understanding and designing appropriate facilitator interactions in global virtual project networks.

Keywords: Global; Networks; Project Networks; Transactive Memory Systems; Virtual Teams

² This paper was co-authored by Josh Iorio, Professor John E. Taylor and Professor Carrie Sturts Dossick and was accepted for publication in the Journal of Construction Engineering and Management. Comu, S., Iorio, J., Taylor, J., and Dossick, C. (in press). Quantifying the Impact of Facilitation on Transactive Memory System Formation in Global Virtual Project Networks. J. Constr. Eng. Manage.
**Introduction**

Global demand for construction services, particularly in developing countries that lack the sufficient technology, resources or experience to carry out complex design and construction projects, is creating new business opportunities for many construction companies (Han and Diekmann 2001). As the architecture, engineering and construction (AEC) industry globalizes, new collaborative approaches, such as joint ventures (Berkema et al. 1997) and offshoring (Bryant 2006), have gained increased popularity as firms expand beyond domestic markets. In industrialized countries, the offshoring of architectural and engineering services has become a common practice (Messner et al. 2007), because high labor costs have forced companies in many industrialized countries to consider shifting services to countries with lower wages, such as India, China and countries in Eastern Europe (Lewin and Furlong 2005). These trends require collaboration to take place between more geographically distributed project participants.

To succeed in global collaborations, firms need to create new, geographically independent pathways across international borders and overcome the ambiguity associated with organizational restructuring on account of global cooperation (O’Hara Devereaux and Johansen 1994). These firms must utilize local knowledge to bridge knowledge gaps and reduce risks (Javernick-Will and Scott 2010). Technological advancements, such as the development of virtual workspaces, have made it easier to collaborate across geographical boundaries because they provide access to the qualified individuals for a specific job irrespective of their location. We refer to Global Project Networks that utilize virtual collaboration tools, such as email, teleconference, videoconference and virtual workspaces as Global Virtual Project Networks (GVPNs). GVPNs are able to respond faster to increased competition and can provide greater
flexibility to individuals working from multiple locations, as is the case with virtual teams (Bell and Kozlowski 2002).

The use of virtual platforms as a means to collaborate in a global economy benefits firms across the AEC industry because time zone differences and geographic distance limits opportunities to collaborate in face-to-face settings (Kayworth and Leidner 2000; Pauleen and Yoong 2001b). However, virtual work introduces new challenges that firms must overcome in order to establish a high level of network performance. Many of these challenges arise from difficulty in transferring social, emotional, and non-verbal information that is implicitly communicated in traditional face-to-face settings (Townsend et al. 1998). Moreover, establishing trust and managing cultural and linguistic differences between individuals as well as feelings of isolation (Cascio 2000) are typically more difficult in virtual settings. Because of these challenges, successful GVPNs need effective forms of support from both a technological and relational standpoint in order to achieve project success.

**Background**

**Facilitating Global Virtual Project Networks**

Some researchers have proposed the use of facilitators to overcome the challenges associated with virtual collaboration (Warkentin and Beranek 1999, Sarker et al. 2000, Pauleen and Young 2001b). Facilitators can help virtual teams to achieve an outcome more easily (Clawson et al. 1993) by helping to establish stronger interpersonal and relational ties between team members that are associated with effective communication (Warkentin and Beranek 1999; Sarker et al. 2000; Pauleen and Yoong 2001b) Since GVPNs develop across cultural, geographic and organizational boundaries, they are inherently more complex than traditional project networks. Paul and Seetharaman (2004) argue that facilitators can help to build cooperative relationships
between globally networked project participants, mediate conflicts within the network, encourage individuals to participate in work activities, and help participants overcome technological challenges by guiding the development of appropriate norms for technological use. Facilitators can play a variety of roles within a GVPN. For instance, Miranda and Bostrom (1999) describe two different types of facilitation—process and content—and evaluate the impact of each type on the meeting process, team satisfaction, and task quality in terms of decision-making processes. They define *process facilitation* as “the provision of procedural structure and general support to groups through the meeting process” (1999: 98). Griffith et al. (1998: 24) argue that “the main objective of process facilitators is to enhance the communication and interactions of group members in order to help the group achieve outcomes that make better use of the resources available within the group”. While process facilitation supports team processes, *content facilitation* supports interventions that are directly related to the task being performed. For example, a content facilitator might supply suggestions, insights, or interpretations of facts about the task (Weaver and Farrell 1997).

Process and content facilitation have different effects on the interactions of GVPNs. Interventions directed toward work processes contribute to productive meeting structures, while content interventions are more likely to limit participation in the decision-making process (Miranda and Bostrom 1999). As a result, researchers have proposed that the primary task of a facilitator should be process facilitation and that their involvement in content facilitation is detrimental to the meeting process and satisfaction (Miranda and Bostrom 1999). Miranda and Bostrom used five different variables to quantify the meeting process, including relationship development, issue-based conflict, interpersonal conflict, equality of participation and negative socioemotional participation. At the end of each meeting they assessed these variables by using
self-reported responses on a Likert scale. They found that content facilitation decreased satisfaction, but did not significantly impact product quality. Building on this work, Iorio et al. (2012) studied interactions in virtual workspaces and found that it is difficult for process facilitators to avoid content interventions because interactional norms develop over time that place process facilitators at the center of task-based network interactions. When facilitators are effective at creating process interventions for the network, the network often learns to depend on process facilitators for content interventions. In cases where process facilitators provide content interventions, there is a negative impact on performance which may negate the benefits of the process facilitation.

While facilitators support team interactions through process facilitation (Griffith et al. 1998), others, such as Miranda and Bostrom (1999) and Paul and Seetharaman (2004), have found that the facilitation of project content as opposed to the facilitation of project processes can have a detrimental impact on network performance, particularly in cases where process facilitators are involved in content decision-making. For example, Iorio et al. 2012 found that process facilitators who engage in content discussions can lengthen time spent in resolving task-related conflicts. While current research suggests that process facilitators may become key figures at overcoming the difficulties of working virtually if they can manage to isolate themselves in task interactions and avoid providing content-related insights and suggestions. However, research to date has not explicitly quantified this impact on collaboration effectiveness in global virtual project networks. In our study, we aim to fill this gap in the literature by quantifying how process facilitators who engage in content discussions impact the performance of global project networks collaborating in virtual workspaces.
Research Methodology

Measuring the Impact of Facilitation on Performance

To observe the impact of process facilitators on GVPN performance, we formed two types of networks—facilitated and non-facilitated—where only the facilitated networks had a designated facilitation team of two students solely dedicated to a facilitation role. In order to quantify the performance of each GVPN, we utilized the development of cohesive Transactive Memory Systems (TMSs) in each network as a proxy for collaboration effectiveness. TMSs are shared knowledge systems through which groups “collectively encode, store, and retrieve knowledge” (Wegner 1987:189). In a TMS, group members are able to identify knowledge domains within the group and direct their communications to the appropriate domain. Wegner (1995) describes the TMS as a three-stage process. The first stage is called directory updating, where network participants learn what fellow participants know. The second stage, information allocation, involves communication of new information to the participant whose expertise will facilitate its storage. The final stage, retrieval, involves the coordination of a plan for retrieving the information based on relative knowledge and expertise of the individuals in the network. Therefore, developing a TMS throughout the process of executing a project has benefits to both individuals and to the network itself.

The individuals within a network invest in a TMS to improve network performance (Moreland and Myaskovsky 2000) by developing an awareness of individual expertise (Borgatti and Cross 2003). In this sense, the most crucial aspect of a well-functioning TMS is whether individuals within the network are aware of the existence of expertise that they need to access and how fast they can access specific knowledge from the correct expert. In other words, the performance of a team can be improved through the development of a TMS by establishing an
awareness of “who knows what” and “who needs to know what” (Moreland and Myaskovsky 2000; Oshri et al. 2008). Given that TMSs have a positive impact on team performance, when the barriers to TMS development are removed, we expect to observe an increase in network performance. The implementation of a TMS may be even more critical in virtual settings, as knowledge domains must be clearly identified across geographically distributed teams and all network members must understand where they can get the specialized knowledge that they need in order to effectively collaborate.

Another aspect of effective GVPN collaboration is network cohesion, i.e. the “total field of forces causing members to remain in the group” (Festinger et al. 1950:164). In the group dynamics literature, the concept of group cohesion is widely studied (Festinger et al. 1950; Mullen and Copper 1994; Webber and Donohue 2001; Beal et al. 2003) because of the strong relationship between cohesion and group performance. Researchers generally agree that there is a positive relationship between group cohesion and performance (Mullen and Copper 1994; Beal et al. 2003). Wech and colleagues (1998) identified a significant positive correlation between cohesion and effective communication level. Evans and Dion (1991) support this claim and identify that the frequency and duration of interactions within cohesive group collaborations contribute to a higher level of performance. Moreover, Rempel and Fischer (1997) found a positive correlation in that cohesion leads to higher levels of problem solving. Given these associations between communication and group cohesion, we expect to find well-formed TMSs in cohesive GVPNs.

**Hypothesis Development**

We aim to examine differences in the creation and the maintenance of TMSs in facilitated and non-facilitated GVPNs. The facilitated GVPNs are networks with process facilitators who
become involved in content discussions. The non-facilitated GVPNs provide a control group of cases for comparison. A TMS is created within a network once all three of the stages (i.e. directory updating, information allocation and retrieval) are successfully established. After the creation of the TMS, the GVPN must continue to utilize each stage in order to maintain the TMS. Given the high level of task interdependency in construction projects, project developers must retrieve information from various knowledge domains and reuse internal knowledge (Demian and Fruchter 2006), which will ideally lead to highly cohesive interactions on task relations.

Facilitators seek to create cohesive networks with strong TMSs by directly influencing the process of collaboration, not affecting the content of decision making (Anson et al. 1995). Process facilitators have been found to occupy central positions in global project network task collaborations in a virtual workspace (Iorio et al. 2012), thereby biasing the decision process by unintentionally not reflecting all aspects of an issue and having a relatively powerful role (Griffith et al. 1998). In virtual work settings, it may be challenging for facilitators to isolate themselves in task interactions while being highly active in process discussions. Correspondingly, information seekers may direct their inquiries to the facilitators who established their centrality via technological expertise, instead of benefiting from cohesive and rich interactions with actual knowledge domains. Consequently, process facilitators may block robust knowledge transfer, which can result in the prevention of TMS formation and cohesive collaboration. Therefore, our first and second hypotheses are postulated accordingly;

*Hypothesis 1*: Process facilitators that engage in content facilitation do not support the creation and maintenance of a TMS in global project networks collaborating in virtual workspaces.
Hypothesis 2: Process facilitators that engage in content facilitation do not support cohesive collaboration on task interactions in global project networks collaborating in virtual workspaces.

The research reviewed thus far demonstrates that cohesive groups have higher levels of communication and problem solving skills that lead to better performance. Therefore, we also expect to observe a positive correlation between cohesion and the existence of a well-structured TMS within a GVPN as the networks progress through and maintain all three stages of TMS. If a group collaborates cohesively, we are likely to observe a well-functioning TMS, which implies better performance of the network when compared to groups with either partially or inconsistently functioning TMSs. Hence, our third hypothesis is postulated such that;

Hypothesis 3: A well-structured TMS in a global virtual project network is positively correlated with the cohesiveness.

Research Setting

In order to test these hypotheses, we observed, recorded, and analyzed task interactions among four global engineering project networks (two facilitated and two non-facilitated networks) collaborating in a virtual workspace over a two-month period to investigate whether there was a difference in the development of cohesive TMSs in facilitated versus non-facilitated networks. The GVPNs were comprised of teams of graduate students from Columbia University, the Helsinki University of Technology, the Indian Institute of Technology - Madras, the
University of Twente, and the University of Washington in Seattle. All the students, had related educational backgrounds in construction engineering, architecture or management and had varying levels of industry experience prior to starting graduate study. Graduate students participated in this study as a part of their course objectives and collaborated together on the hypothetical design of a real construction project. Students met in the virtual workspace once a week for two and a half hour periods from February through April 2010. The virtual workspace was called the CyberGRID (Cyber-enabled Global Research Infrastructure for Design) (Iorio et al. 2010), and was built with affordances designed specifically to support the work of geographically distributed engineers and architects. Each assembled project network was collectively responsible for developing and refining a construction project that encompassed two main components, i.e. BIM-based modeling and estimation. BIM-based modeling included 3D modeling, 4D modeling and organizational modeling while the estimation component considered cost analysis.

There were multiple knowledge domains in each GVPN, so each team required task information from more than one knowledge domain to successfully complete the project. In the non-facilitated networks, there were four main knowledge domains: 3D modeling, organizational modeling, 4D modeling and cost analysis. The facilitated networks consisted of the same knowledge domains but included facilitators, who were outside of these knowledge domains. Process facilitators lacked any training related to architecture, engineering and/or construction. They were graduate students in an engineering management program who received training in best-practices for facilitation as a component of their coursework. In short, based on our research design, non-facilitated networks were composed only of specialists in the AEC domain, while the facilitated networks contained both AEC specialists and facilitators.
Figure 3 presents a schematic representation of the resultant network structure for non-facilitated networks. N (Network) includes all the teams within the network. In non-facilitated networks, N and NT (Task Relation Network) are identical since they do not include facilitators. N_Ts (Task Relation Network Subgroup) encompasses only the subgroup comprised by BIM-based modeling teams (i.e. the 3D, 4D and organizational modeling teams) since we expect them to collaborate relatively more cohesively with respect to teams outside of the subgroup. In other words, if we observe cohesive subgroup formation, it indicates that the BIM-based modeling teams are primarily retrieving information from each other and not from the facilitation team.

In network analysis, there are two basic elements, links and nodes. Links are the ties between individual actors or groups and nodes are those individual actors or groups in the network. In Figure 3, ties represent the direction of the task relation and reflect who attempts to retrieve information from a given knowledge domain. For example, in Figure 3, the organizational modeling team needs to retrieve information from the 3D modeling team, so it is represented by a directed tie originating from the organizational modeling team toward the 3D modeling team. Similarly, both the 4D and cost analysis teams must retrieve information from the 3D and organizational modeling teams.
Figure 3: Expected Network Subgroup Configuration in Non-Facilitated Networks

In $N_T$, the ties among the three BIM-based knowledge domains are represented as solid lines because we expect to observe cohesive interactions within $N_T$. Effective project networks should progress in the following sequence to accomplish the tasks associated with the construction project. First, once the 3D modeling team finalizes the CAD model, they collaborate with the organizational modeling team to agree upon the activities that should be included in the construction schedule and an appropriate sequence for the activities. Second, the 4D modeling team receives both the 3D and organizational models and connects each activity in the construction schedule to the corresponding geometry in the 3D model. During the integration process, it is possible that a conflict will occur between the construction schedule and the 3D model geometry, so the 4D modeling team must collaborate with the teams developing the organizational schedule and 3D models to negotiate an intervention that resolves the mismatch between the organizational schedule and 3D model. These three teams work on the necessary adjustments in the 3D and organizational models as a BIM-based modeling subgroup. Until each of the teams involved in this subgroup are satisfied with the quality of the intervention result, the
cost analysis for the project cannot be started. Once the 3D, 4D and organizational models are completed and any conflicts addressed, the output is transferred to the cost analysis team.

Based on these workflow expectations, the cost analysis team was not included in the $N_T$ (Task Relation Network Subgroup) because there was no reciprocally interdependent interaction required between the estimators and the BIM-based modeling subgroup in the experiment. We simplified the experimental task, because given a limited time-frame; students could not complete their projects if they were also asked to optimize their project under a certain budget. Since there was not any budget limit, students were only responsible for estimating the entire project cost. Therefore, the cost analysis solely depended on the $completed$ 3D, 4D and organizational models and thus did not require additional interactions with BIM-based modeling teams. To reflect this relationship between the cost estimators and BIM-based modelers, the cost estimation team was not included in $N_T$, and the ties between the cost analysis team and 3D and organizational modeling teams are represented as dashed lines in Figure 3.

In the facilitated networks, since the facilitators did not have any AEC domain training, they should not be observed within $N_T$. However, given the findings of Iorio et al. (2012), the facilitators may be observed within $N_T$ because of their highly influential and central role (Griffith et al. 1998; Miranda and Bostrom 1999) in other aspects of the network interactions. If facilitators are observed in $N_T$, then information seekers are directing their inquiries to the facilitators instead of to the knowledge domain specialists as illustrated in Figure 4.
Since we utilized the development of TMS as a proxy for performance, we had to ensure that all four networks had the same opportunity for the development of a TMS within their GVPN. To sustain the directory updating stage of TMS formation, each participant’s membership in the knowledge domain specializations was made explicit to all members of the networks. Prior to the start of the experiments, all participants were told explicitly about the nature of the project including the sequence of work, with emphasis paid to the role of each team within the project network. In addition, each team within the project networks was trained on how to use a related software program to complete their contribution to the project. For example, the organizational modeling team learned SimVision, the 3D modeling team learned Revit and the 4D modeling team learned Navisworks as a core component of the courses in which they were enrolled at their respective universities. In this way, we ensured that there was little overlap in the knowledge domains represented by the networked teams. Therefore, the task-specific information required by one team was only accessible from one of the other teams and
was crucially not accessible from the facilitators. Thus, we ensured that both network types implemented and maintained the directory updating stage of TMS development. However, implementation of the last two stages—information allocation and retrieval—will depend on whether the networks form and maintain a TMS or not. Since all of the networks have established the first stage, our analysis moving forward focuses on the second and third stages.

**Data Collection and Preparation**

During the data collection period, each project network met in the CyberGRID and meetings were recorded. To quantify the recorded data, we used a multi-modal, open-source annotation software called ELAN. Utilizing ELAN enabled us to create, edit, visualize and search annotations that we mapped to the video and audio timelines for the recorded interactional data (Wittenburg et al., 2006). To guide our coding, we adopted a modified version of Anderson et al.’s (2007) typology of work interactions. Anderson and colleagues’ typology described the amount of interaction among team members, the content of the discussions, and the patterns of interaction. Their typology for work interactions included categories for attention to task, information transfer, social interaction, task-focused interactions, and talk about technology. We developed a six-category typology of discussion topics: interpersonal, facilitation, technology, clarification, process, task, and other. We coded the recorded interactions based on this typology to distinguish when network participants were engaged in discussion about different topic types, which allowed us to identify when knowledge domain specialists were interacting within their domain specialization and when they were engaged in interactions outside of their specialization. To ensure coding validity, two researchers individually coded the data based on this typology and a third researcher reconciled differences between the coding efforts of the individual
researchers. The consistency between the coders for all relations (i.e. interpersonal, facilitation, technology, clarification, task, and process) was initially 79.08%. Then a third coder analyzed each case of disagreement and resolved 98.97% of all coded interactions. Consequently, each video and associated coding was reviewed by three researchers working independently. Overall, we coded 417 interpersonal, 498 facilitation, 1,035 process, 562 technology, 306 clarification and 415 task interactions. For the purpose of this analysis, only those interactions coded as “task”, i.e. interactions that required specialized knowledge of AEC were considered in our analysis. Task interactions deal with the content of the work, while other interactions such as interpersonal, facilitation, clarification and process were not considered content work. When facilitators were involved in the task discussions, it would indicate that task related information is directed to them, which implies that they are acting as the content facilitators.

**Data Analysis**

Social network analysis (SNA) has been used in studies of relationship structure, social mobility, contact among members of deviant groups, corporate power, international trade exploitation, class structure, and many other areas (Scott 1988). SNA is also an accepted quantitative method in construction and engineering scholarship (Loosemore 1998; Pryke 2004; Chinowsky et al. 2008; Di Marco et al. 2010; Ramalingam and Mahalingam 2010), used to observe and describe patterns between the interactions of project network participants. SNA allows for the measurement of structures and systems which would be nearly impossible to describe without relational concepts. Moreover, SNA facilitates the testing of hypotheses about the networks’ structural properties.
SNA focuses on patterns of relationships between actors and examines the availability of resources and the exchange of resources between these actors (Wasserman and Faust 1997). In our case, the “resource” is the information essential to effectively execute the modeling design project. SNA consists of applying a set of relations (ties) to an identified set of actors (nodes). The collection of ties of a specific kind among members of a group is called a relation (Wasserman and Faust 1997). Relations may be between different sets of entities, which indicate the number of modes in a network. For example, in our study, non-facilitated networks are one-mode networks, i.e. the actors are all of the same type (modelers within the AEC domain). The facilitated networks are two-mode networks, i.e. the network participants are of conceptually different types—modelers and facilitators. In this sense, networks with process facilitators participate in two-mode networks because they have no domain expertise in construction engineering and management modeling. Therefore, we expected to observe the following task relation structures in one-mode versus two-mode networks:

<table>
<thead>
<tr>
<th>One-mode Network</th>
<th>Two-mode Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N = {g_1, g_2, g_3, g_4}$</td>
<td>$N = {g_1, g_2, g_3, g_4, g_5}$</td>
</tr>
<tr>
<td>$N_T = {g_1, g_2, g_3, g_4}$</td>
<td>$N_T = {g_1, g_2, g_3, g_4}$</td>
</tr>
<tr>
<td>$N_{Ts} = {g_1, g_2, g_3}$</td>
<td>$N_{Ts} = {g_1, g_2, g_3}$</td>
</tr>
</tbody>
</table>

Where:
- $g_1 = 3D$ Modeling Team
- $g_2 = Organizational$ Modeling Team
- $g_3 = 4D$ Modeling Team
- $g_4 = Cost$ Modeling Team
- $g_5 = Process$ Facilitation Team
Exponential Random Graph Model

Researchers have been utilizing new statistical approaches in the study of social networks in order to develop a better understanding of work relations by avoiding some of the limitations of deterministic methods. In recent years, the Exponential Random Graph Model (ERGM) has gained increasing popularity among many researchers since it uses stochastic approximation rather than deterministic methods, which ensures that whether network substructures are more commonly observed in the network than might be expected by chance (Wasserman and Pattison 1996; Robbins et al. 2007). In practice, an ERGM analysis appropriately estimates the degree to which the theoretically hypothesized substructures are likely to occur in the collected data set (Robbins et al. 2007). In this analysis, we use ERGM to determine whether the expected network structures are likely to be observed within the collected data set.

We utilized Statnet, which is a statistical network analysis package available in R (R Development Core Team 2007) that implements recent advances in the statistical modeling of random networks (Handcock et al. 2008) and the ERGM package that allows the user to fit exponential-family random graph models to network data sets (Goodreau et al. 2008). The Statnet suite of packages provides a comprehensive framework for ERGM-based network modeling including tools for model estimation, evaluation and simulation. This broad functionality is powered by a central Markov Chain Monte Carlo (MCMC) algorithm that can handle networks of several thousand nodes or more, though the size of the problem is dictated more by the number of edges (and edge attributes) than by the number of nodes (Handcock et al. 2008). In our model, we looked at two network statistics, i.e. dyadic task relation and subgroup formation. The dyadic relation is represented by edges among all network members and subgroup formation is measured by triangles among three BIM-based teams.
\[ \log P(Y = y) = \sigma L(y) + \tau T(y) \]

Where the networks statistics and model parameters are as follows;

\( Y = \) Random network

\( y = \) Given network

\( L(y) = \) Dyadic task relation

\( T(y) = \) Subgroup formation

\( \sigma = \) Model parameter of dyadic task relations

\( \tau = \) Model parameter of subgroup formation

**Cohesiveness of a Subgroup**

Cohesive subgroups are subsets of actors among whom there are relatively strong, direct and frequent ties (Wasserman and Faust 1997). In the social network analysis literature, many researchers have developed methods to analyze cohesive subgroups (Alba 1973; Seidman and Foster 1978; Freeman 1992). Alba (1973) introduced the cohesive subgroup ratio by comparing two aspects: the concentration of ties within the subgroup and a comparison of strength or frequency of ties within the subgroup to nodes outside the subgroup. Alba refers to this concept as the “Centripetal-Centrifugal” dimension of cohesive subgroup formation as represented in equation 1.

\[ CS = \frac{\text{Centripetal}}{\text{Centrifugal}} \quad (1) \]

The centripetal part of the equation is the measurement of cohesiveness of a subgroup, which is determined based on the average strength of ties within the subgroup, i.e. its density.
The centrifugal part of the equation is the measure of how sparse the ties to actors outside the group are. This indicates the average strength of ties that are from subgroup to nodes outside of the subgroup. The cohesive subgroup calculation for our study is expressed as follows:

\[
CS = \frac{\sum_{i \in N_{T_s}} \sum_{j \in N_{T_s}} \chi_{ij}}{g_{T_s}(g_{T_s} - 1)} \frac{\sum_{i \in N_{T_s}} \sum_{j \in N_{T_s}} \chi_{ij}}{g_{T_s}(g - g_{T_s})}
\]  

Where,

\[
\chi_{ij} = \text{the value of the tie from } n_i \text{ to } n_j \text{ on relation } R
\]

\[
g = \text{members in whole network} = \sum_{i=1}^{5} g_i
\]

\[
g_{T_s} = \text{members in subgroup } N_{T_s} = \sum_{i=1}^{3} g_i
\]

Given the fact that the numerator of the ratio represents the measurement of cohesiveness of a subgroup and the denominator is the measure of how sparse the ties are to actors outside the group, if the cohesive subgroup ratio is equal to 1 then the strength of ties within the subgroup does not differ from the strength of ties from the subgroup to nodes outside of the subgroup. However, if this ratio is greater than 1, then ties between nodes within the subgroup are stronger than ties from the subgroup to nodes outside of the subgroup, which implies that the subgroup is cohesive. If the ratio is less than 1, the subgroup is considered to not be cohesive.

**Findings**

The coefficients of network statistic (i.e. the subgroup coefficients) acquired from the ERGM analysis are presented in Table 9. Networks 1 and 2 are one-mode (non-facilitated) networks and Networks 3 and 4 are two-mode (facilitated) networks. In Table 9, values in parentheses
represent p-values for coefficients of the network statistic. According to the ERGM results, all networks have significant negative dyad relation coefficients as the p-values are substantially less than 0.05 in both one-mode and two-mode networks. Therefore, the probability of observing a one-mode or two-mode network in task relations with a higher value of the dyadic collaboration is lower than group collaboration (i.e. clique). Although the dyadic relationships are significant in all network types, the ERGM results indicate that, only one-mode networks have significantly positive subgroup formation coefficients, which implies that TMS formation occurred only in one-mode networks. Table 9 indicates that the subgroup coefficients have extremely high p-values in two-mode networks, i.e. 0.775 for Project Network 3 and 0.722 for Project Network 4. However, the subgroup formation coefficients are positive and have p-values that are significantly less than 0.05 in one-mode networks, which implies that subgroup formation occurs only in one-mode networks, not in two-mode networks. Positive coefficients indicate that a clique relation occurs more frequently among the BIM-based teams. Therefore, there is support to reject the null hypothesis for Hypothesis 1 because the expected network structures for task relations in both the one-mode and two networks are likely to be observed. Thus, the facilitators did not help to maintain transactive memory systems in the two-mode networks.
Table 9: The Coefficients of Network Statistic in One-mode and Two-mode Networks

<table>
<thead>
<tr>
<th>Project Network</th>
<th>(\sigma)</th>
<th>(\tau)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Network 1</td>
<td>-1.835</td>
<td>0.31463</td>
</tr>
<tr>
<td></td>
<td>(&lt;1e-04) **</td>
<td>(0.000128) **</td>
</tr>
<tr>
<td>Project Network 2</td>
<td>-3.944</td>
<td>5.526</td>
</tr>
<tr>
<td></td>
<td>(0.00129) *</td>
<td>(&lt;1e-04 )**</td>
</tr>
<tr>
<td>Project Network 3</td>
<td>-1.289</td>
<td>0.05074</td>
</tr>
<tr>
<td></td>
<td>(&lt;1e-04 )* *</td>
<td>(0.775)</td>
</tr>
<tr>
<td>Project Network 4</td>
<td>-1.067</td>
<td>0.05505</td>
</tr>
<tr>
<td></td>
<td>(&lt;1e-04) **</td>
<td>(0.722)</td>
</tr>
</tbody>
</table>

** ** p<0.001 = Very Strong Evidence against the Null Hypothesis
* p<0.01 = Strong Evidence against the Null Hypothesis

Table 10 shows the subgroup cohesiveness ratios in both the one-mode and two-mode networks. The results of this analysis are consistent with the ERGM output. While the subgroup cohesiveness ratio is above 1 in both one-mode networks, it is less than 1 in both two-mode networks, which means that we observe highly cohesive subgroups in the one-mode networks and that cohesive subgroup formation does not exist in two-mode networks. Therefore, there is evidence to reject the null hypothesis for Hypothesis 2. This means that the inclusion of process facilitators in the networks did not support cohesive collaboration on task interactions. We also analyzed the two-mode networks by excluding the facilitators’ interactions to determine whether or not cohesive subgroups could potentially form among the 3D, 4D and organizational modeling teams. In this context, the cohesiveness ratio increased from 0.39 to 1.33 in Network 3 and from 0.48 to 1.71 in Network 4 (as indicated in Table 10), which provides evidence that the formation of cohesive collaboration is possible in two-mode networks.
Table 10: The Cohesiveness Ratio in One-mode and Two-mode Networks

<table>
<thead>
<tr>
<th>One-Mode Network</th>
<th>Cohesiveness Ratio</th>
<th>Two-Mode Network</th>
<th>Cohesiveness Ratio with Facilitators</th>
<th>Cohesiveness Ratio without Facilitators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Network 1</td>
<td>2.81</td>
<td>Project Network 3</td>
<td>0.39</td>
<td>1.33</td>
</tr>
<tr>
<td>Project Network 2</td>
<td>10.0</td>
<td>Project Network 4</td>
<td>0.48</td>
<td>1.71</td>
</tr>
</tbody>
</table>

Since, there is a positive correlation between subgroup formation (i.e. TMS development) and cohesiveness; there is support to reject the null hypothesis for Hypothesis 3, which is compatible with the first two hypotheses. In two-mode networks, process facilitators who engage in content facilitation have been observed to produce a detrimental effect on both TMS development and cohesive subgroup formation, yet in one-mode networks, we observe well-functioning TMSs and a high level of cohesive subgroup formation. In sum, TMS development and cohesiveness are positively associated with non-facilitated networks but not with networks where facilitators are active during task interactions.

Discussion

In this study, we aimed to explore the impact of process facilitators on the performance of global virtual project networks engaged in task work. To this end, we designed an experiment to compare the performance of two different types of project networks, non-facilitated (one-mode) and facilitated (two-mode). Researchers have claimed that process facilitators that engage in content interactions can be detrimental to network performance (e.g. Miranda and Bostrom 1999;
Iorio et al. 2012). To quantify this phenomenon, we examined whether process facilitators who engage in content facilitation impact the creation and maintenance of TMSs and thus contribute to cohesive collaboration in task interactions. To analyze this we initially used UCINET to develop the sociograms. Our preliminary results indicated that, in non-facilitated networks, the BIM-based teams had dense interactions surrounding the task, while in the facilitated networks, we observed facilitators in the center of task interactions. However, our preliminary results are only descriptive, in that they do not indicate whether these observations are due to chance. Therefore, we utilized an ERGM to test the statistical likelihood for the hypothesized network structure to be observed in the experimental data (Su et al. 2010). These ERGM results are crucial because they are able to determine whether the expected network structures are likely to be observed within the collected data set.

Our research design also allowed us to test the probability of having solely dyadic task relations between project network participants. According to the ERGM results, dyadic task relations had a negative coefficient in all four networks, which indicates that dyadic relations occur infrequently. This result is congruent with the general facts associated with the task interdependency of construction projects. To be able to execute these types of projects, participants must retrieve information from different knowledge domains. These results confirm that, in the observed networks, there was a higher probability of observing cliques compared to dyads, which is consistent with the interdependency of the project knowledge domains.

For our analysis, we concentrated on subgroup formation only for task relations since these relations are associated with TMS formation. Moreover, we excluded other relations (i.e. interpersonal, facilitation, technology, clarification and process) because previous research agrees that facilitators are effective in supporting these types of relations. According to the
ERGM results, only non-facilitated networks have significantly positive subgroup coefficients, which indicate that non-facilitated networks are tightly clustered across the task network subgroup \(N_{Ts}\). On the other hand, the facilitated networks did not have significant coefficients, which means that observing the hypothesized network subgroup in task relations is not likely to occur in the experimental data. As we illustrated via the expected network structure in Figure 4, when process facilitators moved into \(N_T\) they became a central actor in task related discussions. This provides quantitative support for the findings of Iorio et al. (2012). The existence of facilitators in \(N_T\) impeded the formation of the TMS, which indicates that information seekers could not recognize that facilitators were not AEC knowledge domain experts. By becoming involved in task discussions, facilitators were treated as AEC specialists, even though their specialty was limited to process facilitation. When the facilitators became active participants in interactions within the AEC knowledge domain, they were treated as content facilitators by the teams. To be able address the directed inquiries within the AEC domain, facilitators had to retrieve information from the AEC specialists, which resulted in inefficient interactional pathways through the network. As Griffith and colleagues (1998) claimed, we observed that facilitators had more power compared to other network members, which suggests that their comments were more likely to be recalled and considered compared to AEC specialists in the network. Thus, our findings imply that TMS formation is not likely to occur in GVPNs when process facilitators are drawn into engaging in task interactions since their existence in \(N_T\) does not sustain collaboration effectiveness.

In addition to the ERGM analysis, we also calculated the subgroup cohesiveness ratio (Alba, 1973) for both network types. Based our findings, non-facilitated networks had a cohesive subgroup ratio greater than 1, while facilitated networks did not achieve this condition.
Thus, while highly cohesive hypothesized network subgroups formed in the non-facilitated networks, it was not the case that cohesive subgroups formed in the facilitated networks. Therefore, when process facilitators cross into knowledge domains where they have no specialization, they impede the formation of a cohesive subgroup among the 3D, 4D and organizational modeling teams. The test for subgroup cohesion can be also considered as a means to internally validate the findings produced through the ERGM analysis. Both analyses extend research done by Miranda and Bostrom (1999) and Griffith et al. (1998) by quantitatively demonstrating that process facilitators involved in task interactions are detrimental to GVPN performance.

We also calculated the subgroup cohesiveness ratio of the facilitated networks without including facilitators. While analyzing the network data, we hypothetically removed the facilitators from the network, with his way we transformed the original experimental data from facilitated to non-facilitated. The results show that if facilitators were not involved in $N_T$, then a cohesive subgroup focused on task interactions would most likely form. Actually, the recalculated subgroup cohesiveness ratios are very conservative since all ties to and from facilitators are also disregarded when we remove the facilitators. In this case, if facilitators were not engaged in $N_T$ interactions, information seekers would be more likely to direct their questions to the AEC domain specialists. This suggests that the subgroup cohesiveness ratio for the observed networks would be even higher. Again, this supplemental analysis indicates that when process facilitators acted as content facilitators, the development of a fully functioning TMS was impeded. Consequently, TMS development and cohesive subgroup formation were observed only in non-facilitated networks, not in facilitated networks with process facilitators.
that engaged in content discussion. Therefore, we found a positive correlation between well-functioning TMSs and cohesive subgroup formation in GVPNs.

According to Alavi and Tiwana (2002), boundaries between project participants such as geographic distance, communication through virtual channels, lack of collaborative work history and cultural diversity constrains the development of TMS. They argue that since participants in a network cannot easily integrate their specialized knowledge and bring it to bear on the project task, the quality and/or efficiency of knowledge integration suffers as individuals expend considerable resources on attempting to acquire or to locate and retrieve the needed complementary knowledge (Alavi and Tiwana 2002). Based on this argument, we propose that information seekers create more sources from which to retrieve information in order to overcome challenges to enacting complex design work in virtual settings. In our experimental setting, this approach might have been reasonable if process facilitators had specialized knowledge of the project tasks. Facilitators initially introduced themselves as process facilitators—explicitly indicating their lack of a background in and knowledge of construction processes and techniques—so indeed they were not eligible to perform the role of content facilitators. Their priority was to increase the productivity of the GVPN through process facilitation. However, throughout the course of the collaboration, the process facilitators adopted the role of content facilitators due to their highly influential positioning in the networks as they became central to task discussions. According to Weaver and Farrell (1997), it is critically important to use one primary role for a given work session since changing roles in a given situation can undermine trust within the group. The transformation of the facilitators’ roles might have caused confusion among their fellow network participants as their assigned roles did not match their adopted role.
While other teams within the network had well-defined and structured roles, the role of facilitators was made vague due to their high level of involvement in task-related discussions.

**Limitations and Future Research**

In our study, participants were graduate students and completed the design projects by collaborating with other university teams as a component of their coursework. The study was limited by examining the interactions of graduate students because each network collaborated on projects of differing scopes (e.g. one network designed an apartment complex while another network designed a renovation to an arena). Thus, directly comparing the quality of the final designs was not possible. We allowed the students to select their own projects, which provided more pedagogical value, but which also conflicted with our ability to directly compare the performance of the networks on the design task. The use of students instead of professionals in the experimental design may not accurately represent how a process facilitator would support the collaboration of a GVPN. According to Dobbins and his colleagues (1988), laboratory experimentation provides a method to rigorously test theoretical predictions and provides an insight of organizational practices. Moreover, most of the graduate students had either experience in the industry or they were concurrently holding a professional position while studying. In this sense, observing the student teams is a valid way to increase our understanding of organizational behavior; however, observing interactions of professionals on a real project in the CyberGRID and analyzing the TMS formation is an essential next step to generalizing our results. Our experimental design controlled for the implementation of the first stage of TMS development (directory updating). So we were able to assume that all network participants understood “who knew what”. However, we were unable to draw any conclusions related
discretely to the second (information allocation) and third (information retrieval) stage. Our approach allowed us to analyze interactions in such a way that the second and third stages were conflated. Future research can productively investigate the second and third state discretely, which would provide a more nuanced understanding of the role of facilitators in each stage of TMS formation, e.g. future research may find that facilitator involvement in one stage of TMS formation is more beneficial compared to another.

Another limitation due to our experimental design is that we could not address the impact of cultural and linguistic diversity on the performance of GVPNs. To be able to interpret such an impact, two different data sets are required; mono-cultural vs. multi-cultural. However, in our study, all four GVPNs were multi-cultural and therefore, because the groups were similar in this way, the impact of cultural diversity on the results were limited. However, cultural and linguistic diversity may lead to different interactional patterns between domestic and interactional collaborations, and may thus lead to differences in the performance of GVPNs collaborating in virtual settings. Therefore, future research should account for this diversity in their experimental designs.

In facilitated networks, we involved process facilitators that adopted an additional role, i.e. one of content facilitation. It may be difficult for process facilitators to remove themselves from task discussions after being active and central in the initial GVPN discussions. Therefore, examining the limitations of process facilitators in virtual workspaces and identifying new ways of training facilitators for the new challenges of working virtually may be a fruitful topic for future research.
Conclusions

Globalization of the architecture, engineering and construction industry requires alternative work platforms to overcome the disadvantages of working in globally dispersed project networks. In this sense, virtual workspaces have significant potential to mitigate the cost and increase the project network performance despite the challenges to working in these settings. In our study, we examined the impact of process facilitators who engage in content interactions on the performance of GVPNs. Project network organizations have the potential to encode, store and recall stored information relating to a task through a collective memory system described by researchers as a transactive memory systems. As project participants collaborate, they encode which team members have the needed expertise or access to required information. Research has shown that if a work group has a well-developed TMS, then workers can quickly and easily access what they need to know by recalling the knowledge of collaborators with specialized knowledge domains. Therefore, a well-developed TMS improves the performance level of the network. We found that the inclusion of process facilitators engaged in content interactions hindered the formation of a TMS. Moreover, we found subgroup cohesiveness was not present in the facilitated networks since process facilitators were central figures within the networks and their contributions became more influential compared to members of the task-specific knowledge domains. Future research is needed to explore ways to improve the impact of facilitators in GVPNs. This research is particularly crucial given the increasing use of virtual workspaces to support complex architecture, engineering and construction project work.
CHAPTER 4: COMPARISON OF GLOBAL VERSUS DOMESTIC PROJECT COLLABORATION IN VIRTUAL WORKSPACES

Abstract

Globalization of the engineering and construction industry brings business opportunities, yet it also creates distinctive challenges that firms must overcome in order to establish a higher level of performance. Overcoming diversity-based challenges in a virtual environment, which is a common collaboration platform for global project networks, requires research attention. Given that global virtual project networks (GVPNs) and domestic virtual project networks (DVPNs) have different dynamics due to the impact of cultural diversity, there might be variances in collaboration approaches relating to how they utilize technology facilitators and technological opportunities within the virtual workspace. In the paper, we aim to identify the collaboration techniques unique to GVPNs and develop a fundamental understanding to improve their performance level. We observed two domestic and two global networks working in a virtual space called the CyberGRID. We examined the interactions between network members and utilized statistical approaches in the study of social networks in order to examine whether significant differences in the collaboration approaches of DVPNs and GVPNs exist. Facilitators were utilized more frequently in GVPNs, particularly in the early stages of collaboration. Boundary spanning visualization technologies within the virtual workspace were also utilized more frequently by the GVPN members. We also identified a positive correlation between effective technology usage and cohesive collaboration among project participants.

Keywords: Culture; Facilitation; Global; Networks; Virtual Teams; Virtual Workspace.

3 This paper was co-authored by Professor John E. Taylor and Professor Carrie Sturts Dossick.
Introduction

The construction industry is undergoing a phenomenal transformation. Accenture’s construction industry report identifies seven trends transforming the construction marketplace (Colella 2012). The most important trend identified is accelerated globalization. High construction demand in emerging markets and changing customer demand directly impact the construction industry. In other words, the construction industry plays a vital role in transforming the aspirations and needs of people into reality by physically implementing various construction development projects (Ibrahim et al. 2010).

According to the “Global Construction 2020” report published by Global Construction Perspectives and Oxford Economics, construction in emerging markets is expected to double within a decade and will become a $6.7 trillion business by 2020 (Betts et al. 2011). Consequently, more contractors are looking to emerging markets for potential projects, especially given the increase in construction activities in developing countries (Wong et al. 2010). In this competitive environment, construction companies must respond quickly and effectively to changing customer demand. The expectations of the customers have also been reaching higher levels; they are looking for lower cost and higher quality services. In order to survive in this highly competitive environment, companies are sharing risk by collaborating with complementary partners through, e.g. forming joint ventures (Barkema et al. 1997) or outsourcing the services and design work to countries with lower wages such as India, China and countries in Eastern Europe (Lewin and Furlong 2005).

In this sense, organizations change their structure in order to meet the demands of the fast-paced, dynamic global economy (Limerick and Cunnington 1993). Many organizations are moving from a traditional to a collaborative and networked structure. The changing market
conditions are prompting the formation of Global Project Networks (GPNs). GPNs are comprised of highly dispersed project teams that collaborate over geographical, temporal and cultural boundaries. In addition to organizational transformations, there are also important changes and developments in technology that impact how GPNs collaborate. One of the drivers for the change from a traditional to a networked structure is the introduction of information and communication technologies that have made it easier to collaborate across boundaries (Maznevski and Chudoba 2000). Increasingly, GPNs work remotely by utilizing advanced technology, which leads to the formation of Global Virtual Project Networks (GVPNs). Researchers have developed an extensive understanding of the way GPNs collaborate and the support they need in order to sustain effective collaboration across boundaries (Di Marco et al 2011, Keung and Shen 2012). However, we lack a similarly nuanced understanding of GVPNs that utilize virtual collaboration environments and new information technologies. In this paper, we examine different collaboration approaches developed in GVPNs throughout the organizational and 4D modeling of a construction project and compare them with Domestic Virtual Project Networks (DVPNs). We aim to develop a more robust understanding of the GVPNs that carry out global construction projects.

**Background**

**Features of Global Virtual Project Networks**

As collaborative tools evolve and knowledge transfer becomes easier, virtual collaboration, which enables geographically dispersed members to work together in situ, is increasingly being utilized in the construction industry. Therefore, virtual teams are playing an increasingly important role in project work and offer organizations the flexibility to remain competitive in changing global markets (Mowshowitz 1997). By utilizing virtual environments, organizations
are able to respond faster to increased competition, and provide greater flexibility to individuals working from various locations (Bell and Kozlowski 2002).

While virtual teams provide a great deal of flexibility, the cultural and linguistic diversity among team members can have both advantages and disadvantages (Distefano and Maznevski 2000, Adler and Gundersen 2008). According to Distefano and Maznevski, there are three different types of global teams; the destroyers, the equalizers and the creators (2000). Among them, only the creators value the diversity and perform at high levels since the differences among team members are explicitly recognized and accepted, even nurtured, and their implications are incorporated into every facet of the process which is also known as the Mapping, Bridging and Integrating (MBI) model (Distefano and Maznevski 2000). In the mapping stage, team members learn to understand their differences. In the next stage, they bridge communication and take their differences into account. In the final stage, they integrate ideas by monitoring participants, solving disagreements and creating new perspectives (Distefano and Maznevski 2000). In short, cultural diversity in global business has the potential to promote creativity and the capability for problem solving (Latimer 1998). Latimer suggests that increased diversity among members leads to: 1) lower levels of risk aversion, 2) better decision-making and problem-solving capability since different perspectives brought to bear on any problem lead to the generation of alternatives, and 3) higher levels of critical analysis of those alternatives and all these factors result in higher-quality decisions (Latimer 1998).

However, not all multicultural groups belong to the “creators” class of global teams. There are also other types of global teams that do not value diversity; “destroyers” consider differences as a handicap and “equalizers” suppress differences in ideas and perspectives (Distefano and Maznevski 2000). In unsuccessful multicultural groups, miscommunication, lack
of trust, and within-culture conversations (Adler and Gundersen 2008) may create challenges that can be barriers to establishing a high level of network performance. On the other hand, it has been found that after only a few collaborative projects, as multicultural project network members become accustomed to collaborating and develop strategies to overcome the cultural and linguistic barriers, global project networks start to benefit from the diversity and can even perform better than domestic project networks (Comu et al 2011). GVPNs may require additional support to overcome initial difficulties and to thus fully benefit from the diversity.

However, diversity has also potential negative aspects which can be reduced by using appropriate communication media (Staples and Zhao 2006). Staples and Zhao tested the effects of cultural diversity in virtual teams versus face-to-face teams by analyzing 380 students forming 79 teams that were collaborating in either in virtual teams or in face-to-face setting. Based upon the theory proposed by Carte and Chidambaram in 2004, Staples and Zhao empirically supported that the reductive capabilities of collaborative technologies (e.g., electronic tools such as email, group support systems, computer conferencing) can reduce the negative effects of diversity early in the life of a diverse team. Furthermore, while the reductive capabilities dampen the negative consequences of diversity early on, the additive capabilities that enhance normal communication exchanges can help leverage the informational diversity inherent in such groups later (Carte and Chidambaram 2004). Staples and Zhao also showed that while the performance was higher in the virtual culturally diverse teams compared to the face-to-face culturally diverse teams, there were no statistically significant differences in the performance of the face-to-face and the virtual homogeneous teams which suggests an important role for technology in culturally diverse teams.
The Role of Technology in Global Virtual Project Networks

The physical dispersion among groups of teams that are organized into a GPN makes it extremely challenging to simultaneously execute complementary and interdependent tasks. Considering the enormous amount of information generated and exchanged during the lifecycle of a construction project, sustaining accurate and instantaneous information transfer between teams is challenging. However, these challenges are being addressed by the rapidly developing communication systems that are used to facilitate information transfer in global projects (Tam, 1999). In addition to the development of communication systems in virtual environments, evolving project information formats such as virtual design practice also make it easier to transfer explicit knowledge (Dossick and Neff, 2011). For example, a high quality 3D model of a building can be simultaneously used by project participants in order to communicate the design. Moreover, Koutsabasis and colleagues showed that design activities can be effectively supported in virtual workspaces by instantly manipulating and arranging 3D models and making changes (2012). They also emphasize that embedded complementary sketches, drawings or images in the environment assist during their design process. Koutsabasis et al. (2012) concluded that virtual worlds are a satisfactory collaboration environment for designers because they provide increased communication and awareness. In other words, project visualization in a virtual workspace can be utilized as a platform to exchange and communicate information effectively. Wech and colleagues (1998) identified a significant positive correlation between cohesion and effective communication level; Evans and Dion (1991) also support this claim and identify that the frequency and the duration of interactions within cohesive group collaborations contribute to a higher level of performance. Therefore, in order to achieve higher levels of
performance in a virtual setting, it is crucial that tools be able to facilitate instantaneous and accurate information transfer.

Research examining the impact of adapting new technologies for team collaboration has emphasized the benefits. For example, El-Mashaleh and colleagues (2006) note the importance of using information technology on project performance in terms of cost and schedule. Based on data collected from 74 construction firms, El-Mashaleh et al. (2006) found evidence that information technology has a positive impact on firm performance. Accordingly, for every increase in the use of information technology, there is a positive increase of about 2.5% and 3% in schedule and cost performance, respectively. Similarly, Golparvar-Fard and colleagues (2006) focused on utilizing 3D design tools in the building design process. They demonstrated that by using 3D design technology, it can be easier to identify and visualize potential design problems, support brainstorming activities to investigate different design alternatives and support documentation of the meeting process. Another important aspect of visual modeling is the accommodation of easy data transfer among project participants, which facilitates effective collaboration in virtual environments. Through evolving communication modes, novel project information formats are more practical to transfer.

In summary, the development of information technologies in the construction industry has enabled GVPNs to effectively store, display and exchange project data efficiently. GVPNs display and transfer project information through boundary spanning visualization technologies in virtual workspaces. Consequently, boundary spanning visualization technologies are key elements that facilitate collaboration.
Facilitating Global Virtual Project Networks

Since GVPNs have become increasingly popular in the construction industry, strategies for managing virtual collaboration have attracted the attention of researchers. Researchers have investigated ways to develop more effective virtual practices (Hertel et al. 2005, Chinowsky and Rojas, 2003). Pena-Mora and colleagues (2009) identified several factors that globally dispersed teams need to consider when introducing new communication technologies and they emphasize a support should be provided to use the new technology (Pena-Mora et al 2009). Furthermore, they also found a significant correlation between the support provided to use technologies and the effectiveness of team interaction.

Facilitation is one way of supporting GVPNs that has been shown to enable more efficient collaboration. According to Bostrom and colleagues (1993, pg:147), facilitation is a set of functions or activities carried out before, during, and after a meeting to help the group achieve its outcomes easily and efficiently. In a virtual setting, one of the most crucial objectives of facilitation is at the intersection between team process facilitation and facilitation by the technological affordances available in the virtual setting. Facilitation can help GVPNs to overcome technological problems and develop appropriate norms of technology use. According to Thomas and Bostrom (2005), a technology facilitator’s role can be critically important to virtual team success. Because of their technological expertise, facilitators may occupy a very central position (Iorio et al. 2012) in the network, which demonstrates that they are centrally positioned within the network to provide support on the appropriate use of the information technologies that are the basis of information transfer throughout the project network. Therefore, it may be challenging for facilitators to isolate themselves in task related interactions in virtual work settings (Comu et al 2012).
In addition to their role in supporting the effective use of technology in GVPNs, facilitators also have a role in helping networks to leverage the benefits of cultural diversity in their project outcomes by managing human and social processes across cultures (Pauleen and Yoong, 2001). GVPNs are more complex than traditional face-to-face networks since collaboration is enabled through advanced communication technologies across many boundaries. Returning to Distefano and Maznevski’s (2000) MBI model, in this complex virtual collaboration context, facilitators can help network members become “creators”. In other words, facilitators can assist the GVPN members to go through each stage of the model. Given that the main role of facilitators is to support work processes in the virtual environment, they are well-positioned to help the network members create common ground for communication, encourage and manage participation and use of the tools that support collaboration, and help to resolve disagreements, each of which can help to develop a network of “creators”.

Thus, by including facilitators in GVPNs, the networks are provided with personnel who specialize in supporting two core aspects that distinguish global project networks from domestic project networks and virtual project networks from face-to-face project networks. Given the fact that GVPNs and DVPNs have different dynamics due to the impact of cultural and linguistic diversity, we expect there to be differences in their collaboration approaches, particularly in how they interact with a facilitator and in how they use boundary spanning visualization technologies. In this paper, we aim to identify whether such a difference in approaches exists in order to improve our understanding of the way global project networks collaborate in a virtual workspace.
Research Methodology

Hypothesis Development

The collaborative efforts of team members in GVPNs are likely to result in enhanced creativity, an increased number of innovative ideas, and culturally representative solutions (Zakaria et al. 2004), which make them distinctive from DVPNs. However, restricted communication opportunities in virtual settings might prevent the benefits of diversity from being fully realized but instead increase misunderstandings and conflicts (Hertel et al. 2005). In order to overcome these drawbacks and leverage the advantages of diversity, GVPN members are likely to need more assistance compared to DVPNs. Therefore, in addition to helping DVPNs and GVPNs use new technologies, in GVPNs, facilitators have an additional role of supporting diversity, which we expect to observe as more frequent interactions between GVPNs and facilitators compared to DVPNs. Therefore;

Hypothesis 1: More frequent interactions with facilitators occur in global virtual project networks compared to domestic virtual project networks when executing task interdependent project work.

While developing effective communication norms is an issue for non-virtual teams, the issue is magnified by distance, cultural diversity and linguistic difficulties (Lee-Kelley and Sankey, 2008). According to Henderson (2005), the potential negative consequences of linguistic diversity fall into two categories: the visible consequences of difficulties, directly related to a lack of linguistic competence, and the invisible consequences linked to a lack of communicative competence. The first category consists of well-known factors and includes cases
where people’s inability to fully understand each other due is to using unfamiliar vocabulary, speech rate, strong accents or grammatical errors (Henderson 2005). For the second category, the difficulties are more subtle in that misunderstanding is due to misaligned expectations between the speaker and listener, which may lead to ambiguity (Henderson 2005).

Because boundary spanning visualization technologies allow for the creation of a shared reference and effective communication (Koutsabasis et al. 2012), we expect that they may play an important role in allowing GVPNs to leverage the benefits of their diversity and overcome the aforementioned communication difficulties. Particularly the collaborative technologies are a way through which to improve diverse teams’ development processes and performance (Carte and Chidambaram 2004), as the negative aspects of diversity can be reduced by using communication media appropriately (Staples and Zhao, 2006). Therefore we pose the following hypothesis;

*Hypothesis 2: Global virtual project networks utilize boundary spanning visualization technologies more frequently than domestic virtual project networks when executing task interdependent project work.*

Using boundary spanning visualization technologies within a virtual environment enables better communication since individuals can refer to visualizations instead of or in addition to expressing ideas verbally. Thus, visualization may mitigate the risk of miscommunication by promoting effective communication. Since higher communication levels are positively correlated with cohesive collaboration (Wech et al. 1998), we pose the following hypothesis;
Hypothesis 3: Effective boundary spanning visualization technology usage is positively correlated with cohesive collaboration.

Research Setting

By testing the three posed hypotheses, we aim to develop an understanding of the way GVPNs collaborate differently than DVPNs in terms of utilizing facilitators and the boundary spanning visualization technologies provided in the virtual setting. In order to test these hypotheses, we observed and recorded interactions among two global and two domestic engineering project networks collaborating in a virtual workspace over a two-month period. We focused our investigation on differences in the collaboration approaches by examining interactions that included facilitators and/or with boundary spanning visualization technologies. Both the GVPNs and DVPNs were comprised of teams of graduate students from Columbia University and the University of Washington in Seattle who were studying civil engineering, construction management or architecture. In the GVPNs, all students were from different countries and did not share the same native language, which ensured and controlled for cultural and linguistic diversity in the global network. The DVPNs were comprised of only students from the U.S. and all were native English speakers. Students participated in this study as a part of their academic coursework, i.e. working together on the assigned project was their semester assignment. Columbia University students were asked to develop an organizational model utilizing Simvision and students from the University of Washington were asked to develop 4D models using Navisworks. The 4D modeling process required that they merge a 3D model provided with the organizational model developed by the Columbia University students. Because the Columbia University and the University of Washington teams were each responsible for one component of
an interdependent task, we consider our research setting to simulate an inter-organizational project network. Each networked university team contained two students and each network was comprised of two teams (one from each university). Each network was facilitated by a research assistant who was trained to provide technological support for the students.

**Data Collection and Preparation**

Data collection started in February 2011 and ended in April 2011; during that period students met in a virtual workspace called the CyberGRID (Cyber-enabled Global Research Infrastructure for Design), once a week for a two and one-half hour period. All meetings were recorded by an automated system. The CyberGRID was built with affordances designed specifically to support the work of geographically distributed engineers and architects. The CyberGRID was developed as a virtual suite of collaboration and research tools based in Unity.

The CyberGRID contains a number of collaborative features such as voice and text chat that provide synchronous communication for the virtual project networks. Additionally, document sharing and message board functionalities were integrated to facilitate collaboration on the complex project models. More importantly, the CyberGRID provides boundary spanning technologies including spatial visualization to achieve higher communication levels. These spatial visualization technologies include: 1) an integrated 3D model that students can walk through with their avatar, and 2) a shared visualization space called the Team Wall on which they can project the models they are designing. The CyberGRID provides a rich communication environment through multiple channels that enable participants to speak, share information, and gesture in the virtual work space.

In order to quantify the recorded data, we used a multi-modal open-source annotation software called ELAN to create, edit, visualize and search annotations that are mapped to the
video and audio timelines for the recorded interactional data (Wittenburg et al. 2006). For each meeting, we coded the speaker, addressee and the use of boundary spanning visualization technology. While coding the students’ interactions, we used bidirectional interactions both for the members and the boundary spanning visualization technologies of the network. We considered boundary spanning visualization technologies as an integral member of the networks. For example, if Participant A is referring to a visualization tool while communicating to Participant B, then we coded an information transfer from Participant A to the visualization tool and then from the visualization tool to Participant B.

During the first meeting, students were given the opportunity to get to know each other through icebreaking activities and received training in the use of the CyberGRID’s virtual interactional affordances, including the Team Wall. They also went over the objectives of each team and the overall project assignment’s work flow. The following week, they were provided elaborate information from their instructors about their projects in a simulated client meeting that took place in the CyberGRID. This meeting including conveying the detailed information the students would need to construct the organizational and the 4D models. During the following four weeks, the participants were expected to complete both the organizational and 4D models and perform interventions to improve the models. After finalizing the organizational and 4D models, both types of networks were expected to complete a written report and prepare an oral presentation of their project results. We focused our analysis on data from the organizational modeling, 4D modeling, and the two interventions which each involved a combination of organizational and 4D modeling. These tasks took four weeks to complete and in each period both the GVPNs and DVPNs were expected to refer intensively to the facilitators for technological support. During the final two weeks of the project, students assembled their
written report and oral presentations. In total we coded 18,680 interactions across the two GVPNs and two DVPNs; a total of 10,526 interactions in the GVPNs and 8,154 interactions in the DVPNs across the 4 weeks of project meetings examined.

**Data Analysis**

For the preliminary analysis, we used social network analysis (SNA), which is used to study social relations among a set of actors. SNA focuses on patterns of relationships between actors and examines the availability of resources and the exchange of resources between these actors (Wasserman and Faust 1997). In our case, the “resource” is the information essential to effectively execute the modeling design project. SNA consists of applying a set of relations (ties) to an identified set of actors (nodes). The collection of ties of a specific kind among members of a group is called a relation (Wasserman and Faust 1997). SNA has been used in studies of relationship structure, social mobility, contacts among members of deviant groups, corporate power, international trade exploitation, class structure, and many other areas (Scott 1988). SNA is also an accepted quantitative method in the construction and engineering scholarship (Chinowsky et al. 2008, Di Marco et al. 2010, Ramalingam and Mahalingam 2010), used to observe and describe patterns between the interactions of project network participants. SNA allows for the measurement of structures and systems that would be nearly impossible to describe without relational concepts.

Taking into account that facilitators occupying a highly central role is detrimental to efficient knowledge transfer between information seekers and actual knowledge domains (Comu et al. 2012); we started our analyses by examining centrality measures. Network centrality is important because it identifies who occupies critical positions in the network. Utilizing degree centrality, the number of links incident upon a node can be identified. So, if an actor is central
and dominant, a higher degree centrality value is expected. Similarly, eigenvector centrality is a measure of the influence of an actor in a network. Again if an actor is highly influential, a higher value of eigenvector centrality is exhibited. This initial step in our analysis is to confirm that facilitators did not adopt a central and dominant role. Once we are able to confirm this to ensure facilitators were not drawn into the central actor role as has been identified in previous research (Miranda and Bostrom 1999, Iori et al. 2012), we will apply statistical tests to test the posed hypotheses.

**Findings**

The preliminary findings were achieved by using UCINET to calculate the centrality measures and sociograms. The centrality measures including the normalized in-degree, out-degree and eigenvector values are represented in Table 11. In our case, to be in a central role within a network, actors should be involved in more interactions, meaning that their in-degree and out-degree scores should have been relatively higher comparing the rest of the network. Thereby, a central actor’s eigenvector score would be higher. Yet, by looking at the scores presented in Table 11, none of the facilitators has a higher centrality measure within their network. Therefore, normalized scores indicate that facilitators did not occupy a central position within any of the four networks studied. Therefore, the issue of facilitators becoming overly involved in task execution identified in earlier research (Iorio et al. 2012) was not present in our experiment.
Table 11: The Centrality Measures of Each Network

<table>
<thead>
<tr>
<th></th>
<th>Normalized</th>
<th>Normalized</th>
<th>Normalized</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In-degree</td>
<td>Out-degree</td>
<td>Eigenvector</td>
</tr>
<tr>
<td>GVPN-1 Organizational Modeling Team</td>
<td>18.99</td>
<td>18.49</td>
<td>40.35</td>
</tr>
<tr>
<td></td>
<td>15.38</td>
<td>12.84</td>
<td>33.71</td>
</tr>
<tr>
<td>4D Modeling Team</td>
<td>31.14</td>
<td>31.64</td>
<td>66.95</td>
</tr>
<tr>
<td></td>
<td>26.71</td>
<td>28.70</td>
<td>63.00</td>
</tr>
<tr>
<td>Facilitator</td>
<td>6.18</td>
<td>6.73</td>
<td>13.87</td>
</tr>
<tr>
<td>Boundary Spanning Visualization Technologies</td>
<td>60.68</td>
<td>60.86</td>
<td>92.70</td>
</tr>
<tr>
<td>GVPN-2 Organizational Modeling Team</td>
<td>18.92</td>
<td>14.54</td>
<td>40.75</td>
</tr>
<tr>
<td></td>
<td>23.93</td>
<td>20.67</td>
<td>52.03</td>
</tr>
<tr>
<td>4D Modeling Team</td>
<td>24.08</td>
<td>25.61</td>
<td>53.40</td>
</tr>
<tr>
<td></td>
<td>20.86</td>
<td>28.52</td>
<td>65.00</td>
</tr>
<tr>
<td>Facilitator</td>
<td>5.87</td>
<td>4.30</td>
<td>11.01</td>
</tr>
<tr>
<td>Boundary Spanning Visualization Technologies</td>
<td>51.29</td>
<td>51.29</td>
<td>91.85</td>
</tr>
<tr>
<td>DVPN-1 Organizational Modeling Team</td>
<td>36.94</td>
<td>33.92</td>
<td>65.21</td>
</tr>
<tr>
<td></td>
<td>22.13</td>
<td>25.33</td>
<td>45.31</td>
</tr>
<tr>
<td>4D Modeling Team</td>
<td>34.31</td>
<td>39.25</td>
<td>66.47</td>
</tr>
<tr>
<td></td>
<td>21.74</td>
<td>16.73</td>
<td>38.90</td>
</tr>
<tr>
<td>Facilitator</td>
<td>0.83</td>
<td>0.73</td>
<td>1.19</td>
</tr>
<tr>
<td>Boundary Spanning Visualization Technologies</td>
<td>60.91</td>
<td>60.91</td>
<td>88.10</td>
</tr>
<tr>
<td>DVPN-2 Organizational Modeling Team</td>
<td>28.55</td>
<td>28.70</td>
<td>40.78</td>
</tr>
<tr>
<td></td>
<td>28.84</td>
<td>31.01</td>
<td>43.69</td>
</tr>
<tr>
<td>4D Modeling Team</td>
<td>51.30</td>
<td>52.61</td>
<td>79.69</td>
</tr>
<tr>
<td></td>
<td>44.78</td>
<td>40.29</td>
<td>71.77</td>
</tr>
<tr>
<td>Facilitator</td>
<td>2.17</td>
<td>3.04</td>
<td>3.90</td>
</tr>
<tr>
<td>Boundary Spanning Visualization Technologies</td>
<td>39.28</td>
<td>39.28</td>
<td>70.09</td>
</tr>
</tbody>
</table>

Having confirmed that the networks in our data do not exhibit pathologies relating to facilitators identified in previous research, we moved on to test our posed hypotheses. To test the first hypothesis, we calculated the percentage of interactions that involved facilitators. These percentages are presented in Table 12. We also calculated the average percentages of facilitation...
usage and statistically examined the difference between the two study groups; GVPNs and DVPNs. In the collected data set, we found that the mean percentage of interactions involving facilitators in GVPNs is greater than that in DVPNs. This can be related to previous research (Weaver and Farrell 1997) that presents the additional role of facilitators have in multicultural teams; helping to benefit from diversity. A two-tailed t-test examines two alternatives and since we have only a single alternative, \( \mu_{GVPN} > \mu_{DVPN} \), we completed a one-tailed t-test. We found the difference in the frequency of facilitation involvement to be significant with a one-tailed p value of 0.019. Therefore, we reject the null hypothesis and conclude that GVPNs refer to technology facilitators more frequently compared to DVPNs. Thus, our first hypothesis is supported.

<table>
<thead>
<tr>
<th>Table 12: The Percentage of Interactions That Involve Facilitation</th>
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</thead>
<tbody>
<tr>
<td><strong>Organizational Modeling</strong></td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>GVPN-1</td>
</tr>
<tr>
<td>GVPN-2</td>
</tr>
<tr>
<td><strong>Average</strong></td>
</tr>
<tr>
<td>DVPN-1</td>
</tr>
<tr>
<td>DVPN-2</td>
</tr>
<tr>
<td><strong>Average</strong></td>
</tr>
</tbody>
</table>

*Data is not available due to a temporary malfunctioning of the recording system.

We also conducted a similar analysis for the use of boundary spanning visualization technologies. We initially calculated the proportion of interactions that use spatial visualization technologies to the total number of interactions. These are presented in Table 13. We took the average values for each modeling week and compared the mean value of GVPNs and DVPNs;
According to the one-tail t-test result, the difference in use of boundary spanning visualization technologies between the two groups is weakly significant with a p value of 0.055. Therefore, GVPNs tend to use boundary spanning visualization technologies more frequently compared to DVPNs. We can tentatively reject the null hypothesis and our second hypothesis is also tentatively supported. While a significance level of 0.055 is above the typical threshold of 0.05, we argue that the results are nonetheless informative given that we are able to account for 94.5% of the interactional data. Moreover, since the boundary spanning visualization technology was the only means through which the domestic and global networks could share their models, the significance of the distinction between the distributions was skewed as the DVPNs were also required to use the technology to some extent in order to successfully complete the project. Thus, the DVPNs used the boundary spanning visualization technologies, but not as frequently as the GVPNs.

Table 13: The Use of Boundary Spanning Visualization Technologies as a Percentage of All Interactions

<table>
<thead>
<tr>
<th></th>
<th>Organizational Modeling</th>
<th>4D Modeling</th>
<th>First Intervention</th>
<th>Second Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>GVPN-1</td>
<td>67.98%</td>
<td>82.36%</td>
<td>75.07%</td>
<td>79.28%</td>
</tr>
<tr>
<td>GVPN-2</td>
<td>77.20%</td>
<td>N/A*</td>
<td>77.08%</td>
<td>26.52%</td>
</tr>
<tr>
<td>Average</td>
<td>72.59%</td>
<td>82.36%</td>
<td>76.08%</td>
<td>52.90%</td>
</tr>
<tr>
<td>DVPN-1</td>
<td>N/A*</td>
<td>39.29%</td>
<td>55.80%</td>
<td>10.56%</td>
</tr>
<tr>
<td>DVPN-2</td>
<td>73.49%</td>
<td>62.98%</td>
<td>74.56%</td>
<td>54.66%</td>
</tr>
<tr>
<td>Average</td>
<td>73.49%</td>
<td>51.13%</td>
<td>65.18%</td>
<td>32.61%</td>
</tr>
</tbody>
</table>

*Data is not available due to a temporary malfunctioning of the recording system.

Finally, we checked the correlation between the network density, an indicator of cohesiveness, and the use of boundary spanning visualization technologies. We used UCINET
to calculate the network densities, which are presented in Table 14. The correlation coefficient is 0.74 with a significance value of $p = 0.002$. Therefore, effective technology usage is positively correlated with cohesive collaboration and we can reject the null hypothesis; the third hypothesis is also supported.

**Table 14: The Use of Boundary Spanning Visualization Technologies and the Network Density**

<table>
<thead>
<tr>
<th>Network</th>
<th>Week</th>
<th>Use of Boundary Spanning Visualization Technologies</th>
<th>Network Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>GVPN-1</td>
<td>Organizational</td>
<td>68%</td>
<td>57.67</td>
</tr>
<tr>
<td></td>
<td>4D Modeling</td>
<td>82%</td>
<td>71.80</td>
</tr>
<tr>
<td></td>
<td>First Intervention</td>
<td>75%</td>
<td>47.60</td>
</tr>
<tr>
<td></td>
<td>Second Intervention</td>
<td>79%</td>
<td>44.56</td>
</tr>
<tr>
<td>GVPN-2</td>
<td>Organizational</td>
<td>77%</td>
<td>31.43</td>
</tr>
<tr>
<td></td>
<td>First Intervention</td>
<td>77%</td>
<td>80.43</td>
</tr>
<tr>
<td></td>
<td>Second Intervention</td>
<td>27%</td>
<td>26.05</td>
</tr>
<tr>
<td>DVPN-1</td>
<td>4D Modeling</td>
<td>39%</td>
<td>15.10</td>
</tr>
<tr>
<td></td>
<td>First Intervention</td>
<td>56%</td>
<td>19.80</td>
</tr>
<tr>
<td></td>
<td>Second Intervention</td>
<td>11%</td>
<td>9.90</td>
</tr>
<tr>
<td>DVPN-2</td>
<td>Organizational</td>
<td>73%</td>
<td>84.63</td>
</tr>
<tr>
<td></td>
<td>4D Modeling</td>
<td>63%</td>
<td>48.17</td>
</tr>
<tr>
<td></td>
<td>First Intervention</td>
<td>75%</td>
<td>61.97</td>
</tr>
<tr>
<td></td>
<td>Second Intervention</td>
<td>55%</td>
<td>48.30</td>
</tr>
</tbody>
</table>

**Discussion**

In this study, we aimed to identify whether differences exist in collaboration approaches of GVPNs versus DVPNs. In order to explore this question, we studied two types of networks—
GVPNs and DVPNs—and observed their collaboration in a virtual workspace. Researchers have claimed that, culture affects what we notice, how we interpret it, what we decide to do about it, and how we execute our ideas (Distefano and Maznevski 2000). To be able to quantify the impact of culture in the virtual collaboration setting, we analyzed the differences in the use of facilitation and boundary spanning visualization technologies in both GVPNs and DVPNs. For this analysis, we initially utilized UCINET to develop sociograms and calculate the centrality measures of each network; we checked the in-degree, the out-degree and the eigenvector centralities. We concluded that the facilitators did not gain a central and dominant role within the content related interactions. In this research, facilitators were fully acquainted with the facts that facilitators engaged in content interactions can be detrimental to network performance (e.g. Miranda and Bostrom 1999; Iorio et al. 2012). For this reason, if the facilitators were drawn into a task related interaction rather than for technology support, the facilitators reemphasized the limit of their role during the collaboration. Our observations are also supported by the statistical results which showed that none of the facilitators adopted an additional role that might be detrimental to information transfer and thereby the network performance.

Based on our research design, we were able to identify the participants who were involved in the interactions and whether a boundary spanning visualization technology was utilized or whether the interaction included a facilitator. We initially examined the difference between global and domestic networks in their interaction with the facilitators. To this end, we calculated the proportion of interactions that involved facilitators and demonstrated that the facilitators were interactional participants in GVPNs significantly more often than they were in DVPNs (Hypothesis 1). Figure 5 illustrates the proportion of interactions that included a facilitator to total interactions for the two network types.
In Figure 5, the ratio of utilizing facilitation in DVPNs slightly increases over the first three weeks. A shift in this pattern is observed in the last week of modeling when the networks have to finalize their tasks. Yet, the greatest amount of facilitation that DVPNs exhibit is still less than the lowest level of facilitation usage by GVPNs over the four week task execution periods studied. The difference in the proportional use of facilitators between GVPNs and DVPNs is particularly high at the initial stage of collaboration, but we observe a decline in the following weeks. This may be due to the “mapping” described in the MBI model (Distefano and Maznevski 2000). When developing the MBI model in global teams, it is important to prepare grounds for communicating and managing participation throughout the process and finally helping to resolve any disagreements that arise. In short, leveraging the benefits of diversity is not straightforward and may require additional support, at least initially, which we observe as a relatively high proportion of interactions with facilitators in the GVPNs during the first 3 weeks. Therefore, the decline in the use of facilitation can be explained as GVPNs need more support during the mapping and bridging phases compared to the integration phase. Moreover, the initial
weeks also correspond to the beginning of the design phase which has more potential for the networks to identify and discuss different approaches and alternative solutions.

According to our observations, students mainly wrapped up the organizational and 4D models in the second intervention week. In other words, they did not come across major problems which may require different perspectives to solve the issue. Therefore, the increase in the use of facilitation during the final intervention week may indicate that the integration of the MBI model was completed at the end of first intervention week. If the students could take as much time they needed for the modeling and intervention activities, and if there would not be a next step (students were asked to prepare a report and presentation after intervention weeks) it is possible we might not observe an increasing trend at the end of the period. However, the second intervention week was their last week to finalize their models, information seekers might have utilized the facilitators more than in the previous week in order to solve residual problems and move on to the next set of tasks. From a practical point of view, the second intervention period is a transition period in the project. It is the point where students finalize the modeling work and they were required to submit their models at the end of the session. Increased reference to the facilitator may have been due to the fact that they had questions about this transition (e.g. “when is the model due”, “what if we’re not finished”, “what are we supposed to do next week”, “can we work on this outside of class”). During the life of a project, GVPN members may need more support at the beginning when they start to establish the MBI model and during the transition period when they have inquiries about the following step or steps.

Having demonstrated that the collaborative approaches of GVPNs and DVPNs differ throughout the project in terms of how they interact with facilitators and that the facilitators did not adopt central roles in the project work, we turn now to differences in their approach to the
use of boundary spanning visualization technologies. Given the tendency of miscommunication in GVPNs (Adler and Gundersen 2008) due to linguistic diversity among members, we expected that boundary spanning visualization technologies were more frequently utilized in GVPNs compared to DVPNs since visual models can support effective communication (Koutsabasis et al. 2012). To this end, we initially calculated the proportion of interactions that were supported by technology and showed that GVPNs utilized boundary spanning technologies more frequently compared to DVPNs (Hypothesis 2).

In Figure 6, we present the average usage of boundary spanning visualization technologies and average direct communication without benefiting from visualization technologies. Results indicate a very interesting difference in the collaboration approaches. During the organizational modeling week, both types of networks utilized boundary spanning technologies at the same level. To finish the first week’s tasks, the organizational modeling team projected the 2D models on the shared screen and both teams worked on the 2D model. However, we observed a difference during the second week when teams were utilizing spatial visualization technologies to execute the 4D modeling tasks. While the ratio of GVPNs referring to spatial visualization technologies is 82.36%, the ratio drops down to 51.13% for DVPNs. In short, about half of DVPN interactions were direct communication. Knowing that using spatial design technology makes it easier to identify and visualize potential design problems, support brainstorming activities to investigate different design alternatives and support documentation of the meeting process (Golparvar-Fard et al. 2006), having spatial visualization technologies in a virtual setting has an important impact that leads to effective communication. Moreover we also checked the significance of the difference in utilizing BSVT when the tasks were spatially rich. In other words, we applied a t-test only to the 4D modeling and intervention weeks without
including the first week which was a 2D, non-spatially rich organizational modeling. According to the t-test result, the difference between GVPNs and DVPNs is highly significant with a p value of 0.035. By showing the significant difference of using spatial visualization technologies between GVPNs and DVPNs, we conclude that it is critically important for GVPNs to be provided with visualization-supporting tools. Considering that collaborative technologies can reduce the negative effects of diversity early in the life of a diverse team (Staples and Zhao, 2006), our findings suggest that the GVPNs were able to overcome the challenges associated with their diversity by referring to the boundary spanning visualization technologies more frequently, particularly when the task was spatially rich.

Figure 6: The Average Use of Boundary Spanning Visualization Technologies and Direct Interactions

However, unlike the divergent pattern observed for the first two weeks, during the intervention task weeks (Weeks 3 and 4 of the project), both GVPNs and DVPNs used the boundary spanning visualization technology less than they had during the first two weeks (Figure
Although their patterns of use converged, the use of boundary spanning visualization technologies in GVPNs was still higher than DVPNs, which may reflect the fact that some 4D modeling efforts were required in the intervention task weeks. The declining use of boundary spanning visualization technologies in both the GVPNs and DVPNs provides evidence in support of Carte and Chidambaram (2004), who argue that collaborative technologies are a bundle of capabilities that may prove useful at different points in a team’s development. As they suggest, GVPNs benefit from direct communication, particularly toward the end of the collaboration period, while they utilize boundary spanning visualization technologies more frequently at the earlier stages of their collaboration. The dashed lines in Figure 6 reflect the pattern of direct communication. The data presented in Figure 6 show distinct distributions for the use of boundary spanning visualization technologies and direct communication in GVPNs, which suggests that the use of the technologies is consistent throughout the project life-cycle. Conversely, the zigzag pattern of the DVPN indicates that a consistent trend does not exist, which suggests that the technology use is conditioned by the task type, rather than due to the diversity of the network.

Finally, we examined the relationship between utilizing boundary spanning technologies and network density in an effort to explore the relationship between technology use and network cohesion. In a virtual setting, the ability to transfer the same rich social, emotional, and non-verbal information present in traditional face-to-face settings is limited (Townsend et al., 1998). However, boundary spanning visualization technologies can support effective communication in virtual settings (Koutsabasis et al. 2012). The higher level of boundary spanning visualization technologies observed in GVPNs supports this argument as the global networks with linguistic boundaries utilized the technologies more frequently. Since cohesion is positively correlated
with higher levels of communication (Wech et al 1998), it is likely we would observe a more cohesive network when boundary spanning technologies are more frequently utilized. In order to test such a relation, we ran a correlation test and with a 0.002 significance level the correlation coefficient was found to be 0.74 (Hypothesis 3). In other words, if a project network is encouraged to utilize boundary spanning visualization technologies more frequently, then the probability of having cohesive collaboration is 74%. Therefore, the use of boundary spanning visualization technologies can support effective communication, which we observe through increasingly cohesive collaboration.

According to Distefano and Maznevski (2000), cultural differences provide the greatest potential for creating value by having an enormous wealth of material to create innovative approaches for complex organizational challenges and a broad range of operating modes to develop new ways of implementing solutions. We also know that cultural diversity has drawbacks and “the purposeful introduction of key collaborative technology capabilities can mitigate the negative aspects of diversity and simultaneously leverage its positive aspects—such as informational diversity” (Carte and Chidambaram 2004, pg:464). In this sense, the advanced technologies in virtual workspaces provide for effective communication. Therefore, when forming GVPNs, it is extremely crucial to support them by providing boundary spanning visualization technologies. Moreover, GVPN members should be encouraged to utilize these technologies more efficiently at the earliest stages of their collaboration.

Another important way of supporting GVPNs is through facilitation. The facilitators supporting GVPNs must help to identify and communicate the differences resulting from cultural diversity. In addition to that, the facilitators should be well trained to help GVPN members with any technological problems. In short, the combination of providing well-functioning boundary
spanning visualization technologies and facilitation leads to better functioning and more cohesive GVPNs.

**Limitations and Future Research**

In this research, we utilized graduate students as subjects in lieu of having participants from industry. Whether students are the appropriate representative of the studied research group or not has been a question of debate for some time. Researchers examined this phenomenon from various disciplines and many studies report that there is a remarkable degree of similarities between the results of students and non-student data sets (Host et al., 2000, Liyanarachchi and Milne 2004, Svahnberg et al. 2008, Tih et al., 2008). Moreover, according to Dobbins and colleagues (1988), laboratory experimentation provides a method to rigorously test theoretical predictions and provides an insight of organizational practices, therefore using students as the experimental surrogates has important theoretical contributions. However replicating this experiment with industry representatives can be a future research topic in order to empirically validate that using students to represents GVPNs is appropriate.

Another important limitation of this research was related with the experimental setting. The network sizes were quite small which prevented us from running more sophisticated social network analysis. Instead of having a network composed of two teams with two students in each team, a future study may involve more teams and more students. This way, advanced methods of social network analysis can be utilized to develop a deeper understanding of network relations in GVPNs. Additionally, such methods can be used to further validate the weak statistical support we found for differential use of boundary spanning visualization technologies between GVPNs and DVPNs.
Conclusions

In order to have a competitive advantage in the global construction market, many organizations are forming GVPNs to respond faster to changing market demand and to have greater flexibility. However, collaborating through advanced communication technologies over many boundaries is extremely challenging. Moreover, cultural and linguistic diversity among GVPN members might cause variances in collaboration approaches. In this study, we identified a significant difference in the collaboration approaches of DVPNs and GVPNs. First, facilitators were utilized more frequently in GVPNs, particularly in the early stages of collaboration. Second, boundary spanning visualization technologies within the virtual workspace were also utilized more frequently by the GVPN members. We observed greater differences in spatial visualization tool utilization when the task required more spatially rich understandings. Finally, we also identified a positive correlation between effective boundary spanning visualization technology usage and cohesive collaboration among project participants, which implies that virtual project networks that utilize visualization affordances in virtual settings may perform better. Consequently, in order to achieve well-functioning and effective GVPNs, both the appropriate mode of communication and a support to use technology efficiently and value diversity should be provided.
CHAPTER 5: CONTRIBUTIONS

In this research, I aimed to develop a robust understanding of how GPNs can perform more effectively and efficiently. I constructed my research questions by considering two fundamental features of GPNs which are the cultural and linguistic diversity and the role of technology in global collaboration. According to my empirical analyses, the following theoretical and practical contributions were concluded.

The Impact of Cultural and Linguistic Diversity

In the first stage of my dissertation, I examined the impact of cultural and linguistic diversity on the initial performance and adaptation performance of simulated project networks. From the statistical analyses of both initial performance and adaptation performance of multi-cultural and mono-cultural networks, I concluded that multi-cultural project networks performed worse initially but learned faster throughout the experiment. Once members of the multi-cultural networks identified ways to overcome cultural and linguistic difficulties, they made productive use of their diversity. In other words, the multi-cultural networks needed to invest additional time to overcome the initial cultural and linguistic difficulties but they were able to introduce new approaches and tactics that eventually led them to perform better. I demonstrate that despite the significant initial performance difference, the multi-cultural networks end up attaining the performance level of the mono-cultural networks. I also show that multi-cultural networks were even able to perform better than the mono-cultural networks over sustained collaboration across projects. Therefore, in general there were positive returns to the new approaches and knowledge contributed by members of the network as a result of their different cultural backgrounds.
The findings of the experiment demonstrate that in the initial stages of global project collaboration, performance can suffer significantly when compared to domestic collaborations. Therefore, although partnering with a local firm in an overseas project has advantages due to access to the local knowledge, firms should take into account the potential performance loss in the initial projects that can occur when establishing a global collaboration. To mitigate the initial performance loss, firms may consider cross-cultural communication training. Nevertheless, the findings also exposed that after only a few projects, as multi-cultural project network members get accustomed to collaborating and develop strategies to overcome the cultural and linguistic barriers, the global project network starts to benefit from the diversity and outperform monocultural project networks. Thus, researchers that have found a significant and positive relationship between cultural distance and performance (Park and Ungson 1997) and others that have found a significant and negative relationship (Barkema et al. 1997) may both be correct. The dual impact of cultural and linguistic diversity means that studies of initial cross-cultural interactions are likely to find performance liabilities while studies of longer-term, sustained interactions are likely to find performance benefits associated with cultural and linguistic diversity. What matters is at what point in the multi-cultural project network collaboration the performance data is considered.

The initial phase of my research also has important practical implications for design and construction firms. In the global AEC industry, there is a strong sentiment toward developing strong collaborative relationships on projects using partnering techniques. However, projects are still largely temporary organizational networks where the firms participating on one project are unlikely to be working with the same set of firms on the next project. This experimental research suggests that adopting a partnering strategy, a common collaborative process in global
construction projects, is critically important. If a firm works with a different foreign partner firm on each project, they will invest time and resources to address cultural and linguistic differences with each partner without benefitting from the significant performance gains which may be possible with sustained collaboration in a global project network.

**Facilitating Global Virtual Project Networks**

The research in Chapter 2 informs us about the difference between initial performance of domestic and global networks. Considering the main objective of facilitators, which is helping to make an outcome easier to achieve, facilitators may be able to reduce the initial difference found in the first study. Besides facilitating the process and providing technological support, the facilitators should have been able to support GPNs to benefit from the diversity which would have made GPNs’ performance closer to the domestic project networks at the beginning of their collaboration. Yet, the role of a facilitator may be misinterpreted in a virtual setting, in other words the GPNs may rely too heavily on the facilitators which is known to be detrimental in terms of project performance.

Accordingly, in this study, I aimed to explore the use of facilitation in GVPNs. More specifically, I was interested in the impact of process facilitators on the performance of GVPNs engaged in task work. To this end, I examined whether process facilitators impact the creation and maintenance of transactive memory systems (TMSs) and thus contribute to cohesive collaboration in task interactions. The existence of a well-formed TMS indicates cohesive collaboration, and cohesive collaboration is associated with better performance. Therefore, if global virtual project networks can collaborate cohesively, then the gap between the initial performance of the domestic and global project networks observed can be reduced. I hypothesized that the facilitating team would be drawn into task-related discussions and become
a dominant and central actor with respect to the BIM-based modeling teams and the estimation team. This hypothesis was confirmed. The existence of the facilitating team within task related interactions obstructs the formation of cohesive subgroup among BIM-based modeling teams. Thus, the preliminary findings suggest that process facilitators who engage in content facilitation do not support the creation and maintenance of a TMS in global project networks collaborating in virtual workspaces and they do not support cohesive collaboration on task interactions in global project networks collaborating in virtual workspaces. Yet, these findings are not adequate to conclude the statistical likelihood for the hypothesized network structure to be observed in the experimental data.

I continue the analysis utilizing the exponential random graph method (ERGM). The ERGM results are essential since they conclude that the expected network structures are likely to be observed within the collected data set. The ERGM results conclude that only non-facilitated networks are tightly clustered across the task network subgroup not the two-mode networks. When process facilitators moved into task interactions they became central actors. Their existence in task interactions impeded the formation of the TMS, which indicates that information seekers could not recognize that facilitators were not actual knowledge domain experts. By becoming involved in task discussions, facilitators were treated as domain knowledge specialists, even though their specialty was limited to process facilitation. When the non-specialist facilitators became active participants in the specialized knowledge domain, they were treated as content facilitators. However the facilitators had no specialized knowledge that would allow them to function effectively as content facilitators. To be able to address the directed inquiries, facilitators had to retrieve information from actual knowledge domains that caused redundant interactions. As Griffith and her colleagues (1998) claimed, I also observed
that facilitators had more power compared to other network members. Therefore, their comments are more likely to be recalled and considered than any other member in the TMS. This implies that TMS formation is not likely to occur in GVPNs when process facilitators are drawn into engaging in task interactions since their non-specialist existence in task content does not sustain collaboration effectiveness.

Consequently, I propose that to overcome the challenges to enacting complex design work in virtual collaboration settings, information seekers might attempt to create more sources from which to retrieve information. However, facilitators were not eligible to perform the role of content facilitators. In other words, their priority was to increase the productivity of the GVPN through process facilitation, not through being an additional and central knowledge source. Yet, throughout the course of the collaboration, the process facilitators undertook the role of content facilitators due to their highly influential positioning in the networks and became centrally engaged in task discussions.

The AEC industry is changing due to globalization. According to Weaver and Farrell (1997, pg:173), people may react to the change; in this sense facilitators must play a leading role in supporting groups successfully to anticipate, respond and create the change. Even though facilitators have a crucial role in changing organizations, previous research has emphasized that not all types of facilitation is beneficial. According to Miranda and Bostrom (1999), content facilitation is detrimental in terms of project performance. Moreover, Griffith et al. (1998) also point out the unintentional influence of facilitators in content discussions which might be also detrimental. My research builds upon these earlier studies and I contribute a new perspective unique to virtual collaboration. Chapter 3 concludes that the role of facilitators in a virtual setting might be misinterpreted by project participants and additional roles can be imposed.
Accordingly, facilitators may become unintentionally more dominant and central within the networks; and as a result they can be inadvertently dragged into content related discussion, which has been proven as being detrimental by earlier studies. We also know from previous research that it is critically important to use one primary role for a given work session since changing roles in a given situation can undermine trust within the group (Weaver and Farrell 1997). Therefore, firms being a part of a global project should support GPNs collaborating in virtual workspaces, which is essential, yet they must also consider the appropriate way of facilitating GVPNs. Facilitators supporting GVPNs should provide process support without involving in task interactions, in other words adhering to a specific role and not switching between various roles, especially in a virtual collaboration suite.

**Comparison of Global Versus Domestic Virtual Project Networks**

In the third study I aimed to identify the differences in collaboration approaches that GVPNs develop with respect to DVPNs. To be able to quantify the impact of culture in the virtual collaboration setting, I analyzed the differences in the use of facilitation and boundary spanning visualization technologies in both GVPNs and DVPNs. Accordingly, the proportional use of facilitators and boundary spanning visualization technologies is significantly different between GVPNs and DVPNs.

I found the use of facilitation to be particularly high at the initial stages of collaboration. This may be related to benefits derived from diversity. Since it is important to prepare grounds for communicating and managing participation throughout the process of valuing differences, GVPNs may require additional support, at least initially. While I observe a relatively high proportion of interactions with facilitators in the GVPNs during the first 3 weeks, a similar inclining trend is observed in both types of networks at the end of intervention period.
According to my observations, the experiment participants mainly concluded the organizational and 4D models in the second intervention week. The second intervention week was their last week to finalize their models, information seekers might have utilized the facilitators more as they finalized their models. The second intervention period was a transition period in the project. It is the point where students finalized the modeling work (i.e. they submitted their models at the end of this class) and transition to their writing and presentation work. Increased reference to the facilitator was probably due to the fact that they had questions about this transition (or about the process of transitioning between two discrete task types). Consequently, during the life of a project, GVPN members may need more support at the beginning when they start to benefit from diversity and during the transition period when they have inquiries about the following step.

Given the tendency of miscommunication in GVPNs due to linguistic diversity among members, I expected that boundary spanning visualization tools were also more frequently utilized in GVPNs compared to DVPNs since visual models can support effective communication. By showing the significant difference of using spatial visualization technologies between GVPNs and DVPNs, I concluded that it is critically important for virtual project networks to be provided by visual facilities. Given the significant additional reference to such facilities by the GVPNs, such facilities are even more important for GVPNs. Considering that collaborative technologies can reduce the negative effects of diversity early in the life of a diverse team (Staples and Zhao, 2006), my finding suggests that the GVPNs were able to overcome the challenges associated with their diversity by referring to the boundary spanning visualization technologies more frequently, particularly at the early stages of the project.
However, unlike the divergent pattern observed for the first two weeks, during the intervention task weeks, both GVPNs and DVPNs used the boundary spanning visualization technology less than they had during the first two weeks. This similarly declining pattern provides evidence in support of Carte and Chidambaram (2004), who argue that collaborative technologies are a bundle of capabilities that may prove useful at different points in a team’s development. As they suggest, GVPNs benefit from direct communication, particularly toward the end of the collaboration period, while they utilize boundary spanning visualization technologies more frequently at the earlier stages of their collaboration.

Finally, I also examined the relationship between utilizing boundary spanning technologies and network density in an effort to explore the relationship between technology use and network cohesion. Since cohesion is positively correlated with higher levels of communication (Wech et al. 1998), it is likely to observe a more cohesive network when boundary spanning technologies are more frequently utilized. According to the correlation test, I concluded that, if a project network is encouraged to utilize boundary spanning visualization technologies more frequently, then the probability of having cohesive collaboration is higher. Therefore, the use of boundary spanning visualization technologies can support effective communication, which can be observed through increasingly cohesive collaboration.

In order to benefit from cultural differences that provide the greatest potential for creating value, the differences should be well defined and clearly communicated. In this sense, the advanced technologies in virtual workspaces enable effective communication among participants. Therefore, when forming GVPNs, it is extremely crucial to support project participants by providing boundary spanning visualization technologies. Moreover, GVPN members should be encouraged to utilize these technologies more efficiently at the earliest stages.
of their collaboration. Another important way of supporting GVPNs is through facilitation. The facilitators supporting GVPNs must help to identify and communicate the differences due to cultural diversity. In addition to that, the facilitators should be well trained to help GVPN members with any technological problems. In short, the combination of providing well-functioning boundary spanning visualization technologies and facilitation leads to better functioning and more cohesive GVPNs. Knowing that cohesive collaboration is a key element to achieve better performance, GVPNs should be founded on visualization technology and facilitation support.

Consequently, as DiStefano and Maznevski (2000) concluded, the differences between project participants can create value as long as participants can identify and communicate the differences. Yet it might be challenging to manage the differences and GPNs may need support to leverage the benefits of diversity (Pauleen and Yoong 2001). In order to mitigate the negative aspects of diversity, Carte and Chidambaram (2004) proposed the introduction of key collaborative technology capabilities; they further argued that collaborative technologies are a bundle of capabilities that may prove useful at different points in a team’s development. My research builds upon these earlier studies that emphasize the importance of getting value from diversity. In chapter 4, I contribute a new perspective for GVPNs that to gain the benefit of diversity, appropriate facilitation and providing key collaborative technologies is necessary in virtual workspaces as global project networks require more interaction with both facilitators and such boundary spanning visualization technologies.

In the global world, a key success criterion is turning diversity into a competitive advantage. Therefore, firms in the AEC industry should support GPNs in a way that overcomes challenges of diversity and virtual collaboration. In this sense, the research presented in Chapter
3 and Chapter 4 proposes providing two types of support mechanisms; appropriate approaches toward facilitation (identified in Chapter 3 and Chapter 4) and boundary spanning visualization technologies which ensure clear and effective communication in a virtual setting (identified in Chapter 4). Without having appropriate support, project participants may not capitalize on the value of diversity; indeed they may consider differences as an obstacle. Overcoming problems related to linguistic diversity, which is a common issue in global collaborations, are greatly enhanced through the use of boundary spanning visualization technologies. This study emphasizes the importance of providing appropriate support mechanisms during a global collaboration. It also identifies types of support a GVPN would need in each phase of collaboration; including initial phase, design phase and transition phase. Moreover, excessive interaction with facilitators at the beginning of the collaboration is coherent with the initial performance liabilities identified in Chapter 2. That chapter introduced the dual impact of cultural and linguistic diversity showing that the negative impact of diversity is greater at the early stages of the collaboration. As the global project participants continue to work together, they gain competency and are able to establish the MBI model; thereby they begin to benefit from diversity. During this initial stage when they struggle to manage diversity, their performance level is lower. Consequently, it is rational that project participants would refer to facilitators more frequently to get support during the initial stage of their collaboration. The decreasing trends in figures 2 and 5 which indicate worse initial performance and decreasing need for facilitation, respectively, provide internal validation for the findings in this dissertation.
CHAPTER 6: LIMITATIONS & FUTURE RESEARCH

The focus of this research is on global project networks collaborating both in face-to-face and virtual settings. I aimed to use empirical research techniques to investigate the impact of cultural and linguistic diversity on GPNs, how to support GPNs effectively that are collaborating in virtual workspaces and identify different collaboration approaches that GVPNs develop throughout the lifecycle of a design project. With this method, I attempt to establish a robust understanding of global project network dynamics, yet this research has both its shortcoming that must be considered and possibilities for future research that may be undertaken by other researchers.

Statistical Distinction between the Domestic and International Networks

An important limitation in the first study that analyzes the impact of cultural and linguistic diversity is the limited time frame provided to participants to complete each experiment. According to the experimental design, students were allocated only 1.5 hours to finish building the five Lego structures. Since multi-cultural networks utilized most of their time during the first structure, the majority of the networks could not complete all five structures in the allocated time. Among the ten multi-cultural networks, only one managed to finish all five structures, and only four networks were able to complete four structures. In other words, the adaptation performances of five multi-cultural networks are calculated based on their performance on first three projects. This limitation indicates that, if they were given enough time to finish all five structures, then their adaptation performance may be lower. Indeed, the average adaptation performance of multi-cultural networks that finished more structures is less than the average adaptation performance of five multi-cultural networks that managed to complete only three
structures. If I could observe each multi-cultural network’s actual performance instead of forecasting the unavailable data utilizing the learning curve formula, then the difference between mono and multi-cultural networks at the fourth and fifth project may be statistically distinct. Current data shows that the adaptation performance of multi-cultural networks outperforms that of mono-cultural networks, but without having a clear statistically distinct relationship in terms of project performance across study groups in the latter projects executed. The difference between mono and multi-cultural project network performance over five successive projects can be observed in Figure 7.

![Figure 7: The Difference between Multi and Mono Cultural Project Network Performance](image)

Therefore, I conclude that the multi-cultural networks’ performance is comparable to that of the mono-cultural networks, yet further data collection and larger data sets are required to
show if a statistically significant difference exists between mono and multi-cultural networks at the later stages of their collaboration.

**Domestic Engineering Teams Are Often Quite Culturally Diverse**

Another important limitation regarding the research presented in the second and fourth chapters is regarding the characteristics of domestic project networks. In each study, the domestic networks were composed of graduate students who were born in the U.S. and whose native language was English. Yet, considering that domestic engineering teams in the U.S. and elsewhere are often quite culturally diverse, there is a lot of opportunity to study gradations of cross-national diversity in domestic project networks as well. For the purpose of this research, I compared heterogeneous global versus homogenous domestic project networks, yet a future study may consider heterogeneous combinations of domestic network participants with diverse cultural backgrounds to examine the resulting impacts on performance, the use of facilitators and the use of boundary spanning visualization technologies to execute complex interdependent work in project networks.

**Content versus Process Facilitation in Virtual Workspaces**

According to the findings of the second study, process facilitating teams adopted an additional role and, along the way, they became a dominant and central figure within content related discussions. In other words, they performed not only process facilitation but also content facilitation, which is known to be detrimental in teams where facilitators do not have content expertise since it prevents appropriate transactive memory systems from forming and cohesive collaboration from developing. The facilitators in my study were trained only to be process facilitators; they did not have any content related background appropriate to the project. They
retrieved information from actual knowledge domains and transferred it to information seekers instead of allowing direct communications between information seekers and knowledge domain experts. In short, they facilitated the networks inappropriately. In this sense, the contribution of the second study is extremely crucial since it identified that pathologies can arise when GPNs are facilitated while collaborating in virtual workspaces. Yet, a further study was needed in order to directly compare correctly facilitating and inappropriately facilitating study groups. Instead, in the third study, (Chapter 4) I directly utilized appropriately facilitated GVPNs having learned about the potential pathologies that can develop in the second study (Chapter 3). In none of my studies do I compare content facilitation versus process facilitation. Consequently, a comparison study of pure process facilitation and pure content facilitation with respect to a control group of non-facilitated networks can be considered as a further step toward improving our understanding of the role of facilitation in determining the performance and cohesion of virtual project networks.

**Replication Studies with Industry Practitioners**

Across all three of my studies, I used student participants as surrogates for industrial representatives. Whether students can appropriately represent industry subjects has been a debate for decades. Many researchers have examined this phenomenon from various disciplines including human resources (Covin and Brush 1993), psychology (Ward 1993), communication (Basil, 1996), software engineering (Host et al. 2000, Sjoberg et al. 2002), accounting (Liyanarachchi and Milne 2005), politics and international relations (Mintz et al. 2006), retailing (Tih et al. 2008) and international business (Bello et al. 2009), among others. Unfortunately a consensus has not been achieved by researchers; some studies reported that students should not be used as subjects in theory application research (Covin and Brush 1993, Mintz et al. 2006),
while many studies report that there is a remarkable degree of similarity between the results of students and non-student data sets (Host et al., 2000, Liyanarachchi and Milne 2004, Svahnberg et al. 2008, Tih et al., 2008). More importantly, studies that do not support the use of students as research subjects tend to lack clear supporting evidence and since it is easy to access students to collect data, there is an increasing trend of using students in many disciplines (Peterson 2001).

In 2004, Liyanarachchi and Milne replicated an existing study on the investment decision of accounting practitioners with a student study group. The initial study was conducted by Milne and Patten (2002) to observe the investment decisions in the context of disclosures of significant environmental liabilities information. When the same study was replicated with students, Liyanarachchi and Milne found students to be valid experimental surrogates for industry professionals. They aimed to examine whether less skills and experience would impact the information processing and cause different results than professional practitioners. They concluded “the information processing skills required to produce similar effects within the given experimental design are sufficiently basic to be possessed by most any business student” (Liyanarachchi and Milne, 2004:133).

Many researchers support using student samples in empirical studies under certain circumstances. They emphasize that researchers must interpret results correctly so results obtained by using student samples require extra scrutiny. For example Stevens who studied the use of student samples in supply chain management research claimed that it is appropriate to use student samples when theories are universalistic or the purpose of the study has an internally valid relationship (2011). Bello and colleagues studied student samples in international business research and identified four cases where student samples are appropriate to use; a well-defined theory with sophisticated predictions, results based on students samples are likely to be valid if
the study is replicated with professionals, strong arguments for the generalizability of the results and finally when it is used in concert with comparable managerial samples (Bello et al. 2009). There are also studies that object to the use of students as surrogates for industry practitioners. For example, in 1993 Covin and Brush compared the attitudes of students and human resource professionals toward work and family issues and they identified significant differences. Similarly Mintz and colleagues studied using student samples in political science, military affairs and international relations (2006) and they observed significant statistical differences between actual decision makers and students. Furthermore they claimed that relying on student samples may bias results (Mintz et al. 2006).

Research focused specifically on engineering design processes, which are most similar in nature to my own research, compared the engineering design process of freshman (not declared a specific major yet) and senior students (10-civil engineering, 7-mechanical engineering, 7-industrial engineering) (Atman et al. 1999). In 2007, using data from senior students, they examined the design behaviors of students and experts. They posed twelve hypotheses relating the differences in the design process of students and professional practitioners. These twelve hypotheses covered the following five main themes: i) problem scoping and information gathering, ii) project realization, iii) considering alternative solutions, iv) total design time and transitions, and v) solution quality. They expected that as the expert engineers displayed expertise in each of the process measures, it would contribute to an overall better solution. They also anticipated that the expert engineers’ solutions would achieve higher scores when rated for final design quality than the students. Based on literature, they initially expected that experts do not typically consider alternative solutions, but rather tend to focus on a single solution and modify it or they focus on a very small number of solutions. Yet, Atman et al.’s study proved
the opposite (2007); they found that expert engineers worked with twice as many design alternatives compared to senior students. More interestingly, they also rejected a hypothesis relating to design solution quality. The quality of final design scores was not statistically significant between expert engineers and senior students (students $M=0.51$, $SD=0.1$, experts $M=0.54$, $SD=0.06$). Considering that expert engineers performed better in problem scoping, information gathering, and project realization, it is remarkable that both senior students and expert engineers could achieve similar quality scores.

The literature supports that the use of students as surrogates in studies on engineering topics can lead to important theoretical contributions. In my study, the experiments were conducted using graduate students and some of the students did have industry experience. Given the fact that in most of the previous research studies undergraduate students were used, my study, which utilized graduate students, many with industry experience, is more likely to represent professional practitioners. Nevertheless, a potential following step of this study is to replicate the experiments presented in this dissertation using professional practitioners as recommended by some researchers (e.g. Peterson 2001, Carver et al. 2003). By examining industry data, it would be possible to observe how the findings from the earlier pedagogical experiments are externally validated.

**Experiments Comparing Face-to-face versus Virtual Project Networks**

In Chapter 2, I compared global and domestic project networks collaborating in a face-to-face setting. In Chapter 3 I add in the important element of technology in GPNs, which leads to the formation of GVPNs. I explore ways to improve the efficiency and cohesiveness of GVPNs through facilitation. In short I concentrate on only the global, not the domestic networks, in order to understand and decrease the potential gap in the initial performance of the global networks. In
Chapter 4, I compare GVPNs and DVPNs that are working in a virtual workspace to examine collaboration differences among them. Yet in none of these studies do I compare global or domestic project networks collaborating in a face-to-face versus a virtual setting. Such a comparative study has many fruitful contributions in terms of developing a deeper understanding of the dynamics of GPNs. By observing GPNs collaborating in different settings, the way they benefit from diversity can be isolated and identified.

Carte and Chidambaram (2004) propose that different combinations of face-to-face and virtual collaboration modes can be beneficial in terms of GVPNs’ performance. For example, they propose having technological capabilities can reduce the negative effects of diversity early in the life of a diverse team and they suggest having normal communication exchanges later in the collaboration. This proposition contradicts the common belief of establishing face to face kick off meetings and then continuing to collaborate virtually. Therefore, empirically testing the impact of different combinations of collaboration modes in a virtual workspace may be a fruitful future research topic.
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