The Role and Use of Communities of Practice to Facilitate Knowledge Sharing in Project Based Organizations

By

John Wanberg

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Written by John Wanberg

Has been approved for the Department of Civil, Environmental, and Architectural Engineering

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Dr. Amy Javernick-Will
(committee chair)

____

Dr. Paul Chinowsky

____

Dr. Matthew Hallowell

____

Dr. John E. Taylor

____

Dr. Raymond E. Levitt

Date _________________

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline

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ABSTRACT

Wanberg, John Stanton (Ph.D., Civil, Environmental, and Architectural Engineering)

The Role and Use of Communities of Practice to Facilitate Knowledge Sharing in Project Based Organizations

Dissertation directed by Assistant Professor Amy Javernick-Will

This dissertation builds theory regarding the form, creation, and role of communities of practice (CoPs) in project based organizations. In practice today, organizations employ CoPs as a tool to manage knowledge; however, they have deviated significantly from their theoretical roots. As such, the current practice of creating CoPs to facilitate knowledge sharing has little theoretical guidance. To further understand this current state of practice, and to help companies adapt the CoP concept to business practice, this dissertation addresses three primary research questions. *1) What are the effects of geographic dispersion and organizational divisions on communities of practice in project based organizations? 2) How do knowledge sharing connections form within distributed communities of practice in project based organizations? and 3) How do communities of practice coordinate knowledge in project based organizations?* In response to these questions this research uses social network analysis to examine informal knowledge sharing networks in three distributed CoPs within two multinational project based organizations. To begin, informal networks are compared to business unit and disciplinary boundaries to determine the relative influence of organizational structures on knowledge flows (Chapter 2). Results discovered that organizational boundaries can limit knowledge flows, but are not consistent across CoPs. Subsequently, the informal networks within each CoP were analyzed relative to geographic and cultural boundaries. In all three CoPs, knowledge flows were restricted between geographic and cultural groups, and structural boundary spanning only occurred with management interventions (Chapter 3). The next chapters employ qualitative analysis to explore how and why these connection patterns occur. From the qualitative data, Chapter 4 creates a framework for understanding how CoPs form within multinational project based organizations. This analysis identified a broad range of mechanisms of

connection, indicating that CoPs are heavily influenced by both social and organizational forces. Finally, Chapter 5 takes a knowledge based view of the firm, and investigates the different types of coordination occurring within CoPs (Chapter 5). Taken together, these findings create a holistic illustration of CoPs as they are applied in project based organizations. Through a greater understanding, companies can better adapt CoPs to current business practice.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction

Despite the widespread application of communities of practice (CoPs) in engineering and construction organizations, their role as structures for managing knowledge lacks guiding theory. As a result, the contribution of CoPs to the organizations that host them is uncertain at best (Hildreth et al. 2000). While communities of practice are not a phenomenon specific to the engineering and construction industry, the principles and benefits behind improved knowledge management are particularly applicable to project-based firms. At their root, construction and engineering organizations are institutions that integrate specialist knowledge to produce unique products that meet client needs (Grant 1996). As one of the largest industries in the world (Kim et al. 2011), and a critical provider of the infrastructure needed by society, there are enormous benefits to increasing the efficiency and effectiveness of engineering and construction firms. While innovation in safety, quality controls, estimating, and productivity are important, one way to improve performance in this industry is to better understand and design project based organizations to optimally coordinate specialist knowledge. The goal of such an effort is to make the knowledge possessed by individuals within the organization perpetually available when and where it is needed. When done effectively, this can reduce repeated mistakes, spread innovation and best practices, and help organizations avoid dedicating resources to problems that have been solved elsewhere in the organization (Javernick-Will and Hartmann 2011).

Knowledge management, although essential, is a complex management task. Even though many construction companies are initiating knowledge management efforts (Carrillo and Chinowsky 2006), prior work has shown that upwards of 50% of initiatives to manage knowledge fail to meet their original objectives (Akhavan et al. 2005). One possible reason for this widespread failure is that certain types of knowledge "tacit," meaning it is invariably associated with the person who knows (Polanyi and Sen 1983). To transfer this type of knowledge, impersonal, online repositories are not sufficient. Rather, employees must personally connect with one another to transfer knowledge through socialization (Nissen 2002). This becomes a challenge for global firms, because there is no economy of scale to creating knowledge sharing connections that exchange unique content. Yet, these informal networks, rather than formal hierarchical structures within the organizations, often provide a better descriptor of how work gets done within organizations (Cross and Parker 2004). Recently, CoPs have emerged as a "way of managing knowledge" (Roberts 2006) while acknowledging that organizational charts, manuals, job descriptions, and training programs are insufficient to describe the ways that individuals actually work and learn within a firm (Brown and Duguid 1991). These CoPs fit most closely with the definition offered by Manville and Foote of:

> *"a group of professionals informally bound to one another through exposure to a common class of problems, common pursuit of solutions, and thereby themselves embodying a store of knowledge"* (Manville and Foote 1996)

When originally conceptualized, CoPs were intended to describe the importance of practice and social participation in learning theory (Lave and Wenger 1991), and organizational learning (Brown and Duguid 1991) within localized groups of professionals. Realizing the benefits of knowledge creation and collaboration that occurred in these small communities, many organizations have attempted to increase the scope and scale of CoPs to facilitate knowledge sharing across the entire company (Saint-Onge and Wallace 2012). At the same time, increased global demand for infrastructure has led contractors to expand overseas to capitalize on new opportunities (Neves and Bugalho 2008), expanding into multiple different sectors and services (Han et al. 2010). The application of CoPs has followed this trend, and has progressed to the degree that the organizational structures currently called "communities of practice" are distinctly different from their theoretical roots in both their global reach, and multi-disciplinary membership (Chiu et al. 2006; Lindkvist 2005; Roberts 2006; Wasko and Faraj 2005). Because CoPs are often self governed, their contribution to the organizations that host them is tenuous (Hildreth et al. 2000), and with the significant deviation from cognitive learning roots, as well as global expansion, CoPs purpose within organizations is even more uncertain.

As such, this dissertation explores the application of CoPs to engineering and construction organizations as a way of managing knowledge. To reduce the uncertainty surrounding the contribution of CoPs to these organizations, and to help companies effectively adapt CoPs to their business practice, this work answers three primary research questions to address specific gaps in our current understanding of CoPs within project based organizations. To begin, CoPs have expanded globally, yet operate within multinational organizations. We do not know how both of these fundamental changes in environment affect knowledge sharing within CoPs. This leads to the first research question: *What are the effects of geographic dispersion and organizational divisions on communities of practice in project based in organizations?* Secondly, when CoPs originated, they were localized groups of professionals who worked together in a community setting. Now that CoPs have been re-purposed to deliberately create connections between professionals, we no longer know *how* CoP members become connected with one another, and therefore how CoPs truly form. This leads to the second primary research question: *How do knowledge sharing connections form within distributed communities of practice in project based organizations?* Finally, due to the environmental changes undergone by CoPs, as well as the new mechanisms by which they form, we do not know how CoPs serve the companies that host them. More specifically, if we see firms as institutions for coordinating specialist knowledge, we do not know how CoPs contribute to this basic function. We address this gap in our third research question: *How do communities of practice coordinate specialist knowledge in project based organizations?*

DISSERTATION SUMMARY

The first step in this research is to explore the effects of organizational structures and geographic distribution on patterns of knowledge sharing in each CoP. Within the current literature, there is significant criticism regarding the global distribution of CoPs (Lindkvist 2005; Roberts 2006), and the degree to which CoPs are influenced by organizational structures (Thompson 2005; Wenger et al. 2002). Although there is some disagreement as to the precise definition of CoPs, experts generally agree that inter-personal knowledge sharing is the primary activity that CoPs facilitate (Brown and Duguid 1991; Lave and Wenger 1991; Roberts 2006; Thompson 2005; Wenger 2011). The primary objection to global dispersion and organizational influence is that both destroy the close knit community characteristic of CoPs that was originally described by Lave and Wenger (1991). So then, to evaluate the role of CoPs in managing knowledge within the organization, we must understand how patterns of knowledge sharing connections are affected by organizational or geographical boundaries. This leads to the first gap in literature, and subsequent research question:

Gap 1: *We do not know how informal knowledge sharing networks that comprise CoPs are affected by organizational or geographic boundaries.*

Research question 1: *What are the effects of geographic dispersion and organizational divisions on communities of practice in project-based organizations?*

In part, we do not know how geographic dispersion and organizational divisions affect CoPs because knowledge sharing cannot be directly observed in global networks. For this reason, it is necessary to first visualize the informal knowledge sharing networks that comprised each CoP using social network analysis. Prior work has shown the value of social network analysis in revealing relationships that were previously hidden (Moreno 1960), and examining relationships within and between groups (White et al. 1976). We first identify the informal knowledge sharing networks of each CoP. We then analyze whether two organizational boundaries—business units and disciplinary groups—limit the formal structures of the organization. The results of this study are presented in Chapter 2. We discovered that organizational boundaries do limit knowledge sharing, but that this effect is not consistent across multiple CoPs. Rather, knowledge sharing is limited between organizational groups when management encourages distinct divisions through different profit centers, competition, and other divisive techniques.

Given the dispersion of engineering and construction firms, we then examined knowledge sharing connections between cultural and geographic groups defined by country. The results of this analysis are presented in Chapter 3. Results indicate that there are far more connections within cultural and geographic groups than between them, which is consistent across all CoPs studied. This means that CoPs tend to be both geographically and culturally fragmented in their ability to share knowledge. Although geographical and cultural fragmentation is the dominating trend, there are a number of exceptions in which to specific geographies or cultures would be strongly connected. The second half of Chapter 3 identifies these exceptions, and determines that managerial intervention can effectively remedy structural fragmentation. This finding indicates that direct management of CoPs can have a profound influence on the structure of informal knowledge sharing networks, and led to the next gap in literature and resulting research question.

While prior work has examined individuals' motivations (Javernick-Will 2012; Wasko and Faraj 2005), and thought process for seeking knowledge (Borgatti and Cross 2003), we do not know the mechanisms that initiate knowledge sharing connections within CoPs. Javernick-Will (2011) explores why inter-regional knowledge sharing connections form in multinational CoPs, and identifies "project-based reasons" and "familiarity-based reasons" as two primary drivers of connection. To build a greater understanding of CoPs as a whole, it is necessary to expand this exploration beyond inter-regional knowledge sharing connections, and to explore how knowledge sharing connections form across the entire CoP. Furthermore, CoPs as they are applied in business practice are significantly different from the localized groups of professionals that they originally described (Brown and Duguid 1991; Lave and Wenger 1991). Scholars doubt that the scope and spatial distribution of modern CoPs are able to provide the community atmosphere that is part of their core definition (Kimble and Hildreth 2004; Lindkvist 2005; Roberts 2006). While we do know that CoPs can be leveraged to facilitate knowledge sharing (Saint-Onge and Wallace 2012), we don't know whether social mechanisms, or management initiate connection between professionals within CoPs (Thompson 2005). This leads to the second research question:

> ***Gap 2:*** *We do not know how knowledge sharing connections are formed within CoPs as applied in business practice.*

Research Question 2: *How do knowledge sharing connections form within distributed communities of practice in project based organizations?*

Chapter 4 answers this research question using the data from the initial social network survey, and then semi-structured phone interviews. We began by selecting a representative portion of the population of each CoP to participate in qualitative interviews. Participants were asked to describe how they became connected to other professionals, allowing us to create an emergent framework describing the different mechanisms of connection within the CoPs. We find that knowledge sharing connections form through a variety of social and organizational mechanisms including: organizational control, organizational opportunity, social networks, and non-person centered searching. The primary takeaway of Chapter 4 is that CoPs are both socially and organizationally created entities, where each mechanism serves a distinct, yet important, role in the formation of robust social networks.

Chapter 5 moves beyond the mechanisms of connection to address a distinct lack of theory explaining the role of CoPs as an environment for coordinating specialist knowledge. While there is an abundance of literature written for managers outlining how to create CoPs, and the benefits that they produce (Saint-Onge and Wallace 2012; Wenger et al. 2002), there is very little theory describing CoPs from an organizational perspective. More specifically, we do not know if there are specific advantages to using CoPs as a form of organization for the purpose of coordinating knowledge. Although the theoretical origins of CoPs are from organizational learning (Brown and Duguid 1991) and cognitive learning (Lave and Wenger 1991) literature, the application of CoPs as a knowledge management tool requires a theoretical orientation of organizations as institutions for coordinating specialist knowledge (Grant 1996), which has yet to be produced. This leads to our final research question:

Gap 3: *There is a dearth of theory regarding the role of communities of practice to coordinate specialist knowledge within the firm*

Research Question 3: *How do communities of practice coordinate specialist knowledge in project based organizations?*

To answer this final question, Chapter 5 presents a qualitative study that uses data from interviews with CoP members. Within this chapter, we explore the different types of coordination facilitated within the CoP, and how the type of coordination varies depending on the degree of overlap of participants' knowledge bases. From this framework, the diversity of coordinative activities indicates that knowledge coordination between specialists is necessarily individualized. Furthermore, our framework reveals that coordination activities are dependent on the degree of overlap or "common knowledge" possessed by CoP members. From these conclusions, we discuss how CoPs are a supplement to the bureaucratic hierarchy of the organization that partially overcomes the bounded rationality of managers by increasing member's ability to choose knowledge sharing connections that suit their needs. At the same time, CoPs increase the efficiency of locating relevant knowledge resources by intentionally limiting group membership to relevant knowledge bases.

To summarize, this dissertation investigates CoPs as they are applied in construction and engineering organizations to determine their role in managing knowledge. We do so by first examining how organizational (Chapter 2) and geographic (Chapter 3) boundaries impact the capacity of the knowledge sharing networks that comprise CoPs, then investigating how knowledge sharing connections form within CoPs (Chapter 4), and finally through exploring the role of CoPs in coordinating specialist knowledge (Chapter 5). Taken together, these four chapters create a holistic picture of CoPs as they are currently applied in construction and engineering organizations, as well as the theoretical purpose behind CoPs as a tool for knowledge management.

METHOD OVERVIEW

To research these questions, we use a mixed-method approach to study three multinational CoPs in two construction and engineering organizations. To accomplish this task, we employ two methods of collecting data (social network surveys and interviews), and two methods to analyze data (social network analysis and qualitative coding). There are several reasons for this approach. First, we choose a study site where we can evaluate CoPs in a business application. This allows us to make claims as to the actual use of CoPs, and to build theory that describes the current state of practice. Secondly, a mixed methods approach provides complementary methodologies that synergistically strengthen one another through quantitatively mapping knowledge sharing that was previously invisible, then qualitatively describing how different patterns may have emerged. As an added benefit, the quantitative network visualization and analysis is used as input to select interview participants according to both demographic and network criteria, which greatly increases the value of our findings. Furthermore, the complex and varied nature of the networks requires us to use quantitative and qualitative data in tandem to provide rich, contextually based analysis. In many cases, quantitative data from the social network surveys is used to validate qualitative constructs, and qualitative data is used to validate quantitative data collection and trends.

Research Context

As a first step in this research, three CoPs were selected from two multinational construction and engineering organizations. Because CoPs are known by many different names within organizations, knowledge communities, technical networks, practice networks, etc., the CoPs were selected with input from managers who identified communities that were comprised of *"individuals making a collaborative effort to improve their practice"* (Saint-Onge and Wallace 2012 p. 33). Further criteria required that the CoPs were self governed, had formal membership lists, were globally distributed, spanned multiple business lines, and existed for the purpose of facilitating knowledge exchange among the members. Furthermore, the CoPs all received sponsorship from the organization in terms of an online platform to facilitate collaboration. The names of participating companies have been redacted to protect their privacy, so the pseudonyms Company A and Company B will be used. The CoPs studied are listed below.

Process Improvement CoP

Within Company A, there are a group of professionals that work as internal consultants to improve the processes used during design and construction. In addition to those serving as active consultants, approximately 50% of the CoP members have been reassigned to full time project work. These professionals are globally distributed, and have a presence in all of the different business lines and disciplinary groups within the company. Members are deployed to work on projects to improve adherence to cost, quality, and budget, and can work on a project for short periods of time, or for the duration. Members of the CoP have all gone through a process improvement certification process, where they are taken from their original job role to be educated, then after several years are reassigned out of the process improvement program. Thus, the members are embedded within project work, yet have in common their process improvement training, and the goal of improving processes within the organization. Linking these members is an online collaborative platform that provides information on other process improvement professionals throughout the world, a forum for posting technical questions, and a document repository for project reports. In total, there are 273 members in the Process Improvement CoP that are distributed across 16 countries.

Transportation CoP

The Transportation CoP is hosted within Company B, and is bounded in terms of employees working on transportation projects. Although it is not limited to a particular business unit, the Transportation CoP loosely adheres to transportation business unit within Company B. For this reason, it is excluded from the organizational boundaries analysis performed in Chapter 2. Membership to the CoP is voluntary, and consists of signing up for a virtual group on a SharePoint site. Due to the broadly defined and open membership, the Transportation CoP includes professionals from a wide variety of disciplinary groups ranging from pavement design to economics. The sharepoint site is equipped with an enterprise level search tool that allows members to search through an extensive document repository as well as other professionals' resumes. Furthermore, there are forums for posting questions, events, or best practices, and additional collaborative tools such as a chat function. The Transportation CoP boasts 365 members distributed across 10 countries, although the majority of that population is concentrated in North America.

CAD CoP

As the largest of the three, the CAD CoP is also hosted within Company B, and consists of professionals working on computer aided design (CAD). This includes a wide variety of software including Autodesk products, Revit, ArcGIS, and Microstation products. While many of the CoP members work directly with drafting software, some members manage drafters, and still others provide support through programming and design of CAD systems and standards. Furthermore, drafters and managers specialize to work within particular business lines, even when they use the same software. For instance, one drafter using Autodesk may specialize in water projects, while another would primarily draw roadways. Therefore, the CAD CoP is inter-disciplinary and spans all of the major business units within the company. The CAD CoP has access to the same online resources as the Transportation CoP, although they have a distinct group site on that platform. As mentioned previously, this includes a search feature, forums, profile directory, and document repository. The CAD CoP is the largest of the three CoPs with 1153 members spanning across 19 different countries.

Data Collection: Social Network Surveys

To begin, social network surveys were deployed to each CoP. Participating companies provided us with complete membership lists of the CoPs being studied, as well as basic data regarding employees' geographic locations, business unit affiliations, and disciplinary groups. Questions in these surveys have three distinct purposes. First, we asked individuals about their knowledge sharing preferences and demographic information. This portion of the survey exclusively gathers data that is specific to individuals. Next, we asked each participant with whom (in the CoP) they have exchanged knowledge with on job related practices in the past 6 months to identify informal knowledge sharing networks within the organization. Finally, we asked participants to provide data on characteristics of each reported connection such as the frequency of interaction. The result is a robust data set with a wide variety of individual and relational measures.

Data Analysis: Social Network Analysis

The data was then input into quantitative social network analysis software, NetMiner 4, to sort and clean the data, and produce basic network visualizations. When necessary, a second social network analysis software, UCINet (Borgatti et al. 2002), was used for analysis that was not available in NetMiner 4. Ultimately, we developed a new tool for analyzing social networks relative to boundary conditions, which was written in C++ specifically for this study. This tool allowed us to simulate the number of relationships occurring within and between groups in the informal knowledge sharing networks, where groups could be defined as business units, geographies etc. The resulting networks were used to analyze the effects of boundary conditions on the informal knowledge sharing networks, and to select potential interviewees.

Data Collection: Interviews

Interview participants were selected to represent a broad array of different perspectives using a stratified quota sampling technique. Using the networks generated from the survey, CoP members were sorted according to the number of connections that they had with others (degree), their classification by geographic location, business unit, functional discipline, generation, and grade level. We initially selected all individuals with unusually high in-degrees in the network. For each network there was a natural break after 5-10 people. These highly connected individuals usually have insights on the network organization because of their centralized positions. Next, equal numbers of participants were chosen who had average and low degrees in the network. Within each of these categories, we iterated across other demographic classifications to obtain balanced representation of the largest business units, disciplines, generations, and grade levels. Next, 5-10 individuals were selected based on their specific network roles, whether they spanned a certain boundary, served as a broker for several different groups, or were periphery members. Once again, these individuals are targeted specifically because they hold positions that may give them a different perspective on knowledge sharing in the network. In the end, approximately 5-10% of the CoP members were selected to participate in interviews, including individuals from each demographic group in both central and periphery network positions, with an over-sampling of individuals in rare network positions.

For each interview we created a customized interview guide using data from the social network survey. Participants were asked a series of semi-structured questions about specific knowledge sharing connections that they maintain, as well as the influence of particular boundaries on those connections. This format allows participants to conceptualize network questions in terms of actual connections that occur in their localized context, while simultaneously allowing the researchers to ask questions that pertain to greater network trends.

Data Analysis: Qualitative coding

Each interview was recorded, transcribed, and entered into qualitative analysis software called QSR NVivo®. NVivo provides a platform in which multiple researchers can manage and query data in a process called coding (Bazeley 2007). NVivo was selected as a tool to help us discover emergent concepts in the interview data through an iterative coding process. As more interviews were coded in the first community, the researchers allowed the new data to influence the existing conceptual codes. Throughout this process, we maintained close contact with CoP leaders to root our ideas in practice and increase external validity.

Data Analysis: Mixed methods validation

In Chapters 2 and 3, qualitative data from the interviews are used in tandem with quantitative network data to create a holistic picture of each CoP, and to build theory regarding global knowledge sharing communities of practice. Although Chapters 4 and 5 exclusively use qualitative data for their analysis, the quantitative portions of the study were used for interview selection, and served an important role to ensure construct validity. Ultimately, the quantitative portions of the study are heavily used to generate theory regarding distributed CoPs in project based organizations. Because of its complexity, the mixed methods process that we followed is summarized in Figure 1-1. We began with social network surveys, and then used that data to visualize and analyze informal knowledge sharing networks. The analysis, visualizations, and direct data (e.g. demographics), were then used to select interviewees during the qualitative portion of the study. After interviewees were selected and the interviews were performed, we analyzed the qualitative data, and then used both the social network analysis and qualitative analysis to generate theory regarding multinational CoPs. As an external validation, we remained in discussion with CoP leaders to validate our theory and our findings.

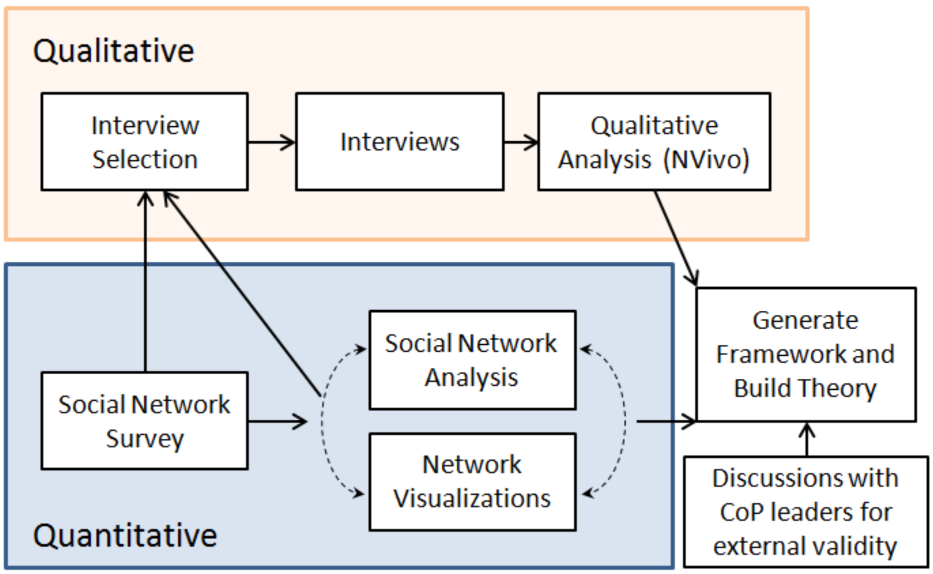

Figure 1-1: Research Method Overview

DISSERTATION FORMAT

This dissertation follows a journal article format, so that Chapters 2, 3, 4, and 5 are written as full length, stand alone journal articles. Each chapter has its own list of references, which are compiled into a complete list presented at the end of this work. Furthermore, the introductions to each chapter, though different, may repeat aspects of the theoretical basis of this work, and the methods sections detail similar analysis. More specifically, Chapters 2 and 3 will have similar methods sections, and Chapters 4 and 5 will have similar methods sections. Finally, this dissertation includes extensive appendices that further elucidate methods of data collection and analysis, validity checks, and many other resources to ease the effort required to repeat or build upon this work.

Chapter 2 has been submitted to the Engineering Project Organizations Journal, and is currently under review, while Chapters 3, 4, and 5 are currently being revised for submission. Currently, we plan to submit Chapter 3 to the ASCE Journal of Construction Engineering and Management, Chapter 4 to the Journal of Knowledge Management, and Chapter 5 to the Academy of Management Journal.

To more clearly outline each section in this proposal, the identified gaps, research questions, methods and selected contributions from each chapter are outlined in Table 1-2 below.

Table 1-1 – Summary of Dissertation Chapters

Practical Problem		Gaps in Literature	Research Questions	Methods	Selected Contributions
Deviation between CoPs in Theory and practice	Chapter 2	Lack understanding of organizational boundaries within CoPs	What are the effects of geographic dispersion and organizational divisions on communities of practice?	Social network surveys, SNA	• Organizational environments can limit knowledge flows
	Chapter 3	Lack understanding of geographic boundaries within CoPs		Social network surveys, SNA, qual. coding	• Geog. And cultural silos • Silos disrupted through org. control
	Chapter 4	Lack understanding of mechanisms that form knowledge sharing connections in CoPs	How do knowledge sharing connections form in CoPs?	Social network surveys, semi-structured interviews, qual. coding, analysis	• 5 mechanisms of connection • CoPs as hybrid social/org. structures
	Chapter 5	Lack understanding of role of CoPs using organizational theory	What is the role of CoPs in coordinating expert knowledge?	Social network surveys, semi-structured interviews, qual. coding, analysis	• Coordination based on overlap in knowledge base • CoPs increase agency and search efficiency

The table above describes a body of work that cohesively addresses CoPs in current business practice, and creates new theory to explain the role of CoPs in managing knowledge within project based organizations. To do so, Chapter 2 examines the effects of organizational environments on CoPs, finding that organizational boundaries can powerfully fragment knowledge sharing. Next, Chapter 3 studies the multi-national environment that hosts CoPs, finding that geographic and cultural boundaries tend to fragment knowledge sharing, but that silos can be overcome by targeted management strategies. Taken together, these first two chapters describe the practical environment in which CoPs operate, and its fragmenting effects on knowledge sharing. Next, Chapter 4 investigates the mechanisms by which knowledge sharing connections form in CoPs, to determine the relative influence of social and organizational forces on informal networks. The resulting contribution of this study is a perspective of CoPs as both socially and organizationally created. Finally, Chapter 5 examines the types of coordination facilitated within CoPs, and creates a knowledge based theory to explain the role of CoPs within project based organizations. In total, these four chapters provide a realistic view of CoPs as they are applied in business practice, and generate theory to explain the role and proliferation of CoPs in project based organizations.

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Chapter 2: The Effects of Organizational Divisions on Knowledge Sharing Networks in Multi-lateral Communities of Practice

ABSTRACT

Knowledge is a fundamental resource for project based organizations, and it resides within individual employees. By dividing employees according to their abilities, job roles, and areas of expertise (e.g., business units, functional disciplines), managers create groups within the organization without seeing the impact on underlying knowledge flows. Knowledge sharing across business units and disciplinary groups can produce immense benefit, yet anecdotal evidence suggests that these groups produce "silos" that limit connection between people across the organization. Although communities of practice (CoP) have recently emerged as a mechanism to encourage practice based knowledge sharing across organizational silos, it is not clear if the influence of business units and disciplinary groups has a similar effect on knowledge sharing within CoPs. There are few studies that quantitatively assess the impact of organizational structures on informal knowledge sharing networks. To clarify this anecdotal evidence, this study analyzes more than 1600 knowledge sharing connections in two CoPs to determine whether informal knowledge sharing networks are constrained by business units and disciplinary groups. Results show that in the first CoP, knowledge sharing connections were constrained by business units, with few connections existing between business units. In the second CoP, knowledge-sharing connections were constrained by disciplinary groups. In our discussion of these findings, we evaluate the applicability of the term "community of practice" to manager initiated knowledge sharing groups, and discuss how formal structures created by management produce differential opportunities to connect that influence network structure within CoPs.

INTRODUCTION

Knowledge management is one of many complex problems facing multinational construction and engineering organizations as they seek to design and build projects. As many firms have realized, the collective knowledge of their employees is a strategic resource of equal value to financial capital (Grant 1996), and the key to capturing this value is the social networks that serve as a conduit for knowledge

(Chinowsky et al. 2009). Traditionally, organizations manage employees, in part, by creating structures to group employees by industry (e.g., business units) and discipline. Both of these groupings are *epistemological* in nature, meaning that they delineate different domains of knowledge. Unfortunately, group membership in these structures can rapidly become a boundary that restricts knowledge flows within the company, isolating expertise to a particular industry or disciplinary setting. Restricted knowledge flows, also known as "silos," lead to conditions in which construction companies repeat mistakes across projects, fail to learn from innovation occurring elsewhere in the company, and dedicate resources to solving problems which have already been addressed within the organization (Javernick-Will and Hartmann 2011). In other words, silos are a "suboptimal organizational construct" that can limit the productivity and quality of projects (Yuventi et al. 2013).

Over the past several decades, communities of practice (CoPs) have emerged as a potential solution to this problem. CoPs originated as close knit groups that emerge through the social interaction of everyday activity (Lave and Wenger 1991). More recently, literature has suggested that these organically emergent groups can be cultivated and grown to include many different subgroups (Wenger et al. 2002). In line with this trend, project based organizations frequently initiate communities of practice (CoPs) for the express purpose of sharing knowledge throughout the company. Manville and Foote (1996) provided a succinct definition of a community of practice as:

> *'a group of professionals informally bound to one another through exposure to a common class of problems, common pursuit of solutions, and thereby themselves embodying a store of knowledge'* (Manville and Foote 1996).

The impact of CoPs can be enormous within project based organizations. When professionals are united across the company in terms of common problems that they face, each project execution becomes an opportunity to apply the best of what the company knows to the project at hand. Because these companies perform projects in diverse markets, this learning process can provide a competitive advantage if knowledge is exchanged between various projects and knowledge bases (Amy Javernick-Will and Levitt 2009; Javernick-Will and Scott 2010; Kogut and Zander 2003). Although each project, industry, and discipline is unique, there are common processes, lessons learned, and project management expertise that apply across multiple business lines and disciplines. CoPs bring together knowledge workers in such a way that they are able to share their experiences and lessons learned with others who face similar problems, thereby working, learning, and innovating as part of a global community of practitioners (Brown and Duguid 1991).

In practice however, managerial trends have shied away from cultivating existing CoPs in favor of a higher degree of control. Rather than trust that CoPs will emerge that are serendipitously aligned with the goals of the organization, managers wish to strategically leverage knowledge sharing to generate value (Saint-Onge and Wallace 2012). Thus, many managers create large CoPs with a membership that spans multiple disciplines and business units, in the hope that socially based knowledge sharing will organically occur, thereby creating consistency of practice and generating innovation across these formal organizational groups (Wenger et al. 2002). Because these CoPs span multiple dimensions of different knowledge, (i.e. business units and disciplinary groups), we refer to them as *multi-lateral.* Within CoPs, employees can connect with one another regardless of formal organizational groups or reporting structures, and therefore have the freedom to meet their individual knowledge sharing needs. The topical focus unites business units and disciplinary groups by channeling discussion towards common problems and solutions, rather than contextual differences. In the past few decades, CoPs with this goal have become commonplace in project based organizations trying to increase knowledge sharing.

Creating and launching CoPs is common, although it is a significant deviation from the original “emergent” model of CoPs that has been proposed by many theorists (Brown and Duguid 1991; Kimble and Hildreth 2004; Lave and Wenger 1991; Lindkvist 2005; Roberts 2006; Wenger and Snyder 2000; Wenger et al. 2002). This has led to broad criticism regarding the application of the term “community of practice” to knowledge sharing groups initiated by managers (Amin and Roberts 2008), and skepticism that these loosely bound groups would operate independently from the existing structures of the organization (Roberts 2006). At the same time, most of this criticism has relied on theoretical arguments, due to a lack of empirical network data. Fundamentally, the effects of formal business units and disciplinary groups on knowledge sharing networks within manager initiated CoPs are unknown.

POINT OF DEPARTURE

The purpose of this research is therefore to determine whether business units and functional disciplines constrain knowledge flows within knowledge sharing networks in global CoPs. Because knowledge is intangible, it is difficult to monitor and track (Liebeskind 1996), so that informal networks consisting of relational connections between employees are largely invisible. Thus, we seek to answer the question: *To what degree do business unit and functional discipline boundaries fragment informal knowledge sharing networks within multi-lateral communities of practice?*

To fill this gap, we empirically investigate knowledge sharing connections between organizational groups in two multi-lateral CoPs. Specifically, we analyze whether organizationally imposed business units and disciplinary groups create silos in informal knowledge sharing networks. We employ a social network approach to observe, analyze, simulate, and visualize knowledge sharing network structures. Using statistical re-sampling, we quantitatively determine the degree to which individual business units and disciplinary groups limit knowledge sharing networks within multi-lateral CoPs. Ultimately, we wish determine if manager initiated CoPs are able to span existing organizational groups, or if business units and functional disciplines inherently limit knowledge flows within their domains.

Business Units

While the title, (e.g., business units, business lines) and scope (e.g., type of contract/client, sector of project) varies from company to company, nearly all construction and engineering companies group employees according to project type or economic sector. Business units are knowledge based divisions with distinct sources of knowledge and expertise. From this idea, previous work has found that business units with central network positions (and thus more access to different knowledge bases) perform better. Similarly, other studies found that creativity and innovation are fostered when knowledge is shared, or recombined, between business units (Hargadon and Sutton 1997; Leonard-Barton 1995; Tatum 1989). This work theorizes that new ideas and more rapid improvement would result from increased knowledge sharing between business units.

While inter-business unit knowledge exchange can lead to new ideas, the distinct knowledge bases can create communication problems and thus, is seen as a simultaneous source and barrier to innovation (Carlile 2002). Perhaps the greatest danger of poor knowledge flows between business units is that each business may be trying to solve similar problems, and are dedicating resources to problems that have already been solved within the organization (Carrillo and Chinowsky 2006).

In sum, classifying employees into different business units helps delineate what employees know by specifying the type of project they typically work on. Business units represent differing knowledge bases that can share knowledge of specific project types. However, this organizational classification may also cause business units to become siloed from one another, and thus, not gain the benefits from knowledge exchange across the organization.

Disciplines

In addition to business units, many multinational project-based organizations group employees by specialty or function to differentiate, for example, between civil and electrical engineers. These divisions group together people with similar expertise to form knowledge bases within the firm. Past studies have found that each disciplinary group has a different perspective (Boland and Tenkasi 1995), and that the interpretive schemes that people use in the workplace are determined heavily by their functional or departmental 'thought worlds' (Dougherty 1992). In the construction literature, this sentiment is echoed as research claims that different disciplines develop their own language consisting of the use and understanding of specialized terminology (Fong et al. 2007).

Consistent with prior research on different knowledge bases, heterogeneity in disciplinary perspectives can easily lead to communication barriers (Bechky 2003), and failures of interpretation due to a lack of mutual understanding (Catherine Durnell Cramton 2001). In fact, most studies explicitly frame inter-disciplinary knowledge exchange as difficult because each discipline has a unique knowledge base. Communication between disciplines can therefore pose a "translation" issue. At the same time, there can be individual and project level benefits to inter-disciplinary knowledge sharing (Cross and Cummings 2004; Cummings 2004), and crossing disciplinary boundaries can lead to the production of new knowledge through novel re-combination of existing ideas (Alin et al. 2011).

Similar to business units, disciplinary divisions clearly represent distinct knowledge bases that help the company organize. While sharing between different disciplinary knowledge bases is difficult, it can also add value and productivity for a firm.

RESEARCH APPROACH

Research Setting

To conduct this research, we selected two CoPs within two different multinational construction and engineering companies. Within each of these CoPs, knowledge sharing between organizational divisions was not inhibited in any way; rather all members were on equal standing to help solve problems.

Although there is significant debate surrounding the applicability of the term "communities of practice" to manager initiated groups, the CoPs selected for this study fit several criterion that are consistent with prior management theory. Because this study is focused on the business practice of using CoPs as a mechanism to manage knowledge, we draw from the practice based model of CoPs provided by Wenger et al. (2002). By this model, CoPs are structures that have three elements; a domain of knowledge, a community of people, and a shared practice that is being developed. First, each CoP has an established domain of knowledge established through a topical boundary. The members of each CoP are engaged in knowledge intensive work, and belong to the CoP because they have an interest in the expressed topic (domain) of the CoP. Because they face a common class of problem (such as applying CAD to projects), they are not so different that there are problems with "translation" between two completely different fields of work (Bechky 2003). Membership to these CoPs is controlled by a subscription list, but participation in the CoP is voluntary, and therefore indicates an interest in the knowledge domain. Because this membership is clearly defined, we were also able to select communities whose membership spanned both business units and functional disciplines, providing the diversity required to analyze organizational divisions within the same CoP. Second, both CoPs must have an element of *community,* which is difficult to define. Both are driven by volunteerism, and are more "loosely connected, informal, and self managed" (Wenger et al. 2002 p. 41) than business units and functional disciplines. Each has a membership that actively participates in the CoP on some level. Prior to the study, this was evaluated on the basis of visible participation in an electronic platform, however the social network design of this study means that we partially evaluate the degree to which members "interact regularly on issues important to their domain" (Wenger et al. 2002 p. 34). As an additional note, CoPs are not limited in size as long as it provides the opportunity to learn while embedded within a social context (Brown and Duguid 1991; Lave and Wenger 1991), maintains a specific and defined knowledge base which constitutes a "common class of problems" (Manville and Foote 1996), and elicits participation from its members. This means the networks can be large enough to display significant trends to determine whether organizational divisions constrain informal networks. Finally, each CoP has an established *practice,* which includes the socially acceptable ways of doing things, common approaches, shared understandings, and resources that provide a basis for action. The practice of each CoP is captured in both concrete and explicit documents, as well as less tangible behaviors and perceptions.

The two CoPs selected for this study each have a domain, demonstrated elements of community, and a set of documents and behaviors that can be considered a practice. Because the CoPs are housed in two different companies, each one has different terminology for classifying business units, and disciplines although the fundamental concepts are the same. These CoPs are discussed more in depth below. Throughout this paper, business units and disciplines are referred to as divisions, while the specific units, disciplines, and levels (i.e. Water Resources Engineering, Contracts, etc.) are referred to as groups. In some cases, we do not have group data for all employees, forcing us to exclude individuals from the networks. In these cases, the reduced number of network participants is reported in parenthesis.

Process Improvement CoP – Company A consists of more than 50,000 employees in more than 40 different countries. The company has grown organically through a long history of construction megaprojects, and is divided into five distinct markets, each of which forms a formally defined business unit. Although each business unit is run as a separate profit center, management wants knowledge to flow across the entire company, as evidenced by employee mobility to different business lines, and several multi-lateral CoPs. Within this context, the Process Improvement CoP is a group of 273 process improvement professionals acting as internal consultants for individual projects. Of the 273 members, we were able to capture grade level data for 271 (99%). There were no missing data in regards to business units in the Process Improvement CoP, and 96% of the 273 members are represented in 5 business units: Government services (29%), Power (25%), Oil Gas & Chemical (17%), Civil (15%), and Mining & Metals (11%). Within the Process Improvement CoP, 20 different disciplines are represented, although 83% of the 273 members are captured in 8 disciplinary groups. These include Engineering (28%), Project Controls (16%), Field Supervision (15%), Field Engineering (9%), Project Management (8%), Procurement (7%), Quality Assurance (5%), and Contracts (4%).

> *Domain:* Employees in the Process Improvement CoP were individually selected and trained in Six Sigma. Thus the topical knowledge domain is focused around using Six Sigma methodologies to improve processes on projects.
>
> *Community:* The membership list of the PI CoP is defined through training certification. Individuals seek nominations into the program where they are trained together, often forming tight social bonds. Although membership comes from a formalized training process, the Process Improvement CoP is still driven by volunteerism because employees are not required to participate in the knowledge sharing activities which define the CoP. During training, individuals are introduced to a number of knowledge sharing tools by which they can connect with one another and read about completed process improvement projects. Using these tools, CoP members can choose to share best practices, success stories, and project ideas that could potentially be used in other areas of the company. After training, members participate in community through an electronic platform (formal knowledge management system), face to face

meetings, informal interactions, common task assignments, ongoing training (top down), and community awards (formal benchmarking). The complex array of interactions within the PI CoP therefore contains elements of self organizing, technocratic, and best practice systems (Kasper et al. 2013).

Practice: Members are constantly developing new tools, reviewing past process improvement projects, and working to determine their role in the organization. The practice is therefore focused on using an established set of methodologies, behaviors, and worldviews to perform process improvement work.

Computer-Aided Design (CAD) CoP – Company B consists of more than 40,000 people in 150 countries. The company has grown rapidly through aggressive acquisitions, and currently has operations in numerous business sectors (i.e. energy, transportation, etc.) and functional areas (i.e. consulting, planning etc.). The CAD community exists within Company B as a collection of 1152 CAD draftspersons, engineers, and managers. The CAD CoP spans 10 different business units, 6 of which capture 90% of the 1152 employee population. These business units include Transportation (33%), Water (18%), Building Engineering (16%), Planning Design & Development (16%), Environment (4%), and Minerals &Industry (3%). Company B did not have a formal record of employees' functional disciplines, although they do have more formalized functional groups, so the question was included in the survey and is therefore subject to response rates. Because of this we only captured disciplinary data for 489 (42%) members of the CAD population, where there are 20 different disciplinary groups represented. Of these, 8 disciplinary groups capture 82% of the known disciplinary classifications. These 8 are Civil Engineering (20%), Structural Infrastructure (15%), Transportation Engineering (11%), MEP Disciplines (11%), Architecture (10%), Water Resources Engineering (6%), Drafting (5%), and Electrical Engineering (5%).

Domain: The CAD CoP was chartered to bring together employees concerned with the use of computer aided design software. This includes managers, drafters, technicians, and support personnel using AutoDesk products, Microstation products, Revitt, and BIM software.

Community: The basis for the CoP is an online knowledge sharing platform that allows members to freely join and share problems that they are working on. Using this platform, CoP members exchange global CAD practices and standards, share templates, and discuss CAD issues. Interactions are not limited to the online platform however; members interact locally with other CAD workers, share project tasks, and occasionally travel for work rotations, collaborative projects, conferences, and trainings. In contrast to the PI CoP, the CAD CoP is primarily facilitated through bottom up informal personal networks and the online sharepoint system. There is however a global CAD council that facilitates personal exchanges between top managers. Thus the CAD CoP facilitates exchange through self organizing as well as technocratic systems, but lacks the formal benchmarking that characterizes best practice knowledge management (Kasper et al. 2013).

Practice: The CAD CoP has a strong body of practice around drafting and modeling that includes specific tools, with their requisite struggles and intricacies, as well as a particular role within the company. CAD workers understand themselves as undervalued, behind the scenes workers whose skills and tools are rapidly coming to the forefront of design and construction. As a result, their practice is very focused on technological progression, advancement of technical skill, and a rapidly changing work environment.

Data Collection

A social network perspective is an excellent platform to examine the interaction of formal organizational structures and informal relationships between members of the organization (Paul Chinowsky and Taylor 2012). To assess the degree to which formal organizational divisions constrain informal knowledge sharing networks, we used social network analysis (SNA), which enables us to graphically portray network relationships (Moreno 1960). SNA is particularly useful for examining patterns of relationships, and can be used in such a way that network structures are evaluated by the number of connections within and between differently sized groups (White et al. 1976). Social network methods are a relatively new approach to research in project based organizations, although they have been gaining popularity in recent years because of their ability to describe underlying relationships (Paul Chinowsky and Taylor 2012). Furthermore, by assuming *knowledge sharing connections* as the unit of analysis instead of discreet exchanges, this study adheres to a view of knowledge as socially constructed, rather than an object for exchange (Noorderhaven and Harzing 2009).

For this reason, we use a social network survey methodology to capture knowledge sharing connections between employees in a defined community. Social network surveys include person-centered questions, which capture individual demographic attributes such as level of education or prior geographic work locations, a network identification question, and network questions regarding characteristics of connections, also known as dyads. Because of our specific interest in knowledge sharing connections, the network identification question asked participants *"with whom have you exchanged knowledge on job related practices in the past 6 months?"* We further specified the type of exchange as CoP specific knowledge which includes *"any practice-oriented knowledge that is required for you (or those with whom you interact) to perform job related tasks. 'Practices' can be project related or organization related."* Participants were allowed to select their knowledge sharing connections from a pre-defined list of all other identified CoP members. At this point, it is important to clarify the definition of knowledge used in this study. Because we focus on *knowledge sharing connections* rather than discreet interactions, we are capturing social patterns of interaction that are focused on job related tasks. For the sake of data collection, "knowledge exchange" is portrayed as an activity where an objective commodity is exchanged (knowledge). This reduces the need to explain to study participants the theoretical nuances of defining knowledge, while simultaneously capturing the *practice* of interacting with others surrounding a particular knowledge domain. Due to the inherent limitations of surveys in creating clear constructs, we followed up with 5-10% of the CoP population using phone interviews, and validated a sample of knowledge sharing connections from the survey. For the validated connections, we identified that discreet interactions within a given relationship are sharing knowledge, rather than information or data (Alavi and Leidner 2001), and that the relationship constituted ongoing social interaction. Overall, 93% of the connections from the survey were validated, providing a high degree of confidence in our knowledge sharing connection construct.

As noted above, we obtained business unit data for all community members from each respective HR department. Data for functional disciplines were obtained from HR for the Process Improvement CoP, but had to be included as a survey question in the CAD CoP due to limitations in the HR dataset. The disciplinary responses were then grouped by community managers into disciplinary categories that reflected cohesive groups within the CoP.

Several days before deploying each survey, the community leaders sent an email to CoP members inviting them to participate in the survey and giving them instructions on how to use the NetworkGenie online survey interface. During survey deployment, each employee in the CoP received a personalized email with a unique login ID and password to complete the survey. Surveys were left open for 4-6 weeks to increase response rates, during which community members were sent several reminder emails. When the survey was closed, 100 people responded within the Process Improvement CoP, representing a 36.6% response rate and 483 people responded to the CAD CoP, representing a 41.9% response rate.

Network Assessment and Silos

Using NetMiner, a social network analysis software, we created blockmodels based upon the organizational divisions for each CoP. A blockmodel is a square matrix that displays the number of connections within and between different groups (White et al. 1976). In a blockmodel, the rows and columns are group names, and each cell in the matrix represents a specific relationship. For instance, when the Process Improvement CoP was sorted by business unit, the row and column headers would display the names of each business unit. Within the cells, the number of knowledge sharing connections between two groups (i.e. Civil Business Unit to Water business unit) are counted and tallied in the appropriate cell. As a result, the diagonals represent connections that occur within each business unit, while the other cells represent relationships between business units. As an example, Table 2-1 displays a block model for the Process Improvement CoP organized according to business units. In the first column, there are 61 knowledge sharing connections between employees in the Government Services business unit, but only 4 connections going from the Civil business unit to Government Services.

Table 2-1 - Blockmodel of Process Improvement CoP by Business Unit

	Gov. Service	Civil	M&M	OG&C	Power
Gov. Service	61	1	1	1	1
Civil	4	84	3	2	7
M&M	1	1	132	3	6
OG&C	1	1	1	51	4
Power	5	5	1	6	121

Networks can be a powerful tool for examining relationships, although each network is unique (e.g., density, degree distribution, clusters, etc.), so there is no definitive benchmark by which to compare networks to each other. This poses a problem when we try to conduct cross case analysis. To address this problem, network researchers create a comparative baseline using two main methods: simulation, and statistical re-sampling. Exponential random graph modeling (ERGM), is perhaps the most widely used simulation tool in network research. It works through generating *connections* according to a known set of assumptions, such as preferential attachment (higher probability of connection to the person with the most connections). In contrast to ERGM, methods based on statistical re-sampling like relational contingency tables (Borgatti et al. 2002), generates a simulated population of networks by holding constant important network properties, but altering the base assumptions within the network. For instance, if we know that there are 40 connections within the civil business unit, we would like to know how many connections we could *expect* if business units were not associated with how individuals chose to connect with one another. Thus, the goal of our simulation is to hold constant as many network properties as possible, but simulate a null condition in which business units and disciplinary groups are independent of patterns of connection. For this reason, we hold constant the number of connections in the network (e.g., 640 connections in the PI CoP), number of groups (e.g., 5 Business Units in PI CoP), and number of people within each group (e.g., 273 people in PI CoP, 27% in government services business unit, etc.), and then simulate new networks by randomly pairing network members with a business unit or functional discipline. The result is an expected number of connections for each relationship in the blockmodel (connections according to disciplinary group or business unit), where the expected number of connections is based on the assumption that there is no association between organizational divisions and patterns of connection. Furthermore, we generate a histogram that serves as a random sampling distribution for each cell in the blockmodel by aggregating the simulated number of connections over 10,000 iterations. These generated distributions provide a point of reference to the number of ties observed (based upon responses to the questionnaire). With this point of reference we can claim whether a particular relationship is higher, lower, or relatively close to an expected value. Re-sampling techniques such as this one are common in statistical methods for cases when the underlying distribution of values is unknown (Efron and Efron 1982). To accommodate these simulations, groups were excluded from the analysis if their average expected number of within group connections based on 10,000 iterations was less than one. This cutoff was determined because knowledge sharing ties are integer values, so expected frequencies less than one have no practical significance.

With the simulated random sampling distributions we use error tolerances of $\alpha=0.05$ for both the upper and lower tails. For each potential relationship within or between a group, observed values that fell in the 95th percentile (observed is much larger than expected) of the random distribution were classified as *strong levels of connection*, visualized as a bolded tie between two groups. This reveals whether there are far more connections than we would expect, giving a reasonable degree of confidence that there are more than enough knowledge sharing connections to equitably share knowledge for that particular relationship. Next, observed values that fell in the bottom 5% (observed far less than expected) of the random distribution were classified as having *no connection*, visualized by no tie between two groups. Because the observed values are significantly lower than the expected values, we expect that knowledge flow is limited for that particular relationship due to a lack of connections. Finally, those ties that fell in the middle 90th percentile are simply *normal levels of connection,* and are visualized through a non-bolded tie. This is summarized in Table 2-2.

Table 2-2 – Connection Visualization

Classification	Definition	Visual Representation
Strong levels of connection	The observed number of connections is in the 95th percentile of the simulated random sampling distribution (observed >> expected value)	*Bolded Tie*
Normal levels of Connection	The observed number of connections is in the bottom 5th percentile of the simulated random sampling distribution (observed << expected value)	*Normal Tie*
No Connection	The observed number of connections is in the middle 90th percentile of the simulated random sampling distribution (observed ≈ expected value)	*No tie*

On a network level, a single business unit or discipline may be isolated, yet the network as a whole is not considered "silo-ed." Because of this, we created a scale based on majorities to assess the degree to which silos occur on a network level. If, for instance, every business unit displays strong internal ties, we classify this network as being "completely constrained" because knowledge flows are contained within business unit groups. As the degree of constraint increases, the organization has a higher risk of developing harmful knowledge based silos. This scale is detailed in Table 2-3.

Table 2-3 – Network Level Constraint Classification

Classification	Description
No constraint	Normal or strong ties exist between all groups; represents the ability of the informal network to distribute knowledge equitably.
Weak constraint	Some groups have strong internal ties, displaying a preference for sharing knowledge internally, but the majority of groups have normal levels of internal ties.
Strong constraint	The majority of groups have strong internal ties, displaying a preference for sharing knowledge internally.
Complete constraint	Every group has strong internal ties, displaying a preference for sharing knowledge internally; there are no ties between groups.

RESULTS

A network diagram was generated for business units and functional disciplines in each community. As a general guide, each diagram displays the network within a CoP based upon one division (business units are displayed in Figure 2-1 and 2-2, disciplinary groups are displayed in Figures 2-3 and 2-4), where nodes are the individual groups that belong to that particular division, and the links reflect the strength of a given connection *relative to the randomly generated network.* By displaying the *relative* strength of these ties, we mitigate the effects of different group sizes. Circular ties, which point at their node of origin, show the relative number of connections within a group, instead of between groups. In the caption of each visualization, both the number of people (n_p), and the number of individual ties (n_t) are recorded to show the size of each CoP, and to report our relative sample sizes. For ease of reporting, the networks have been symmetrized according to the highest number of ties, so these networks are not directional in nature.

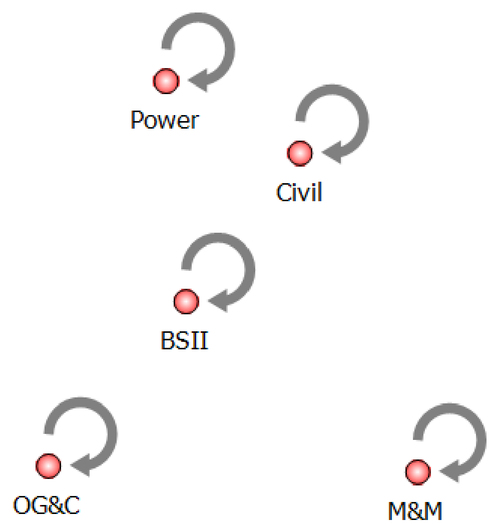

Figure 2-1- Process Improvement CoP by Business Unit (np = 263, nc = 504)

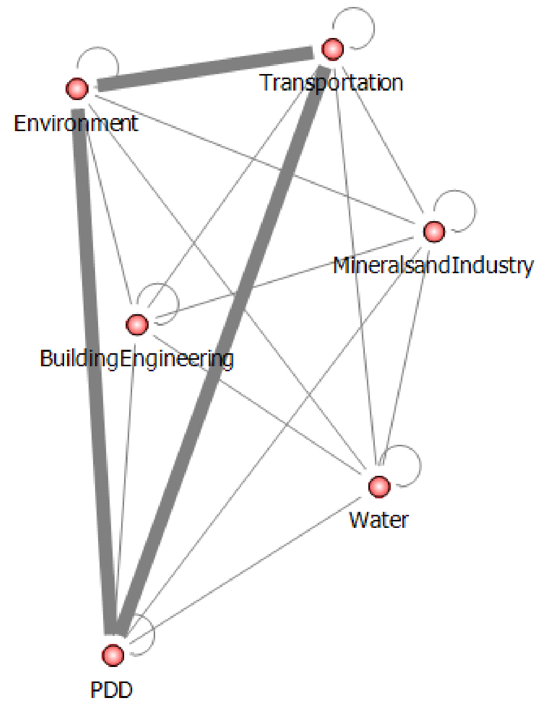

Figure 2-2- CAD CoP by Business Unit (np=1045, nc=939)

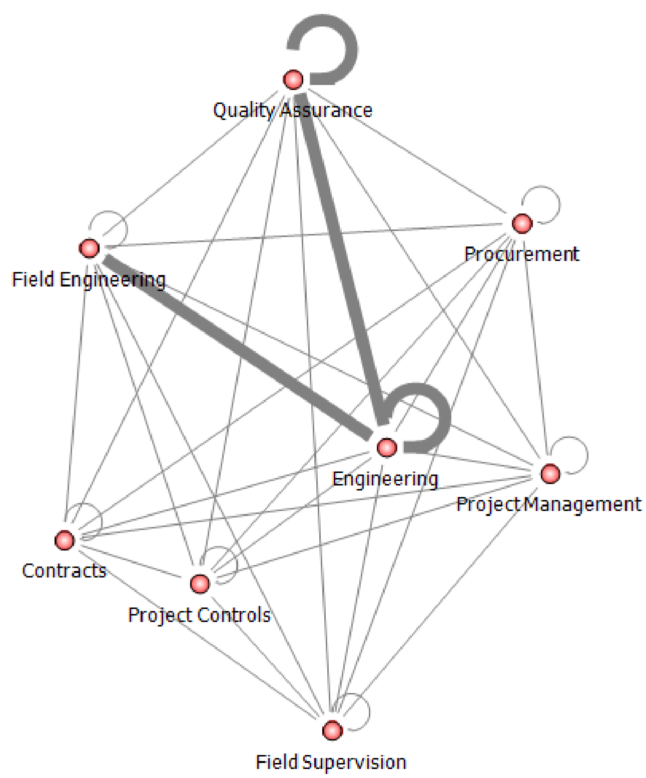

Figure 2-3 – Process Improvement CoP by Discipline (np=228, nc=386)

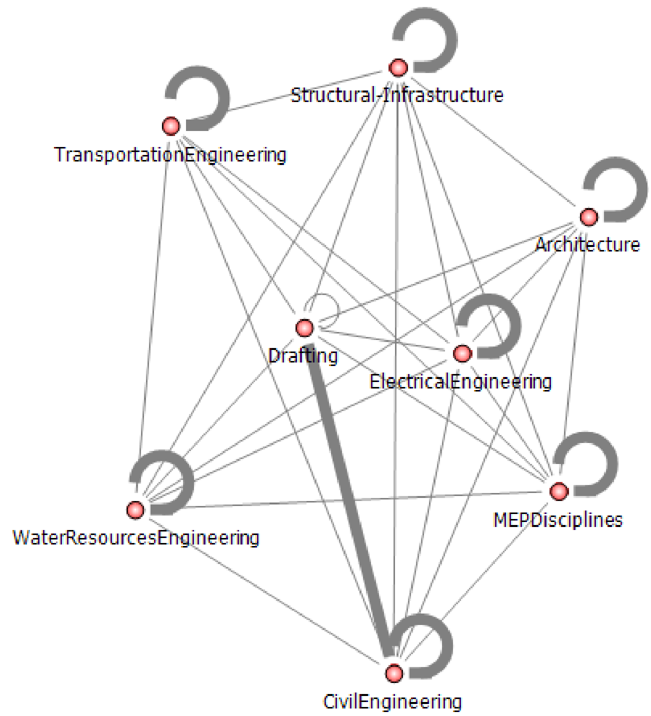

Figure 2-4 - CAD CoP by Discipline (Np=402, nc=394)

As evidenced by Figures 2-1 through 2-4, there are varying degrees to which informal networks are constrained by formal organizational divisions, although the degree of constraint varies by the attribute considered as well as the community.

To start interpreting the results, the Process Improvement CoP shown according to business units in Figure 2-1 offers a clear example of silos. This visualization shows that the network has an extremely limited number of channels through which to share knowledge between business units, and that the informal knowledge sharing networks are completely constrained by business unit boundaries. This is in contrast to the CAD CoP shown according to business units in Figure 2-2, which has normal or strong ties between each business units.

The Process Improvement CoP is shown according to disciplines in Figure 2-3, which has normal levels of internal ties for most groups, with connections with normal levels of connection between all groups. Looking at disciplinary groups, the CAD CoP shown according to disciplines in Figure 4 shows a strong tendency to share knowledge within disciplinary groups, but still has connections between all groups. Using the scale detailed in Table 2-3, we classified the degree to which each organizational division constrains the informal knowledge sharing network in Table 2-4.

Table 2-4 - Summary of classifications for each CoP

CoP	Division	Figure	Classification
Process Improvement	Business Unit	1	***Complete constraint****; No between group ties, all groups display strong preference for sharing knowledge internally*
	Discipline	3	***Weak constraint,*** Some groups have strong internal ties, displaying a preference for sharing knowledge internally, but the majority of groups have normal levels of internal ties*, and connections exist between all groups*
CAD	Business Unit	2	***No constraint;*** Normal or strong ties exist between all groups, there is not perceived preference to share knowledge within any group.
	Discipline	4	***Strong constraint****; Most groups exhibit a preference to share knowledge internally, but between group ties still exist*

From the figures and Table 2-4 above, there are a number of observations that clearly advance our understanding of knowledge flows in multinational construction and engineering organizations. For Figure 1, there are obvious silos according to Business Units, but for Figures 2-2 through 2-4, it is less clear whether or not this constitutes a "silo-ed" organization. In Figure 4 there is more connectivity within disciplinary groups than between them, the network has some capacity to share knowledge between these groups. This leads to our first major observation: formal organizational structures do not produce dichotomous outcomes in which knowledge sharing is silo-ed or not. Rather, silos must be evaluated in terms of the degree of constraint, which is a continuum.

Analyzing the remainder of the data, we observe that no single division produces the same degree of constraint in both communities. In Figures 2-1 and 2-2, we see that there is complete constraint according to business units in the PI CoP, but no constraint by Business Units in the CAD CoP. In Figures 2-3 and 2-4 we observe weak constraint by disciplines in the PI CoP, but strong constraint according to the same partition in the CAD Cop. This leads to our second major observation:

organizational divisions do not produce consistent effects across communities on informal knowledge sharing networks. The implications of these observations are discussed in the following section.

DISCUSSION

As multinational construction and engineering organizations try to benefit from their global expertise through CoPs, it is vital to recognize and remedy silos that impede knowledge flows. Although business units and functional disciplines are visible divisions within a company, research has yet to determine if these organizational divisions create silos in the informal networks that constitute interaction within multi-lateral CoPs.. In the prior section, this study produced two observations: first, that business units and functional disciplines can create silos within CoPs, but there the strength of their effect can vary from group to group within the community. Secondly, we observed that organizational divisions do not exhibit uniform effects on informal knowledge sharing networks in different contexts, so that business units and functional disciplines are not inherently limiting structures. Each of these observations is discussed below.

Evaluating CoPs: The Strength of a Silo

The results of this study clearly show that organizational structures can constrain informal knowledge sharing networks, but that the degree of constraint varies depending on the community and the structure considered. This raises an interesting question: are these large, manager prescribed CoPs functioning as cohesive communities? Phrased differently, we would like to know how many connections are needed between groups to capture the benefits associated with healthy knowledge flows, and avoid the dangers of limited knowledge flows within CoPs.

In our analysis, the degree of constraint does not indicate absolute numbers of connections, but rather the balance of connections based on the size and connection density of the network. We chose this method of analysis because it allows each network to be analyzed according to its own baseline density. For instance, weak constraint indicates that there is a normal balance of within and between group connections, while strong constraint would indicate that the majority of connections are between people in the same business unit or discipline. Because of this, we can say that networks that are weakly constrained have the *capacity* to share between different knowledge bases, while strongly constrained networks lack this capacity. This is because strongly constrained networks have such a high percentage of their connections dedicated to sharing knowledge within groups, that there cannot be the same level of knowledge flow between groups.

For CoPs, it is very important to determine whether knowledge flows are limited within the CoP membership, because it determines how we evaluate the "community" element of CoPs. Wenger et al. (2002 p. 34) makes the case that *"A community of practice is not just a Website, a database, or a collection of best practices. It is a group of people who interact, learn together, build relationships, and in the process develop a sense of belonging and mutual commitment."* While this study did not evaluate belonging and mutual commitment, we do determine patterns of interaction that are a necessary condition of relationship. To the degree that there are severe silos within the boundaries of a CoP, we must re-evaluate whether the group is a "community." When silos do exist along epistemological boundaries like business units (industry specific knowledge), and disciplines (field specific knowledge), then it could be indicative that the prescribed boundaries of the CoP do not describe the true social patterns of practitioners. This could be because cross-business unit or cross-discipline knowledge sharing is not useful, indicating that there is no practical value to facilitating knowledge sharing. On the other hand, it could be because there is not adequate facilitation of connection through the CoP. When this occurs, there may be groups of practitioners who *would* benefit from interacting with one another, but have thus far not had the opportunity.

To return to the results, within the Process Improvement CoP, where very few connections between business units exist relative to the size and density of the rest of the network, we conclude that silos exist because there are limited channels through which knowledge can be transferred. In the CAD CoP however, there is some connectivity between disciplinary groups, although there is a distinct preference for within group knowledge sharing. This is not sufficient evidence however, to claim that disciplinary groups are silo-ed to the point of damaging knowledge flows. Even though there is an imbalance of network capacity to distribute knowledge within groups (many connections) as opposed to between them (far fewer connections), it is difficult to say whether the few connections which span disciplinary groups are sufficient to create a cohesive community. This leads to the following proposition: *Fragmentation in CoPs is a continuous, rather than dichotomous concept and can be evaluated in terms of the proportion of groups that are siloed.*

In the past, the theory surrounding CoPs has focused on learning, meaning, and identity (Wenger 1998), or knowledge management outcomes (Saint-Onge and Wallace 2012) rather than network concepts. At the same time, one of the critical components of CoP functionality is the degree to which participants interact with one another. From a business perspective, it is important to measure these patterns of interaction to determine whether the CoP is functioning as a cohesive community that has the *capacity* to share knowledge between different organizational structures. Through viewing CoP cohesion as a continuous measure comprised of the proportion of siloed groups, it is possible to evaluate the health of large, multi-lateral CoPs with respect to formal organizational boundaries, and to specifically target areas of the network that are under-performing.

First, however, let us consider the difference between organizational boundaries, like business units, and CoP boundaries, which may span business units, but include professionals with a common interest who would benefit from interaction. If a CoP is siloed, as is the case with the PI CoP by business unit, it may indicate that there are *practice boundaries* along business unit lines. If this is the case, then it would not be useful for professionals to interact across business units, because the group lacks a cohesive knowledge domain, and a particular practice that is agreed upon (Wenger et al. 2002). On the other hand, low levels of interaction do not necessarily indicate a practice boundary. When managers prescribe CoP boundaries, they may include employees who have a cohesive knowledge domain and practice, but have not been connected to one another, and thus do not have community. If this is the case, then a lack of interaction can be remedied through relatively simple strategies such as networking events, job rotations, and mutual tasks. The potential for business units or functional disciplines to induce silos does not indicate that these are not useful structures. Furthermore, the fragmentation that occurs within CoPs is not an indication that multi-lateral knowledge sharing will not be beneficial to the CoP members. Instead, group level analysis can be used to find potential boundaries, determine if they are practice boundaries, or organizational boundaries, and then managers can work to eliminate organizational boundaries through mutually assigned work tasks and integrated training sessions. Thus organizations can gain the benefits of multi-lateral knowledge sharing without generating superfluous interactions, or CoPs that do not usefully group professionals into a cohesive knowledge domain.

Although there are many theoretical objections to managers unilaterally creating CoPs to facilitate strategic knowledge sharing, group level evaluation allows us to get at the root issue. If there is relatively little interaction between formalized groups, then it is important to determine if the lack of interaction is due to a practice boundary, or to an interaction opportunity boundary. In one case, the CoP boundary delineates a phantom community, bringing together multiple, unrelated groups of practitioners. If however, we are witnessing the influence of an organizational boundary on a CoP that otherwise has a cohesive knowledge domain and practice, then the group should be considered a CoP with unrealized potential. This fragmentation can occur on a group level.

Lastly, even in strongly constrained networks, there are connections that defy the trends of the majority and link different groups. Practically speaking, these boundary spanning connections should be identified and exploited by managers. They represent existing channels of communication between organizational groups which do not require the relational start up of initiating new connections. Furthermore, boundary spanning connections can give managers a template for successful knowledge sharing across boundaries in the event that they want to expand the inter-group knowledge sharing capacity of the network. On a theoretical level, the presence of boundary spanning connections in the midst of highly constrained networks raises a number of interesting questions such as: How did these connections form? What purpose do they serve in the network? What capacities do boundary spanning connections have to distribute knowledge throughout the network? Although several studies have breached this topic for small teams (Di Marco and Taylor 2011; Di Marco et al. 2010), examining the role of boundary spanners in diverse, multinational organizational settings is a ripe area for future research.

Contextual Differences

One of the most interesting findings of this study is that business units and functional disciplines did not exhibit the same degree of constraint across both communities. Going back to Table 2-3, we see that business units completely constrain the Process Improvement CoP, but only weakly constrain the CAD CoP, and functional disciplines weakly constrain the Process improvement CoP, and strongly constrain the CAD CoP. From this we conclude that knowledge based organizational structures do not have inherent characteristics that limit connection between groups. Instead, the community context determines which organizational divisions constrain knowledge sharing networks.

Although it is not a part of the formal methodology, the authors have conducted exploratory interviews with members of the Process Improvement and CAD CoPs to determine the differences between them. Through discussions with CoP participants and leaders, we determined the basic management structure, purpose, and culture of these knowledge sharing communities to assess why business units so strongly constrain the Process Improvement CoP, and functional disciplines have such a strong effect in the CAD CoP. Through these talks we learned that Company A, which houses the Process Improvement CoP, encourages competition between the business units, and runs each of these divisions as separate profit centers. Because of this, each business unit develops unique processes and languages that have limited transferability between business unit contexts. Interestingly enough, one of the goals of the Process Improvement CoP is to facilitate inter-unit knowledge exchange, although based on our analysis this does not occur. As one interviewee stated:

> *'Our entire company is organized around these business lines; how each business line executes work is typically dictated by the type of clients within that business line etc. So they have a management style and an execution culture. And so we align all of our different functions within that business unit when in essence in our company the business unit is the ranking entity for work execution.'*
>
> \- *Manager, Process Improvement CoP*

In contrast, Company B is not rigidly organized into business units, but has grown aggressively through acquiring smaller companies. The CoP provides a platform to encourage knowledge sharing across business units and disciplines, but affiliation is stronger with legacy companies than it is with proscribed business units. In contrast to the Process Improvement CoP, the CAD CoP members specialize in certain disciplinary areas such as pipelines or road design. Most of the drawing blocks, CAD standards, and systems that they use are discipline specific. Therefore, when CAD employees share knowledge, it is frequently discipline specific, so it appears that employees seek out connections that have similar educational backgrounds. They see people in different fields as having less relevant knowledge to what they do. One employee, when explaining why they did not have a strong knowledge sharing connection with another said this:

> *'I think we do completely different lines of work. He's a structural modeler, I do electrical drafting. So we might talk about Revit, but we wouldn't talk about the finer details of what we do.'*
>
> - *CAD Drafter, CAD CoP*

Many of the connections which span these disciplinary boundaries exist to coordinate between multiple disciplines for a project based need, not to transfer best practices or solve problems. This is consistent with prior studies, which found that project based needs were a common driver of boundary spanning connections (Javernick-Will 2011b). Aside from project coordination, cross-disciplinary interactions are typically very general and limited to issues with the software that are general to all types of drawings.

On a theoretical level, the differential constraint exhibited by knowledge based structures across communities shows that commonality between people does not universally drive connection. Cognitive studies that consider homophily consistently document that demographic and socioeconomic similarity tends to breed connection between people (McPherson et al. 2001). Taken in the context of the Process

Improvement CoP however, homophily (as demonstrated by within group connection) does not occur according disciplinary groups. Similarly, in the CAD CoP, we do not observe behavior consistent with homophily according business units. So then, even though business units and functional disciplines help to define similarity between people, it is not reasonable to conclude that individual association with these knowledge bases is strong enough to create a cognitive "love of the same" which will cause organizational silos. This leads to our second observation: *Within organizations, commonalities according to business units and disciplines cannot be used to predict the formation of knowledge sharing ties across multiple contexts.*

To summarize, the root cause of silos within the Process Improvement CoP is the organizational structure, which does not encourage inter-business unit knowledge sharing. On the other hand, the CAD CoP has a tendency to silo according to functional disciplines due to the physical placement of employees and the project based needs that those employees tend to have. Future research should continue to explore why silos occur, and document the managerial and organizational causes of this fragmentation. For construction organizations, the inconsistent effects of organizational divisions across communities means that silos might occur along business unit or disciplinary boundaries, but it is not safe to assume that these divisions interrupt knowledge flows. Even so, the high levels of constraint observed along business unit boundaries in the Process Improvement CoP and along disciplinary boundaries in the CAD CoP indicate that the visible boundaries within a company can be a powerful predictor of the underlying patterns of informal knowledge sharing.

Limitations and Future Research

As with any study there are a number of limitations that must be addressed. First, the generalizability of this study is limited due to the small number of communities included in our sample. For this reason, these findings only apply to CoPs that span more than 3 different disciplines and 3 different business units, and have a membership larger than 150, enough to exceed the capacity of a single individual to have social relationships with all other group members (Dunbar 1993; Gladwell 2000). In spite of this, our dataset is unusually large relative to other social network data on knowledge sharing, so each community represents a large number of knowledge sharing connections. Furthermore, we are not making a universal claim about the effects of a given organizational division. Instead, we have discussed the ability of formal organizational divisions to constrain informal knowledge sharing patterns. The generality of these conclusions makes them conceptually robust despite the small number of cases in this study. Even so, it would be beneficial for the knowledge management literature to generate additional social network datasets that can be compared to formal organizational divisions. This study provided a preliminary look into why silos emerged in informal networks, though this is a topic that requires more rigorous qualitative research methods. This study found that mechanisms of organizational control that group employees into business units and disciplinary groups can impact informal knowledge sharing networks. Future research could go far beyond interaction patterns, and begin to explore why these patterns have occurred. While business units and functional disciplines are formal, epistemological boundaries that are capable of creating fragmentation across potentially relevant domains of knowledge, there are many other organizational forces that can influence patterns of connection. For instance, there are strong numbers of ties between the Civil Engineering and Drafting groups in Figure 4. Why is there so much knowledge sharing between these groups? Is there a practice boundary around these two disciplines? Explaining this complexity is not possible with quantitative SNA methods. Furthermore, although important, this study did not examine the influence of location of connection opportunity, or the dual influence of business units that may be geographically located. Future research would do well to continue this line of inquiry, exploring how and why informal networks are structurally impacted by the dual influence of physical location and management strategies.

CONCLUSION

Silos that limit knowledge flows in construction organizations can have widespread impacts on a company's efficiency in using its knowledge resources. Business units that become silo-ed will fail to learn from other business units, compartmentalizing innovation and best practice within a small fraction of the organization. Isolated disciplinary groups lack the coordination required to offer integrated solutions, leading to repeated mistakes and wasted resources. Previously, academics have struggled with a method to quantitatively assess silos within an organization. Through statistical re-sampling, this study proposes a method to establish a statistical baseline that can be used to meaningfully judge whether silos occur. We found that even though CoPs have been explicitly introduced to facilitate global knowledge sharing and prevent these pitfalls, we demonstrate that knowledge based silos continue to form along the boundaries created by organizationally defined business units and functional groups within multi-lateral CoPs.

Assessing the relationship between formal organizational structures and informal knowledge sharing networks is an important step for theory and practice, yet it remains unaddressed in knowledge management literature. This study empirically examines business units and functional disciplines to determine whether formal organizational structures cause silos in multi-lateral CoPs. To accomplish this task, we conducted a literature review to examine how these divisions affect knowledge sharing, and then examined patterns of knowledge sharing connections within and between groups in two multi-lateral CoPs. We created a methodology based on statistical re-sampling and visualization that allowed us to analyze the underlying patterns of knowledge sharing connections, and used these data to classify group level ties relative a simulated network. As a result of this analysis, we observed that formal structures limit knowledge sharing along a continuum of constraint, which requires group level analysis to determine where silos actually affect knowledge flows. Secondly, commonalities according to business units and functional disciplines are not an accurate predictor of knowledge sharing ties between employees, and that the effects of these divisions vary according to the larger context of the organization.

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Chapter 3: Knowledge Sharing Networks in Multi-National Communities of Practice: fragmentation, pipelines and anomalies

ABSTRACT

Multinational construction and engineering companies are increasingly adopting communities of practice (CoPs), as a means to encourage geographically dispersed and culturally diverse professionals to share knowledge on a global basis. If successful, these CoPs form rich, informal knowledge sharing networks that mobilize a company's global knowledge base to be applied when and where it is needed with relatively little managerial oversight. However, homophily, a social tendency that leads people to connect most strongly with similar others, may create geographic and cultural silos within CoPs that limit knowledge flows and curb the strategic advantage of a global workforce. Through empirical analysis of social network questionnaires and semi-structured interviews, this research analyzed network patterns within three CoPs to determine if geographic and cultural silos exist, identify structural patterns that defy homophilous trends, and explore why these network level patterns exist. The research found that, in the absence of intentional organizational structuring and strategic control, silos induced by homophilious behavior were standard for global communities of practice. To encourage knowledge exchange across geographic and cultural boundaries, managers can create mutual task requirements, provide opportunities through integrated training and learning experiences, and encourage workforce mobility among different geographic and cultural locations.

"Birds of a feather flock together."

- *Wyllyam Turner, 1543* (Turner 1543)

INTRODUCTION

Communities of practice (CoPs) are more than a management trend. As predicted by Wenger and Snyder (2000), CoPs have become part of the standard business lexicon as a way to increase performance in knowledge based industries. CoPs do this by creating informal networks of professionals that span geographies and organizational groups, thereby allowing specialists to connect on the basis of their knowledge needs to a global community of professionals. Manville and Foote (1996 p. 80) define CoPs as:

> *"A group of professionals informally bound to one another through exposure to a common class of problems, common pursuit of solutions, and thereby themselves embodying a store of knowledge"*

Within the construction and engineering industry, many companies are launching CoPs to make knowledge accessible and useable when and where it is needed. In practice, a CoP is a supplemental organizational structure that involves grouping employees who have similar knowledge bases, and providing them with online collaborative tools. Through online forums, document repositories, and the standard communication platforms provided by the organization, managers hope that employees will share what they know with one another, and turn to the CoP for help when they need it. For large construction organizations, effective CoPs reduce repeated mistakes, efficiently reuse prior work, advance technical practice, and consistently apply the best expertise available to projects.

To coordinate, manage, and share this knowledge, managers of engineering and construction organizations use CoPs (Yu et al. 2012). At the same time, CoPs are typically left to self-organize, so that professionals can find one another as needed. In this environment, *"because they [CoPs] are self-managed and self directed, their contribution to the organization will always be uncertain."* (Kimble and Hildreth, 2004, p. 5). Given that CoPs self organize, their structure is not designed formally, as with organizational charts. Rather, they are subject to both social and environmental forces that influence how professionals connect with one another. In these situations, similarity between people is one of the greatest predictors of connection (McPherson et al. 2001). This effect, called homophily, suggests that, when given a choice, people overwhelmingly choose to associate with others who are similar to themselves (Kleinbaum et al. 2013).

Consequently, although CoPs are primarily implemented in practice to bring professionals working on common problems together regardless of demographic or location attributes, social tendencies indicate that people will connect most frequently to others who are geographically proximate and culturally similar. This can create geographic and cultural silos within multinational CoPs, isolating employees into homogeneous ways of thinking and destroying the individual (Burt 1992; Cross and Cummings 2004), and project level (Cummings 2004) benefits that accrue from sharing knowledge with dissimilar others. As a result, this study examined the informal networks that comprise multinational CoPs to determine the effects of geographic dispersion and cultural diversity on patterns of knowledge sharing connections, identify and classify network patterns, and explore why these patterns occur.

COMMUNITIES OF PRACTICE

At present, there is no consensus between academic theory and business practice as to the definition and role of CoPs in global organizations, so it is important to clarify the differences in theory and practice. When the term "community of practice" was coined, the goal was to emphasize the role of practice in learning theory, rather than create a tool for managing knowledge (Amin and Roberts 2008). Within learning theory, Lave and Wenger (1991) described CoPs in terms of legitimate peripheral participation, where individuals start at the periphery of a community, and are gradually drawn into more central roles as they learn and become recognized as experts. Simultaneously, Brown and Duguid (1991) harmonized practice based learning and organizational theory to conceptualize organizations as "communities of communities," where small groups of people (CoPs) engage in localized processes of working, learning, and innovating to build effective, flexible, learning organizations.

Since these original theorists, CoPs have proliferated in knowledge-driven industries, although it is generally acknowledged that the current business application of CoPs is not aligned with the theoretical origins (Lindkvist 2005). Instead, current business practice maintains that CoPs are a "way of managing knowledge" (Roberts 2006) that can create a strategic advantage by increasing knowledge sharing on a global level (Manville and Foote 1996; Saint-Onge and Wallace 2012; Wenger et al. 2002). Instead of describing the importance of practice based learning, CoPs have become distinct intra-organizational structures that are created and sustained to facilitate topical knowledge sharing (Probst and Borzillo 2008). This paper is not attempting to re-define the conceptual foundation of CoPs. Rather, we study communities of practice as they are being implemented by construction and engineering firms to manage knowledge.

In spite of the conflicting views of theory and current practice, managers are initiating new organizational structures that bear the namesake of "communities of practice." In addition to facilitating smaller, emergent groups of practitioners, managers have prescribed the creation of large, geographically distributed CoPs that align with a given business practice. To understand the basic nature of these larger, prescribed CoPs, this study evaluates the capacity of these communities to facilitate inter-geographic and inter-cultural knowledge sharing in business practice.

Network Capacity

Regardless of size and geographic distribution, the goal of large CoPs is to facilitate knowledge sharing among global experts. While CoPs were originally theorized to facilitate learning through engaging in practice (i.e. work tasks), and social interaction, many scholars doubt that geographically distributed CoPs can be considered cohesive communities, or that their networks are sufficient to facilitate practice based learning (Amin and Roberts 2008; Lindkvist 2005; Roberts 2006). Despite these objections, there have been few studies that evaluate large, distributed CoPs to determine if they facilitate global knowledge sharing. Because knowledge is inherently difficult to track or measure (Liebeskind 1996), one of the few ways to assess the degree to which knowledge is shared is by analyzing social networks (Cross and Parker 2004). By visualizing and analyzing who is connected with whom relative to a given attribute, social networks reveal patterns of connection within the CoPs. For example, by comparing the number of connections between individuals within a particular country in contrast to the number of connections that span geographic boundaries (Javernick-Will 2011b). While the pure number of connections is not an indicator of the value or quantity of knowledge sharing, it does reflect the *capacity* of the network to sustain knowledge flows. In other words, if there is an extreme imbalance in the number of within country connections and the number of between country connections, we can reasonably claim that the network has a higher capacity to share knowledge within, as opposed to between, countries.

Network capacity is not a sufficient indicator that a CoP is equitably distributing knowledge, although it is a necessary factor in CoP performance. Without knowledge sharing connections between two geographies, it is safe to assume that there is no active knowledge sharing. Studies that examine dispersed project teams have evaluated the efficacy of relationships that already exist (El-Tayeh and Gil 2007), yet it is equally important to study whether there are systematic failures in the network leading entire groups of people to be disconnected. Because so few studies have examined patterns of knowledge sharing in multinational CoPs, we will analyze two divisions—geographic distribution and cultural diversity—within multinational CoPs. We ask: *what affects the capacity of informal networks to share knowledge within large, manager initiated, geographically and culturally diverse CoPs?*

Homophily

Social scientists has extensively documented that people overwhelmingly choose to associate with others who are like themselves (McPherson et al. 2001) within organizations (Kleinbaum et al. 2013), and outside of them (Moody 2001). This phenomenon is called homophily, meaning "love of the same," and in most studies it affects connections and communication patterns. There are two main drivers of homophily; first, individuals choose to connect with similar others, and second, opportunities to connect with heterogeneous others are limited due to group composition, organizational structures (i.e. business units or other formal groupings of employees), or physical location (McPherson and Smith-Lovin 1987). While homophily is a driving force for connection, CoP members may be more united by their common problems than demographic differences.

The practical effect of homophilious connection within CoPs is fragmentation into geographically and culturally homogeneous groups. Although geographic work location and cultural affiliation frequently overlap, it is important to realize that they are distinct. In this study, we are not claiming that either geographic or cultural silos would be more damaging, or that one boundary is more important than the other. Indeed, we do not really know if the effects of geographic work location and culture are additive, or multiplicative in their effect on structure. In this study, we focus on connections as dichotomous, meaning that they either exist or not, and evaluate whether network patterns display fragmentation along either geographic or cultural boundaries. Because homophily is so widely documented, we expect to observe higher network capacities within geographic and cultural groups than between them.

RESEARCH METHODS

This research quantitatively identifies patterns of connection in global CoPs, explains why these patterns are occurring, validates the findings, and builds theory about the forces affecting network capacity. The exploratory nature of this study makes a mixed methods approach especially appropriate for two primary reasons. First, the progressive steps from quantitative to qualitative methods allow us to first visualize the informal networks, and then ask interview participants about specific patterns that we had observed. Secondly, social network studies are rife with confounding factors that are difficult to control from a quantitative perspective. By triangulating quantitative network data, qualitative interview data, and secondary survey measures, we are able to establish a reasonable degree of internal validity.

To conduct the research, we (a) deployed social network surveys to ask CoP members with whom they shared knowledge, (b) performed quantitative network analysis on the survey results, and (c) conducted interviews and performed qualitative analysis to explain observations and verify the findings.

Research Setting

Our research setting is comprised of three CoPs within two construction and engineering companies. Each of these CoPs is structured, funded, and initiated by the organizations that host them. They each have a defined membership, but vary in size, function, and demographic composition; as described below. Geographic work location was obtained from HR departments at each company, while culture is self-identified as part of the survey, and is therefore subject to response rates.

Process Improvement CoP – Housed within Company A, the process improvement CoP consists of 273 Six Sigma professionals acting as internal consultants for individual projects. Employees in the Process

Improvement CoP currently work in 16 different countries. The network is highly centralized with 60% of the employees (n=268) currently working in the US. Other large populations work in England (10%), Australia (8%), and Chile (6%). While globally distributed, more than 85% of the respondents (n=119) to the Six Sigma survey identified culturally with three cultures, including the US (67%), UK (12%), and Australia (4%).

Computer-Aided Design (CAD) CoP – The CAD CoP exists within Company B as a collection of 1152 CAD draftspersons, engineers, and managers. Employees in the CAD CoP work in 19 different countries including USA (24%), Australia (20%), Canada (16%), UK (15%), and UAE (11%). 80% of the members (n= 469) identify with 6 different cultures, including USA (25%), UK (14%), Australia (14%), Canada (14%), India (8%), and the Philippines (5%).

Transportation CoP – The Transportation CoP within Company B contains 365 members and is loosely defined as professionals that work on transportation related projects. Membership is distributed across 10 different countries, although the majority of the employees are concentrated in North America. The largest geographic groups which represent 93% of the total population include the USA (65%), Canada (15%), Australia (10%), and UK (3%). 81% of the members (n=154) identify with USA (48%), UK (13%), Australia (8%), Canada (7%), and India (6%).

Social Network Surveys

To begin, we deployed social network surveys to the complete membership of each CoP. Using NetworkGenie, an online social network survey tool, we asked participants to identify others within the CoP with whom they shared knowledge. When the survey was closed, response rates were 100 (36.6%), 387 (29.9%), and 142 (35.2%) for the Process Improvement (PI), CAD, and Transportation (Trans) CoPs respectfully.

To focus our study on knowledge sharing, the network identification question directly asked participants *"who have you exchanged knowledge with on job related practices in the past 6 months?"*

We further specified the type of exchange as *"any practice oriented knowledge that is required for you (or those with whom you interact) to perform job related tasks. 'Practices' can be project related or organization related."* This construct was validated in interviews through participants' explanations of the actual knowledge shared with specific connections. During the survey, respondents were also asked to identify their culture through an open ended question: *"Please indicate the country that you would identify as your primary cultural influence."* Tying culture to national affiliation is a popular practice (Hofstede 1980), and meaningfully captures a different way of thinking and approaching problems.

Social Network Analysis

To examine patterns of connection in each CoP, we used social network analysis (SNA), a method that portrays network relationships graphically (Moreno 1960). Social network analysis is particularly valuable in its ability to reveal patterns of relationships and examine connections within and between different sized groups (White et al. 1976). As such, it has gained increasing popularity as a tool that can be applied to engineering project organizations (P. Chinowsky and Taylor 2012).

Because each network is unique, it is difficult to make reliable and repeatable claims about network patterns that are consistent across multiple contexts. To address this issue, we created a new method for analyzing the relative capacities of networks by examining the number of observed within and between group connections and contrasting these to values obtained from a customized simulation for that particular network. This allows us to evaluate whether the observed number of connections is higher, lower, or similar to an expected value. This method is generically applicable to any grouping chosen by the researchers, although for this paper we used geographic work location and cultural affiliation for group boundaries. For this reason, we will refer to this new routine simply as "boundary analysis."

The initial inspiration for creating boundary analysis was the "relational contingency tables" routine in UCINet (Borgatti et al. 2002), which generates a single chi squared statistic to evaluate blockmodels (White et al. 1976) in their deviation from expected values. In contrast to this routine, boundary analysis establishes a statistical baseline of what we would expect each CoP to look like given a fixed set of assumptions. More specifically, we generate a "null condition" network through statistical re-sampling, which holds constant the number of connections, people, and groups within the network, and then randomly assigns people to groups. By aggregating the results from 10,000 iterations, we produce a histogram showing the simulated number of connections for each within group (e.g., people in Canada connected to others in Canada), and between group (e.g., people in Canada connected to people in the USA) relationship. We eliminated smaller groups that had expected values for inter-group relationships of less than 1 connection. The histogram serves as a generated random sampling distribution based on the assumption that geographic work location or culture has no effect on patterns of connection, and allowed us to statistically compare our observed numbers to a null baseline. Re-sampling techniques such as this are well established in statistical methods, especially for cases in which the underlying distribution of values is unknown (Efron and Efron 1982). For each within and between group relationship, the observed value can be significantly higher than expected, or lower than expected, at an $\alpha=0.05$ level, or similar to the expected value, enabling us to identify different network patterns.

Qualitative Analysis

Once we identified network patterns, we used a stratified sampling technique to select interviewees that proportionally represented the different geographical work locations and cultures in each CoP. We then conducted 30-50 minute, semi-structured interviews with 5-10% of each CoP population. In total, we performed 77 interviews (27 interviews within PI, 28 within CAD, and 22 within Trans). As mentioned previously, we used data from the social network surveys to ask interviewees about specific connections and trends within the CoP. For instance, when interviewees had connections that spanned cultures or international boundaries, we would ask how they originally became connected with that person and the content of knowledge shared (to verify that there was business related knowledge exchange). By tailoring each interview to ask about specific connections, we captured rich, situated data in questions that were simple to answer, and yet gave us insight into how and why network patterns may have emerged.

Each conversation was recorded, transcribed, and entered into qualitative analysis software. During analysis, researchers worked in pairs to generate a coding library that accurately reflected explanations for different network patterns. Interviews were independently analyzed by multiple researchers to increase the validity of qualitative support. While the qualitative data provides evidence as to why different network patterns have emerged, there is always the possibility of detecting spurious associations. To increase the internal and construct validity of our findings, we elected to triangulate our results from the qualitative analysis with related measures in our quantitative analysis wherever possible. For instance, if we detected a cross geographic pipeline that qualitative data indicated was a result of business unit tasks, we verified this finding by calculating the relative frequency of connections across the same geographic boundary that were exclusively between employees within that business unit. Through this triangulation process, we were able to achieve a high degree of internal validity.

NETWORK LEVEL ANALYSIS

First, we analyzed the network level structures within each of the three CoPs. Using the boundary analysis program developed by the research team, we tested if the networks displayed homophily, meaning that the number of within group connections was significantly higher than expected at an $\alpha=0.05$ level. Table 3-1 provides descriptive statistics for this analysis, including the number of people, reported connections, number of groups based upon geography or culture, and percentage of groups that displayed homophily. Because physical work location was provided by each company's HR department and cultural data was subject to survey response rates, the number of people, groups, and connections vary within each CoP depending on if we group people by geographic location or by culture. The percentages of homophilious groups are aggregated statistics from Tables 3-2 through 3-7, which show the simulated and observed values for each possible within/between group relationship.

Table 3-1 – CoP Overview with Group Level Homophily Analysis

Grouping	CoP	# people	# connections	# groups	% groups homophily
Geography	PI	239	551	5	100%
	Trans	330	334	3	100%
	CAD	1082	969	7	100%
Culture	PI	98	209	2	50%
	Trans	118	134	4	75%
	CAD	387	419	6	100%

Homophily

As expected, Table 3-1 shows that in all three communities, 100% of countries demonstrate statistically significant (at a $\alpha=0.05$ level) tendencies toward homophily for geographic location. Thus, there is a significantly higher capacity to share knowledge within each country than between countries in each CoPs. The low degree of oversight and informal nature of CoPs makes them an environment in which employees can choose with whom to interact. If social tendencies lean toward homophily, then geographic dispersion does not help employees access new ideas, but instead fragments CoPs. Lau and Murnighan (1998) describe this phenomenon as a "faultline," where breakdowns in communication lead to sub-optimal coordination within a group. While the premise of CoPs is to reduce traditional barriers to facilitate multi-lateral knowledge sharing, this finding demonstrates that, left unattended, regional geographic silos remain.

We observe similarly uniform trends along the cultural partition, although it is not as consistent as the geographic partition. Two out of twelve cultural groups did not show statistical trends of homophily. Despite these two groups, our original expectation has been confirmed, as the majority of groups showed patterns consistent with cultural homophily.

GROUP LEVEL ANALYSIS

These findings empirically confirm anecdotal and theoretical evidence that large, manager initiated CoPs do not facilitate balanced "interaction on an ongoing basis" as emergent CoPs claim to do

(Wenger et al. 2002 p. 4). However, this research further explored other capacity influencing patterns by examining individual geographic and cultural groups, as shown in Tables 3-2 through 3-7. Within the tables, the rows and columns are titled with countries or cultures such that each cell on the diagonal of the matrix represents the number of connections within that group, while the other cells represent the number of connections for one directional relationships between groups (where the directional connection is from row to column). The number of network members belonging to each group (n) is included in parenthesis adjacent to the row labels. For each cell *i,j* we report the observed number of connections from the survey, the number of connections expected using the simulation, and whether or not the difference is statistically significant using the generated random sampling distribution. Two plus (++) indicates that the observed values were significantly higher than expected, while two stars (**) shows that the observed value is significantly lower than expected. Each cell reports this information according to the format: $(\text{obs/exp})^{\text{significance}}$.

Table 3-2 - Process Improvement by Geography

Country (n)	**Australia**	**Canada**	**Chile**	**UK**	**USA**
Australia (23)	(44/4.8)++	(3/2.6)	(10/3.5)++	(1/5.7)	(11/35.5) **
Canada (12)	(0/2.7)	(8/1.3)++	(2/1.9)	(0/3)	(0/18.9) **
Chile (16)	(10/3.6)++	(4/1.9)++	(32/2.3)++	(0/4.1)	(8/25)
UK (26)	(2/5.8)	(0/3)	(0/4)	(48/6.3)++	(8/41.1) **
USA (162)	(24/36)	(4/18.9) **	(3/25.2) **	(8/40.9) **	(324/252.9)++

Table 3-3 - Transportation by Geography

Country (n)	**Australia**	**Canada**	**USA**
Australia (37)	(17/4.1)++	(4/6.2)	(9/26.9)
Canada (55)	(1/6.3) **	(41/9.2)++	(9/40.5) **
USA (238)	(1/27.1) **	(5/40.3) **	(247/173.5)++

Table 3-4 - CAD by Geography

Country (n)	**Australia**	**Canada**	**Qatar**	**UAE**	**UK**	**USA**
Australia (229)	(182/40) ++	(6/34.1) **	(0/10) **	(0/23.2) **	(14/31.3) **	(12/55.4) **
Canada (181)	(14/34.1) **	(134/28.7) ++	(0/8.5) **	(3/19.7) **	(12/26.4) **	(30/46.9)
Qatar (53)	(0/10.1) **	(0/8.6) **	(29/2.5) ++	(14/5.9) ++	(0/7.9) **	(0/13.9) **
UAE (124)	(0/23.4) **	(0/19.9) **	(1/5.9) **	(88/13.4) ++	(1/18.2) **	(2/32.1) **
UK (178)	(12/31.3) **	(5/26.5) **	(0/7.8) **	(0/18.1) **	(92/24.2) ++	(1/42.9) **
USA (282)	(13/55.3) **	(15/46.9) **	(0/14) **	(1/32) **	(11/43.1) **	(246/75.9) ++

Table 3-5 – Process Improvement by Culture

Culture (n)	**UK**	**USA**
UK (16)	(25/5.2)++	(14/28.7)
USA (82)	(17/28.8)	(153/146.3)

Table 3-6 – Transportation by Culture

Culture (n)	**Australia**	**Canada**	**UK**	**USA**
Australia (12)	(6/1.3)++	(2/1.3)	(4/2.4)	(4/8.8)
Canada (11)	(1/1.3)	(4/1.1)++	(2/2.1)	(1/8) **
UK (20)	(1/2.4)	(1/2.1)	(2/3.7)	(8/14.6)
USA (75)	(1/8.8) **	(3/8)	(6/14.5) **	(88/53.7)++

Table 3-7 – CAD by Culture

Culture (n)	**Australia**	**Canada**	**India**	**Philippines**	**UK**	**USA**
Australia (64)	(54/12)++	(5/12.6) **	(1/6.9) **	(2/4.8)	(14/11.9)	(8/22.3)**
Canada (66)	(5/12.6) **	(58/12.7)++	(1/7) **	(2/4.9)	(1/12.1) **	(3/23) **
India (36)	(0/6.9) **	(0/7) **	(17/3.7)++	(1/2.7)	(1/6.7)**	(0/12.5) **
Philippines (25)	(1/4.8)	(3/4.9)	(4/2.7)	(6/1.8)++	(1/4.6)	(1/8.8) **
UK (62)	(8/11.8)	(1/12.2) **	(0/6.6) **	(0/4.6) **	(50/11.2)++	(0/21.5) **
USA (117)	(10/22.2) **	(4/22.9) **	(0/12.6) **	(0/8.7) **	(9/21.5) **	(135/40.3)++

From these results, we observe numerous instances when the observed values are statistically different from the simulated null condition. Not all of these discrepancies can be attributed to homophilious behavior. For instance, there are some cases in which there are significantly more connections between two groups than we would expect. In these cases, such as the relationship between Chile and Canada in Table 3-2, there is an increased knowledge sharing capacity between two groups due to the higher number of connections. We call this effect a '*pipeline*', defined as between group connections that are significantly higher than expected (at an α=0.05 level), because it represents the conduit for knowledge flows between two groups.

Next, some networks are saturated with homophilious trends and holes such that a normal level of connection between groups is '*anomalous*'. We define anomalies as minority group(s) that defy a strong network-level trend (i.e., all groups display homophily) and have normal or higher than expected numbers of connections. For instance, when the CAD CoP is analyzed according to geographic location, many connections exist within each group and there is very weak network capacity between groups; and yet, there are normal levels of connection between Canada and the USA. Table 3-8 summarizes the pipelines and anomalies observed in Tables 3-2 through 3-7.

Table 3-8 – Summary of Pipelines and Anomalies

	CoP	Geography	Culture
Pipelines	*PI*	Australia/Chile, Chile/Australia, Chile/Canada	None
	Trans	None	None
	CAD	Qatar/UAE	None
Anomalies	*PI*	None	None
	Trans	Australia/Canada, Australia/USA	None
	CAD	Canada/USA	Philippines/all other countries

To explore the formation of network patterns, we interviewed network managers and participants to build an in-depth case knowledge of all three communities. Using this case knowledge, we identified that inter-geographic network patterns were created through proximity and common language, as well as organizational structures, while inter-cultural patterns were driven by expatriate workers. The following sections analyze proximity and common language, organizational structures, and expatriate workers to determine how they influence network patterns, and then validate our findings using additional quantitative measures from our social network data.

Geographic Proximity and Common Language

The basic premise of homophily is that similarity breeds connection. When there are multiple cultures and geographic locations within a multinational CoP, we expect each country to have far more connections internally than externally, as was confirmed through the quantitative analysis. Secondly, we would expect that, to some degree, similar countries or cultures would exhibit higher levels of connection than dissimilar countries or cultures.

Table 3-4, which shows the CAD CoP by geography, portrays an organization with prevalent geographic silos. We observe that each country has a much higher knowledge sharing capacity within its borders than outside of them. Within this network there is one pipeline and one anomaly. First, there are higher than expected numbers of connection from Qatar to the UAE (but not in the other direction) and normal levels of connection between Canada and the USA (also one sided). For these relationships, the countries are linked by a common language and proximity, both of which are expected to breed connection.

In reality, the inter-geographic connection between these countries is facilitated through strategic control, manifested in employee movement and mutual task requirements. In the case of Qatar-UAE, the Doha office is relatively new, so the company has been strategically moving employees from the UAE to Abu Dhabi to build local expertise and capacity. This employee mobility has broken down the geographic silos between Qatar and the UAE to create the anomaly that we observe in Table 3-4. Furthermore, many knowledge sharing connections between Qatar and the UAE result from mutual task requirements. As the senior CAD manager stated "*CAD workers in Qatar and the UAE interact when there is a project* *requirement."* When they are not able to source resources locally to meet their project requirements, they turn instead to their neighboring office for help.

Similarly, normal levels of connection between Canada and the USA represent an anomaly to the otherwise silo-ed CoP. Of the 30 connections from Canada to the USA, 77% of them are to Minnesota, Wisconsin, and Illinois. These constitute the most geographically proximate offices to Alberta and Ontario, where the majority of Canadian CAD workers reside. Many of these connections result from mutual project tasks that employ workers from both sides of the border.

When two countries are geographically proximate and share a common language, we would expect that the similarity between them would lead to higher numbers of knowledge sharing connections. All else considered equal, employees seeking knowledge will likely *choose* to connect with common language speakers because the knowledge is transmitted more easily and, because language is a deeply rooted part of culture, the person with whom they obtain knowledge are more similar to themselves. Interestingly, employees only interact across country boundaries when there is a mutual task requirement. While proximity and common language reduce the barriers to mutual contribution to a project, there is little evidence that individuals are choosing to connect with one another. In reality, they are connecting because the organization requires them to collaborate with people in other countries and distribute work within regional labor pools.

Organizational Structures and Geographic Pipelines

While employees' social tendencies lead to geographic silos, the organization itself can create pipelines between different countries. While Table 3-2 shows that the PI CoP exhibits homophilious tendencies according to country, there are stronger than expected numbers of connections from Chile to Australia, Australia to Chile, and Chile to Canada. These three pipelines represent disproportionately high numbers of connections relative to the number of network members and connection density in these two groups. Upon further investigation, Company A has a mining business unit that conducts the majority of its operations in these three countries. In describing his connection to another PI CoP member, one employee stated, *"I was working with him and coordinating all the activities for the three* *regions that we have in Mining."* The fact that the business unit (Mining) to which these employees belonged had very strong task requirements that demanded travel and high levels of employee mobility, was echoed through the CoP interviews, with most respondents having worked in, or traveled to, the three locations (Chile, Canada and Argentina).

Frequent contact with individuals from different geographies initiated connections: as one manager reflects on a past role, she noted that *"for my role as the business unit process improvement manager, I would have to do round the world trips".* In other cases, employees were moved between regions to satisfy differential work requirements: *"In Montreal the workload has backed off a bit, whereas Chile or Latin America has boomed and they've got a lot of work at the moment."* To further strengthen the relationship between these three countries, process improvement education brings together new trainees and instructors to have classes on a quarterly basis. One instructor informed us that "*right now we have a wave [of training] going where we have six candidates from Santiago, one from North America, and one from Australia, …[a] lady from Australia came and helped …[then] a process improvement guru from North America came … so that's just the way Mining does their business.*" These training sessions frequently lead to lasting connections, as another Process Improvement member recalls *"just the other day I had a colleague from my training wave email me to ask a question about a prior project."*

To summarize, the strong connections between Canada, Chile, and Australia are primarily driven by involvement in the mining business unit. We further verified this supposition by revisiting the social network data. Although only 16% of the Process Improvement CoP belongs to the mining business unit, 82 of the 113 connections (73%) occurring between Canada, Chile, and Australia are between people in the mining business unit. Within mining, common work tasks and coordination activities, a mobile workforce, travel, and mutual training have led to sustained connections across geographies. Although the PI CoP had social networking and communication tools for the purpose of encouraging inter-geographic knowledge sharing, employees have not connected across geographies unless it is required of them. However, task requirements and organizational structures created pipelines within the CoP that facilitated knowledge flows between different geographies. Without the explicit task requirements, job assignments, and trainings of the Mining business unit, the interviews suggest that the geographic silos would be even more extreme.

Expatriate workers and Cultural Silo 'busting'

In many cases, employees work in the same countries with which they are culturally affiliated. Upon this basis, we expect that cultural network patterns would largely mirror the patterns observed with geography, although that is not the case. There are three instances in which cultural patterns do not match geographic patterns that we wish to examine. First, Table 3-2 shows the Process Improvement CoP by geography, and there is a lack of connection between USA and the UK in both directions. However, if we look at the Process Improvement CoP by culture, Table 3-5 shows normal levels of connection between the USA and UK. The same trend resurfaces in the Transportation CoP, where there are limited geographic connections between Australia, Canada, and the USA (Table 3-3), yet normal levels of connection between the Australian, Canadian, and USA cultural groups (Table 6). Next, there are significantly sized groups that are culturally Indian and Philippine, even though the company does not have large workforces in those countries. Of the 25 culturally Philippine workers, 24 (96%) are working as expatriates.

Why would the cultural partition be less homophilous than geographies? As with most global workforces, all three CoPs have significant international mobility. Employee connections are limited by geographic location, because there are fewer opportunities to connect with people who are spatially distant. On the other hand, if people are relocated frequently, their opportunities to form inter-cultural connections are not limited in the same way. Most expatriates form local knowledge sharing connections once they relocate while maintaining contact with people from their home country. One CoP member discussed his recent move, and responded to a question of where he commonly sought help with:

> *"I just arrived in South Africa, never been in sub Saharan Africa in my life. When I run in to a technical problem, and I ran into one about the first week I was here, I first ask, 'who in the building can help me with this technical issue?"*

From this response, we see that he first searches locally for a knowledge resource. These expatriate workers not only form new knowledge sharing connections where they are sent to work, which breaks down cultural silos, but they also maintain ties to their prior networks, which help facilitates knowledge exchange across geographies, allowing them to serve as a bridge between geographies and cultures. The same Transportation professional continued in his explanation of where he goes for help:

> *"…but if I think that we're going to have some additional questions that go beyond the ability of what the local guy can give me, I'll reach out to our informal ports and marine network in the Middle East and Australia, and the east coast and the West Coast of the US."*

In addition to providing continuous contact between cultures and geographies, expatriate workers can serve as a mechanism to connect local experts to global resources. Within the CAD CoP, expatriate workers originally from Australia served to connect colleagues in the Middle East with connections back in Australia. As one expatriate indicated:

> *"So there are a lot of Australian experts in the Middle East… When they had a big problem, George from the UK, who I know very well, was over there, and put my name forward." Gloria, CAD CoP*

As verification that expatriate workers tend to disrupt cultural silos, we separated each CoP into two groups, locals and expatriates, and calculated the relative frequency of their inter-cultural connections. The results are summarized for each community in Table 3-9, along with (number of inter-cultural connections/ number of total connections):

Table 3-9 - Expat vs. Local relative frequencies inter-cultural connections

CoP	**Expat**	**Local**
PI	50% (34/68)	11% (15/141)
Trans	83% (10/12)	18% (22/119)
CAD	37% (31/84)	17% (55/322)

The interpretation of this table is simple; in every case, expatriates have a higher percentage of inter cultural connections. This helps explain the elevated levels of inter-cultural connection observed between the UK and USA (PI CoP), USA and Canada (Trans CoP) and UK and Australia (CAD CoP), when we would otherwise expect homophilious patterns. Each of these pairs is comprised of countries that commonly exchange workers, which would lead to higher expatriate populations, and hence more inter-cultural connections.

This leads us to observe that cultural boundaries produce patterns that tend to be less restrictive to knowledge sharing than geographic boundaries. When transferred to a new country, expatriate workers have the opportunity to make local inter-cultural connections. These cultural boundary spanners, once expatriated, serve a vital role in translating and communicating knowledge, which provides a number of benefits on a project and organizational level (Di Marco and Taylor 2011; Di Marco et al. 2010). Structurally speaking, these expatriate workers help to break down silos that would otherwise exist from limited cross-cultural interaction, providing key access to global knowledge resources (Haas 2006).

DISCUSSION

Implications

This study has two primary implications for the way that we view multinational communities of practice. First, it challenges the underlying assumption that CoPs implemented in practice are cohesive knowledge communities, which may indicate that CoPs as they appear in business practice are not cohesive communities, as they were originally theorized by Brown and Duguid (1991). Secondly, it causes us to re-conceptualize the role of CoPs in knowledge management as a mechanism for maintaining, rather than creating connection among geographically distributed professionals.

At a time when companies are spending massive amounts of money to create social networking tools for people to use, one of the underlying assumptions is that online communities are relatively cohesive, practice driven groups similar to the examples given in Lave and Wenger (1991). As a result, managers can falsely assume that employees will naturally share knowledge with only mild facilitation of IT (Akhavan et al. 2005). This study evaluates some of the organizational structures that bear the namesake "communities of practice" in a global, project based environment, and finds that employees still connect most strongly with others who are culturally similar, and geographically co-located. We conclude therefore that rather than view large, distributed CoPs as cohesive communities because they share a common set of problems (Manville and Foote 1996), we would do better to think of large, global, CoPs as a loose marketplace consisting of many smaller groups. Each group is cohesive due to mutual tasks or demographic commonality, which is more consistent with the original definition of CoPs proposed by Lave and Wenger (1991). Disrupting this pattern requires active management of networks through shifting task requirements and organizational structures. Despite this discrepancy, it is not accurate to abandon "communities of practice" as a concept that is applicable to these globally distributed groups of professionals. In fact, even low numbers of cross geographic connections can facilitate practice based learning in geographically distributed CoPs. In reality, management interventions created numerous opportunities for learning in practice, which is consistent with original CoP theorists. By this account, even large, distributed CoPs may, in fact, justify the name they are given.

In light of this re-conceptualization, we must situate CoPs within a more cohesive knowledge management strategy. Recently, CoPs have emerged as a strategy for managing knowledge (Roberts 2006) on global level, although they do not appear to be doing this on their own. Instead, the majority of connections that work to distribute knowledge equitably to all geographies and cultures occur for reasons unrelated to the CoP. So then, what is the role of CoPs in knowledge management strategy? We propose that CoPs serve the purpose of maintaining initiated connections, as was the case with expatriate workers who maintained ties to their original co-workers. Tasks shift, but employees will tend to form latent ties that make the organization more flexible in the future, but need a venue in which to operate. Mutual belonging to a CoP facilitates re-connection to old ties. Thus the role of the CoP may not be initiating connection, but maintaining connections and providing a platform that encourages the health of existing networks. In this role, CoPs are a necessary part of a global knowledge management strategy, but are not sufficient on their own. Future work should further examine the role of CoPs in global KM strategy, with a specific focus on the strategic benefits of CoPs as they are being applied in global organizations.

Limitations

As with any study, there are several limitations which must be addressed. To begin, the mixed methodology employed in this study necessarily limited the number of cases we could examine. Because of this, we chose to study three CoPs in two multinational organizations. Our selection allowed us to gain some insight into the generalizability of our findings across different organizational and CoP setting, adding to the robustness of our conclusions. Even so, we must limit the application of these findings to manager initiated, global CoPs within multinational project based organizations. Furthermore, the CoPs studied varied widely in terms of their scope, participation, management, and size. While our CoPs are not as tightly defined as we would like them to be, there is neither theoretical nor practical agreement as to the definition of CoPs (Lindkvist 2005; Roberts 2006). We selected CoPs that we believe are typical of the business environment, which have common goals of knowledge sharing within the organization. Finally, in our quantitative analysis, we were forced to exclude a number of small subgroups for both geographic and cultural partitions in all three CoPs. While the robustness of our analysis is not subject to these exclusions, small subgroups likely play a key role in global CoPs that deserves investigation. Very little research has been done on the configuration of subgroups, and how it affects knowledge flows (see O'Leary and Cummings 2007 for an exception), but CoPs provide a rich environment for this line of study.

Despite these limitations, this study used a unique quantitative method to empirically confirm geographic and cultural silos in three multinational CoPs, identify and explore other network patterns, and explain the driving factors behind network patterns.

CONCLUSIONS

As multinational construction and engineering firms implement CoPs as a way to address organizational silos, we need to understand the forces that influence global knowledge sharing networks. This study empirically confirmed that within global CoPs, informal knowledge sharing networks still show overwhelming evidence of homophily, where people overwhelmingly choose to associate with others who are like themselves when given a choice, leading to geographic and cultural silos. As a result, the network capacity of CoPs to share knowledge between different countries and cultures is limited, preventing employees and project teams from accessing a global knowledge base. Unfortunately, the freedom allowed within CoPs shows tendencies to create fragmented silos and may prevent CoPs from achieving the intended benefits of reducing repeated mistakes, avoiding duplication of efforts in different areas of the company, and ensuring the spread of best practices.

When analyzing network patterns for homophily, we also identified two other network patterns that defy these homophilous trends: pipelines, characterized by higher than expected numbers of connection between two geographic or cultural groups; and anomalies, which occur when the network patterns of a minority of groups/relationships defy a network-level trend within the CoP. We found that strategic control, through organizational structures, mutual task requirements, work rotations, and expatriate workers helps produce pipelines and anomalies which facilitate knowledge sharing across cultures and geographies.

Even though CoPs are created from a managerial standpoint to share knowledge equitably throughout the organization, our results indicate that in absence of organizational intervention, cultural and geographic silos will continue to dominate global CoPs. Rather than relying on individuals to form their own meaningful ties, organizations who wish to encourage global knowledge exchange across cultures and geographies appear to need to exert strategic control by actively moving people, creating mutual task assignments, and creating opportunity for cross border connections to form. The latent ties formed through strategic control and maintained within CoPs are both a rich area for future work, and a key benefit of hosting CoPs within an organization.

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Chapter 4: Mechanisms Leading to the Formation of Knowledge Sharing Connections in Communities of Practice

ABSTRACT

Within global, multiunit construction and engineering organizations, communities of practice (CoPs) have become an important means for managing knowledge. These CoPs connect distributed professionals and facilitate knowledge sharing to reduce repeated mistakes, drive technical practice, and quickly solve project based problems. CoPs provide a number of benefits to the organizations that host them; however, they deviate significantly from their theoretical roots. Instead of localized groups of practitioners who work, learn, and innovate through practice in a social setting, they are frequently initiated within organizations as a means for coordinating specialist knowledge within groups of distributed professionals. As a result, we no longer know how distributed professionals locate and connect with one another within distributed CoPs. This qualitative study began with social network surveys to determine patterns of knowledge sharing within three distributed CoPs hosted in two project based construction and engineering organizations. We analyzed the social network data to select and interview CoP members about their connections. The analysis of this data enabled us to investigate the mechanisms of connection leading to the formation of informal knowledge sharing networks through semi-structured interviews. Our findings indicate four primary mechanisms, including organizational control, organizational opportunity, social networks, and non-person centered searching. The diversity of mechanisms, as well as the prevalence of organizational control as a mechanism of connection leads us to situate CoPs at the nexus of bureaucratic systems, project tasks, and social tendencies of the members. This has implications for the reach of organizational power within CoPs that are supposedly independent from hierarchical control, and the progression of CoPs within business practice. Together, these conclusions demonstrate that project assignments and direct hierarchical control is an effective means to establish baseline networks within distributed CoPs.

INTRODUCTION

When a small, passionate group of pavement designers sit down for lunch and discuss problems they are having with their current projects, they are working, learning, and innovating with each other outside of their formal responsibilities to the organization. This type of behavior is the essence of a community of practice (CoP), and the envy of managers looking to harness their worker's knowledge for strategic gain (Wenger and Snyder 2000). As they were originally conceived, CoPs described practice based learning within social groups of practitioners (Brown and Duguid 1991), and how novices to a mature field of work are gradually educated by more seasoned experts, in turn becoming experts themselves (Lave and Wenger 1991). The bounds of these informal CoPs were determined by who was actually working with whom. In recent years however, it has become much more difficult to see how the complex, global networks of knowledge sharing connections have formed within CoPs. This is because CoPs have grown into distributed entities with hundreds, or even thousands, of members distributed across multiple geographies and areas of expertise.

This shift in CoPs from localized groups of practitioners to globalized entities came about as managers recognized the potential of CoPs to drive business practice. This led managers to attempt to leverage the collaboration and learning of localized CoPs on a company-wide scale (Saint-Onge and Wallace 2012). Further, as companies have globalized, their collective knowledge is more distributed and diverse (Becker 2001), and the definition of CoPs has become even more generalized. In spite of these changes, inter-personal connection and knowledge sharing has remained the central purpose of CoPs. In business practice today, CoPs are not defined by actual work patterns, but in terms of *"a group of professionals informally bound to one another through exposure to a common class of problems, common pursuit of solutions, and thereby themselves embodying a store of knowledge"* (Manville and Foote 1996 p. 81). With such a broad definition, CoPs have become a powerful way of managing knowledge by connecting specialists for the purpose of knowledge sharing (Lindkvist 2005; Saint-Onge and Wallace 2012). They are self governing, facilitate collaboration through a wide variety of different channels, and generally receive online collaborative space from the organization (Saint-Onge and Wallace 2012). Some scholars have argued that recent changes in CoPs are so significant that what we observe in business practice is no longer a CoP. This has led to the proliferation of new terminology, including "collectivities of practice" (Lindkvist 2005), "virtual communities of practice" (Ardichvili 2008), and "practice networks" (Brown and Duguid 2001). In spite of this re-branding, the namesake "communities of practice" has remained in businesses, and the name has become synonymous with knowledge sharing for the purpose of driving professional practice (Brown and Duguid 1991; Manville and Foote 1996). However, given the recent shifts in CoP form and structure, we no longer know how knowledge sharing connections between professionals are formed.

Scholars agree that social networks facilitate knowledge sharing between professionals (Cross and Parker 2004). At the same time, CoPs, in theory, are self governed, meaning that nobody directs who becomes connected with whom, thus making their contribution to the organization uncertain (Kimble and Hildreth 2004). To compound this uncertainty, CoPs have expanded to the point that their membership possess a knowledge base that is too large and dispersed to be comprehended by any single person or manager (Becker 2001). As a result, we do not currently know how professionals become connected to one another within these CoPs. This leads us to ask the research question: *how do professionals initiate knowledge sharing connections in dispersed CoPs?* Answering this question will help us understand how global knowledge sharing networks form in organizationally initiated CoPs. This understanding of how CoPs are shaped and managed is necessary to determine the value of CoPs, and how they can be used to further management practice.

THEORY AND PRACTICE IN DISTRIBUTED COPs

As they were originally conceived, CoPs formed as professionals engaged in practice with one another. The theoretical basis for calling these groups "communities of practice" was to describe practice oriented learning theory, where individuals began at the periphery of a social group, and through mastering a subject were gradually drawn into its core (Lave and Wenger 1991). Further work sees CoPs as the underlying structures of organizations, such that organizations are more like "communities of communities" where individuals work, learn, and innovate in localized groups of practitioners (Brown and Duguid 1991). Both of these seminal papers examined how individuals learn, and adopted the term "community of practice" to describe the patterns they observed. As many researchers have pointed out, the current practice of managers establishing CoPs *as a means* to facilitate knowledge sharing constitutes a significant change from these origins (Kimble and Hildreth 2004; Lindkvist 2005; Roberts 2006).

In spite of the deviation between CoP theory and business practice, managers are initiating organizational structures that bear the namesake "communities of practice." Due to the deviation of these structures from guiding theory, it is now necessary to examine how changes in the basic form and function of CoPs may influence the mechanisms by which professionals become connected within the CoP. Despite the changes in CoP structure, interpersonal relationships are still central as a means for finding and sharing knowledge (Cross and Sproull 2004; Lave and Wenger 1991).

With this in mind, processes of connection between distributed professionals are likely influenced by four distinct characteristics of CoPs: 1) organizational tasks, directives, and divisions (Thompson 2005), 2) global distribution of CoP members (Lindkvist 2005), 3) the application of IT platforms (Alavi and Leidner 2001), and 4) social and relational norms (Borgatti and Cross 2003).

Organizational Tasks, Directives, and Divisions

CoPs are intra-firm networks, so we suspect that the organization that hosts CoPs will heavily influence how professionals become connected. Employees will naturally be brought into contact with one another as they perform their typical job tasks and work in their offices. Although CoPs exist to facilitate knowledge sharing among *all* experts working on a common problem, daily work tasks necessitate contact between individuals working on similar tasks. Indeed, prior work has shown that connection can be initiated within project based organizations because of project based needs, or because employees have met face to face during their work with the organization (Javernick-Will 2011b). In addition to facilitating connection, the organization can limit connection by dividing employees into hierarchical and formal organizational structures such as business units. Research has shown that people tend to connect more within these formal structures than between them (Kleinbaum et al. 2013), and that between unit communication is increased primarily through joint tasks and meetings (Ghoshal et al.

1994). Thus, professionals connecting with one another, even in self governed CoPs, can be subject to forces from the organizations that host them.

Global Distribution

In addition to organizational pressures, the global distribution of many CoPs poses some practical challenges to connecting with one another. Differences in terms of local contexts (Haas 2006; Oshri et al. 2008; Yanow 2004), and cultures (Di Marco et al. 2010; Nissen 2007; O'Hara-Devereaux and Johansen 1994) can help or hinder how people connect with one another. When the formation of informal knowledge sharing networks is limited to demographic groups that share common contexts or cultures (Wanberg et al. 2012), the result is fragmentation and demographic "faultlines" that inhibit knowledge sharing within the community (Hinds et al. 2011; Lau and Murnighan 1998). Formation of natural communities along the lines of physical proximity would naturally limit interactions with distant others, affecting the means by which distant individuals become connected. Prior work showed that proximity tends to breed connection between people (Reagans 2011), and that this tendency can lead to a higher incidence of geographically proximate connections than connections that span geographic boundaries (Javernick-Will 2011b). While we do not expect that geographic distance will be a mechanism of connection, this prior work does indicate that connection opportunity be partially dependent on proximity.

IT Platforms

IT systems, which provide communication and collaboration tools for distributed, global users have helped drive the globalization of CoPs. As Alavi and Leidner (2001) find, there are two significant trends in knowledge management related to IT platforms. The first is to use IT as a way to map expertise and create knowledge directories to facilitate people connecting with one another. The second is the increasing use of IT platforms to try and form knowledge networks between professionals. In both cases, companies view IT platforms as a way to facilitate the initial connection and continued interaction between knowledge workers. IT platforms however, are distinct from non-virtual methods of communication. As prior research has shown, knowledge shared through IT platforms can be void of social interactions and social motivations, such as reciprocity (Wasko and Faraj 2005). At the same time, other work has indicated that the relationship between the seeker and provider of knowledge is as important as the actual content that is shared. Thus, although IT networks can increase people's ability to locate one another through powerful search tools (Alavi and Leidner 2001), we do not know if IT platforms are a mechanism that enables more enduring knowledge sharing connections between professionals.

Social Forces

Lastly, CoPs are by nature comprised of workers that are engaging in work based, social interactions to share knowledge with one another. This means that the ways in which people become connected in distributed CoPs will be somewhat subject to peoples' social tendencies within an organizational context. Indeed, prior work has examined the ways in which social forces influence connection. On one hand, we know that people have a social tendency to connect with others who are similar to themselves (Lau and Murnighan 1998; McPherson et al. 2001, Chapters 2,3). Because people have to be aware of what other people know to seek knowledge from them, this social tendency to connect with similar others can confine CoP members to cliques where they do not encounter new information (Borgatti and Cross 2003). Furthermore, people have a limited capacity, to retain knowledge. This bounded rationality (Simon 1957) means that people are often not aware of what their colleagues are doing (Kogut and Zander 1996), which can limit their ability to connect and seek knowledge from others. Furthermore, social forces can be a powerful motivator for individuals to connect with one another (Javernick-Will 2012), although we do not really know how well personal networks serve as a mechanism to connect professionals within the company.

Because CoPs have deviated so significantly from their theoretical basis, we no longer know how informal networks are created within these global, distributed communities, or whether theses mechanisms are consistent with original theory regarding CoPs. In this section we discussed several characteristics of CoPs that may affect how people become connected to one another, yet we know surprisingly little about how people actually become connected. Because knowledge sharing connections are the building block of global communities of practice, we must determine how these connections are initiated. This research serves to build upon knowledge in this area by analyzing the mechanisms that lead to knowledge sharing connections in global, distributed CoPs.

METHODS

To explore the mechanisms of connection in multi-national, distributed CoPs, we focused on individual knowledge sharing connections within three CoPs situated in two multinational engineering and construction firms. The CoPs were selected to be consistent with the characteristics of structured CoPs outlined in Saint-Onge and Wallace (2012). These include an effort to utilize productive inquiry, collaboration via multiple channels, self governance, generation of knowledge supporting practice, and the receipt of support from the organization. Furthermore, each of the selected CoPs are intended to facilitate knowledge sharing in line with the strategic goals of the organizations that host them. Due to the qualitative methodology employed, three CoPs was a sufficient number of study sites to draw conclusions, and to fit within the logistical constraints of this project.

This research was performed in two phases. To begin, we administered a survey questionnaire to the entire population of each CoP. This helped to identify who shared knowledge with whom and to create infographic maps that show knowledge sharing networks. Next, interviews were conducted with a portion of the CoP members, who were asked how they became connected to others within the CoP. These interviews were transcribed and coded to determine the mechanisms of connection observed in the CoPs.

Social Network Survey and Interviewee Selection

Rather than begin with qualitative interviews, we deployed social network survey questionnaires to each CoP to determine who was connected with whom, and to visualize the knowledge sharing networks (Moreno 1960). Questionnaires were sent to the entire population of each CoP, and asked members *"with whom have you shared knowledge in the past six months?"* Knowledge sharing was defined as the exchange of information that directly supported employees' ability to act in their particular job role. This definition, used in the survey, represents a theoretically consistent definition of knowledge as opposed to data or information (Alavi and Leidner 2001; Orlikowski 2002). These surveys were administered to three CoPs in two different companies. For the purpose of confidentiality, the pseudonyms "Company A" and "Company B" are used within the study. The context of each CoP is described below:

Process Improvement CoP: Members work as internal consultants for construction and engineering projects to provide process improvement services for Company A. Membership includes a wide variety of disciplinary backgrounds from computer modeling to project management. There are 273 members distributed across more than 10 countries, with membership at all hierarchical levels and in each business line. Members have access to an intranet that links to a project report repository and online process improvement forums.

Transportation CoP: Formed along one of the major business lines of Company B, the members of this CoP all work in the transportation sector. This includes 365 members across a wide variety of disciplinary groups and more than 10 countries, although the majority of members are concentrated in North America. An online platform was initiated by managers approximately 5 years ago, and it includes a search function, document repository, and online forums.

CAD CoP: Rather than bounding itself along a business line, the CAD CoP was created to link global practitioners using computer aided design (CAD). There are 1153 members across all business lines and geographies within the company. Topically, CAD includes a range of different software that is used to create construction drawings across all industries and geographies. Housed within Company B, the CAD CoP has access to the same online platform as the Transportation CoP, although the structure and content of online interactions is specific to CAD rather than transportation.

Survey response rates were 36.6%, 35.2% and 29.9% in the Process Improvement, Transportation, and CAD CoPs respectively. Using the data from these surveys, we selected interviewees using a stratified sampling technique (Singleton and Straits 2005), where we ensured representation from each geography and from the core and periphery of the network. This allowed us to gather a wide variety of different opinions and perspectives that are representative of the CoP as a whole.

Qualitative Interviews and Analysis

For each interviewee we used the survey data to select up to three knowledge sharing connections for further questioning. By customizing the interview guides to ask participants about specific, named, knowledge sharing connections, interviewees were able to situate their responses in experience, which increases the internal validity of our findings. Interviewees were asked how they originally became connected in 30-50 minute, semi-structured interviews via phone. To increase construct validity, they were further asked what types of knowledge they exchanged, and how their relationship had changed over time. These questions allowed us to validate if these connections were exchanging knowledge, rather than information or data.

Each interview was transcribed, and imported into QSR NVivo, qualitative analysis software. The researchers followed the process outlined in Haney et al. (1998) to create an emergent coding framework. To begin, the researchers examined the interview data independently and established separate opinions regarding the mechanisms of connection. Next, the researchers discussed their observations, and created an agreed upon framework that was mutually exclusive and collectively exhaustive to describe how CoP members became connected to one another. Once the framework was developed, the researchers began to analyze the interview data independently, periodically comparing their work to ensure reliability of the framework categories, and creating new codes if the existing coding structure did not describe the mechanism of connection observed. In each CoP, we stopped conducting interviews when we reached theoretical saturation regarding mechanisms of connection, and had a representative sample of the population as per our stratified sampling. That is, when we had a breadth of representation from each CoP, and additional interviews did not identify new mechanisms of connection, the data were deemed sufficient. In total, we conducted 27 interviews in the Process Improvement CoP, 22 interviews in the Transportation CoP, and 28 interviews in the CAD CoP and asked CoP members about more than 150 connections that were coded into our framework.

RESULTS

Within all three CoPs, we found that members' connections were initiated through five distinct mechanisms. First, the influence of *"organizational control"* was immediately apparent: many connections were initiated because of reporting structures or direct commands from figures of authority. Next, *"organizational opportunity"* describes connections initiated as a result of working in the organization, but not explicitly required by the organization. For instance, many knowledge sharing connections in CoPs began because members sat next to each other, or were involved on the same project. Even though there was no explicit command to collaborate with one another, the contact resulting from physical co-location or mutually assigned project tasks commonly led to enduring connections. *"Social networks"* were a mechanism of connection that used social relations rather than structures, tasks, or groupings within the organization. For instance, when CoP members were either introduced to one another by common colleagues, or were actively searching for knowledge and began by asking colleagues, they became connected because of the inter-personal relationships that their colleagues had formed. *"Social networks"* is a distinct mechanism from *"non-person centered searching,"* in which CoP members use impersonal search tools like online platforms or job titles to locate someone who can solve their problem. Finally, there were a few connections that were initiated due to random, yet purposeful interactions that are best described as *"serendipity."* When, for instance, two colleagues initially met working at a previous company, but then were both hired to work at a new company, we saw their mechanism of connection as being outside of their current organization, and somewhat related to chance.

In the three CoPs studied, we asked interviewees about 152 connections. Of these, 7 did not yield useful data because participants could not remember how they became connected, or provided vague descriptions, 54 (36%) resulted from organizational control, 65 (43%) were initiated due to organizational opportunity, 18 (12%) originated due to social networking, and 8 (5%) came from non-person centered searching. Mechanisms of connection are considered to be mutually exclusive, so each connection is attributed to a single mechanism. Table 4-1 below shows summary statistics for each CoP.

Table 4-1 – Summary of Mechanisms

		CAD	Transportation	Six Sigma		Sums	
Org Control	Connect through directive from authority	26	20	19		***65***	***43%***
Org. Opportunity	Connect as part of company, but without requirement	18	12	24		***54***	***36%***
Social Network	Connect through existing contacts	7	10	1		***18***	***12%***
Non-person search	Connect due to search tools or job roles	4	3	1		***8***	***5%***
Sums		***55***	***45***	***45***			

We will now describe each of these mechanisms below, please note that all quotations have been redacted, and that all names used in quotations are pseudonyms.

Organizational Control

Although CoPs are self governing, and therefore not subject to direct hierarchical control (Kimble and Hildreth 2004; Thompson 2005), the authority and directive endemic to the organization is a mechanism that frequently initiates connections. Organizational control involves authoritative directive, and generally involves two separate processes. First, the formal structure of the organization can require CoP members to report to one another as part of the hierarchy. This raises the legitimate question of whether these types of connections can be claimed as part of CoPs, or should be considered as part of the formal organization. Although this is a valid concern, we would be loath to exclude reporting structures as a powerful mechanism of connection in CoPs, because knowledge sharing connections frequently endure beyond job roles, and often serve purposes that cannot be contained within oversight functions. Take the example of an interviewee in the CAD CoP, who describes how he originally became connected to a colleague: *"Sam at one point had line management oversight of me. We initially got to know each other because I was a few levels below him, so my line manager reported to him."* Even though the relationship began due to a formal reporting structure, these two CoP members continue to share knowledge even though there is no longer a requirement for reporting or oversight. Similarly, Beth from the Process Improvement CoP describes a connection that was initiated through formal reporting structures, but has endured beyond those initial job roles: *"For my role as the quality practice leader, I would have to do around the world trips. Marissa was the deployment coordinator in Santiago, so the relationship started with her briefing me as I would come through."* Even though Marissa soon moved to a role in which she no longer reported to Beth, they continue to have a rich, knowledge sharing connection within the CoP that is not subject to hierarchical control.

Some connections initiated through reporting structures continue to operate within their original job roles. In these cases, the CoP members are still engaging in valid knowledge sharing that is consistent with the goals and patterns of the CoP. In fact, the type of knowledge being shared pertains to a "common class of problems" (Manville and Foote 1996 p. 80), not just oversight functions. Samuel of the Transportation CoP states that *"Letty is the director of our Transportation group here in California, so I report to her through the chain of command. Sometimes, however, she will approach me with questions pertaining to my expertise, and I will give her my two cents worth."* Samuel sees these knowledge sharing interactions as distinct from the chain of command that initiated the connection between he and Letty. In spite of the fact that he continues to report to her, they are usefully sharing knowledge in a manner consistent with the definition and function of the CoP.

In a second process, two CoP members are paired with one another by a higher authority, and the form and function of the knowledge sharing connection is prescribed rather than emergent. Take the example of Charlie in the CAD CoP, who remembers that "*when I first started as a trainee, Annie used to sit next to me and explain everything before I would do it with CAD and drafting. She was assigned to me by our boss at the time, who was the expert leading the group."* The training that Annie is giving Charlie fits perfectly in line with the legitimate peripheral participation originally described by Lave and Wenger (1991). Again, within the Process Improvement CoP we see the same pattern. One CoP member describes a connection initiated through organizational control saying: *"he was my formally assigned mentor, being a trainee; he was the one I interacted with most frequently to build my technical skills and to prepare for tests and presentations. We were assigned to one another by the deployment champion due* *to our geographic proximity so we could meet face to face."* Even though their roles are prescribed by an authoritative source, the relationship is not confined to the original definition. When we spoke to the CoP member above, she indicated that the formal mentorship had matured into a more informal relationship where she could seek advice and receive counsel.

Thus, the CoP may be self organizing, but organizational control is an important means for initiating knowledge sharing connections. While many of these connections mature beyond the initial directive, the ones that continue to function within the hierarchical structure, although mandated, can be considered part of the CoP. This is because hierarchical interaction is part of what constitutes "everyday practice" within the company. That is, even though individuals may be required to share knowledge in a particular way, they can still engage in practice based learning and social participation. Thus, we do not see these connections as disqualified from participation in the CoP.

Organizational Opportunity

In the absence of a clear, authoritative directive, the organization itself provides many other opportunities to connect with other employees. Organizational opportunity is a mechanism that is facilitated by the organization, but there has been no authoritative directive dictating the manner in which participants are supposed to share knowledge. More specifically, working on a project together, being co-located, and attending organization sponsored events are mechanisms of connection that fall under organizational opportunity.

When two employees work on a project together, the coordination required to execute their respective job roles increases employees' awareness of what the other does and can create strong knowledge sharing connections. Annete of the CAD community recalls that she and another employee *"became connected when we were working on the same project, I find that is a really easy way to personally meet someone."* The same process applied in the Transportation CoP, in which Louise describes how she became connected to a colleague "*well, he arrived from London in Doha and he joined the project I was working on. We could see that we were going to be working together, so we walked into* *a meeting room, closed the door, and started talking about our backgrounds."* In this way, projects provide a bridge for individuals to meet, interact, and work together as a means to initiate a connection.

Another manifestation of organizational opportunity is when people become connected because they work in the same physical geographic location. Penny in the Process Improvement CoP stated that she became connected with a fellow CoP member because "*we both worked in the same quality department. We were reassigned out of the program, but continued to work together closely."* Even though they have moved on to different areas, the two CoP members continue to interact. Working in the same place can be a powerful mechanism of connection as people get to know those who work near them. Pappas of the CAD CoP remembers that "*Doug and I started working together because we sat right next to each other."* Although simple, co-location brings people together and reveals their relevant expertise within the CoP.

Finally, a number of connections begin due to formal events that the organization hosts that intentionally or indirectly bring CoP members together in an environment that they can connect. One such example occurs within the Process Improvement CoP, where Eugene remembers "*Mary and I first met during a summit, where process improvement professionals come together to talk about the issues that we face. It is a small group of people, so you sit in a conference room and introduce yourself. Over the course of the week you work on activities together, which is what kicked off our friendship."* At the summit, there was no requirement for Eugene and Mary to become connected. By nature of mutually attending the event, they got to know one another, learned about what the other person knew, and maintained that connection over time.

Without explicit direction or even a particular need, CoP members will frequently become connected as the organization gives them opportunity to do so. Whether members are working on a project together, sitting in the same office, or attending an event, these opportunities for connection facilitated by their membership to the organization are an important mechanism of connection within the organization.

Social Networks

Social networks are distinct as a mechanism of connection from the previous two because they leverage interpersonal relationships rather than authority or opportunity. Once people are connected to one another, they can use those same connections to initiate new connections. In some cases, a CoP member has a particular knowledge need, and begins the search by approaching people that they know, and then getting passed along to a second degree connection. Other times, social networks will act as connectors to bring together people who do common types of work. In these cases, a third party brings together two colleagues because of the perceived value of their interaction.

In the first case, using social networks as a search tool can be a powerful and efficient way to locate someone with relevant expertise. Melvin in the CAD community typifies this approach: "*I have a group of people that I know and recommend. Just by virtue of knowing another person I'll call my contact in New York, and he'll say 'I'm not sure how that works, but why don't you call so and so."* Benjamin experienced this process with a specific connection that he had within the CoP, stating that "*Jay was directed to me by our CAD manager, when the CAD manager was asked some questions about a particular tool we were using, he said 'I'm not your guy actually, you need to talk to Benjamin."* The network of referrals, colleagues, and friends is far reaching, so CoP members are often successful in locating what they need just by asking their network. Louise in the Transportation CoP recalls that "*when we ran into a technical problem, I first asked who was in the building that could help. One person handed me off to another person who handed me off again, and I eventually came across a guy who gave me an answer that worked."* Through this process of referrals, Louise is able to participate in a directed search for relevant knowledge without having to personally know everyone in the local office. As a mechanism of connecting two people so that they can meaningfully exchange knowledge, interpersonal social networks are intentional, individualized, and powerful.

Along the same lines, social networks can act as a mechanism for connection even when there is not a clear need. This happens most frequently to pair professionals who do similar work. Lopez of the CAD CoP experienced this phenomenon, even across geographic boundaries. Although Lopez was in

North America, his contacts in Australia connected him with a specialist who does similar work. He recalls that "*I have good connections with the CAD managers in the Australian offices. As soon as Garrett was hired as a Revit structural specialist, I was told about him and we got into contact.*" Maureen in the Transportation CoP had a similar experience as she was visiting a different office. She told us that *"one of my colleagues told me that I needed to talk to Dustin because he was the resident economics expert, so I sat down and had a meeting just to get to know him."* Even though there is not an explicit need for them to share knowledge, Maureen and Dustin initiate a connection that increases their awareness of each other's expertise, and forms an important tie that is later activated when it is needed.

In contrast to connections that are initiated due to the organization itself, it is also important to see the interpersonal relationships of employees as an important mechanism of connection within global CoPs. While many scholars doubt the ability of large, dispersed CoPs to provide a "community" setting for knowledge exchange (Lindkvist 2005; Roberts 2006), social networks as a mechanism of connection may indicate otherwise. Although social networking mechanisms did not occur as often as organizational control or organizational opportunity, it did occur in all three CoPs.

Non-Person Centered Search

Over the past several decades, the invention and application of information technology and communication tools has introduced new mechanisms for connection in distributed CoPs. Specifically, when we refer to IT, we mean the forums, online platforms, and search tools that enable CoP members to virtually browse for information and potential connections. When CoP members use tools or directories to try and locate someone who would be a good knowledge resource, it constitutes a different mechanism for connection than the authoritative, opportunity, or network options mentioned previously. In addition to IT tools, CoP members can use other impersonal search methods that use organizational charts or job titles as the basis of information. In both of these cases, CoP members are engaging in a non-person centered search, because they are not using networks of people, but rather other tools or explicit, formalized information about peoples' roles to locate relevant expertise.

The classic non-person centered search uses IT support tools that exist for the purpose of searching for knowledge. CoP members who respond to queries through IT tools typically receive notifications that someone needs help with a particular topical problem, as is the case with Melvin in the CAD CoP. He recalls that "*I would look at my notifications on a daily basis, and if there was something that someone needed help with, I would recognize the problem and try to get back to them.*" Similarly, Willie in the Transportation CoP said "*I put my name down as an expert in traffic engineering, ITS, and transport planning. So anything within those three fields I receive notifications of questions that people have posted.*" When there is group buy in, these types of open forums can quickly and efficiently connect specialists to one another to solve problems and answer questions. In the CAD CoP, Danielle recalled how she became connected to a colleague saying, *"I started by posting something on the online forum and he responded. From there we kept on talking back and forth over email instead of through the forum."* Systems that enable employees to generally search the population of a CoP can be an invaluable mechanism of connection when they are broadly used. In the quotation above, the forum served to initiate connection, but then the actual knowledge exchange took place primarily through email. During the interview, Danielle indicated that this knowledge sharing connection ended after her question was answered. In fact, we did not observe any concrete evidence that connections initiated through non-person centered network searching endured beyond the initial exchange.

Occasionally we found that CoP members used organizational charts and job roles to locate relevant expertise. Job roles can be useful as a non-person centered search tool because they describe the abilities that a particular employee is expected to have. By searching for people with relevant formal authority over a particular knowledge base or project, CoP members can quickly locate and connect with relevant other specialists. In the Process Improvement CoP, Stanley typified this approach saying that "*if I had a question about a project, I would find out who is in charge and then contact them.*" Because of the hierarchical nature of the project management, Stanly expects that he will be able to locate the knowledge that he needs simply by approaching the person in charge.

Therefore, in all three CoPs, professionals used impersonal search methods to locate relevant expertise. Although these search methods are provided by the organization, they are not required, nor are individual searches subject to hierarchical control. Next, non-person centered searches occur because the knowledge seeking individual takes the initiative to find and contact another professional, not because of an opportunity that has been presented to them. Furthermore, these search methods do not use existing networks, but frequently connect people who have never met before, and have no obvious ties to one another.

Serendipity

While the mechanisms of connection outlined above described 99% of the connections that we examined, there are any number of serendipitous events that can connect professionals within a CoP. Although rare, it is not unheard of for CoP members to randomly sit next to each other on an airplane, meet each other outside of the company, or to work together prior to their tenure at the organization. Frazier (CAD CoP) recalls that *"I met Chris a long time ago, before both of us worked for Company B. We both went to a conference, and we have contacted each other on various occasions throughout the years."* In another instance, Gloria (CAD CoP) states that "*I first met Daniel at Autodesk University, which is external to the company."* The key to serendipity as a mechanism of connection is that it is neither planned nor managed, and does not occur very frequently. At the same time, to accurately describe a set of collectively exhaustive mechanisms of connection, we must consider it as both a possibility and reality that exists outside of management control.

DISCUSSION

This paper set out to determine the mechanisms by which specialists become connected in distributed CoPs, and created an emergent categorization of these mechanisms into five categories—organizational control, organizational opportunity, social networks, and non-person centered search. Our results show that organizational control and organizational opportunity are the most frequently mentioned mechanisms of connection, and that social networks and non-person centered search were mentioned less frequently, but were not insignificant. First, we discuss how these mechanisms of connection affect our theoretical understanding of CoPs as hybrid social and organizational structures. Using this view of CoPs, we will then discuss the theoretical impacts of CoP formation through the fiat of managers. Secondly, we will discuss the practical impact of this work, namely the extent to which organizations have power to create knowledge sharing connections within distributed CoPs.

CoPs as Hybrid Social-Organizational Structures

Over the past few decades, there has been extensive work to define and re-define CoPs (Ardichvili 2008; Kimble and Hildreth 2004; Lindkvist 2005; Manville and Foote 1996; Roberts 2006; Saint-Onge and Wallace 2012). As of yet, however, there is not a clear consensus between the business and academic communities. Business practice has dubbed distributed groups of professionals who share a "common class of problems" to be a CoP (Manville and Foote 1996), which loosely groups professionals within the organization that may, or may not be a cohesive community. For this reason, Lindkvist (2005) re-defines these loose groupings of specialists as "knowledge collectivities" to exclude the community terminology. Throughout this debate, there has been little, if any scholarship that explores the networks within distributed CoPs, to determine how connections form between professionals.

The original, theoretical conception of CoPs was to describe the role of social practice in learning theory (Brown and Duguid 1991; Lave and Wenger 1991). Beyond this initial conception, the addition of IT infrastructure, the globalization and distribution of workers and the subsequent expansion of CoP boundaries has changed the external environment of CoPs, and the physical characteristics of CoPs (spatial distribution, mode of interaction, size, epistemological boundaries, etc). Despite these changes, we believe that the CoP terminology should not be abandoned simply because a CoP is established by managers.

To start, it is evident that CoPs are heavily influenced by the organizations that host them. Physical office locations and projects bring people into contact; many relationships are actively prescribed by management, or initiated by authoritative control. Although this apparently runs contrary to CoPs as emergent phenomena, it is important to situate these structures in the organizations that host them. If, in fact, "communities of practice are realized in the lived-in world of engagement in everyday activity" (Lave and Wenger 1991 p. 47), then we must consider hierarchical structures and their resulting demands to be part of this activity. From this perspective, the knowledge sharing patterns occurring within CoPs are as much a factor of organizational structure as the social practice that occurs within that structure. Indeed, this view is not inconsistent with either theory or practice. Although CoPs are supposedly independent from hierarchical control (Wenger and Snyder 2000), many connections are initiated through the bureaucracy. Indeed, connections made through hierarchical channels can endure far beyond the authority that initiated them. Furthermore, it can account for the contrasting view that CoPs are simultaneously available to be strategically leveraged (Saint-Onge and Wallace 2012; Wenger et al. 2002), while their contribution to the organization is fundamentally uncertain (Kimble and Hildreth 2004). This is because CoPs are simultaneously reflective of the organizations that host them, while being subject to the inherent social participation of the members.

If we further explore organizational opportunity, social networks, and non-person centered searching as mechanisms of connection, it is evident that these are both practice-based and socially-based mechanisms of connection. With organizational opportunity, professionals come into contact with one another through project work, yet maintain connections beyond their initial shared task as part of the CoP. In the context of the organization, this process embodies practice-based learning and knowledge sharing as professionals work together in practice to problem solve, learn from one another, and execute a project. Once the project is complete, these same knowledge workers move on to their next assignments, yet maintain their original connections as part of an expanding social network. Even in the least dense network studied, CoP members were at most 3 connections removed from one another.

When managers prescribe CoP boundaries, there is a risk that the membership will not reflect underlying groups of practitioners. This is the concern expressed by Wenger et al. (2002), which indicates that CoPs will develop regardless of organizational endorsement. To this concern there are four obvious possibilities. First, prescribed CoP boundaries could align with existing groups of practitioners. If this were the case, we would expect to see constant interaction that was initiated through organizationally situated practice. This includes connections initiated through hierarchical control, project work, and social networking, much as we see here. Second, the prescribed CoP boundaries may completely envelop informal CoPs that already exist in the organization. If this is the case, there would likely be a higher incidence of connections initiated through organizational control that do not endure past their required lifespan (which we did not observe). Given that CoPs are initiated along strategically significant lines, the second scenario would be characterized by a misalignment between organizational structures and informal CoPs. Third, the prescribed CoP boundaries may have no bearing on the reality of work practice, in which case there would be few connections initiated through organizational opportunity. Fourth, it is possible that practitioners would like to share knowledge with others within the organization, but have not had a mechanism to do so, or do not know that others exist. As an example, there are pavement design engineers working in both airport and roadway construction, but these professionals do not come into contact with one another through reporting structures or project work. In this case, prescribed CoP boundaries could create a mechanism for sharing knowledge that did not exist in the existing structures or day to day work activities of the organization. Therefore the CoP would be the initiator and facilitator of connection, and prescribing a boundary could usefully group professionals who could then connect through social networking and non-person centered search within the CoP. The CoPs used in this study adhere most closely to the first and second scenarios. Although the majority of connections are initiated through organizational control and organizational opportunity, there are relatively few knowledge sharing connections that are broken because they are not relevant to members' work practice. While the CoP delineates relevant boundaries for practice, none of the three CoPs appear to create connection that is unmet by other mechanisms within the organization. With that said, these structures can be considered CoPs because they are enacted through the social process of initiating and maintaining connection with a group of practitioners that shares a common interest, concern, or set of problems (Wenger et al. 2002).

It is true that the geographic distribution of employees limits opportunity for interaction between CoP members, especially if there is not a mutual task to link professionals together. Within the existing body of research, there is evidence that proximity is a powerful motivator for connection (Kleinbaum et al. 2013; Reagans 2011). Even so, the geographic distribution of workers in a CoP is not completely limiting. There are mechanisms, such as non-person centered searches that circumvent geographic boundaries easily, even if they are less common. In fact, the use of IT infrastructure has expanded non-person centered searching as a mechanism of connection, but there is less evidence that these connections are enduring. Rather, they seem to meet one off project or task based needs, which was an identified motivation for connection noted by Javernick-Will (2011). Finally, consistent with the theoretical roots of CoPs, there is also robust networking, where referential awareness of other people's expertise creates a social community that directs inquiry. The main difference is that current CoPs are larger, and hence the social community has to span multiple different fields of knowledge that are too large to be comprehended by a single, overseeing mind (Becker 2001; Lindkvist 2005).

Taken together, our findings indicate that CoPs must be understood as entities that are inseparably situated at the interface of organizational structures, tasks, and the social communities that they facilitate. We propose that organizational control and organizational opportunity seed informal networks and allow them to form. Only after project tasks and authoritative directives have begun to bring people together is there an interconnected social network that can facilitate other mechanisms of connection on the basis of individual needs. Rather than downplay the role of organizations in managing CoPs, this view situates CoPs in the context of organizations. This contrasts with prior work indicating that direct managerial intervention that prescribed relationships can harm the dynamics of CoPs (Thompson 2005). Furthermore, this leads to the second major impact of this work; understanding the reach of organizational power in structuring employee networks.

Impact to Practice

In our analysis, far more connections came from organizational control and organizational opportunity than from social networks or non-person centered searches. Most organizational scholars acknowledge that organizations have authority to create formalized, hierarchical structures that influence employee behavior (Ouchi 1980), although the influence of these power structures on CoPs is uncertain (Roberts 2006). Our findings indicate that organizational control is an important mechanism to form individual connections that align with the definition and purposes of the CoP. That is to say, formal reporting structures and authoritative direction create lasting knowledge sharing connections between professionals that share a common class of problems. So although CoPs may not be subject to the same degree of governance (Wenger and Snyder 2000), they are positively and directly influenced by the power of the organization.

Practically, this means that managers can directly create knowledge sharing connections by changing reporting structures, which is a common managerial tactic for managing knowledge. Beyond direct intervention however, it is important that not all relationships within the CoP are prescribed through this mechanism. Allowing the formation of knowledge sharing ties through organizational opportunity, social networks, and non-person centered searching affords employees with a greater degree of choice in whom they connect with, which distributes decision making to the knowledge workers who know best what they need (Lindkvist 2005). Indirectly, managers can encourage employees to share their backgrounds with one another to enhance social networking and the effects of organizational opportunity. Furthermore, non-hierarchical mechanisms of connection require far less oversight, and are therefore less costly (Jensen and Meckling 1976). We would therefore recommend using organizational control to initiate strategic connections within the CoP that are in line with business goals. This reduces the uncertainty pertaining to strategic direction of CoPs (Kimble and Hildreth 2004), and may also facilitate increased connection through social networking, and non-person centered searches. In contrast, when CoPs are left to initiate connection solely through social networking, non-person centered searching, and organizational opportunity, there is agency risk that employees would try to opportunistically structure their networks for personal benefit (Burt 1992), leading to power and information hoarding (Wasko and Faraj 2005). So then, CoPs may have originally been conceived as entities void of hierarchical control, but our study indicates that the organization still wields significant power within the bounds of distributed CoPs. Rather than remain undirected, we suggest that managers use their power to create connection for strategic gain. This includes linking strategic areas of the company through work based opportunities and reporting structures to increase referential “who knows who” knowledge among employees. Instead of requiring interaction in these connections, managers should create the initial opportunity, and then allow employees to choose when these connections are activated.

CONCLUSION

This paper presents a qualitative study of the mechanisms of connection within distributed CoPs. We show that specialists become connected through four primary mechanisms, organizational control, organizational opportunity, social networks, and non-person centered searching. The variety of mechanisms observed in each CoP led us to see the CoP as an entity that sits at the nexus of formal bureaucracy, project tasks, and social tendencies, and is influenced by each one in turn. Next, the prevalence of organizational control as a mechanism for connection indicates that manager fiat can be used to create strategic connections to support practitioners in their everyday job tasks by tying them in to the global knowledge community.

As with any study, there are a number of limitations to this work that must be addressed. To begin, there is not agreement on the terminology that should be used to describe the CoPs in this study. Other scholars would undoubtedly classify what we have studied as virtual communities of practice (VCoPs) (Ardichvili 2008), practice networks (Brown and Duguid 2001), collectivities of practice (Lindkvist 2005), or simply not CoPs (Roberts 2006; Thompson 2005). This lack of agreement draws into question the external validity of this work, and the differing contexts to which it can be applied. To this threat, we have aligned ourselves with business practice in our definition. To begin, managers identify all three of the communities that we studied as CoPs. Beyond the commonality of name, each of the CoPs possesses several common characteristics. They are self governing, have online facilitation, span at least three geographies and multiple business lines within the company, and boast a formal membership greater than 150, the upper bound of human capacity for social interaction (Gladwell 2000). Thus, we limit the application of our findings to CoPs that have these characteristics. Secondly, we are limited in our conclusions by the qualitative process, as well as the selection of connections within the network. Without a 100% response rate, we cannot perform a random selection of connections, and therefore are unable to make strong numerical claims regarding the relative frequency of different mechanisms. Although we observed more incidences of organizational control and organizational opportunity than the other mechanisms, we can only speculate as to the veracity or magnitude of this difference. Future work would do well to examine the mechanisms of connection within distributed CoPs, using a random sampling methodology.

This study provides a firm foundation for future work, which should study CoPs as a relatively new organizational phenomenon. For instance, future work could further explore the outcomes of different mechanisms of connection, revealing the relative value of each mechanism for more relational (Cross and Sproull 2004) or information based (Borgatti and Cross 2003) needs. Along this same line of inquiry, future work could explore whether the mechanism of connection is an accurate predictor of the longevity of the relationship. Are there certain types of connection that tend to be more enduring than others? Finally, we do not know how the structure of CoPs is affected by mechanisms of connection. Overlaying methods of connection onto network structure would allow us to see whether certain mechanisms have a higher tendency to become central in the network. It may be possible, for instance, that strategic connectors and hubs within the network are initiated by the organization, rather than emerging organically as part of the community. This would have far reaching implications for understanding the influence of bureaucracy on the structure of informal knowledge sharing networks within CoPs. By gaining a better understanding of how networks form within distributed CoPs, we can alter and refine how these structures are used for strategic gain.

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Chapter 5: A Knowledge Based Theory of Coordination within Communities of Practice

ABSTRACT

Communities of Practice (CoPs) have proliferated in business practice as a means to coordinate knowledge within globally distributed organizations. Well functioning CoPs can be a powerful tool for intra-organizational problem solving, knowledge creation, and practice diffusion, because they facilitate interaction that is not limited by bureaucratic organization. At the same time, there has been relatively little research into coordination within CoPs, because typical bureaucratic coordination mechanisms like rules, sequencing, and routines are inherently task focused. In contrast, CoPs focus on relational belonging, and the patterns of interaction that describe everyday engagement in work practice. This paper assumes a knowledge based view of the firm, which states that the primary function of organizations is to coordinate specialist knowledge to optimally create a product or service, then explores the role of CoPs in achieving this aim. Through a qualitative evaluation of three global CoPs, we investigate the types of coordination occurring within CoPs, and generate a typology of coordination based on the degree of overlap in specialists knowledge bases, consisting of three primary types of interaction: 1. Overlapping connections, where specialists have similar knowledge bases, common vocabulary and experiences, and can interact deeply on highly contextual issues; 2. Complementary connections, where specialists have separate knowledge bases, and could not perform the same function as one another, yet there is a common task that requires both knowledge bases; 3. Growth type connections, where less experienced knowledge workers are learning and growing from more experienced workers. CoPs provide a non-bureaucratic means of organization where individuals can choose which type of coordination will satisfy their knowledge based needs. Therefore, they are the host of non-bureaucratic coordination within the firm. From this basis, we propose that coordination between knowledge specialists is relationship specific, and must be situated within practice networks. Secondly, we propose that the level of mutual knowledge in a relationship dictates the coordination activities that are possible between specialists. This view has

implications for our understanding of CoPs within the firm, and opens the door for future work at the bureaucratic/relational interface within organizations.

INTRODUCTION

As communities of practice (CoPs) have been adapted to business practice, they have slowly deviated from their theoretical roots. When they were originally theorized, the term "community of practice" explained the environment in which people learn through practice oriented participation in a social group (Lave and Wenger 1991). The intention was to situate learning theory within the context of practice, and social participation. Its most practical application to business was to uncover the ways in which people actually work, learn, and innovate within formal organizational structures (Brown and Duguid 1991). When managers saw the knowledge creation, collaboration, and technical growth that occurred when people participated in situated learning, they wanted to create structures in their organizations to *"increase knowledge creation as well as expand the extent and accelerate the speed at which knowledge is exchanged around the organization"* (Saint-Onge and Wallace 2012). To do so, companies initiated CoPs as formal organizational structures created to facilitate knowledge exchange. In most global organizations, managers began using CoPs as a "way of managing knowledge" (Roberts 2006) through topical communities created to facilitate knowledge sharing across distributed communities of professionals (Hildreth et al. 2000). Thus, the role of CoPs has undergone a fundamental shift as they were adopted by organizations. Instead of describing the importance of practice and social interaction in learning theory, CoPs are being used as an organizing principle to facilitate the coordination of specialist knowledge within firms.

Since their conception, CoPs have become so widespread that the term "community of practice" has become part of the standard business lexicon (Wenger and Snyder 2000). In spite of their proliferation, there is a dearth of theory to explain the coordination between specialists that is facilitated within a CoP setting. Grant (1996) presents a "knowledge based view of the firm" in which organizations are institutions for integrating the knowledge of specialists. Namely, the goal of firms is to organize specialists into an optimal configuration to efficiently apply knowledge to produce a product or service.

At the same time, Grant (1996) downplays CoPs as a location for knowledge exchange, which is seen as an inefficient means of coordination based on unnecessary replication of what people know. He identified four task based coordination mechanisms, including sequencing, rules, routines, and group problem solving. His conclusion is that firms generally benefit from an increased use of rules, sequencing, and routines, because they are more efficient means of task coordination. This would indicate that an increase in bureaucratic structuring would produce better utilization of knowledge within firms.

Other scholarship has opposed this conclusion because coordination is not all task focused. Szulanski (1996) focused on the transfer of best practices, which is valuable, but not task driven. His work concluded that knowledge is difficult to "move around," and therefore poses unique challenges that are specific to relationships. Other scholarship (Becker 2001) has opposed coordination of knowledge through bureaucratic management, and noted the uncertainty associated with structuring relationships and desired outcomes.

Within this debate, it is important to realize that CoPs are a non-bureaucratic means of knowledge coordination. In contrast to typical coordination mechanisms, CoPs focus on social participation and relationships, which are often in conflict with bureaucratic structures (Brown and Duguid 1991; Cross and Parker 2004). This fits with other work that shows seeking help from others is primarily relational (Borgatti and Cross 2003). For this reason, even recent scholarship in coordination sees CoPs as a mechanism for expertise management rather than an a platform for knowledge coordination (Bruns 2013). While existing scholarship on coordination has focused on macro level bureaucratic structures and micro level inter-personal interactions, it has largely passed over CoPs as a mechanism for coordinating specialist knowledge. This is in spite of the fact that CoPs supposedly emerge through the "lived in world" of everyday engagement (Lave and Wenger 1991), and would therefore provide a rich environment for understanding day to day coordination between specialists in a firm. Within a business setting, CoPs group knowledge specialists according to a shared knowledge domain (can be broad or narrow), evidences of community participation, and a basis for applying their knowledge through practice

(Wenger et al. 2002). By this definition, CoPs are not a one dimensional tool for expertise management or knowledge exchange, but constitute the very basis of non-bureaucratic coordination within the firm. In spite of this, there is a dearth of research that explores coordination activities within CoPs.

This study advances a non-bureaucratic view of coordination within the firm that focuses on the integration of specialist knowledge through communities of practice. Furthermore, it draws attention to different types of coordination which are vital to the function of the organization without an explicit focus on a task. In fact, knowledge coordination consists of *how* knowledge specialists interact with one another in a social setting to influence each others' understanding of the basic problems and solutions faced by professionals in their field. Because CoPs emerge from the everyday practices of professionals, this study examines three CoPs within two project based organizations to determine the types of knowledge coordination occurring within a CoP setting. Through our observations of knowledge coordination in terms of problem solving, sense-making, education and training, as well as cross pollination of ideas, we develop a framework for understanding the coordination of knowledge specialists within CoPs.

COMMUNITIES OF PRACTICE IN PRACTICE

In business practice, CoPs have deviated significantly from their theoretical roots along three dimensions, size, disciplinary scope, and governance. This section elucidates each of these differences to demonstrate the degree to which CoPs are a new phenomenon that is best understood as a means of coordinating specialist knowledge. To begin, CoPs, as they are applied in practice, have expanded to facilitate coordination between geographically dispersed professionals. When Brown and Duguid (1991) defined CoPs as "tight knit" groups, they likely did not intend the term to be applied to loosely coupled, geographically distributed groups with thousands of members. The recent expansion of CoPs has served the coordination needs of business managers, and simultaneously caused theoretical objections. More recent scholarship has re-defined the business practice as electronic "practice networks" (Brown and Duguid 2001) that are loosely knit and geographically distributed, or "collectivities of practice" characterized by a knowledge base that is distributed and individualized, but aligned through specific project goals (Lindkvist 2005). Rather than being purely social communities, Lindkvist (2005) acknowledges the intrinsic ties between the CoP and the organization that hosts it. Both the size and spatial distribution of global CoPs decrease key social aspects of the community like “local lore, shared stories, inside jokes, and knowing laughter” (Wenger 1998 pp. 125–126). At the same time, CoPs can continue to provide social participation and learning on a global basis through clustered network structures (Wenger et al. 2002).

The next significant deviation of practice and theory is in CoP governance. When Brown and Duguid (1991) and Lave and Wenger (1991) originally conceived CoPs, they envisioned groups of people that operated relatively free from the hierarchical control of the organization. Only later did scholars begin to postulate that CoPs may be amenable to hierarchical control, or managerial oversight (Wenger et al. 2002). In theory, CoPs operate outside of hierarchical control because they are not initiated by management, but rather emerge organically as the way that people work, learn, and innovate in community settings. In current practice however, the boundaries of CoPs are frequently manipulated by managers to increase the scope of membership (Saint-Onge and Wallace 2012 pp. 78–79). The introduction of this type of hierarchical control is new to CoPs, and has the potential to change their nature. At the same time, CoPs are not bureaucratically managed. Although managers can establish the topical boundaries of CoPs, and create opportunities for interaction, over management of CoPs can easily kill otherwise healthy social interactions (Thompson 2005). Within CoPs the actual patterns of interaction are mostly reliant on social patterns dictated by the individuals who participate, rather than bureaucratic reporting structures. At the same time, both theory and practice have tended towards CoPs as a mechanism for knowledge coordination, with the primary goal of harnessing CoPs for strategic gain through better integration of knowledge specialists (Saint-Onge and Wallace 2012)

Lastly, because the boundaries of CoPs are decided by managers rather than enacted, the scope of these communities has expanded beyond a single “field of mature practice” (Lave and Wenger 1991 p. 122), and now encompasses a distributed body of knowledge (Becker 2001) that is “radically dispersed, distributed or individualized, being impossible to gather or comprehend by any single, overseeing mind”

(Lindkvist 2005 p. 1200). To understand the role of CoPs in coordinating specialist knowledge, we have to consider the interactions between many, diverse knowledge bases. These nebulous, geographically dispersed, inter-disciplinary groups bear the namesake "communities of practice," and are marketed as "the most significant, tangible example of knowledge management at work in an organization" because of the enormous benefits that they produce (Saint-Onge and Wallace 2012). So we see then that CoPs play a vital role in integrating and coordinating a wide variety of different knowledge bases, yet there is no cohesive theory explaining what this coordination may look like.

To explore how CoPs coordinate specialist knowledge, we will start by identifying connections between specialists using social network methods (Paul Chinowsky and Taylor 2012), and then gather qualitative interview data about connections occurring within the network. By analyzing CoP members' descriptions of their own connections, we can create an emergent framework describing the types of coordination occurring within CoPs, and then discuss the implications of such a framework for both CoP and coordination theory.

Knowledge and Coordination

Because knowledge is a topic addressed in many fields of academia, it is important to pause and consider the characteristics of knowledge that affect the coordination of specialists within a firm. There is an enormous body of literature on this topic, so we will only examine the key properties of knowledge that make it difficult to manage within an organization, and describe the intersection of knowledge management and coordination theory.

The Nature of Knowledge

While there are many areas of disagreement, most scholars agree on the concept of a knowledge hierarchy that distinguishes between data, information, and knowledge. Each builds upon the other such that data is raw numbers and facts, information is assembled and processed data, and knowledge is authenticated information that supports action (Alavi and Leidner 2001). Within this hierarchy we are most concerned with the transfer of knowledge, rather than information or data. Indeed, economic theory indicates that firms have an advantage over markets in knowledge transfer (Kogut and Zander 2003), where the same advantage would not apply for information or data transfer. Both data and information can be explicit, written resources, so they may be more readily protected via conventional property laws (Liebeskind 1996). Further, data and information are not subject to hazards like appropriation, limited exchange due to cognitive ability, and strategic accumulation or hoarding (Nickerson and Zenger 2004). Thus, coordinating specialist knowledge rather than information or data is the main challenge given to the firm, and the focus of our study.

Furthermore, scholars agree that knowledge can be both tacit and explicit. When knowledge is written down or communicated through formal, systematic language, it is considered to be explicit (Polyani 1966). On the other hand, tacit knowledge is rooted in action, commitment, and context, so it is inseparably linked to the individual who knows (Nonaka 1994). For the purposes of this paper, it is not worthwhile to take a deep dive into this distinction, but simply note that when specialists coordinate with one another, they generally transfer a blend of tacit and explicit knowledge.

Possession of knowledge

Drawing from Nonaka (1994), there is a second dimension of knowledge that we attend to beyond the tacit/explicit boundary. The *ontological* dimension characterizes whether something is known at an individual or collective level. Individuals may know how to perform certain tasks, while a group of individuals performing tasks may be able to execute a complex process collectively. This can be seen as tacit knowledge held at the organizational level. Because communities of practice are not focused on completing tasks, and, instead, have topical rather than task oriented boundaries, we will primarily observe what Nonanka calls "socialization," namely knowledge sharing between individuals. For the purposes of this paper we assume that knowledge is possessed by individuals, and that coordination involves interactions between discreet, individual knowledge bases.

There is debate as to whether knowledge is a 'thing' that can be moved around, or a concept that is only constituted through practice. According to Orlikowski (2002), it is not possible to know something without practicing it, so sharing "know how" is a matter of enabling others to learn a practice rather than passing along the 'thing' that is knowledge. By this view, knowing is contextual and provisional, so practice is not transferred directly between people. Rather, other people can be enabled to act in their particular context. Once again, this distinction is important, but not critical, to evaluating coordination between specialists in the firm. Whether interaction between professionals creates the exchange of information that enables knowing, or if knowledge itself is a thing that can be transferred, there is necessarily a dyadic level interaction that fosters the exchange. We will look specifically at the nature of these dyadic interactions to determine the types of coordination occurring in global CoPs.

Coordination of Specialists

When Grant (1996) elucidates the knowledge based view of the firm, he recognizes that, it is not beneficial for everyone within the organization to know what everyone else knows, for this reason, coordination between knowledge specialists is the key challenge faced by managers. The work goes on to describe four mechanisms for integrating specialist knowledge within the firm: rules and directives, sequencing, routines, and group problem solving and decision making (Grant 1996). Rules, directives, and sequencing are firmly rooted in bureaucratic structuring, while routines and group problem solving have significantly less process-oriented structure. Although routines and problem solving are not highly structured, the focus remains on task performance. While CoPs aim to drive task performance through providing increased access to knowledge resources, they are not fundamentally task focused. Instead, CoPs are a relational mechanism of coordination that produces new knowledge and social participation.

Prior work has examined coordination between different units within the company, yet contains only a brief mention of social interaction as a coordination mechanism for inter-unit knowledge sharing (Tsai 2002). To fully describe CoPs, we must take a more micro-level view of coordination as interactions between individuals, rather than entire units. Along these lines, Cross and Sproull (2004) classified knowledge sharing relationships in terms of their function, presenting five types of information relationships; solutions, referrals, problem reformulation, validation, and legitimation relationships. While this classification is useful for decomposing the purpose behind knowledge coordination, it does not detail how these relational interactions occur. In addition to these relational interactions, there is a body of work that discusses the role of “common knowledge” in facilitating collaboration. Cramton (2001), identified a variety of collaboration breakdowns on mutual tasks that were the result of not having enough common knowledge. Grant also acknowledged the importance of having "common knowledge" which he defined as the "intersection of their common knowledge sets" (Grant 1996 p. 115), so that people can communicate. Although we know that common knowledge is important to facilitate knowledge sharing (C. D Cramton 2001; Espinosa et al. 2007), there is very little work to describe how types of coordination are affected by differing levels of common knowledge. Thus far, neither one of these approaches acknowledges that the degree of mutual knowledge creates different relational environments, such that the level of common knowledge impacts coordination. Because CoPs function across organizational boundaries instead of within them, it necessitates a better understanding of how different knowledge bases (i.e. individuals in different business units) coordinate with one another.

This paper specifically investigates how CoPs coordinate the knowledge of geographically dispersed professionals with a broad array of different, yet related knowledge bases. By focusing on dyadic level exchange, we hope to create a robust understanding of the types of coordinating interactions facilitated by CoPs in business practice.

METHODS

In practice, CoPs have evolved on a separate trajectory from the theory supporting them. To build theory based on practice, we analyzed three CoPs within two firms to explore the interactions between specialists with diverse knowledge bases. By investigating these interactions we are able to build theory regarding the role of CoPs in coordinating the knowledge of their members. First we deployed social network surveys to the entire CoP to create infographic maps showing who was connected with whom. From these maps, we selected participants for semi-structured interviews which enabled us to ask detailed questions about the type of exchange in specific knowledge sharing connections.

Social Network Survey and Interviewee Selection

To help evaluate types of coordination that occur in multinational CoPs, we first deployed social network surveys to each of the three CoPs studied. Each CoP is large, geographically distributed, facilitated and defined by managers, and covers a knowledge base that is too large for a single individual to comprehend. For purposes of confidentiality, we use the pseudonyms “Company A” and “Company B” for the two companies involved in the study. .

Process Improvement CoP: Members work as internal consultants for construction and engineering projects to provide process improvement services for Company A. Membership includes a wide variety of disciplinary backgrounds from computer modeling to project management. There are 273 members distributed across more than 10 countries, with membership at all hierarchical levels and in each business line. Members have access to an intranet that links to a project report repository and online process improvement forums.

Transportation CoP: Formed along one of the major business lines of Company B, the members of this CoP all work in the transportation sector of business. This includes 365 members across a wide variety of disciplinary groups and more than 10 countries, although the majority of members are concentrated in North America. An online platform was initiated by managers approximately 5 years ago, and it includes a search function, document repository, and online forums.

CAD CoP: Rather than bounding itself along a business line, the CAD CoP was created to link global practitioners using computer aided design (CAD). There are 1153 members across all business lines and geographies within the company. Topically, CAD includes a range of different software that is used to create construction drawings across all industries and geographies. Housed within Company B, the CAD CoP has access to the same online platform as the Transportation CoP, although the structure and content of online interactions is specific to CAD rather than transportation.

Survey response rates were 36.6%, 35.2% and 29.9% in the Process Improvement, Transportation, and CAD CoPs, respectively. The survey was sent to the entire population of each CoP, and each participant was asked *“with whom have you shared knowledge in the past six months?”* where knowledge was defined as information that directly enabled action in participants' particular job role. Within the survey form, participants could select their connections from a complete list of CoP members. Using the data from the survey, we selected interviewees using a stratified sampling technique (Singleton and Straits 2005) so that we could gain perspectives from different geographies, as well as from the core and periphery of the network. To do so, we calculated the number of connections held by each person within the network, and stratified our interviewee selection with high, medium, and low levels of connection.

Semi-Structured Interviews and Qualitative Analysis

For each interviewee, we selected three knowledge sharing connections from the survey data to discuss in depth, and created customized interview guides to ask participants about those specific connections. Typically, qualitative research employs a convenience sampling technique to achieve conceptual saturation. By using a sampling technique based on social network surveys, we reduce the effects of self selection and increase the internal and external validity of our findings. We conducted semi-structured interviews via phone call that lasted between 30 and 50 minutes. During the interviews, participants were asked to describe their job role, their involvement in the CoP, and the selected knowledge sharing connections from the survey. For each connection we asked if participants were aware of their connection's area of expertise, the type of knowledge that they share with that person, and the degree of overlap between their knowledge bases.

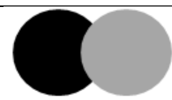
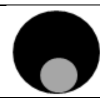
In total, we conducted 27 interviews in the Process Improvement CoP, 22 interviews in the Transportation CoP, and 28 interviews in the CAD CoP. Interviews were recorded, then transcribed, and entered into QSR NVivo, a qualitative analysis software. To analyze the data, we followed a process similar to that outlined in Haney et al. (1998) to create an emergent coding structure. Initially, two researchers independently examined the data to search for emerging themes of coordination between specialists. There was a particular emphasis on the type of knowledge being shared, and the degree of overlap between specialists' knowledge bases. Next, the two researchers compared notes to discuss any discrepancies and the emergence of prevalent themes. After reaching consensus, we created coding structure to typify these connections into groups characterized by different degrees of overlap in participant's knowledge bases. The emergent categories were collectively exhaustive and mutually exclusive in their description of connections. Once these concepts were developed, two researchers analyzed the interview data independently, and checked the reliability of these categories to increase both reliability and construct validity. As the coding structure was applied to our interview data, we periodically conducted quality control checks to verify consensus among the two researchers. In total, we asked participants about more than 150 knowledge sharing connections that were coded into our framework.

TYPES OF CONNECTIONS

During the initial examination of the data, we attempted to define "common knowledge" and determined that it was specific to each relationship. From this initial observation, we identified four types of connections characterized by different degrees of overlap in participants' knowledge bases. The type of connection quickly became a dominating concept, because the type of coordination (i.e. problem solving or task coordination) between specialists depended on the degree of overlap.

Professionals with a high degree of overlap typically have the same job roles, and similar knowledge bases. We call these "overlapping" connections, even though two knowledge bases are never perfectly identical, and overlapping connections tend to coordinate specialist knowledge through problem solving, sense-making, and the identification of subtle expertise. Next, there were a group of professionals with very little overlap in their knowledge bases, but both needed to coordinate to accomplish a common task. We called these "complementary" connections. For instance, within the Transportation CoP, there are both economists and project managers. Both work on transportation projects, are familiar with what the other professional is capable of, yet each is unable to step into the others' job role. Complementary connections occur in all three CoPs, and tended to coordinate specialist knowledge by task focused coordination, cross pollination of ideas, and creating networked connection between pockets of different expertise within the organization. Next, we identified "growth" connections, in which a knowledgeable professional is teaching a less knowledgeable one. Although the exchange in growth type connections is one sided, specialists coordinate with one another in training, education, and reproduction of expertise. Finally, there were a few rare occasions when CoP members experienced "non-overlapping" connections due to misguided job assignments or social obligations, in which their two knowledge bases were so different that there was no coordination between specialists. These findings are summarized in Table 5-1.

Table 5-1 - Types of Connection and Coordination

Type of connection	Visual Representation	Types of Coordination
Overlapping		Problem Solving Sense-making Identification of subtle expertise
Complementary		Task coordination Cross pollination of ideas Structural holes
Growth		Training/education Replication
Non-Overlapping		No coordination

To maintain anonymity, we use pseudonyms to identify interviewees in these quotations. Due to the relational nature of the quotes, we elected to use names rather than impersonal identification codes. All four types of overlap were observed in each of the three CoPs.

Overlapping

One way that specialists coordinate their knowledge within CoPs is problem solving, sense-making, and building awareness of subtle areas of expertise with other professionals who are similar to themselves. Within all the CoPs studied, there were connections characterized by a high degree of overlap between the two participants' knowledge bases. In these cases, the two employees are mostly interchangeable as knowledge resources in the company because they perform similar job roles, and have the same basic knowledge base and experience.

While two people will not have exactly the same experience, knowledge, and ways of thinking, overlapping interactions allow professionals who perform similar tasks to coordinate richly on a wide variety of deeply contextual issues. As one respondent from the Process Improvement CoP described *"both of us think along the same lines when we are looking at what we need to do and how to make improvements and those kind of things… I think we are very aligned because we both have the same background."* This alignment generally facilitates high quality knowledge exchange, which provides opportunities to efficiently problems solve. When asked the type of knowledge that she exchanges with another CoP member, one interviewee in the Transportation CoP said *"I would brainstorm with him where we would look at any issue and talk through our ideas as a way to come up with a solution."* Because they have heavily overlapping knowledge bases, the two CoP members do not have to educate the other on their ways of thinking or fields of work. This enables close coordination between specialists who wish to brainstorm and solve problems.

Individuals with overlapping type connections also coordinate through sense-making to define their roles and their field of practice. When this happens, it pushes the company towards consistency of global practice and provides opportunities to critically review and improve technical practice. Kerry (Process Improvement CoP) discussed her connection to a co-worker, saying that "*We were just playing the same role of coordination for different regions… we were just working together and defining the roles or the activities for the different regions."* Even though Kerry's connection works in South America while she is in North America, an overlapping connection through the CoP allows them to coordinate with one another by sense-making. By mutually defining their field across geographic boundaries, overlapping connections create global consistency of practice by aligning geographically dispersed employees. This type of sense-making in overlapping connections similarly provides an opportunity to improve technical practice.

Finally, a high degree of overlap in knowledge bases facilitates networking to help specialists locate subtle areas of expertise and create latent connections that can be activated when needed. In the CAD CoP, one interviewee shows how his overlapping connection has allowed him to precisely identify Bill's strengths. *"Bill could probably do 80% of the things I could do and I can do 75% of the things he can do. I don't design as well as Bill, but there are certain features that have been updated in CAD that I* *have more exposure to."* Specialists do not need constant access to the subtle strengths of their colleagues, although identifying these strengths in others will create latent connections that are activated when needed.

So then, one way that specialists are coordinating with one another in CoPs is by problem solving, sense-making, and networking through overlapping connections. These interactions facilitate immediate solutions to deep contextual problems, ensure continuity of best practice and innovation within specific fields, and generate latent networks of connection to help locate more subtle individual expertise within the company.

Complementary

Through complementary connections, specialists coordinate their knowledge through tasks requiring both knowledge bases, cross pollinating ideas, and forming network bridges to different areas of expertise in broadly focused CoPs. Complementary connections occur when two CoP members have different areas of expertise, yet both knowledge bases are required to accomplish a given task or goal. Generally both have a high awareness of the other's area of expertise, and what they are capable of doing within a particular task, but the two participants do not have the knowledge required to switch jobs.

Although complementary connections can be initiated for a variety of reasons, this type of coordination is typically task focused. Because complementary knowledge bases are required to perform complex tasks, it is the task itself that helps bridge the two knowledge bases. For instance, when one employee was asked about her connection with Sam, she stated *"Sam is a hydraulic engineer. If we were designing something and it is going to affect stream flow, or stream capacity, we will share knowledge back and forth to coordinate, but as far as technical knowledge; there is not a lot of exchange there."* (Marguerite, Transportation CoP). As a structural engineer, Marguerite has very little technical overlap with Sam, yet there are times that projects and tasks bring them together. During these times, they need to interface with one another to produce a complex project. This leads to a high level of awareness of others' knowledge bases, but not the ability to do what they do.

Within complementary connections, specialists also coordinate through non-task focused cross pollination of ideas. The application of several diverse knowledge bases to solve problems can usefully create more robust solutions. As one CoP member stated, "*The risk is when you all have the same mindset, you all think the same way and make the same mistakes, so it's good for different people to mix in. My boss is from a completely different background, and we think differently, but we come up with a better overall solution." (Faye, Process Improvement CoP).* While cross pollination of ideas can be productive on a more general level, there is less benefit to sharing in depth technical or field specific knowledge. Arthur in the CAD community demonstrates this concept "*We do completely different lines of work. He's a structural modeler, I do alarm systems. So we might talk about Revit, but we wouldn't talk about the finer details of what we do."* In this case, the two CoP members can usefully share ideas about the software that they use, because they recognize the inefficiency of everybody knowing what everybody else knows (Grant 1996), and therefore do not discuss details that do not relate to both of their work.

Finally, complementary type connections provide CoP members with access to different and diverse knowledge bases within the organization. As Burt (1992) theorized, this produces network structures that provide swift access to resources within the community, even if not immediately apparent. In the previous section we discussed the role of overlapping connections in producing latent networks of ties that can be activated when needed. Complementary type coordination is like the bridge between different topical knowledge bases that allows people to use their connections to find the right specialist for their project. Talking about one of her connections, Maureen in the Transportation CoP described how she located an economist through her connection Ryan. "*So once Ryan had a better understanding of the issues on this particular project, he identified a person who is a specialist in land use economics. We were able to bring that person out to New Zealand to work on the project, all because Ryan had a bit of knowledge regarding some of the specialists in the wider company."* Even through Ryan is an economist, he realized that he did not possess the specific expertise required for the project. However, through his overlapping connection with another land use economist, Ryan was able to evaluate the specialist knowledge required for Maureen's project, to connect her with the correct person for the job.

In addition to overlapping type interactions that occur within global CoPs, complementary connections facilitate different types of coordination between knowledge specialists. Rather than connecting experts with similar knowledge bases, complementary connections facilitate coordination between specialists with diverse areas of expertise. Specifically, complementary connections within CoPs facilitate coordination of specialists through task coordination, cross pollination of ideas, and interpersonal ties that bridge different areas of expertise within the company.

Growth

While overlapping connections allow experts to mutually define their field, growth connections allow continuity of practice by passing knowledge from more experienced to less experienced professionals. In growth connections, there is a fairly clear mentor and mentee, where the mentor could perform most, if not all, of the mentee's job role. Coordination occurs through training and education as the less knowledgeable participant tries to accumulate expertise and grow their knowledge base into one that overlaps with their mentor.

Within CoPs, growth connections are frequently initiated through formal organizational roles, where the difference in knowledge base is linked to tenure in the field or organization. Coordination between specialists happens through training and replication as experts with more experience pass on what they know, growing their mentees' knowledge bases and replicating their knowledge. Anita, talking about her mentor within the CoP states that "*I am sure that he could do everything I am doing, and I would only be able to do a small portion of what he does due to his experience. There is a 30 year age gap between us." (Anita, CAD CoP).* Because of the knowledge gap between mentor and mentee, it is clear that coordination consists of one party learning from the other.

Over time, the mentee learns and grows, significantly narrowing the gap between the two knowledge bases. When asked about the degree of overlap between his knowledge base a colleague's, Charlie stated that "*now there is a lot of overlap, but at the time we started interacting, I didn't know* *anything at all."* Throughout this process, the exchange between mentor and mentee becomes richer, more detailed, and more contextually nuanced, so that the participants become peers. Janice recalls that she "*finally got to a point where I knew enough to have a conversation, so it was more bouncing ideas off one another instead of me taking direction from him" (Janice, Process Improvement CoP).* As this quote shows, the tacitness of the interaction tends to increase as the mentee becomes more knowledgeable, and acquires the vocabulary required to discuss problems related to the field.

Non-Overlapping

Because CoPs are topically bounded to specific practices or business lines, it is uncommon for CoP members not to have any useful overlap in their knowledge bases. On several occasions however, members described non overlapping connections, where there was no useful coordination of knowledge. When asked why a particular connection was not seen as useful, Davidson from the CAD CoP stated that "*I guess it is primarily because the work that we do does not overlap. She's in the rail group and was working in microstation, which I do not use. So there would be no benefit to me trying to get knowledge from her."* In this case, Davidson perceives that his connection will not have any useful knowledge to share with him due to a complete lack of overlap. With complementary connections, there is very little overlap, but both knowledge bases are required to perform a more complex task. Here, we see that non-overlapping connections do not have any sort of useful commonality. Marcus in the Transportation CoP talked about his frustrations in dealing with another professional that has a non overlapping connection in terms of geographic specificity. He recalls that "*with Lindsay there is less overlap in what we are doing. She has been focused on geographically specific technical projects. I have gone to her with several issues, but there is a disconnect in terms of her focus and mine. It's partly geographical, and partly because her projects are so theoretically based that they haven't had a direct relevance to my work."*

Non-overlapping connections do not appear to provide any sort of useful coordination between specialists in the CoP. Rather, professionals spend time that would otherwise be productive interacting with somebody who cannot satisfy their knowledge based needs. Although rare, we observed several non-overlapping connections in each of the broadly focused CoPs.

KNOWLEDGE COORDINATION IN COPs

Knowledge coordination within the three CoPs was characterized by a diverse mix of overlapping, complementary, and growth connections. In addition to these productive relationships, there was a low incidence of non-overlapping connections that represent unproductive relational expense. Although non-overlapping connections did not yield useful knowledge coordination, we identified only three non-overlapping relationships for over 150 connections. As we described in the previous section, these three types of connection facilitated eight distinct coordination activities between knowledge specialists. The result was a very complex, networked environment, where knowledge sharing connections are differentially suited to users' needs. The results of this study allow us to conceptualize multi-lateral CoPs as key locations for non-bureaucratic knowledge coordination, and to determine the unique characteristics of CoPs that facilitate these complex, networked environments.

The framework makes two significant contributions to our current understanding of coordination within firms. First, it explains the complexity of a networked system through a general understanding of knowledge domain overlap. Because employees in an organization have unique knowledge, and therefore a different degree of overlap in each of their connections, it is important to understand inter-personal coordination as relationship specific. This conclusion can easily lead to an infinite degree of complexity based on incremental degrees of overlap. Our framework accounts for the degree of knowledge-base overlap in relationships, and explains this phenomenon through a manageable typology of overlapping, growth, complementary, and non-overlapping connections. Secondly, this emergent framework discovered that the degree of overlap dictates the type of knowledge coordination that is possible, linking eight different mechanisms of coordination to three different types of connections.

Complexity and Classic Coordination

To discuss these contributions more in depth, the central challenge given to the firm is to optimally coordinate specialists to produce a product (Grant 1996), and yet we know that all humans are naturally bounded in their ability to understand complex problems and act rationally (Simon 1957). Because of this, managers are unable to use their authority and directive to optimally structure interactions between workers. This is especially apparent in knowledge-workers due to the tacit nature of knowing. As put by Polyani (1966), we all "know more than we can tell," making it incredibly costly for managers to try to learn what people know, and what they need to know, then pair them accordingly. Returning once again to the coordination mechanisms outlined in Grant (1996), bureaucratic organization through rules and sequencing is less suited to identify individual knowledge needs, and to create static processes to meet those needs. This is because the type of relationship, coordination mechanism, and content of exchange are unique. Although our framework begins to simplify our understanding of knowledge coordination within CoPs, it would not reduce the high administrative costs of trying to organize individuals' knowledge bases through rules and sequencing. Instead, knowledge coordination based on the degree of overlap reveals the underlying complexity of knowledge sharing networks that make them relationally dependent, and therefore difficult to bureaucratically manage. Unfortunately for managers, they must make choices as to the formal structuring of the organization, including where people are located, who reports to whom, and the manner in which business lines or practice groups are structured. In this way, managers can easily limit potentially useful connection by creating organizational structures that are less than optimal.

On the other hand, Grant (1996) also identified two non-bureaucratic mechanisms of task coordination: routines, and group problem solving. These two mechanisms are less subject to bounded rationality, yet still rely on mutual tasks to organize individual contributions. In contrast, the goal of CoPs is knowledge sharing through social participation, which once again indicates individual and sometimes divergent goals among the membership. In spite of this, we identified significant interactions between CoP members who meaningfully coordinate what they know to provide greater access to knowledge resources, educate one another, solve conceptual (in addition to task oriented) problems, and share best practices. Among all of these interactions, only task coordination within complementary type connections resembles the "routines" outlined by Grant (1996). Thus communities of practice highlight non-task based coordination within the firm that is essential to utilizing the knowledge resources of an organization. The complexity of interactions further emphasizes that the coordination activities are relationally dependent, and thus unique.

Given the relational dependence of non-task coordination, it is likely that CoPs are performing a unique role within bureaucratic organizations. Within CoPs, individuals participate in a flexible community that allows them to seek and meet their own knowledge based needs. By introducing an element of choice and control to knowledge workers, distributed expertise is accessed by those who know best what they need rather than proscribed by reporting structures (Lindkvist 2005). Although we see that certain interactions with CoPs are *initiated* due to reporting structures or task requirements, the connections formed have a venue for knowledge exchange that is not regulated or managed. So then, individuals can maintain connections that they believe are particularly valuable regardless of role changes, project turnover, or organizational restructuring. Thus, by understanding that knowledge coordination is relationally specific, the non-bureaucratic environment of CoPs can be seen as uniquely flexible to accommodate different types of coordination.

Common Knowledge Dependencies

The second significant contribution of this study was detailing the common knowledge dependence of non-task coordination between knowledge specialists. Organizations, according to the knowledge based view, are institutions for coordinating knowledge (Grant 1996), so the primary challenge is one of optimal coordination. Although task-based coordination through rules, sequencing, routines, and group problem solving are highly visible, it is equally important to provide employees with opportunities to coordinate in less tangible ways. This includes sense-making, non-task problem solving, cross pollination of ideas, locating expertise, and training one another. As discussed in the prior section, this research has revealed the relational dependence of non-task based coordination, and created a framework to conceptualize the complexity of knowledge sharing networks. However, this framework also reveals the dependency of coordination activities on the degree of common knowledge within a given relationship.

On the surface, this means that individuals with highly overlapping knowledge bases are limited by what they know to a few kinds of coordination, namely problem solving, sense-making, and identifying subtle expertise. This has important implications for determining CoP membership. The more tightly bound a community, the more overlap there is between CoP members. Broadly bounding a CoP in terms of the transportation business line gives employees a more flexible environment with many possibilities for coordination. For instance, the Transportation CoP includes economists, pavement design engineers, project managers, and everything in between. If an economist needs to speak with a pavement design engineer to determine the average lifespan of a road, it is more arduous to find relevant expertise in the Transportation CoP than it would be in the Pavement Design CoP. Although searching within the Transportation CoP is more efficient than searching through the entire company, narrower groups increase search efficiency. At a certain point, the scope of groups begins to negatively affect individuals' access to different, but relevant knowledge bases, and therefore restrict cross-pollination, task coordination, and structural holes type coordination. If the pavement design CoP was further bounded to pavement designers in North America with more than 30 years of experience, there would be such a high level of overlap in knowledge among the specialists in that group that complementary, growth, and non-overlapping connections are effectively eliminated. This reduces the characteristic of the CoP that facilitates interaction with different, yet useful knowledge bases. So then, there is a tradeoff between the role of CoPs as structures that provide greater flexibility, and CoPs as bounded groups that efficiently group practitioners with a degree of common knowledge within the organization.

Search Tools and Social Networks

Given that most CoPs are facilitated or supported by online search tools and forums (Ardichvili 2008), we would be loath not to address their role in our theory. Furthermore, searching for knowledge resources is often inseparable from the peer-to-peer social networks that comprise CoPs (Borgatti and Cross 2003). Online forums, knowledge repositories, search tools, and social networks increase individuals' access to unique knowledge bases. They simultaneously reduce the effort required to locate specific individuals whose knowledge is required.

The social networks cultivated within global CoPs facilitate a "who knows who" culture increases the different knowledge bases that people are aware of, therefore increasing their choice of who is visible to connect with. Higher visibility allows people to swiftly locate others, gain personal introductions, and gain the marginal benefits of belonging to a community, which increases search efficiency. A sense of belonging can activate many social motivations to share knowledge such as reciprocity (Javernick-Will 2012), where members feel the need to contribute because they have received knowledge from others, therefore increasing efficiency of access to knowledge once it is located. Robust social networks in distributed CoPs need a diversity of types of connection to create a cohesive awareness of who knows what, where each type of connection plays an important role in the network. Taken together, overlapping, complementary, and growth connections form robust social networks that flexibly and efficiently direct people to the knowledge resources that they need. Complementary coordination can provide access to a pool of overlapping connections, where the experts familiar with the field can select the best person or resource to apply to a knowledge based need. Within these pools of experts, growth connections serve to replenish knowledge stocks by passing knowledge from experts to less experienced workers, multiplying the number of people who have capabilities within a given field (Lave and Wenger 1991).

Similarly, search tools expand the pool of candidates that CoP members can seek out and connect with (Alavi and Leidner 2001), while simultaneously making that search more efficient. Previously, individuals had to invest time and effort to locate people with relevant expertise to their problems and evaluate whether they can provide useful knowledge. Each person that they evaluated represented an incremental cost in terms of searching and evaluating. Now, with a simple forum post or email, many experts can be polled who can individually evaluate whether their expertise applies to the problem, so that the cost of searching is distributed among the knowledge providers rather than the knowledge recipient. This greatly increases the efficiency of search for individuals.

IMPLICATIONS AND FUTURE WORK

Given that knowledge coordination is relationally specific and dependent on common knowledge, there are significant impacts to both theory and practice regarding CoPs and coordination within the firm. First, if coordination of knowledge in practice networks is relationship specific, then it may be too expensive to govern knowledge exchange through traditional, bureaucratic coordination mechanisms. Although this study did not examine the outcomes of different governance strategies, the complexity revealed by our framework is a firm starting point for future work to consider the relative outcomes of different coordination mechanisms in non-task coordination. Within CoPs, this research could be particularly beneficial. Thompson (2005) proposed that there are certain loose structures that managers can create within CoPs that help to generate a positive environment for knowledge coordination, however this work can be expanded to include distributed populations mediated by virtual communication.

Secondly, this framework provides a basis from which managers can practically influence knowledge coordination through indirect control. To the degree that companies can classify what people know, they can intentionally group practitioners depending on the type of coordination that is aligned with strategic goals. For instance, transferring capabilities from older, retiring employees to younger employees consists of replication and training type coordination. This would occur most readily through topically narrow CoPs that involve more and less senior practitioners. Thus the function of the CoP is controlled through its membership boundaries. Within the CoP, investments made to strengthen social networks and provide efficient search tools will increase the flexibility of the space, and make room for the relational dependence of knowledge coordination. While this would seem to be fairly straightforward, knowledge management systems have upwards of a 50% failure rate in meeting their desired goals (Akhavan et al. 2005). Perhaps this is because managers did not account for the relational specificity and common knowledge dependence of knowledge coordination. Future research could examine the efficacy of strategic control through epistemological grouping, to determine the interactions between bureaucratic structures and underlying work patterns. If so, then strategic control of knowledge coordination would be possible through intentionally grouping employees.

Finally, because grouping limits or expands opportunities for interaction, future work could explore the relative benefits of increasing coordination possibilities within a given CoP. While managers can try to initiate broader CoPs to facilitate more cross pollination of ideas, this strategy could also introduce more non-overlapping connections through poor identification of practice boundaries. To the degree that CoPs expand, they will have a more diverse pool of specialists with whom they can coordinate, but search efficiency will be less due to the larger number of people, lack of common vocabulary, and inability to identify subtle expertise in different areas. Understanding the role and nature of CoPs helps direct strategic bounding of these communities. If the primary goal of a CoP is to drive technical practice, then a broad group is simply decreasing search efficiency among different groups of experts due to a lack of "mutual knowledge" (C. D Cramton 2001). Similarly, if a narrowly focused group decides that their practice is stagnant and needs to come up with new ideas, then they need greater agency in connection to find complementary knowledge bases, not higher search efficiency to locate specialists with overlapping knowledge bases who are caught up in their own departmental "thought worlds" (Dougherty 1992). This raises an important theoretical question: as connections become increasingly non-overlapping, is there valuable knowledge sharing that occurs? Cohen and Levinthal (1990) introduced the idea of "absorptive capacity," which implies that a lack of mutual knowledge would fundamentally limit the ability of two individuals to share knowledge. This study, through showing different types of coordination with less overlap, aligns more with a *combinative capabilities* (Kogut and Zander 1992) perspective. From this view, individuals learn by building upon what they already know. Therefore complementary connections facilitate different learning in each individual, as each change the way they think about their tasks through interaction with the other. So, cross pollination of ideas and task coordination is not the rote replication of "how to," but the social construction of knowledge through building upon their individual through worlds. In this way, a relational coordination view of CoPs can be informed to evaluate and strategically direct the membership of dispersed CoPs. It is also vital to understand the differences between the *size* of CoPs, and the logistical, networking challenges that it creates, and *domain expansion* which gives increased access to new and novel ideas within a given practice. Future work could explore the relative effects of each on CoP functionality, to determine the value tradeoffs between increased physical reach (size expansion), and conceptual reach (domain expansion).

On a theoretical basis, the knowledge based view of CoPs provides a rich foundation for future work. To our knowledge, there are very few studies that have examined the degree of overlap between specialist knowledge bases, and how overlap affects the types of coordination in knowledge sharing connections. Future work could evaluate the relative benefits of each type of coordination to the organization, or study the synergistic effects of different degrees of overlap in social networks. Quantitative studies could perform social network analysis on networks and overlay the degree of overlap to see if boundary spanners tend to have a certain type of connection, and explore how this affects knowledge flows within social networks. From this study, there are a number of concepts that could be empirically verified. It would be simple, yet theoretically valuable to test the different types of connection and coordination occurring in broad and narrow communities.

One potential area of interest would be in valuing CoPs as an organizational resource resistant to appropriation. Liebeskind (1996) states that firms can 1. Differentially reduce the probability of knowledge being stolen (expropriated), and 2. Reduce the observability of knowledge. To do this, they need to construct legal frameworks, monitor employees, and alter reward structures to decrease employee mobility. Using this framework, Future work could value CoPs by analyzing the coordination between these knowledge specialists, or attempt to measure the value produced by different portfolios of broad and narrow communities.

CONCLUSIONS

Although business practice has embraced communities of practice as a means for managing knowledge, CoPs do not use classical coordination mechanisms, so their contribution to the firm is uncertain. While the business goals of CoPs focus strongly on coordination of different knowledge bases, there is not theory explaining the mechanisms by which CoPs coordinate specialist knowledge. This paper uses qualitative methods to generate two primary contributions. First, we explore the different types of coordination facilitated within CoPs based on the degree of overlap between participants' knowledge bases, and conclude that coordination must be understood as relationally specific. Next, the framework identified the dependence of coordination mechanisms on the degree of overlap in participants' knowledge bases. These contributions imply that the bounded rationality of managers may render classical bureaucratic coordination mechanisms ineffective for knowledge coordination. At the same time, CoP members seem to have increased flexibility to satisfy their knowledge based needs without hierarchical oversight. Furthermore, the dependence of knowledge coordination on the degree of overlap indicates that the strategic focus of communities is amenable to manipulation through intentionally bounding membership.

As with any study, there are inherent limitations to the scope and application of this work. To begin, we must be careful with the application of these findings do different contexts. The external validity of the study is limited by convenience based selection of CoPs, and the lack of consensus among industry leaders in managing and defining CoPs. Although the researchers were careful to select three CoPs that were globally distributed, multi-disciplinary, supported by online infrastructure, and initiated by managers, there are external factors that were still difficult to control. Because our three CoPs came from two different organizations, there are different management cultures, geographies, and histories that created discrepancies in the communities. This was partially remedied by examining dyadic level connections, and consistently finding overlapping, complementary, growth, and non-overlapping connections in each CoP. Furthermore, both companies do project based work in the engineering and construction industry. Because of this, we must acknowledge that the application of these findings outside of project based industries is unknown.

A second limitation occurs from a methodological standpoint. Due to the exploratory nature of this study, data collection was not initially targeted to verify our final findings. Through inter-coder reliability and following the qualitative analysis processes outlined by (Haney et al. 1998), our results are as robust as possible in terms of construct and internal validity, yet there is always more to be desired. Future work verifying the association of particular types of coordination to different types of connection would be welcomed.

Despite the limitations, this work presents a significant step forward in understanding different types of coordination which occur in distributed CoPs, as well as the role of these CoPs in coordinating specialist knowledge within the firm. This second contribution provides a framework to guide our theoretical and practical understanding of CoPs as they are being applied in business practice. Our hope is that an organizational approach to CoPs would open a new field of study that would lead us to a deeper understanding of the organizations that we have created.

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Chapter 6: Summary and Conclusions

The four research chapters of this dissertation are a robust examination of communities of practice as a means to facilitate knowledge sharing in project based organizations. This work is important because the business application of CoPs has deviated significantly from the theoretical roots that should guide industry based practice. In order to use CoPs to increase the performance of construction and engineering firms, we must understand how these deviations affect knowledge flows, the formation of knowledge sharing connections, and the role of CoPs as a means for managing knowledge within the firm. Therefore, this work addresses three primary research questions. First, because the environment in which CoPs operate is different from its theoretical roots, we ask: *what are the effects of geographic dispersion and organizational divisions on communities of practice in project-based organizations?* Next, because the size and scope of CoPs has obfuscated the means by which professionals become connected, we ask: *how do knowledge sharing connections form within distributed communities of practice in project based organizations?* Finally, because CoPs have shifted from cognitive environments to a way of managing knowledge in absence of guiding theory, we ask: *What is the role of communities of practice in project based organizations?*

To briefly answer these questions, this dissertation shows that knowledge flows within distributed CoPs are fragmented by organizational (Chapter 2) and geographic (Chapter 3) boundaries, but can be united through targeted management. This work further explores the mechanisms of connection (Chapter 4), finding that knowledge sharing connections form through both social and organizational mechanisms. Finally, it proposes that CoPs help to overcome the bounded rationality of managers by allowing employees to choose and structure their own knowledge sharing connections to suit individual needs (Chapter 5). The resulting impact of this work is a renewed focus on CoPs as supplementary organizational structures that increase individual agency and search efficiency in the quest for applicable knowledge resources within project based organizations.

Figure 6-1 summarizes the contributions of this dissertation.

	Gaps in Literature	Research Questions	Contributions
Chapter 2	Lack understanding of organizational boundaries within CoPs	What are the effects of geographic dispersion and organizational divisions on communities of practice in project-based organizations?	1) Business units and functional disciplines can limit knowledge flows 2) Impact of org. boundaries depends on context
Chapter 3	Lack understanding of geographic boundaries within CoPs		1) Cultural and geographic silos 2) Pipelines, holes, anomalies as network patterns & identify effects 3) Influence of organizational structure and strategic control on CoP networks
Chapter 4	Lack understanding of mechanisms that form knowledge sharing connections in CoPs	How do knowledge sharing connections form in CoPs?	1) 5 mechanisms of connection 2) CoPs as both socially and organizationally created
Chapter 5	Lack understanding of role of CoPs using organizational theory	What is the role of CoPs in coordinating expert knowledge?	1) Types of coordination based on overlap in knowledge base 2) CoPs overcome bounded rationality 3) CoPs increase agency/search efficiency

Figure 6-1 - Summary of Dissertation Contributions

CONTRIBUTION TO THEORY

The most significant theoretical contribution of this dissertation is using the knowledge based view to describe the role of CoPs in project based organizations. There are many calls in literature to examine the deviation of CoPs in business applications from their theoretical roots (Kimble and Hildreth 2004; Lindkvist 2005; Roberts 2006), and yet this literature lacks a theory of CoPs using the knowledge based view (KBV) of the firm. Prior work examining the globalization and diversification of CoPs typically focuses on individual cognition within the CoP (Hildreth et al. 2000), rather than explaining CoPs as an organizational phenomenon. Using the KBV, we propose that CoPs are supplementary organizational structures that help to coordinate specialist knowledge by partially overcoming the bounded rationality of managers. While the main drive of this theory is in Chapter 5, the work leading up to that chapter creates a foundation to understand the structure and formation of informal knowledge sharing networks within these CoPs, which is itself a large gap in literature. Where prior literature is unable to describe the effects of environmental changes on knowledge flows (Kimble and Hildreth 2004), the first three chapters define the current application of CoPs by evaluating the knowledge sharing capacity of CoPs in organizational (Chapter 2) and geographically distributed (Chapter 3) environments, as well as investigating how knowledge sharing connections form in practice (Chapter 4). Although prior work criticizes the application of CoPs within these new environments (Lindkvist 2005; Roberts 2006), there is very little work that empirically examines the effects of organizational and geographic boundaries on knowledge sharing within CoPs, even though this is essential to discerning their purpose within organizations.

For instance, Chapter 2 examines the impact of organizational structures on the (supposedly) unrestricted knowledge sharing that is theorized to occur in CoPs. Prior to this work, our theoretical understanding of CoPs as structures situated within organizations was limited to speculation, and qualitative studies (Thompson 2005). Chapter 2 examined the impacts of organizational structures on patterns of knowledge sharing connections, and hence provides a strong foundation for future scholarship to explore the persistence of these structures in various parts of the company. This chapter also defined CoPs as structures that are situated within larger organizations, enabling the assumption that CoPs exist within firms to help coordinate specialist knowledge.

Chapter 3 addresses a theoretical gap surrounding the geographic reach of CoPs, which was previously unknown (Hildreth et al. 2000; Kimble and Hildreth 2004), by examining the structure of informal knowledge sharing networks across cultural and geographic boundaries. While critics of global CoPs believe that large, distributed, knowledge sharing groups lack cohesion (Roberts 2006), few empirically demonstrate the effects of geographic dispersion on knowledge sharing. Within this gap, Chapter 3 demonstrates geographic and cultural fragmentation, but also identifies the importance of strategic control in remedying this fragmentation. Independent of the other work in this dissertation, Chapter 3 makes an important contribution toward understanding CoPs as global entities by revealing their capacity to facilitate globalized knowledge sharing. Within this dissertation, this conclusion further cements CoPs as hybrid social and organizational structures, therefore allowing the claim in Chapter 5 that CoPs should be viewed as supplementary, but not independent of, existing organizational hierarchies.

Finally, Chapter 4 begins to explain how the knowledge sharing connections observed in Chapters 2 and 3 could have formed by exploring mechanisms of connection within CoPs. While previous work had created models for information seeking (Borgatti and Cross 2003), and indicated that within CoPs, both social and organizational forces may initiate connections (Javernick-Will 2011b), there has not been a cohesive work exploring how professionals become connected in distributed CoPs. Uncovering these mechanisms directly fills this gap in literature; however, a large theoretical contribution of this work examines the role of organizational power in facilitating intra-organizational knowledge connections. In addition to providing a firm foundation for future research based on each mechanism of connection, this work further emphasizes the importance of organizational facilitation of informal knowledge sharing networks. Chapter 5 builds on this work with the theoretical assumption that organizations can meaningfully intervene and craft CoPs for strategic purposes. Each chapter therefore fills a small theoretical gap in our current understanding of CoPs, while simultaneously contributing to a more cohesive knowledge based view of CoPs within project based firms.

CONTRIBUTION TO PRACTICE

While this dissertation makes a number of strong theoretical contributions, it can also be used to better understand and improve CoPs in business applications. As a first step, this work reveals that organizational boundaries can powerfully limit knowledge sharing, and that these boundaries persist in CoPs, even when they are supposedly removed (Chapter 2). Along these same lines, social forces drive CoP members to connect primarily with others who have the same culture, and are located in the same geography (Chapter 3), which similarly limits global knowledge flows and prevent knowledge from being available when and where it is needed. These findings alert inform managers to important deficiencies in knowledge sharing that may appear in their organizations, but are conventionally not observable. Furthermore, this work demonstrates the ability of management to manipulate informal networks within CoPs for strategic purposes. Although prior work has hinted that CoPs may be amenable to strategic manipulation (Wenger 1998), the mechanisms of connection presented in Chapter 4, and the examples of network pipelines presented in Chapter 3 provide a valuable roadmap to remedy specific knowledge sharing deficiencies though management interventions.

Over the past several decades, the proliferation of literature describing how to start and manage CoPs has developed without any overarching guiding theory. Because of this, the development and use of CoPs in project based organizations has been founded primarily on trial and error. Perhaps the greatest practical contribution of this work is to provide the theoretical guidance that has previously been lacking. Chapter 5 outlines the characteristics of CoPs that make them valuable additions to traditional bureaucratic structures. While many companies may see CoPs as organizations within organizations, where bureaucracy is developed for the purpose of knowledge sharing rather than project work, this dissertation re-directs the focus of CoPs to the ways in which compensate for deficiencies in bureaucracy. Rather than see CoPs as nebulous, purposeless, overhead funded entities that exist to facilitate directionless social interaction, a knowledge based view of CoPs should guide managers toward an understanding of CoPs as necessary, targeted, value adding supplements to traditional reporting structures. Specifically, CoPs re-distribute micro-level decision making regarding who should share knowledge with whom and give that decision to the knowledge workers who know best what they need. They do so by providing a hybrid organizational environment that is both socially and organizationally created. While many connections are initiated through direct hierarchical control or mutual task requirements, there are also powerful social networking and search mechanisms that foster knowledge sharing connections. Once connection is initiated, CoPs provide an environment to maintain knowledge sharing ties beyond initial connection. Through these mechanisms, CoPs provide access to other employees with a diverse range of knowledge bases, enabling interaction with others in the organization that may not currently be required by job tasks or reporting structures. These interactions provide meaningful knowledge sharing that satisfies knowledge needs, and creates a more dynamic and flexible organization with free knowledge flows. Furthermore, CoPs increase employee's efficiency in searching for these knowledge sharing connections by bounding membership to relevant knowledge bases. From these conclusions, the primary goal of managing CoPs should be to increase the pool of potential knowledge bases that employees can choose to connect with, and to intentionally bound membership of CoPs to reduce the potential incidence of inefficient, non-overlapping knowledge sharing connections. Managers can do so by using IT search tools, facilitating robust social networks, and intentionally structuring a portfolio of both broadly and narrowly focused CoPs.

Throughout this dissertation, the deviation of CoPs from their theoretical roots is a persistent theme. In truth, when Brown and Duguid (1991) first examined CoPs, their intention was not to create a new management tool (Amin and Roberts 2008). At the same time, CoPs seem to do many similar things that the originally theorized CoPs also did. Namely, CoPs are an environment to facilitate practice oriented learning in the workplace. In spite of the global, multi-lateral characteristics of the CoPs studied here, professionals have formed social communities. Indeed, Wenger et al. (2002), indicates that especially large CoPs (greater than 150) may become locally clustered, but can still function as a knowledge sharing mechanism. People are tied in with one another, whether they realize it or not. This does allow for legitimate peripheral participation and for the important elements of identity formation and expert turnover that characterize communities of practice. So then, even though CoPs have morphed significantly, and are not necessarily a logical progression from their origins, I think it is still the most appropriate term for these groupings of people.

LIMITATIONS AND SUGGESTIONS FOR FUTURE WORK

An important limitation of this research is the potential impact of self selection bias on both survey participants and interview participants. In all three of the CoPs, survey response rates are between 30% and 40%, even though traditional social network methods claim that anything short of 100% participation invalidates network level conclusions. This study partially addressed this concern by avoiding traditional network measures such as density and centrality, which are meaningless without full participation. Rather than examine network level metrics, this study uses quantitative methods that are scalable to be valid for smaller portions of the network, effectively mitigating the effects of missing data by examining connections as the unit of analysis. This does not, however, change the impact of self selection bias, which may result in qualitative and quantitative systematic differences between respondents and non-respondents. The influence of self selection bias would increase random error in the study. Although it is not a perfect solution, this work did compare the demographic composition of respondents and non-respondents according to geographic location, culture, organizational groups (business units, functional disciplines), hierarchical grade level, age, and sex. We determined that the demographics of the participating group were acceptably similar to that of the non-participating group. Even so, future work could use email records, or another non-survey data collection to confirm or challenge the findings presented in Chapters 2 and 3.

Another potential issue with this study is the validity of the construct "knowledge sharing connection." The practice oriented definition in the survey was consistent with prior literature (Alavi and Leidner 2001; Orlikowski 2002), although this dissertation work consistently makes the assumption that all knowledge sharing connections are qualitatively equal. That is to say, that each connection facilitates an equivalent "amount" of knowledge sharing. This is most problematic in Chapters 2 and 3, which claim to evaluate the capacity of knowledge sharing networks to transfer knowledge across organizational and geographic boundaries respectively. In reality, no two knowledge sharing connections will be exactly alike in the content shared, or the value generated by that knowledge. The uniqueness of each connection is perhaps what leads (Szulanski 1996) to theorize that the "arduousness of the relationship" is an important determinant of whether or not knowledge is transferred within organizations. Furthermore, knowledge sharing connections may not be equally reported by both parties, such that one employee perceives that they are connected with another, yet the reporting of this connection is not reciprocated. This problem is partially remedied through a mixed method validation of connections during interview data collection. We found that 93% of the connections that we asked about during interviews were confirmed as a) existing, and b) meaningfully sharing knowledge as opposed to information or data (Alavi and Leidner 2001). More commentary on this validation procedure and its results are outlined in Appendix H. Furthermore, we conducted a separate analysis that was published as a conference paper (included in Appendix G) within each of the CoPs of connections that spanned geographic and disciplinary boundaries, to determine if they were qualitatively more useful than those that did not span boundaries. We found no difference in the perceived usefulness of those connections that spanned boundaries relative to those that did not. This allows us to make the claim that there is a reduced knowledge sharing capacity between geographic or disciplinary groups if there are fewer connections between those groups.

During the interviews, there is a distinct possibility that limited free-recall of participants biased their responses regarding specific connections. While the consequences of such a bias are relatively minor, people tend to remember more about their job role and the projects that they were working on than their individual relationships. This means that very old knowledge sharing connections tended to be remembered in terms of *what* employees were working on as opposed to *how* they became connected. Furthermore, there is a great deal of ambiguity regarding whether connections formed because of the CoP rather than other exogenous factors. In fact, there does not seem to be a clear methodology for separating CoPs from the organizations that host them. This dissertation does not solve this issue. Rather, it tailors the development of theory to account for CoPs as entities situated within and inseparable from the organizations that host them. Future work could attempt to model the value of CoPs through a better understanding of what happens *because of* rather than simply *within* CoPs.

As indicated on multiple occasions, there is a distinct lack of clarity regarding the definition and role of CoPs within project based organizations. Because of this, it is important to address the external validity of the findings presented in this dissertation. Although we may have wished for a larger sample, the practical and logistical limitations of time and money limited this study to an exploration of 3 CoPs in 2 multinational construction and engineering firms. For each CoP, we built in depth case knowledge in an attempt to describe the subtle complexity of organizational context and culture, the attitudes of management and perspectives of distributed individuals, and the topical nature of three unique communities of professionals. Even so, the specificity of our sample necessitates a rather narrowly focused field of impact. These findings directly apply to CoPs that are manager initiated, have voluntary yet formalized membership, possess greater than 150 members (Wenger et al. 2002), have an average of at least 1 connection per person, and are hosted within a project based organization. Furthermore, the CoP must span at least three organizational divisions, and three geographic. While we suspect that our findings extend beyond these narrow boundaries, future work outside of these bounds must apply our findings at their own peril. We therefore leave the task of validating and exploring these findings in other settings to future work.

This study provides a firm foundation for future work to explore the interactions between mechanisms of connection (CH 4) and different types of coordination (CH 5). Specifically, connections made in a certain manner may tend to serve a given purpose. If, for instance, connections occur through managerial control, they may be created for the purpose of task coordination, rather than intra-domain knowledge sharing. Furthermore, there are a number of rich studies that have explored models for information and expertise seeking (Borgatti and Cross 2003; Hertzum 2014), which focuses on *why* individuals choose to seek out others. The work presented in this dissertation complements this work well through adding *how* individuals become connected. Even so, future work could more fully integrate these findings to create a more comprehensive theory of knowledge sharing within multi-lateral CoPs.

Dreaming and Scheming: Existential Reflections, and the Direction of CoP Research

During the course of my research, I came to see CoPs as a fascinating shift in the nature of organizations. As we march onward to an increasingly knowledge driven economy, the benefits of organizing into bureaucracies and hierarchies to accomplish our goals is brought into question. CoPs are the embodiment of shortcoming in bureaucratic organization. Because employees within these organizations possess a knowledge base too large to be comprehended by any single, overseeing mind, and managers are bounded in their rationality, they are henceforth unable to optimally structure the organizations that they captain. Classical economic theory suggests organizations formed because they were a more efficient manner of governance than markets when creating complex products (Williamson 1975). This would indicate that the inability of bureaucratic organization for structuring knowledge transfer necessitates yet another boundary change within firms. I see CoPs as just such a boundary shift, where managers are relinquishing control to employees regarding the structure of knowledge sharing interactions. In this age of knowledge, organizational theorists must continually ask *"why have we organized thus?"* It is the chief aim of this field to continually answer this question as organizations follow the invisible hand that necessitates change, and to dream of how we might further the cause of humanity through more optimal structuring of our organizations.

So what next? To build upon the work presented in this dissertation, we must further explore how changes in governance within firms affects patterns of knowledge sharing, and to gain a better understanding of the value created through knowledge management. On the level of individual connections, we must use social network analysis to uncover and explore deeper truths about the formation and effectiveness of social networks. For instance, we know now that knowledge sharing connections form through both social and organizational mechanisms, yet we do not know if certain mechanisms of connection lead to stronger or more enduring knowledge sharing ties. Furthermore, there are no known studies that longitudinally evaluate the life cycle of knowledge sharing connections, evaluating the full narrative of their birth, life, and death as they are embedded in social networks. Are the most important knowledge sharing ties active or latent? Are they formed through organizational or social means? Why do connections fade and die? All of these questions require longitudinal network data analyzed in tandem with rich, qualitative narrative that as of yet, does not exist.

Beyond the scale of individual connections, there is much work to do regarding the role of CoPs in business applications. Through understanding CoPs as supplementary structures that increase agency and search efficiency, this dissertation has identified two value adding means by which organizations allow employees to self organize within the boundaries of the firm. Using network analysis, it would be possible to evaluate the differences in network structure between heavily, and lightly governed CoPs. Furthermore, this work lays a foundation for the valuation of knowledge sharing activities, not in terms of their output, but as an equivalent resource not generated through bureaucratic structuring and its requisite monitoring costs.

The paradoxical reality of this work is that both researchers and managers are crippled by the same bounded rationality. In truth, my topical knowledge is far exceeded by the entry level employees of the communities that I study. I know little and less about the connections and relationships that should be formed to optimally produce the next project. While I acknowledge that this study was heavily exploratory, and hence our original objectives were quite broad; my mind, now understanding a larger fraction of the problem, is prone to shout advice at the past. Thinking back, I can only say that I wish I had approached these problems with greater humility. I always thought I would find the one, universal, solution to our organizational problems, although it has been a far richer experience simply to participate in the discussion.

In February of the year 2000, Etienne Wenger and William Snyder made the prophetic statement that communities of practice were going to “galvanize knowledge sharing, learning, and change” over the next several decades (Wenger and Snyder 2000). Indeed, it is difficult to dispute the veracity of this claim. Over the past three years of my studies, I have come to believe that when Lave and Wenger (1991) and Brown and Duguid (1991) published their seminal papers defining communities of practice, that they unleashed a movement that could not be contained by their original terminology or theory. The fact remains that economies, our organizations, and indeed our lives are increasingly driven by what we know, and our ability to locate knowledge relevant to the task at hand. Although construction and engineering organizations are the focus of this dissertation, I see the proliferation of CoPs as evidence that the ways we work, learn, and innovate are in flux. Communities of practice are a hybrid – an evolution of organizations to adapt to a knowledge driven economy. Rather than eliminating existing organizational hierarchies, CoPs supplement and enhance the elements of the organization that were previously in place. This dissertation is an expression of my fascination with communities of practice as part of the long history of humans arranging themselves into the curious structures that we call companies and organizations. It is my hope that this dissertation is a small step towards understanding how our organizations are changing and evolving to meet the needs of the people who have created them.

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Appendix A – Social Network Survey

This section shows the social network survey for the Process Improvement CoP. Only minor adaptations in language were made to customize questions to the CAD and Transportation CoPs.

PERSON CENTERED QUESTIONS

1. Please specify your discipline (e.g. structural engineering).

2. Please select the regions where you have physically worked in an office or project location for 3 months or longer.
    a. North America
    b. South America
    c. Africa
    d. Asia
    e. Australia/New Zealand
    f. Eastern Europe
    g. Western Europe
    h. Middle East

3. Please indicate the country that you would identify as your primary cultural influence (Please type one country).

4. Please select the highest degree of education you have received.
    a. High school
    b. Some college (went to university but did not graduate)
    c. University degree
    d. Graduate degree

5. Please indicate the country in which you attended your highest level of education (Please type one country).

The following questions are related to your involvement in and use of the PROCESS IMPROVEMENT community

1. Please specify the length of time IN MONTHS you have been exchanging PROCESS IMPROVEMENT-related knowledge with other members of the PROCESS IMPROVEMENT community within Company A (Please type a number).

2. Please specify the length of time IN MONTHS you have been a member of the online PROCESS IMPROVEMENT community within Company A (Please type a number).

3. Please describe your frequency of involvement in the online PROCESS IMPROVEMENT community.
    a. Approximately once per day
    b. Approximately once per week
    c. Approximately once per month
    d. Approximately once per quarter
    e. Less than once per quarter

4. How useful is the online PROCESS IMPROVEMENT community for your work?
    a. Extremely useful
    b. Useful
    c. Undecided
    d. Not Useful
    e. Extremely un-useful

5. What is the LEAST useful part of the online PROCESS IMPROVEMENT community?

6. What is the MOST useful part of the online PROCESS IMPROVEMENT community?

7. What are your top two preferred methods for receiving PROCESS IMPROVEMENT knowledge regardless of whether this method is currently available in your organization? (Please select the top two)
    a. Hard copies and text driven material (i.e. books, reports, etc.)
    b. Personal discussion- email
    c. Personal discussion- face-to-face
    d. Personal discussion- phone
    e. Workshops
    f. Meetings
    g. Intranet (i.e. Share Point, forums, etc.)
    h. Blog
    i. Podcast
    j. Collaborative web space (i.e. wiki)
    k. Video
    l. Social interface software

m. Instant Messaging

8. What are your top two preferred methods for sharing (giving) your PROCESS IMPROVEMENT information/knowledge to others regardless of whether this method is currently available in your organization? (Please select the top two)
    a. Hard copies and text driven material (i.e. books, reports, etc.)
    b. Personal discussion- email
    c. Personal discussion- face-to-face
    d. Personal discussion- phone
    e. Workshops
    f. Meetings
    g. Intranet (i.e. Share Point, forums, etc.)
    h. Blog
    i. Podcast
    j. Collaborative web space (i.e. wiki)
    k. Video
    l. Social interface software
    m. Instant Messaging

9. Assume that you are trying to communicate PROCESS IMPROVEMENT related knowledge with another Company A employee who is different from you in the following ways (i.e. Works in a different geographical location etc). Please rate how difficult each of the following factors makes it to maintain a knowledge sharing relationship.
    a. Works in a different GEOGRAPHIC LOCATION
    b. From a different DISCIPLINARY BACKGROUND
    c. Working in a different BUSINESS PRACTICE SPECIALTY
    d. In a different HIERARCHICAL LEVEL WITHIN THE ORGANIZAION
    e. Of a different GENERATION

10. Please select the top two reasons for why you share your knowledge with your peers (Please select top two).

    a. The company provides time or resources for me to share my knowledge
    b. I enjoy helping my peers
    c. Sharing knowledge helps to increase the performance of the firm, if the firm does well, I will be rewarded
    d. It is normal practice in the company (the company expects employees to share)
    e. My knowledge sharing efforts are recognized by my peers
    f. If I help others, they will one day help me in return
    g. I have voluntarily committed to share my knowledge, and I want to honor that commitment.
    h. The company requires me to share my knowledge
    i. Other

11. Please select the top two reasons that make you hesitant to share your knowledge with your peers. (Please select top two).
    a. Maintaining job position
    b. Trust
    c. Maintaining power- if I have the knowledge, I maintain power
    d. I do not know the context in which my knowledge will be applied
    e. I am concerned about who would gain access to the knowledge I shared
    f. I haven't developed a relationship with someone
    g. No one asks me directly to share my knowledge
    h. I don't have time to share my knowledge
    i. I do not feel comfortable with the knowledge exchange methods used in the PROCESS IMPROVEMENT community

NETWORK QUESTIONS

For the purposes of this survey, the term 'PROCESS IMPROVEMENT practices' refers to any practice oriented knowledge that is required for you (or those with whom you interact) to perform job related PROCESS IMPROVEMENT practices. 'Practices' can be project related or organization related.

12. Who have you exchanged knowledge with on job related PROCESS IMPROVEMENT practices in the past 6 months?

13. How often do you exchange knowledge about PROCESS IMPROVEMENT related tasks with each individual listed below?

    a. At least once per day
    b. Several times per week
    c. At least once a week
    d. At least once per month
    e. At least once every six months

14. To assist in determining the flow of information and knowledge within the network, please select the response that best describes the PROCESS IMPROVEMENT knowledge exchange with each individual listed below.

    a. Only receive
    b. Mostly receive
    c. Receive and Give
    d. Mostly give
    e. Only give

15. Please select the top two most frequent methods used to exchange knowledge with each individual listed below for PROCESS IMPROVEMENT related work tasks (please select top two).
    a. Reports
    b. Meetings
    c. Intranet (share point)
    d. Email
    e. Personal Discussion
    f. Instant Messaging

16. If you receive PROCESS IMPROVEMENT knowledge from each of the following individuals, how useful is the knowledge that you generally receive to help you perform job related PROCESS IMPROVEMENT practices?
    a. I use the information regularly and it would have been difficult to figure out on my own
    b. I use the information I received, but I probably could have figured it out with time
    c. the knowledge was basic or somewhat incorrect
    d. the knowledge given made the issue worse/ was incorrect
    e. I generally do not receive PROCESS IMPROVEMENT knowledge from his individual

17. What originally motivated you to connect with each individual listed below and begin sharing knowledge about PROCESS IMPROVEMENT related tasks within Company A?
    a. They have knowledge that will help me perform my duties on a project
    b. They have knowledge that will help me perform my duties for the organization
    c. They have knowledge that was beneficial for my career advancement
    d. They approached me
    e. We had a working relationship before we began exchanging PROCESS IMPROVEMENT knowledge
    f. Other

18. What motivates you to maintain knowledge with each individual listed below?
    a. I rely on the person to complete my task
    b. The organizational structure of our jobs requires me to continue to share
    c. I learn a lot from this person
    d. We work on similar projects
    e. This knowledge sharing connection is beneficial for my career advancement
    f. Other
    g. N/A

Appendix B – Interview Guides and Development

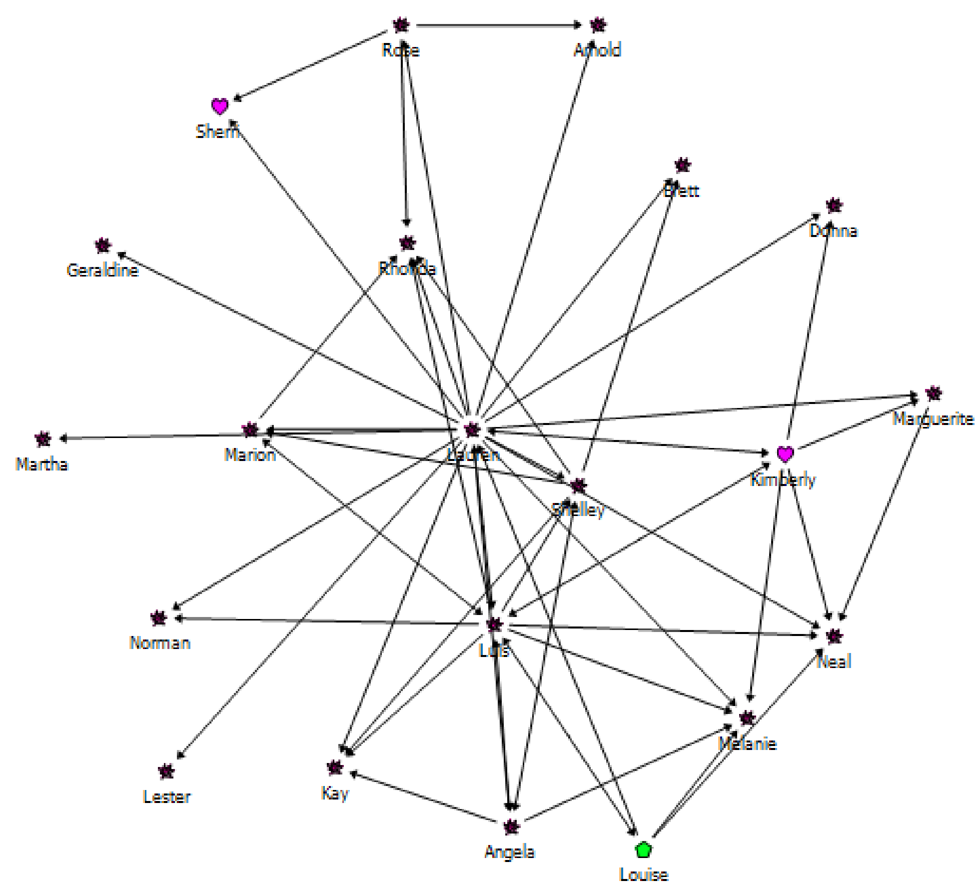
This section shows the interview guides used to gather qualitative data. Note that interviews were conducted for the Process Improvement CoP before they were completed for the CAD and Transportation CoPs. Interviews were transcribed and coded as they were completed, so we had a continuous feedback loop on the efficacy of certain questions. For this reason, we revised the interview guide for the CAD and Transportation CoPs.

PROCESS IMPROVEMENT COP INTERVIEW GUIDE

Interviewee #1			
Name: Aaron Nadler	Pseudonym: Lauren	Survey?: Yes	Location: Vienna, Utah, USA
Orig GBU: Civil	Current GBU: Power	Gen: Y	GL: 24
Function: Project Controls	# of Connections: 19		# of Useful Connections: NA (drop out)
Reason for selection:	Spans GBU 195% by 200 metric, over 50% in each individual metric. GBU, function, and country are all high		
Other Notes			

Social Network Diagram:

Angela
Arnold
Brett
Donna
Geraldine
Kay
Kimberly
Lauren
Lester
Louise
Luis
Malanie
Marguerite
Marion
Martha
Neal
Norman
Rhonda
Rose
Shelly



Introduction + Small talk

- I want you to know that everything you say today falls under a non-disclosure agreement and will be completely anonymous. Is it ok if I tape record this conversation? TURN TAPE ON

Part 1 - All Connections

List the connections we are going to ask about in the following format, **BOLD** if different from the interviewee:

Connection #1 – Name [(Neal)], Location [Vienna, Utah, USA], GBU [Civil], Grade Level [24] Generation [Y], Discipline [**Field Engineering**]

Connection #2 – Name [(Melanie)], Location [Vienna, Utah, USA], GBU [Power], Grade Level [28] Generation [X], Discipline [**Engineering**]

Connection #3 – Name [(Brett)], Location [**Frederick, Massachusetts, USA**], GBU [**Power**], Grade Level [**23**] Generation [Y], Discipline [**Field Engineering**]

Ask of ALL connections

1. We have defined a knowledge sharing connection as someone with whom you share practice oriented knowledge that is required of you to perform job related tasks. Do you feel that you have a knowledge sharing connection with _____________?
    a. Why or why not?
2. Think about past interactions you have had with _________. When you have communicated with _______ what types of knowledge were you exchanging?
3. What did the interaction look like (who contacted whom, how, what method was used?)
4. Can you tell me how you and _________ originally started working together/exchanging knowledge?
5. How has your interaction changed over time?
6. Are there any ways you and __________ don't understand each other? Can you think of any examples of misunderstandings or miscommunications you have had during your time working together? What do you think are the causes of these miscommunications?

Part 2 – Compared Connections

Please list paired connections in the following format:

Compare #1 – Name 1 [], Location 1 [], GBU 1 [], Grade Level 1 [] Generation 1 [], Discipline 1 []
Name 2 [], Location 2 [], GBU 2 [], Grade Level 2 [] Generation 2 [], Discipline 2 []

7. You have a connection with ___________ that you indicated was useful, but one with ________ that you said was not. How are these connections different?

Part 3 – Boundary Specific Connections

These are only asked for specific boundaries, no more than 2 per person.

Connection #1 – Name [(Kimberly)], Boundary [GBU, Civil], Interviewee boundary for contrast [Power]

Connection #2 – Name [(Marguerite)], Boundary [GL,25], Interviewee boundary for contrast [24]

8. You indicated that you maintain a connection with __________ that is a different [attribute category].

How does that affect your interactions?

Part 4 – Boundaries

In this study we have defined boundaries as a difference between two people that may cause a disruption in knowledge sharing. To give you an example, if you are trying to share knowledge with someone who is currently in a different country, geographical location is a boundary. We have also identified grade level, generation, discipline, and business unit as boundaries.

9. If you had to provide advice on how to exchange knowledge across **function, GBU** boundary, what would it be? Do you have an example of how you have used this?
10. Can you think of some people that span boundaries easily? What skills or personality traits do these people possess?
11. How would someone who is new to the CoP use it to connect with someone else?
    a. How is this impacted by different boundaries?

Areas of unusually high connectivity 1,2, etc.
GBU, Function, Country

12. You are very connected with people of different ___________. Can you explain why that is?

Part 5: Specific Trends
Please list:
Attribute category [Country, USA]; Trend: Tendency towards in group homophily in USA (1.4)

13. You are a part of ____________ attribute category, and we have observed that __________ occurs. Does this agree with your experience?
    a. Do you have reasons why this may be occurring?

Part 6 – General Trends

14. Do you feel that the interactions within the community are unique to construction or engineering industry? How might this CoP differ from a CoP in another company that is not in the construction or engineering industry?
15. Are there any areas that you wish you were connected to and are not? What prevents the flow of knowledge or what makes these connections difficult to create?
16. Are there certain groups of people within the CoP that are particularly well known for their knowledge? Would you call them innovators?
17. Are there barriers preventing the sharing and receipt of knowledge?
18. Are there ways that management has specifically tried to connect people in the CoP?
19. Are there any other questions you think we should have asked you or observations that you wish to share now that you know more about our study?

CAD AND TRANSPORTATION COPs INTERVIEW GUIDE

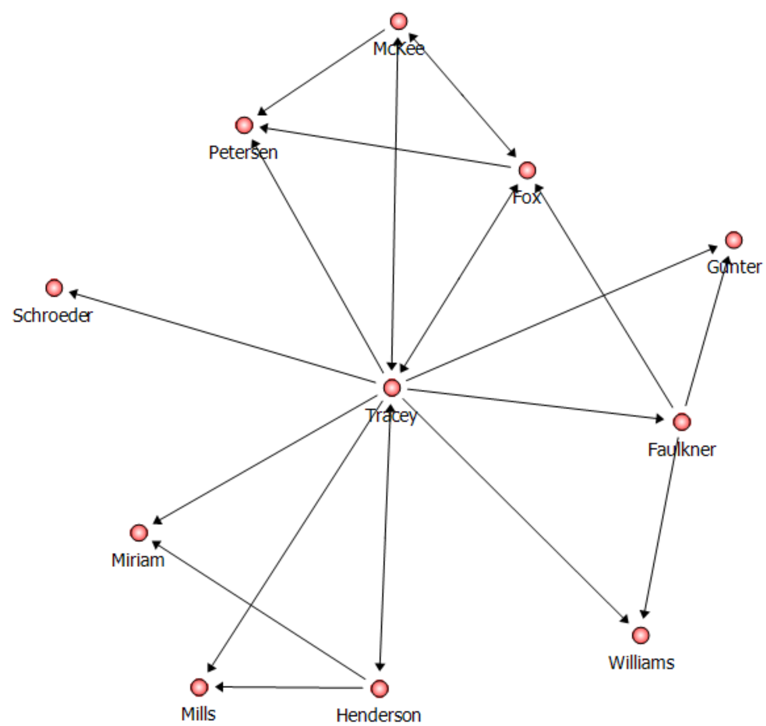
For this revision, we changed the sections on specific trends and general trends. We found that interview participants rarely had knowledge of broader trends within networks that are otherwise invisible to them. There was a free-recall bias, yielding very inconsistent answers, even within the same interview.

Interviewee #1			
Name:	Pseudonym: Tracey	Survey? Yes	Location: Sydney
CoP: CAD	GBU (if relevant) Building Engineering (verify)	Gen: Y	GL: Engineer/Architect/Scientist
Function: Civil Engineering		# of Connections: 10 Outdeg	# of Useful Connections: 1
Reason for selection:	1 usefulness Mills, 3 usefulness Faulkner; 1 usefulness Henderson, 3 usefulness Williams; highest NR (21) for GenY		
Other Notes			

Personalized Social Network Diagra

Example:

Name
Faulkner
Fox
Gunter
Henderson
Mckee
Mills
Miriam
Petersen
Schroeder
Tracey
Williams



Disclosures

☐ I want you to know that everything you say today falls under a non-disclosure agreement and will be completely anonymous. Is it ok if I tape record this conversation? TURN TAPE ON

Part 1 - All Connections

20. Can you start by giving me a 30 second introduction to what it is that you do within AECOM?
21. The reason that we selected you to be interviewed was because you are on the email list for the [CAD TPN or Trans TDN]; what do you think the role of this technical network is within AECOM? [** task driven vs. problem solving? Ask for Paul]
22. How would you explain to someone else within the technical network what your particular expertise

with CAD?

23. As a member of the technical network, where did you go for help the last time you had a [CAD/Trans] question? What was the question? Is this typical?

List the connections we are going to ask about in the following format, **BOLD** if different from the interviewee:

Connection #1 – Name [(Mckee)], Location [**Harrisburg, PA**], GBU [**PDD**], Grade Level [**Technician/Designer/Manager**] Generation [**Gen X**], Discipline [Civil engineering]

Connection #2 – Name [(Mills)], Location [Newcastle, Australia], GBU [Multiple], Grade Level [**Drafter**] Generation [Unknown], Discipline [**Architecture**]

Connection #3 –Name [(Fox)], Location [**Taguig City, Philippines**] GBU [**PDD**], Grade Level [**Technician/Designer/Manager**] Generation [Y], Discipline [**Water Resources Engineering**]

Ask of ALL connections

24. We define knowledge sharing as the exchange of information which directly supports your ability to act in your particular job role. So a knowledge sharing connection would be someone with whom you give or receive information with that enables you to perform your job task. Do you feel that you have a knowledge sharing connection with _____________?
25. Can you tell me how you and _________ originally started working together/exchanging knowledge?
26. Think about past interactions you have had with _________. When you have communicated with _______ can you give me some examples of the knowledge you were exchanging? What was the purpose of this exchange? [Individual, project, network, organizational level?]
27. What did the interaction look like (who contacted whom, how, what method was used?)
28. Is there a specific area of expertise that [Bill] has which causes you to go to him/her with questions? What is that area?
29. Is there any overlap between your knowledge base and [Bill's]? In what ways do you overlap? Are there any areas in which you do not overlap?
30. How has your interaction changed over time?
31. Are there any advantages to connecting with Bill over someone else who may have similar expertise? Are there any disadvantages?

Part 2 – Compared Connections

Please list paired connections in the following format:

Compare #1 –

Name 1 [[Mills] (USE 1)], Location 1 [Newcastle, Australia]

Name 2 [[Faulkner] (Use 3)], Location 2 [Sydney, Australia]

Compare #2 –

Name 1 [[Henderson] (USE 1)], Location 1 [Newcastle, Australia]

Name 2 [[Williams] (Use 3)], Location 2 [Sydney, Australia]

32. You have a connection with ___________ that you indicated was useful, but one with ________ that you said was not. How are these connections different?

Part 3 – Boundary Specific Connections

33. Can you think of any boundaries which may prevent the sharing and receipt of knowledge within the technical network?

These are only asked for specific boundaries, no more than 2 per person.
Connection #1 – Name [(Mckee)], Location [Australia to **Harrisburg, PA**], GBU [Building Eng. To **PDD**]

Connection #3 –Name [(Fox)], Location [Australia to **Taguig City, Philippines**] GBU [Building Engineering to **PDD**], Discipline [Civil to **Water Resources Engineering**]

You indicated that you maintain a connection with __________ that is of a different [attribute category]. Does this affect your ability to share knowledge?

a. Are there any benefits associated with this connection that are specific to your difference in [attribute category]?
b. Are there any challenges associated with your interactions across [attribute category]?
c. How can you be sure that knowledge gained from this person will apply in your particular context?

Areas of unusually high connectivity [Grade Level (i.e. Technicians, principles, etc.]
None

34. We have identified you as a boundary spanner in [specific areas], are there any specific actions that you take when you are sharing knowledge across these boundaries which allow the other person to better understand the knowledge you are providing? Do you have an example of when you have done this?

Part 4 – Costs, rewards, and motivations

35. What makes you hesitate to respond when someone contacts you with a network related question?
36. What makes you want to help when someone contacts you with a CAD/Trans related question?
37. What are your motivations to give/seek knowledge through the technical network?
38. Are there ways that management has enabled or inhibited knowledge transfer within the network?
39. Are there any other questions you think we should have asked you or observations that you wish to share now that you know more about our study?

Appendix C – Blockmodel Analysis

INTRODUCTION

Chapters 2 and 3 employ social network analysis to uncover patterns of connection relative to various boundaries within firms. Social network analysis, however, is a very general term that describes a wide variety of tools and techniques, so using this term in its general form is similar to saying that a study uses "regression analysis." On the whole, the term is too general to build future research upon, or ensure any degree of replication. The purpose of this section is therefore to outline in detail the quantitative methods and procedures used in Chapters 2 and 3, and why it was necessary to create a new method to analyze the influence of boundaries on knowledge sharing networks.

This appendix starts with an overview of social network analysis, which classifies this methodology relative to existing methods. Next, it zeros in on blockmodels as a method of analysis, and explains their relevance to the problems addressed in this dissertation. After that, this section discusses why creating a new method was necessary to achieve the analysis that this project needed, then outlines the procedure used for the method. Finally, this section discusses a visual method for interpreting the results of our new program.

SOCIAL NETWORK ANALYSIS: AN OVERVIEW

Social network analysis (SNA) has emerged as a method for exploring relationships between entities. Although the term "social" implies its applicability to describing relationships between people, SNA is more accurately understood as a particular manner of structuring data that has two components: nodes and edges. In SNA research, nodes are an entity (i.e. people, organizations, etc.), while edges represent relationships between those entities (i.e. co-location, friendship, etc.). As an example, a person (node) can have a friendship (edge) with any number of other people (other nodes), or an organization (node), can have a contract (edge), with another organization (node). The applications are varied, and generally applied to understand how structures of relationships affect systems. With these two core components, nodes and edges; SNA provides a data structure and suite of tools to analyze these entities and the relationships that connect them. To learn more about the structure and application of SNA, see Borgatti et al. (2009).

Moreno (1937) is frequently credited as the father of SNA when he introduced the concept of the “sociometry,” a technique to identify and examine the underlying patterns of connection between humans. Moreno’s hope was to make visible the persistent patterns of interaction that create the fabric of human society and through this, better understand and remedy the woes of society. Because SNA is not a single technique for analysis, but rather a data structure for examining entities and their relationships, it has quickly expanded into many other fields of study and practice. In the time since this original conception, SNA has expanded into biology, physics, sociology, and computing (to name a few). Both Facebook and LinkedIN store their data as nodes and edges, and the interconnectedness of the world has led to ever increasing applications of SNA.

Within the construction and engineering disciplines, SNA is slowly being applied to research problems. In most cases, SNA has been used to understand networks within projects and project based organizations, although there will surely be many additional applications of SNA to include things like objects in BIM models, contractual structures, and safety hazards. For a more complete history of SNA within project based organizations, see Chinowsky and Taylor (2012) and Pryke (2012).

At this point, it should be obvious that SNA can be used in a variety of applications. In addition, there are many mathematical routines that can be applied to different research questions. I begin by outlining some of the major mathematical approaches to SNA, and then talk about the approach used in this study.

> ***Network metrics*** – For this method, we input observed network data, and then calculate properties of nodes, edges, or the whole network. This is similar to calculating descriptive statistics for a population, but can reveal, for instance, who acts as a gatekeeper within the network. Example calculations are centrality, betweeness, and geodesic distance. Centrality (degree) identifies the number of connections that each node has relative to the total possible number of connections, revealing the most connected nodes in the network. In contrast,

betweeness examines all possible paths between different nodes in the network, such that nodes with many paths that must go through them are scored higher. Finally, geodesic distance calculates the average "distance" between people in terms of number of connections. In many cases, researchers will calculate network metrics, and then use them as the independent variables in a regression equation. For instance, a regression of network centrality (independent variable) and career advancement (dependent variable), could reveal that more central network players advance more rapidly in organizations (Orpen 1998).

Structure – This method uses an input of observed network data, and then uses algorithms to determine underlying structures. This function in SNA basically removes the "noise" from networks. In most cases, large network visualizations (dots as people, lines as relationships), when viewed by the naked eye, are a confusing mess. Sub-grouping algorithms allow researchers to see pockets of nodes that are more related to each other than to nodes outside of a group. It would, for instance, allow researchers to examine an individuals' email network and discern friend groups from work people, from high school contacts, etc. These routines are used most often to find emergent groups in the network.

Simulation (ERGM) – This method uses an input of basic parameters about the network, and assumptions about how it formed, and then simulates what the network *would look like* given those assumptions, and compares it to the observed network. If the simulated networks look similar to the observed networks, the assumptions used to create the simulation may reflect reality. Exponential random graph modeling (ERGM) was created to discover how certain "rules" of tie formation lead to network structures. If, for instance, new network members connect to the person who is already most popular within the network, then there would be a network structure with a few, extremely popular people with many connections. To test this hypothesis, ERGM erases connections, and then re-draws them using random simulation, with the assumptions there is a higher probability of forming ties with popular people. If the resulting simulation lines up with reality, the assumption of this "preferential attachment" may be true.

BOUNDAYR ANALYSIS AND ITS UNIQUE CONSIDERATIONS

In Chapters 2 and 3 of this work, we faced a relatively unique challenge. Given that there are inherent, definable, boundaries like geographic work location, culture, business units, and disciplinary groups, how do these groupings affect social networks? It would not be fully descriptive simply to calculate metrics for these subgroups (for instance, E/I index, which shows the relative proportions of external and internal relationships), because these values would purely descriptive, and easily manipulated by group size. For instance, small groups have more *possible* external ties than large groups, so their E/I indexes will be skewed toward having more external ties, even if connection is totally random. Most metrics associated with either individuals or groups have this same problem – they are inherently influenced by group size.

Next, we could have used sub-grouping algorithms to determine the underlying structure of each network, and then compared it to each boundary condition (countries, cultures, business units, disciplinary groups). Although interesting, this would shift the focus of the analysis from the *influence of boundaries* to the *alignment of boundaries* with underlying social structures. This did not align with our research goals.

Finally, we could have used ERGM to simulate new networks under a given set of assumptions, and then compared simulated to observed values. While valuable in many settings, this approach would necessarily assume that the entire population of each CoP would adhere to the same, underlying "rules" of connecting with one another. In reality, each group has a very real possibility of behaving differently. We cannot reasonably assume that Chinese workers will connect with international colleagues as workers from the USA. Finally, we would be simulating structure that would be evaluated in terms of metrics like centrality, etc. These metrics have little bearing on boundaries, but rather express network structure. Because we are not concerned with the emergence of individual nodes as more central, but rather the influence of imposed groups, we wanted to maintain the integrity of observed connections, and simulate the influence of boundaries *on those existing connections.*

To remedy these problems, we use a technique that combines the best elements from multiple analysis approaches. This includes grouping professionals according to their actual boundary assignments (rather than allowing for emergent groups), simulating a network for comparison that has known conditions, while maintaining original network structure. For this simulation, the known condition is one of randomness. We assume that patterns of connection are not associated with the boundaries we want to analyze. We remained focused on analyzing the effects of boundaries on knowledge sharing networks, which requires several components:

- Obtain data for observed network and assignment to boundary groups
- Maintain structure of knowledge sharing networks
- Maintain number and size of boundary groups
- Simulate the null condition of what network would look like without influence of boundaries
- Compare null condition to observed network

This approach is described in depth in the subsequent sections.

Blockmodels and their Applicability for Investigating Boundaries

The first step in our analysis is to create a meaningful summary of the connections that exist within and between boundary groups. To do so, we use blockmodels, which use a matrix structure to compress networks into groups, and then count the connections that exist relative to those groupings (White et al. 1976). Table C-1 below shows raw, social-network data. It is a square matrix, with the same list of peoples' names as the row and column titles. In cell *i,j*, a 1 represents a directional connection from person *i,* to person *j,* while a blank or zero value is a lack of connection.

Table C-1 - Raw Social Network Data

	Sally	***Cindy***	***George***	***Amy***	***Jim***	***Bill***
Sally		1	1	1		1
Cindy	1		1		1	
George				1		
Amy	1	1			1	
Jim	1			1		1
Bill		1	1			

Associated with this data would be assignment of each network member to a given group. For the sake of simplicity, assume that there are two office locations, Denver and Boulder. Sally, Cindy, and George are in Denver, while Amy, Jim, and Bill are in Boulder. If this is the case, then we can understand far more about the influence of office location by grouping these professionals, and counting the number of connections within and between these office locations. We call this tool a "blockmodel," which is shown in Table C-2.

Table C-2 - Blockmodel of Office Location

	Denver	***Boulder***
Denver	4	4
Boulder	5	3

To interpret this table, look at the Denver, Denver cell. If we count all of the connections that occur between Sally, Cindy, and George, (all located in Denver), we see that there are four connections. In this case, and for all of our analysis, we assume that a "connection" is one sided. By this definition, Sally can claim to be connected to Jim (one connection) and Jim can claim to be connected to Sally (a second connection). This process can be done for any number of groups, and any size of network. It aggregates data to a group level, which begins to get at the influence of boundaries on patterns of connection. At this point, the primary problem is that the numbers in the blockmodel are essentially arbitrary. Is four connections within Denver high or low? It would be higher if the network was denser, but without some sort of performance data for multiple network densities, it is impossible to say whether there are an "optimum" number of connections. As networks become larger, the numbers in a blockmodel become more and more arbitrary. What if people have a maximum capacity for interaction with others? How dense would the network be? Are these connections important? Is it possible that fewer connections are needed within certain groups? Each of these is a valid question that cannot be answered by a blockmodel alone. Because of this, other methodologies have been developed, such as relational contingency tables.

Relational Contingency Tables

Relational contingency tables (RCT) are a routine in UCINet (Borgatti et al. 2002) to partially address the arbitrary nature of inter-group relational counts. The premise behind this routine is subtle, but brilliantly uses statistical re-sampling (Efron and Efron 1982) to generate a null condition that can be compared to observed values. Just as ERGM creates a new network under known assumptions, and then compares the simulated network to the observed network, RCT analysis simulates a new blockmodel by randomizing nodes' association with boundary groups. Thus, each iteration of the simulation takes the existing network structure (in terms of which node is connected to which other nodes), the number of people in each group (3 in Denver, 3 in Boulder), and the number of groups (2, Denver and Boulder), but randomly pairs people with groups.

The result is a null condition in which connections have no association with group boundaries, because the association has been randomized. Note, however, that a single simulation only represents *one possibility* for a null condition. So, to generate a maximum likelihood estimate of a null condition, the simulation is performed 10,000 times, and the average number of connections *for each cell in the blockmodel* is considered to be the null condition for the entire network. This result is essentially two separate blockmodels of the network. One represents the observed values, while the other is the *expected* number of connections based on the null assumption that there is no association between group membership and how people connect with one another.

As a final step in the analysis, the RCT routine generates a chi-squared statistic to determine whether the observed and expected values are statistically different from one another. This is calculated by subtracting the observed from the expected value for each cell in the blockmodel, taking the absolute value, adding all of the deviation values together, and comparing to a chi squared statistic. There are several problems with this approach. First, it assumes that deviations above and below the null condition are equal, when in reality they are very different phenomena. Secondly, it assumes that within group relationships are equivalent to between group relationships, which again conflicts with practical experience. Finally, it aggregates group level data into a single statistic that would be of more value if it remained separate, and does not provide access to simulation output to remedy the problem. Although

RCT analysis was boundary focused and adequately simulated the null condition needed for this research, it was insufficient as a primary analysis technique. Instead, we created a program to mimic the procedure of RCT analysis, yet output group level data that could be used to statistically evaluate observed values for each within and between group relationship. We call this approach "Boundary Analysis"

Boundary Analysis

The purpose of creating a new program was to remedy the problems with RCT analysis, and to assess the impact of various boundaries on social networks. Similar to RCT analysis, Boundary Analysis has two inputs: raw network data, and attribute assignments for each person in the network. From there, it randomly pairs network members and group assignments, and then generates a blockmodel for the simulated assignments *using the existing network connections*. In other words, Boundary Analysis ***does not simulate or re-draw connections***. Instead, each iteration of the simulation generates blockmodel based on a single random pairing of people and group assignments, with the assumption that connection data has not changed.

From this point, Boundary Analysis begins to deviate from RCT analysis. Instead of aggregating the output of each simulation into expected values (based on the mean), Boundary Analysis generates a histogram of simulated values that can be used as a random sampling distribution (RSD) of the null condition. Put differently, we create a null scenario in which there is no association between group membership and patterns of connection. Through repeated simulation, we begin to *build a population of networks* that adhere to this assumption. This population is expressed as thousands of blockmodels, each one representing the possible number of within and between group relationships given that there is no association between a boundary and how people are connected with one another. Going back to our original example of the two office network (Denver and Boulder), we now have an estimate for how many connections there *would be* within the Denver office, if office location had no effect on how people connect with one another. Furthermore, we have a distribution of expected values for our null population, so we can make statistical claims about the probability that our observed value could be a part of a null population.

Now that we have explained the concept, we will switch to a more complicated example using real data. Table C-3 below is an observed blockmodel for the Process Improvement CoP (See intro and CH 2-3), for geographic work location as the boundary. This is aggregated from the raw social network data (ex. Table C-1)

Table C-3 - Observed Blockmodel, PI CoP by Country

Country (n)	**Australia**	**Canada**	**Chile**	**UK**	**USA**
Australia (23)	44	3	10	1	11
Canada (12)	0	8	2	0	0
Chile (16)	10	4	32	0	8
UK (26)	2	0	0	48	8
USA (162)	24	4	3	8	324

Boundary Analysis kept the same network structure, number of people, number of groups, and group sizes, but randomly paired people with group assignments. The result is that each simulation puts out a blockmodel that has the same form as Table C-3. When these simulated values are aggregated, we create a histogram of possible values (See Figure C-1 as an example) that represents a population in which there is no association between geographic work location and how people have connected with one another. Using simulation to generate a null population is a technique referred to as "bootstrapping" or "statistical re-sampling," and is commonly used to generate population values under fixed assumptions (Efron and Efron 1982). Each cell in the blockmodel now has a histogram similar to the one in Figure C-1 below. When tested, the histograms generated through Boundary Analysis are not normally distributed. This is part of the justification for using statistical re-sampling, because the distribution of connections will depend on the unique network structure of each CoP. Hence the null population is always unknown unless simulated.

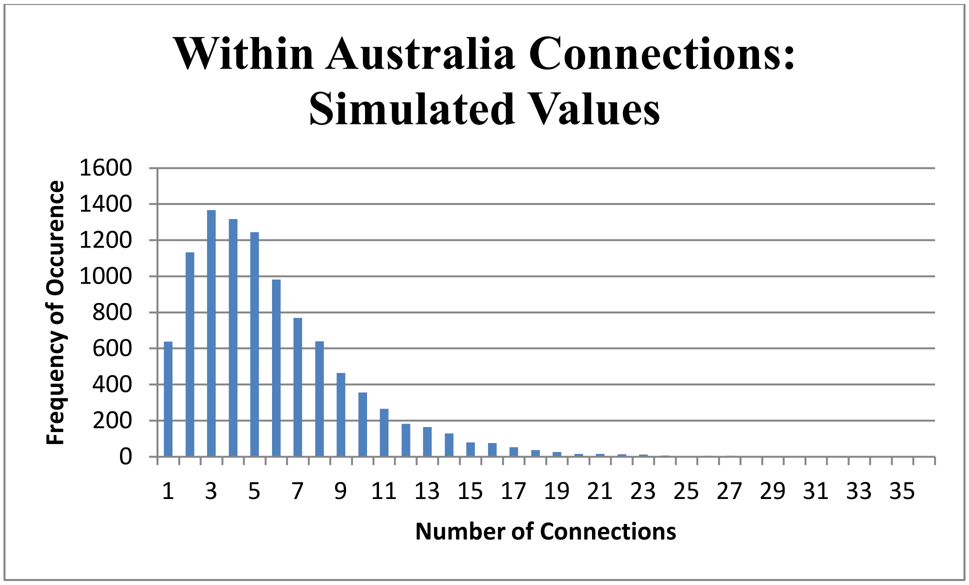


Figure C-1 - Histogram of Simulated Values, Australia to Australia Connections

Next, Boundary Analysis integrates the data from the *Australia, Australia* cell in Table C-3, and notes that we observed 44 connections within Australia. From Figure C-1, we calculate the proportion of the null population that is above the observed value (in this case, 0%), which is equivalent to the p-value for statistical significance. Practically, if the observed value is in the bottom 5th percentile of the null population, we claim that there are statistically fewer connections than expected (corresponds to an α=0.05 value), and if the observed value is in the 95th percentile or above, then the observed value is significantly higher than expected. Thus, in the example, the observed value (44 connections) is higher than expected. In fact, none of the simulations generated a value close to 44 connections.

To summarize the procedure thus far, here is a step by step outlining the boundary analysis program:

1. Input raw social network data
2. Input attribute list (names and group assignments)
3. Randomize pairings in attribute list
4. Use social network data with randomized list to generate simulated blockmodel
5. Repeat steps 3 and 4 for approx. 10,000 iterations
6. Output the blockmodel for each iteration
7. Generate historgram for each cell of blockmodel, these are the null population
8. Calculate percentile of observed value within null population, highly significant if >95th percentile or <5th percentile.

Once this process is complete for each cell in the blockmodel, we can aggregate the results into a single blockmodel that expresses the observed value, expected value, and whether or not the difference is statistically significant. For the Process Improvement CoP by geographic work location, the resulting blockmodel is shown in Table C-4. Each cell represents the observed number of connections, expected number of connections, and statistical significance in the following format:

$$(obs/exp)^{significance.}$$

++ Obs is greater than exp at α=0.05 value
** Obs is less than exp at α=0.05 value

Table C-4 - Final Boundary Analysis for Process Improvement CoP by Country

Country (n)	**Australia**	**Canada**	**Chile**	**UK**	**USA**
Australia (23)	(44/4.8)++	(3/2.6)	(10/3.5)++	(1/5.7)	(11/35.5) **
Canada (12)	(0/2.7)	(8/1.3)++	(2/1.9)	(0/3)	(0/18.9) **
Chile (16)	(10/3.6)++	(4/1.9)++	(32/2.3)++	(0/4.1)	(8/25)
UK (26)	(2/5.8)	(0/3)	(0/4)	(48/6.3)++	(8/41.1) **
USA (162)	(24/36)	(4/18.9) **	(3/25.2) **	(8/40.9) **	(324/252.9)++

The result of this analysis is profound. Previously, there was a high level of ambiguity associated with blockmodels, because the number of connections within the cells is arbitrary in its meaning, dependent on group size, and could not be compared to other networks. With Boundary Analysis as a tool, we can instead look at connections in terms of *relative capacities* as compared to a null baseline. With this tool, the expected number of connections takes into account higher and lower density networks, more and less centralized networks, group sizes, and network sizes. This also allows us to compare a given boundary across multiple networks by analyzing *patterns of statistical significance* rather than numbers of connection. As an example, Table C-4 shows a clear pattern of "homophily," meaning "love of the same." This is demonstrated by higher than expected numbers of connection within every group in the network (diagonal values). We can then compare this pattern to other networks, regardless of differences in density, group sizes, number of groups, or network size.

A Summary of Boundary Analysis Program

Input- Two data tables, one raw network data (see table C-5), and a boundary list (see Table C-6 below).

Table C-5 – Raw Network Data

	Kristina	***Paige***	***Sherri***	***Karen***	***Patrick***	***Jerome***	**…**
Kristina						1	
Paige							
Sherri	1						
Karen							
Patrick				1			
Jerome							
…						1	

Table C-6 - Example Boundary List

	Boundary (country)
Kristina	USA
Paige	USA
Sherri	UAE
Karen	Australia
Patrick	Chile
Jerome	Canada
….	England

Output- A given number of iterations (10,000 is default), each one is a new blockmodel. These are output in Excel, where each row represents a single simulation. Table C-6 gives an example of this output; note that the numbers are purely illustrative. Each column is a cell within the blockmodel.

Table C-7 - Simulation Output Example

	Australia_Australia	***Australia_Canada***	***Australia_Chile***	***Australia_England***	**…**
Test #1	14	3	5	7	
Test #2	6	6	4	4	
Test #3	2	3	2	3	
Test #4	2	0	0	2	
Test #5	3	4	2	9	
Test #6	18	10	2	10	
Test #7	2	1	2	5	
Test #8	3	2	4	3	
…	5	5	3	6	

Procedure

1. Install the program by copying the folder entitled "Awesome" to desktop (program only works on PC operating systems). The program is currently stored on the VOSS drive>> VOSS Overview>>Social Network Analysis
2. Open Awesome>>Input
3. Copy-paste raw data into the Attlist (boundary list) and matrix (network data) files. Save and close each file.
4. Open computer command prompt by typing "cmd" into the start menu search function
5. In the main folder of the boundary analysis program, open the folder "Edge1" and then the .txt file entitled "Command V2"
6. There are 3 steps outlined in the Command V2 file. They are summarized below
    a. Open the command prompt
    b. Copy paste this entire line of text into the command prompt, starting with the "cd…"
    c. Copy-paste the entire second line of text into the command prompt, starting with "type…"
7. Once the command window tells you the program is finished running, In the main file folder, open the folder entitled "output" and the excel file entitled "output."
8. Copy paste the simulation results into a new document
9. Calculate the average of each column; this is the "expected" value for each cell in the blockmodel.
10. Place the observed values at the bottom of each column, then use the COUNTIF() function in excel to determine the percentile of simulation values that falls above or below the observed value. The resulting percentile can be used as a p-value to make statistical claims.

    Re-structure the results of the simulation into a single blockmodel, we found it most useful to use the following format (for an example, reference Table C-4):

$$(obs/exp)^{significance}$$

A Brief Note on Software

The program used in this analysis was a very ad-hoc solution. Although the methodology is robust, the research team had very little programming capability. As a result, the program was written by Ryan Stout, (a computer programmer, not part of the research team) in Java, which is conventionally not used for SNA applications. Many SNA researchers use routines in the statistical software "R" to perform their analysis, because of the flexibility in programming, and a significant library of routines written by other researchers. It would have been more consistent with the research field to write our program in R, although using Java provides greater flexibility in creating a user-interface, and developing this program as a stand-alone tool for analysis in a business setting. In spite of its prevalence in the domain of SNA, R is not a dedicated SNA program. Although new programs continue to emerge, UCINet (Borgatti et al. 2002) was one of the original SNA programs, and contains a host of different routines. It is perhaps the best starting point to understand mathematical network analysis, due to the extensive help files. For much of this research, we used a secondary program, NetMiner to create visualizations of networks, and to create sub-networks based on different attributes (like country of origin). NetMiner is most useful for sorting, refining, and querying data, R has the most computing power and flexibility to do specialized routines, and UCINet has the best help files. In addition to this program, Gephi is a new, free software for visualization, and Pajek (which I have not used) is generally regarded as the best software for large network analysis.

Future Development

There are a number of improvements that could be made to this software, and future development would make the tool more user friendly and reliable. Specifically, we could add the following items:

- A user interface that allowed researchers to upload the two raw data files, select the number of iterations, and then automatically brought up the output file. This user interface would also bypass the command prompt.
- Post-processing of data into a blockmodel format, rather than column format.

- Automatic generation of observed blockmodel and calculation of percentiles, set threshold for p-value calculation and representation.

Interpretation- When interpreting output, look for statistically high observed values, statistically low observed values, and trends of statistical significance. As an example of a trend, we often found that the diagonal values (within boundary relationships) were higher than expected.

Impact – Previously, there was not a robust method to analyze the impact of imposed boundaries on underlying knowledge sharing networks. This allows researchers or practitioners to establish a statistical baseline for the interpretation of network data that would otherwise be arbitrary. Furthermore, patterns of significance can be compared across networks while retaining the unique aspects of each network. Finally, it provides rich, group level analysis that can be used for the relative comparison of groups within a single network.

Re-visualization

Chapter 2 used the Boundary Analysis tool, but added the additional step of re-visualization. Networks are frequently represented in visual terms, because subjective, visual analysis can sometimes detect patterns of connection. As networks become larger, however, it becomes more and more difficult to discern visual trends. Conventional SNA software provides the capability to visualize network data according to a clustered layout. This represents nodes (people) as dots, and edges (relationships) as lines connecting those dots, but groups the nodes according to common attribute. Figure C-2 below shows the CAD CoP by Business Unit, and it is understandably difficult to interpret.

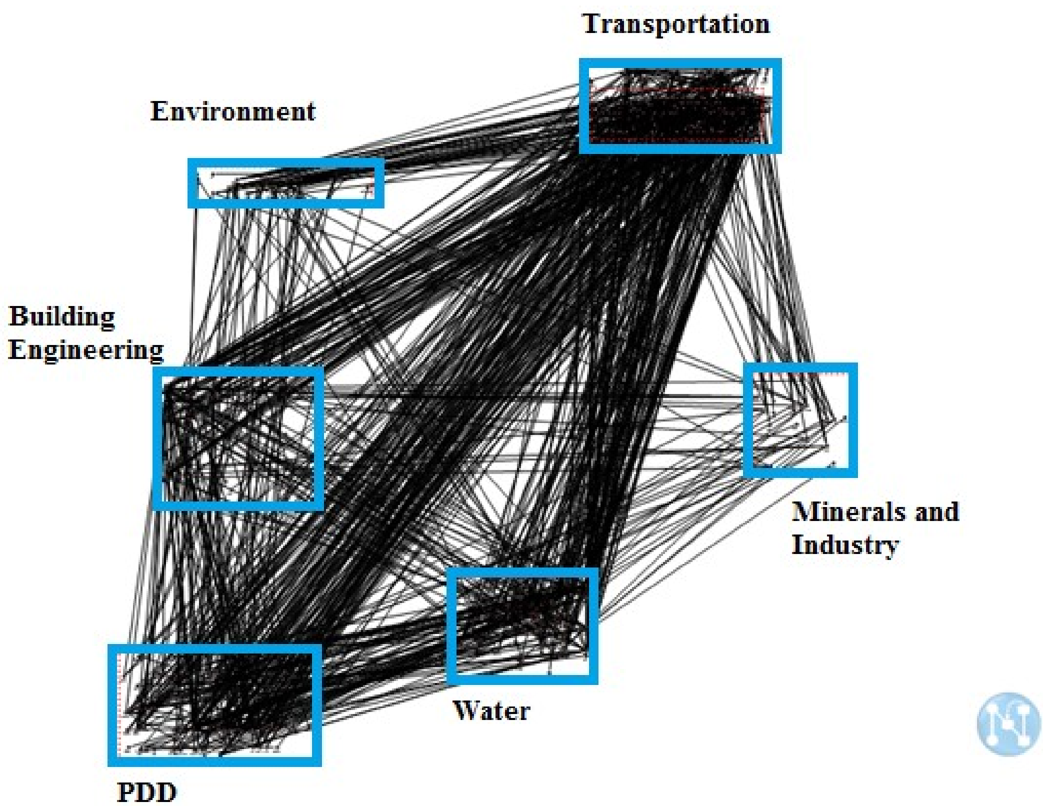


Figure C-2 - CAD CoP by Business Unit

While useful, the result can be difficult to visually interpret because it does not show *relative capacities,* but rather actual numbers of connections. Thus, in addition to the noise of visually displaying almost 1000 connections, even the number of connections displayed is arbitrary in its interpretation because we cannot see whether groups are smaller or larger, and how that affects their capacity to interact with other groups. The Boundary Analysis tool provides a convenient mechanism for simplifying this clustered visualization layout. Instead of visualizing actual connections, we visualize a revised blockmodel based on the statistical significance of relationships between groups. For instance, we take the CAD CoP blockmodel by Business Unit, shown below in Table C-8 below, and code the cells according to their statistical significance.

Table C-8 - Boundary Analysis Output, CAD CoP by Business Unit

	Building Engineering	***Environment***	***Minerals &Industry***	***PDD***	***Transportation***	***Water***
Building Engineering	(18/29.2)	(7/7.0)	(5/6.0)	(21/30.2)	(37/59.8)	(11/33.9)
Environment	(4/7.0)	(1/1.6)	(1/1.4)	(7/7.2)	(11/14.3)	(7/8.1)
Minerals & Industry	(9/6.1)	(2/1.4)	(0/1.2)	(10/6.2)	(15/12.3)	(7/7.0)
PDD	(38/30.1)	(14/7.1)++	(2/6.2)	(40/30.6)	(85/61.3)++	(32/34.6)
Transportation	(49/59.8)	(26/14.3)++	(10/12.2)	(75/61.3)	(145/121.3)	(66/68.8)
Water	(23/33.9)	(3/8.0)	(7/6.9)	(45/34.5)	(67/68.7)	(39/38.6)

If the cell values in Table C-8 are higher than expected, they are given a value of 2. If lower than expected, they are given a value of 0, and if they are not statistically different from the model, they are given a value of 1. The revised blockmodel is shown in Table C-9 below. There are 3 instances of higher than expected connection (PDD to Environment, PDD to Transportation, Transportation to PDD), and an otherwise balanced capacity.

Table C-9 – Re-visualization matrix

	Building Engineering	***Environment***	***Minerals &Industry***	***PDD***	***Transportation***	***Water***
Building Engineering	1	1	1	1	1	1
Environment	1	1	1	1	1	1
Minerals & Industry	1	1	1	1	1	1
PDD	1	2	1	1	2	1
Transportation	1	2	1	1	1	1
Water	1	1	1	1	1	1

As a final step for the purposes of visual comparison and communication, the network is symmetrized, and then Table C-9 is re-import into visualization software (in our case, NetMiner) as its own network. This generates the visualization in Figure C-3 shown below.

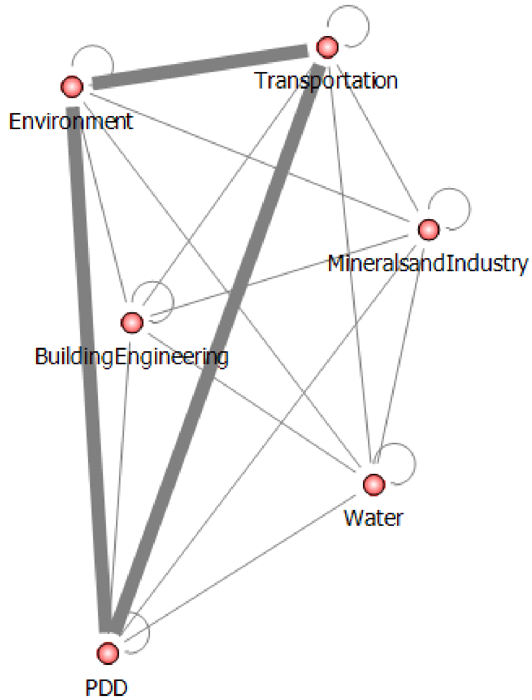


Figure C-3 – Simplified Visualization, CAD CoP by Business Unit (1045 people, 939 connections represented)

From this visualization, it is immediately apparent that the environment, PDD, and Transportation business units have a higher than expected capacity for knowledge sharing between business units. This could be the tangible effect of management efforts, in which case it shows the effect of management techniques on actual patterns of working, or it could be an organic phenomena. In both cases, it provides a meaningful visual of relative capacities that accounts for both number of connections and group size.

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Appendix D - Interviewee Selection

This appendix provides outlines how interviewees were selected. As discussed in Chapters 1, 4, and 5, interviewees were selected according to a stratified quota sampling technique to provide balanced representation of geographic locations, business units, generations, grade levels, and functional disciplines. Additionally, interviewees were selected who held unique network roles, to represent a diversity of opinions. Table 1 shows an example of this interview selection for the Process Improvement CoP.

Table D-1 - Individual reasons for selection

	Survey	Name	Location	GBU	Gen	Grade	Function	Reason for Selection
1	Yes	Marion	Oak Ridge, Tennessee, USA	BSII	X	27	Business Development	One way with Wendy, two way with Janice for useful connection. Why are they different? Connection with Wendy spans GBU boundaries, connections with Rhonda , Janice , and Malcolm do not, but are considered useful.
2	No	Beth	Brisbane, Australia	M&M	Boomer	29	Quality Assurance	Has moved on to her next assignment, but still holds a central network position. Is just a BB, very few GL differences, pretty well connected with other generations (boomer). Has a number of inter GBU connections.
3	Yes	Claire	Brisbane, Australia	M&M	Boomer	28	Engineering	Low on inter function and country, high on GBU, grade level, and generation spanning connections
4	Yes	Dwight	Frederick, Maryland, USA	Power	X	26	Engineering	If danny falls through
5	Yes	Shelley	Frederick, Maryland, USA	Power	X	26	Engineering	Embedded within Power, is in BSII GBU. Intense network surrounds her. Kim , Jimmy , Harriet , Gretchen, and Brandon all get useful info.
6	Yes	Darlene	Richland, Washington DC, USA	BSII	X	27	Project Controls	On a totally separate cluster, only connected to Lee. Disconencted from community as a whole

7	Yes	Glenda	Montreal, Canada	M&M	Boomer	28	Quality Assurance	Only useful connection to Canada (to Eugene), also most connected to outside world within Canada. Not very many reciprocated connections. Overall rank of 1 in boundary spanning by the 200% metric for all 5 boundaries
8	Yes	Scott	Santiago, Chile	M&M	Y	25	Field Engineering	Functions really well as a inter-country boundary spanner in a unique grouping of diversity for useful connections only (BS Not many functional spanning, but has less than half that span country, 173% span GBU (200 metric), high for generation and GL (193%))
9	Yes	Luis	Frederick, Maryland, USA	Corporate	X	29	Six Sigma	Highest In Degree on Semi-annual and monthly basis, VERY connected (25,10)
10	Yes	Eugene	Ras As Zawr, Saudi Arabia	M&M	Boomer	26	Engineering	Is within the "boundary spanning" cluster, connected to Gayle, Ben , Scott, and Glenda. What is it about that cluster?
11	No	Faye	Reading, England	Civil	X	27	Project Controls	Located in UK, interacts significantly with Civil GBU, but is in OG&C. Also has relationship with Louise, who is central player
12	Yes	Diana	Doha, Qatar	Civil	X	27	Quality Assurance	Located in Mid East, ties together Qatar and UAE, relatively central to her network, reciprocal connection with Lloyd
13	Yes	Brandon	Frederick, Maryland, USA	Power	Y	24	Engineering	Has some very big GL differences with Frances and Bradley .
14	Yes	Vincent	Birchwood, England	Civil	X	29	Project Management	On the periphery, only one connection to Marion
15	No	Danny	Houston, Texas, USA	OG&C	X	28	Engineering	low on spanning function and country boundaries, higher on GBU, overall lower boundary spanning
16	No	Kay	Frederick, Maryland, USA	Power	X	26	Engineering	Highest In Degree on "frequently" Basis (6)
17	Yes	Mitchell	Richland, Washington DC, USA	BSII	Boomer	28	Quality Assurance	From BSII when we need more people

18	Yes	Jose	Shanghai, China	OG&C	Boomer	29	Operations	Only employee from China
19	Yes	Kerry	Brisbane, Australia	M&M	X	28	Six Sigma	Highest In Degree on Weekly Basis (8), over 50% BS connections for Geographic and GBU, but very few inter functional
20	No	Ted	Taweelah (Abu Dhabi),UAE	Civil	X	28	Office - Construction	Lower on the list (backup plan); only 3 reported connections, but all are boundary spanning.
21	Yes	Lauren	Vienna, Utah, USA	Power	Y	24	Project Controls	Spans GBU 195% by 200 metric, over 50% in each individual metric. GBU, function, and country are all high
22	Yes	Penny	Marshall Islands, USA	BSII	Y	26	Quality Assurance	Links a more disconnected group to the whole.
23	No	Justin	Haryana, India	ND EU	Boomer	29	Project Controls	Embedded within "boundary spanning" cluster. Connected to Dianne , Gayle , Scott, and Kerry. Is in Power GBU when all else are in mining and metals. Weird connections…. He is located in Gabon, others in Chile, and AUS
24	Yes	Janice	Richland, Washington DC, USA	BSII	Y	25	Contracts	Within BSII, has only 1 inter-country connection, NO GBU spanning connections
25	Yes	Allen	London, UK	Civil	X	27	Engineering	Located in England, relatively disconnected from other clusters of England people as far as useful connections. Interacts with Louise , Michele , and Jane
26	Yes	Wendy	Brisbane, Australia	OG&C	X	28	Project Controls	Looking at only useful connections, Wendy spans boundaries from Civil to BSII(Beth, Martin), and Power (dwight) GBUs, has a number of connections to australia
27	No	Lucille	Soyo, Angola	OG&C	X	29	Project Controls	From OG & C when we need more people
28	Yes	Stanley	Houston, Texas, USA	OG&C	Y	24	Procurement	Within OG&C, fairly central to network as whole, conencted to Luis, has GBU spanning connections with Brandon, Luis, and Ben
29	Yes	Kimberly	Taweelah (Abu Dhabi),UAE	Civil	X	24	Procurement	100% country spanning connections (2 InDeg 7 Out), 100% GBU spanning, high BS grade level, funciton,

								only 50% of in, 0% of outDeg
30	Yes	Barry	Frederick, Maryland, USA	BSII	Boomer	25	na	Periphery Member

Appendix E – Qualitative Analysis

Chapters 4 and 5 are firmly rooted in qualitative analysis from interview data. Chapter 3, while not based entirely on qualitative data, draws heavily from our qualitative data-set for its main theoretical contributions. Each of these chapters provides a brief overview of the qualitative analysis process, but this section is intended to be a more detailed narrative to explain the origins of various ideas, and their formalization into a coding dictionary and theoretical models.

The purpose of this section is to pave the way for future students who would like to see the struggles, frustrations, and ultimately the benefits of qualitative research, as well as to discuss the techniques that were of most use to my work.

QUALITATIVE PROCESS: BASIC STEPS

Qualitative methods sound much more straightforward than they actually are. There are a variety of different techniques that comprise qualitative analysis, and each has its own terminology. There are plenty of books that explain these methods in detail, I recommend Miles and Huberman (1994) for an overview of qualitative methods, Becker (2008) for practical advice on performing qualitative analysis, and Weiss (1995) and Spradley (1979) for data collection through interviewing. At its core, qualitative analysis is trying to answer questions like "*why?*" and *"how?"* that cannot be answered through statistics. Good qualitative research is a compelling story about something that is occurring, and explains why and how that thing is occurring based on evidence. What differs between qualitative analysis and pure opinion is gathering data and conducting a systematic search for patterns and explanations to explain the phenomenon. The work in this dissertation is rooted in "grounded theory," which starts with data, and uses that data to develop theory. Traditional research starts with a theory, and then tests that theory against gathered data. So, with a grounded theory approach, we started with a phenomenon and a research question that we wanted to evaluate:

It is important to note that research involving people is subject to the institutional review board (IRB) approval. This forces researchers to consider the ethical implications of involving human subjects, and to take measures to protect participants prior to collecting data.

Phenomenon: Multi-national CoPs are comprised of global networks in which members have formed meaningful knowledge sharing connections. Thus the members have somehow become connected, and that their knowledge bases fit together in some meaningful way.

Research Questions (paraphrased):

1) How have CoP members become connected?
2) How do CoPs coordinate knowledge sharing between diverse knowledge bases?

Notice that both of these research questions are not hypothesis. There is not a clear way to answer these questions, or even a guiding theory. This is the starting point from which literature review and different data sources will guide the search to answer these questions. The process loosely follows these steps:

1) *Literature review:* The point of reading existing literature is to figure out what previous researchers have found, and topics that have yet to be studied. At the same time, the breadth of literature is such that it is easy to get lost reading papers, and never conduct research. It is important to realize that reading everything is not a necessary condition to collect data: in fact, some researchers advise against prescriptively adding theory too early in the research process. For me, the goal was to read *enough* to understand general patterns of thinking surrounding the topic of communities of practice and knowledge sharing. As I continued on in the analysis process, I continued to read according to themes that showed up in the data (i.e. coordination theory, models of information seeking, etc.). Keep in mind that the end goal is to outline a field of study, and to describe where your work fits within it. This does not fully occur until you have done your analysis. In the meantime, the body of literature that you read should dynamically adjust to the issues at hand.
2) *Data Collection*: Given that this is research, and not editorial writing, there must be some source of data. How am I going to answer this question? In my case, it made the most sense to ask

people about connections that they had within the CoP, and so we spend a lot of time selecting interview participants (see Appendix D) and connections to ask them about that would represent the entire community. I could not, for instance, gather documents; because there are not any documents that record formation of the informal knowledge sharing connections I am looking for. So, in this research, we decided to use an interview basis, where I would personally talk to people, and ask them a semi-structured set of questions, with room to further probe and clarify. These are called semi-structured interviews. We created a list of questions, which are included in Appendix B. Each interview was recorded (you must ask permission to record interviews), and I took notes by hand.

3) *Transcription*: There are two reasons why I recorded the interviews. First, to have something to reference that can be considered objective. When doing qualitative research, your mind will develop and progress its own ideas, and impose those ideas on your data. Thus, it is easy to think that you have found something, but have no practical support in your data. With field notes and memories, this would be difficult to correct. However, with objective transcriptions, it is harder to make themes appear that are not supported by data. Secondly, it allowed me to transcribe the interviews into text for more rigorous analysis. This involves listening to the recordings, and translating it in to written text. It takes approximately 3-4 hours for every hour of footage, or you can pay someone to do it.

4) *Cleaning*: For this study, we had money for transcriptions, so we paid someone else to do the time consuming task of transcription. Some qualitative researchers believe that contracting out transcription is a net loss, because the researcher is far less familiar with their data if they don't transcribe it themselves. In our case, some of the transcriptions were not done very well, so the first phase of post-transcription processing is going through, listening to the recording, and checking the transcript for accuracy. From this, we were able to speed up the research significantly (77 interviews, roughly 40 hours of tape = estimated 3-4 weeks (>120 hrs) of transcription work that I did not have to do). To increase my familiarity with the data, I

conducted all interviews, listened to the recordings, and read the transcripts. At a minimum, researchers should listen to their recordings over again.

5) *Initial Examination of Data*: I think that this is simultaneously the most intimidating and most exciting step of the qualitative analysis process, because it is where the true analysis work begins. At this point we had a significant amount of qualitative data, and I had been thinking about it since it was gathered. For qualitative research, *analysis* happens within the mid of the researcher. It is possible to be rigid and mechanical, even with interview data (i.e. counting certain types of responses), but that is reporting, not analysis. True analysis uses your own perspective, discussion with others, writing, and ongoing experience to critically draw connections between phenomena that occur in your data. With quantitative methods, analysis consists of drawing connections between two ideas through the use of statistics, and these connections are expressed through correlations, coefficients, and p-values. In qualitative methods, the researcher draws the connections between concepts, and then makes a case for them through explanation, storytelling, grouping/ordering the data, and comparing data across multiple sites.

   The initial examination of the data consists of reading through interviews over the course of several days or weeks, and noting things that are interesting, unexpected, consistently recurring, or contrary to existing trends. The purpose of this initial examination is to gain several iterations of reading, and to seed your mind with initial ideas. I kept an open word file, and wrote things down when they occurred to me. These "memos" become the basis for developing concepts. Although I started with specific research questions, my first reading of the interviews was not trying to answer these questions. Instead, my goal was to become familiar with these people that I had spoken with, and the context in which they operate. Practically, read through your data twice, and write down (in short sentences, stream of consciousness) what strikes you.

6) *Discovering Emergent Concepts:* At this point, it is very tempting to jump in and start creating "codes" to classify certain elements of data. Although this is valuable and appropriate for qualitative research to fit in to existing theories, it takes deliberate thought to develop new

concepts. This phase was characterized by writing for me. After the initial examination of the data, I went back to my research questions and tried to answer the questions (in writing) using my data. We call these informal pieces of writing "memos". It would go something like this:

> *How have CoP members become connected? Members of international CoP accomplish knowledge intensive work by importing knowledge available to them within their sphere of influence. Company work processes and activities can facilitate employee interaction, but these "processes" are not enough to form a knowledge sharing connection. There must also be trust between the two individuals, common context… (look at the data), etc.*
>
> *Thus global knowledge sharing networks are formed through a combination of organizational and social forces. In the absence of organizational forces, CoP members have strong tendencies toward homophily in regards to visible attributes... so how do they break away from these social tendencies? We know they come into contact because of their jobs, but do these connections stick? Go back and re-visit data. Maybe we can separate out social vs. job role connection mechanisms – although it can be hard to tell the difference. What if someone is your friend (social) and boss (work based)? How would we classify the connection?*

As you can see, this is very informal writing. I am trying to get ideas down, explore different tangents, and hopefully to develop meaningful categories for thinking about these problems. The end result of this step should be a number of different memos that begin to express themes. Certain ideas will start to stick as being true and useful. Hang on to these ideas, and re-visit them as concepts that you can define and code. From the memo above, I drew out "organizational control" as one way the organization connects people, and "social networking" as a purely social mechanism of connection.

7) *Formalizing Codes:* "Coding" sounds fancy, but is basically a method for grouping bits of interview data into similar clusters. It is very similar to tagging people's photos on facebook, because you can assign multiple people to one photo, and then select a single person, and go through all of the photos that include them. In this case, our interview data is like the photos, and concepts are like the names we are associating with the data. QSRNvivo, a qualitative analysis software, allows us to go back to a single concept, or "code" and see all of the references that we tagged as being relevant to that concept.

Once I developed clearer constructs, I went back to the data and created a list of codes to sort my data. I started out with the constructs that I had developed from the initial observation and memo-writing, but whenever an interview reference did not fit well into one of those codes, I would split it off into a new code. This way, I was not imposing my ideas on the data (because I allowed for new categories to form if ideas didn't fit), but I am still beginning to narrow down how I will answer my research questions.

As I went along, it became fairly obvious which codes were more prevalent in the data, because they had the largest number of references. Throughout this process, I continued writing to refine my concepts to better fit the data. At this point, we also brought in a second person to code based on the developed concepts. I worked independently of the second researcher, and we periodically came together to check and see if we were coding the interview the same. Doing this increases the reliability and consistency of our coding categories, because it reveals areas of conceptual disagreement.

The result of this phase is a "coding dictionary" that is shown in the next section. It defines the different codes used in the study, and provides conceptual definitions of each. Furthermore, some codes are nested within more broadly focused categories.

8) *Coding in practice:* Although it may sound simple, coding as a means of qualitative analysis presents a number of problems. As research tends more towards conceptual and theoretical goals, it will become more and more difficult to get consensus on a given code or concept. I struggled quite a bit to develop a framework that was not simply reporting how people became connected (results, what was observed), but provided deeper insight into the communities of which they were a part (discussion, analysis). It was an even greater challenge to try and describe how CoPs worked to coordinate specialist knowledge, because the codes we developed (based off of the degree of overlap) were based on significant interpretation of responses. The key to overcoming these difficulties was writing about it consistently, and frequently. I would sit down and brain dump all of the complexities of our data, and rant about it to friends, family, and co-workers.

When I hit a road block, it was important for me to verbally process through why the roadblock was occurring, and what underlying themes I appeared to be missing. In some cases, this process led me to believe that common phenomena were more interesting than I had previously thought, and uncommon phenomena were essentially meaningless.

As an example, I chased a significant rabbit trail trying to understand the formation of individual knowledge sharing connections. My focus was not just on *how* they came about, but *why* individuals became connected in the first place. What was it doing for them? This came about because I noticed that when I asked people how they became connected to others, they would typically explain what they did in the company, and what the other person did in the company. This is extra information that people would volunteer instead of just saying "we were introduced" etc. I decided to explore this idea through the concept of relevance. Perhaps people felt the need to provide this other information to justify how they were relevant to the company. I wrote the following into a memo on the topic:

"How does this fit in to the greater picture of creating a theory for KSC formation? What I am doing is explaining how people think of themselves in a relationship. Though it is primarily self serving, this process or mechanism of establishing relevance may be important. Why do they need to establish relevance? Does it give them confidence to assertively claim a knowledge base? Perhaps relevance enables people to understand and "audit" the knowledge that people around them have. For instance, if I say "I am an engineer who focuses on designing bridges," by describing what I do, I have also given you a coded phrase that tells you my knowledge base and skill set. This definition of my work actions and abilities may create the "awareness network" that facilitates connection. If roles within the company do lead to defining our knowledge bases, or providing a framework about which to discuss our knowledge bases, this may be a good place to pull in the idea of "homophily of doing." A homophily of doing would be when people tend to connect (for the purpose of sharing knowledge) with other people who DO similar things, as opposed to other people who are like them."

This is not a bad thought, but our data did not provide too much insight into the idea of relevance. Furthermore, it was beyond our project scope, and did not answer the original research question. As it turned out, it was more valuable to decrease the level of abstraction and talk about the general ways that people become connected. The "homophily of doing" was basically a complicated way to express that people become connected when they do stuff with other people.

Our data indicated that many of the CoP members became connected when they worked on projects together, which led to the development of "organizational opportunity" as a meaningful code that was used in analysis.

CODING DICTIONARY

This coding structure outlines the concepts relevant to work in this dissertation. For the larger VOSS project there were a number of other categories that are not mentioned here. Each category and sub-category is defined, and references appear to the chapters in which they will be used.

Individual Motivations and Understandings – The most basic unit of analysis within a CoP is the individual. CoPs are comprised of individual employees, each with a unique understanding and ability to act within the COP. This category is for non-relational data that does not affect the whole CoP.

- *Motivations* – Prior to seeking knowledge within the CoP, there is necessarily a motivation for doing so. Data within this category will consist of individuals' reasons why they engage/do not engage in knowledge sharing behavior. Data from this section helped determine why people originally became connected (Chapter 4), and the role of CoPs in coordinating specialist knowledge (Chapter 5)
- *Knowledge base identification* – Participants were asked to describe their particular area of expertise within the CoP. This helped researchers profile and understand CoP membership, as well as verify types of coordination based on the degree of knowledge base overlap with others (Chapter 5)

Dyadic Level Behaviors and Perceptions – The next level of analysis involves interaction between two individuals. For instance, knowledge exchange cannot by definition be evaluated at the individual level, because relationships are not exclusively owned by one person or another. For any type of behavior or perception that involves a specific other, we have created these coding categories.

- *Mechanisms of Connection* – Chapter 4 describes the mechanisms by which individuals connect with one another. Within this, there are five mechanisms of connection:

- *Organizational control* – Connection through authoritative directive. This includes knowledge sharing that occurs due to reporting structures, but can also capture when a figure of authority explicitly directs two subordinate employees to share knowledge.
- *Organizational opportunity* – Being brought together through membership to the organization, but not through explicit directive. Working in the same office, working together on projects, and mutually attending events are considered organizational opportunity.
- *Social Network* – Either introduction through a mutual colleague or deliberate search by approaching people rather than search tools. This mechanism is relational in nature.
- *Non-person centered Search* - When search tools provided by the company are the facilitating mechanism for connection, either to another person or to codified knowledge
- *Serendipity* – Connections which occur outside of the organization
- *Other* – Mechanisms that fall outside of the other categories

- *Types of Connections* – During our investigation of the types of coordination occurring within CoPs, we found it necessary to account for different degrees of overlap in knowledge bases.
  - *Overlapping* – When two individuals have similar knowledge bases, and use those commonalities to share best practices, innovate, and generally share knowledge on what they are both working o*n*
  - *Complementary* – Individuals have different knowledge bases, with a small degree of overlap required for coordination. Each performs a distinct task, yet is aware of the expertise of the other party.

    - *Growth* – When one individual is attempting to impart their own knowledge base to another. The receiving individual does not have additional knowledge to add; rather the giving individual is primarily teaching the receiver.
    - *Non-overlapping* – Individuals have such a low overlap in knowledge bases that no meaningful knowledge exchange is possible.
    - *Other* – In some cases, individuals would describe connections that did not cleanly fit in to one of these categories. This occurred when two individuals had different degrees of overlap in different domains. In these cases, it was separately coded, and we selected the type that was most relevant to their current job roles.
- *Knowledge sharing patterns* – In Chapters 2 and 3 we examine patterns of connection which emerge as a result of aggregated individual behavior. Patterns resulting from both organizational and geographic boundaries are coded to this category.
    - *Geography Culture, Business Unit, and Functional Discipline* – each had its own sub-category in which ALL mentions of that attribute will be coded. These were not used as primary analysis in Chapters 2 and 3, but served as a valuable reference to understand context in each CoP.
    - *Patterns*- Once we had performed a statistical analysis of each CoP, several patterns emerged that warranted further investigation. These yielded four emergent categories to describe various pipelines, holes, and anomalies mentioned in Chapter 3.
        - *Subgroup Size* – Any reference to the size of an office location, country group, or cultural group.
        - *Expat* – coded whenever someone was an expat and described how it affected their views/knowledge sharing activities.
        - *Proximity and Common Language* – When examining specific relationships between the UAE and Qatar and the USA and Canada, coded references that showed ease of collaboration due to proximity/common language.

- *Organizational Structures* – When job roles, tasks, or management techniques facilitated connection across geographic boundaries.
- *Boundary Spanners* – When individuals had connections to heterogeneous others, and discussed these differences: all occurrences.

FRAMEWORK DEVELOPMENT

It is easy to get bogged down in the academic jargon surrounding frameworks, models, process models, etc. At their core, however, frameworks break down observed phenomena into meaningful categories constitute its component parts, and models begin to explain how concepts fit together and influence one another. This is by no means an exhaustive account on framework and model development. Instead, the point of this section is to make a simple point: analysis consists of taking the next step beyond description. I will give some brief examples of tips and tricks that worked for me in making this jump.

Moving from Codes to Meaningful Analysis

When I was coding, I was identifying concepts that repeatedly occurred. Chapters 4 & 5, which examine the mechanisms of connection, and types of coordination within CoPs are both *framework development*. In Chapter 4, I wanted to create a better understanding of how people become connected in multi-lateral CoPs, which is a large, complex phenomenon. First, I established that this phenomenon is, in fact, taking place, because knowledge sharing networks exist. Next, to understand the phenomenon of connection within CoPs, I decided that it would be helpful to break down into its component parts. In this case, to understand HOW people become connected, it is important to understand the mechanisms that led to their first contact.

The decision to pursue framework development came because prior work has looked at other aspects of this phenomenon, such as what leads people to seek information from others (Borgatti and Cross 2003; Hertzum 2014). Thus the *gap in knowledge* drove our analysis. We know there are knowledge sharing networks. How did these existing connections get established? To our knowledge this had not been done before.

When we started answering this question with data, it is not generalizable. For instance, when we asked one participant how they became connected to a colleague, they would give answers like:

"Well I started as a trainee in the New Castle office and worked closely with him and learnt things off him through working… through projects since he was a Senior Executive Officer and I was just a trainee. So I was just watching what he was doing a lot and asking him a lot of questions."

This response is specific to this one relationship, and may be similar to many others. Early on, this quotation may be grouped with others in a *trainee* or *projects* code. Both would be legitimate categorizations. For me, the analysis began when I evaluated the commonalities between different literal codes, and asked "*what forces actually drove this connection?"* In this case, learning through working happens because of project assignments. There was not a specific requirement or job description that led the trainee to learn from his more senior colleague. The interaction and subsequent knowledge sharing happened fairly organically because these two employees had the chance to work together. Now, when other people become connected because they sat next to one another in the office, it begins to look like a similar, non-forced, social interaction that comes about because there is an opportunity to interact as a result of doing their jobs in proximity to other people within the organization.

The second question that helped tremendously in my analysis was to ask: *"what is this a case of?"* For each connection, I am making the assumption that there is some underlying commonality with other connections, even though each one is unique. Going back to the quotation above, I would try to generalize what was happening as a case of something more generalizable. Here are a few possible answers:

- This is a case of a work based learning environment
- This is a case of proximity influencing relationship
- This is a case of power balances perpetuating the mentor mentee learning cycle
- This is a case of interaction opportunity facilitated by mutual belonging to an organization
- This is a case of work patterns generating social connection

By answering the same question over and over again, I start to move from codes (trainee, assigned to the same job role, etc…), to a meaningful framework.

Qualitatively Supporting a Framework

Coming from an engineering background, I was initially very uncomfortable with qualitative analysis. It seemed very *soft*. How do I support my findings with any integrity when there is not a p-value or other objective measure? The answer is *narrative*. My development of a meaningful qualitative framework depends entirely on the clarity, consistency, and communication of my different categorizations, and why they are useful. I do this by showing actual data, explaining how it relates to other data, and then aggregating these individual observations into a compelling story. Although this opens the door for many different interpretations of what is going on, it adds depth and complexity to problems that cannot fully be expressed through quantitative methods. Furthermore, competing explanations are an important mechanism for checking the theoretical robustness of qualitative work. This work used mixed methods (See Appendix F), and used triangulation to validate qualitative concepts (Appendix H). Continuing with the example above, there is a diverse array of examples where physical proximity, joint tasks, or inherent patterns of working within the organization bring people together. Not all of these connections stick, but many of the connections that have stuck come from this sort of *organizational opportunity*. This is fascinating because knowledge sharing within CoPs is supposed to transcend these everyday interactions, yet it does not! My data does not directly reveal the influence of organizational opportunity, or realize the impact of organizational opportunity on our understanding of CoPs. It is my job as the researcher to make these connections. Qualitative analysis affords me the opportunity to think deeply about how different people became connected, and what that might mean for the organization as a whole. In contrast, quantitative research cannot hope to explain the underlying conceptual commonalities of such a complex phenomenon.

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Appendix F – Mixed Methods in Practice

Similar to the other methods appendices, the purpose of this section is to provide a narrative of mixed methods analysis for future students. For the sake of scientific clarity, the methods sections in journal articles and polished work rarely explain the true timeline, cross pollination of ideas, and meandering thought that characterizes exploratory research. My hope is to outline this process, and to critically review the particular path that I followed. Perhaps the lessons that I learned can be of use to students who have chosen to wrestle with similarly complex problems.

THE TRUE TIMELINE

Whenever we have presented on this research, we have simplified the methodology down to a two phase, mixed methods design. First, we started with quantitative social network surveys, which we used to select interview participants, and then we performed qualitative, semi-structured interviews, analyzed them, and then drew conclusions. This approach is shown in Figure F-1 below:

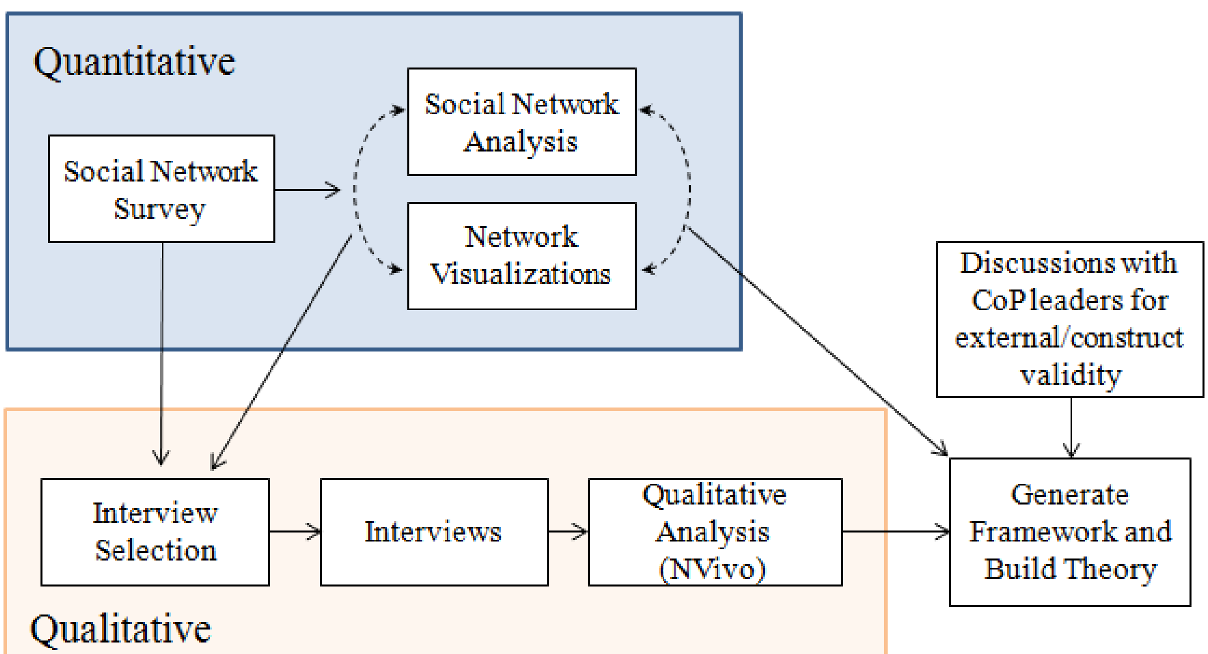

Figure F-1 - Formal research method

Although this was our research design in theory, the actual execution of this project looked a bit different. I gathered data for three CoPs in two companies, and so there were logistical issues with survey response rates, as well as soliciting participation for interviews. This caused delays and overlaps that are not adequately captured in Figure F-1. Secondly, the conclusions presented in this work do not neatly correspond to either qualitative or quantitative analysis. Instead of a neat, linear methodology with nice little conclusions at the end of each phase, I tried to use the continual input of new data to constantly update how I thought about our problems and approached analysis.

To illustrate the continuous data input, I am going to tell the story of developing the ideas found in Chapter 3 of this dissertation, which analyzes the effects of geographic and cultural boundaries on knowledge sharing networks.

We started piloting the idea of boundary analysis using the 2011 pilot study data of sustainability, and supplier quality and expediting CoPs. Amy looked at relative frequencies of connection within and between groups, an found that there was a higher relative frequency of within group, as opposed to between group knowledge sharing. From there, we gathered data from the process improvement CoP, and found similar things. I wrote this in to a conference paper presented at CRC in the summer of 2012. When this paper was presented, we were in the middle of gathering data for the CAD and Transportation CoPs, which added to our data-set, and to our findings. In the CAD CoP, the results did not conform to our original findings (geographic location was NOT limiting to connection), and we were having problems with the quantitative analysis. In the meantime, we wrote consulting reports for the Process Improvement, CAD, and Transportation CoPs that continued to use a relative frequency reporting to analyze geographic boundaries.

In the summer of 2012, we started to consider different quantitative analysis methods, and discovered relational contingency tables (RCT) in UCINet (Borgatti et al. 2002), which provided a better statistical analysis of whether a given boundary affected patterns of connection. The original proposal had us using E/I index to determine the relevance of different boundaries (geographic, cultural, business units, etc.), although we added RCT to bolster the statistical power of our analysis. RCT was a statistical test to determine significance, and then the E/I index gave insight into group level behavior. During the fall of 2012, I traveled to Virginia Tech to learn more about using UCINet from another student. When I started running analysis models, we got a number of conflicting results that we could not explain. Starting in January of 2013, I began conducting interviews in the Process Improvement CoP, and was drafting a paper using RCT analysis for geographic and cultural boundaries. Through these interviews, I started to get a much better idea of why different patterns of connections may be occurring, which was partially incorporated into my discussion in the paper. In the spring, I ended up scrapping the RCT analysis paper and re-writing it, then submitting it to the Journal of Management in Engineering. We were still getting strange results for the CAD CoP, but had reasoned through the RCT results enough to justify submitting the paper. Starting in the summer of 2013, I began conducting interviews in the CAD and Transportation CoPs simultaneously, and through interview validation of geographic location data, found out that our data-set was not accurate for the CAD CoP. I took corrective action with our company contact, and got correct location data.

At this point, I had better input for all three CoPs to explain different patterns of connection, and thought it would be valuable to integrate some of this into the paper. I had also started to develop a new method for conducting boundary analysis, and was pilot testing a program that we had developed in Java to conduct this analysis (see Appendix C). I then re-wrote the geographic and cultural boundaries paper to include some minor quotations from the PI, CAD, and Transportation CoPs as explanations for different chart patterns. This was at the same time that I was conducting interviews for the CAD and Trans. CoPs. Due to unexpected delays, the interviews, transcription, and coding for the CAD and Transportation CoPs spilled over into 2014, and these activities were not finished until February 2014. Once these were complete, I re-wrote the geographic/cultural boundaries paper to be fully mixed methods. In this final version (presented in Chapter 3), the boundary analysis program is used for preliminary analysis, then trends are explained using qualitative data, and then verified through secondary analysis of the quantitative social network datasets.

As this narrative shows, the process did not follow the simple method outlined in Figure F-1. Instead, I iterated between quantitative and qualitative analysis to develop a richer and more nuanced view of knowledge sharing relative to cultural and geographic boundaries. Below is a complete list of data collection phases, different analysis used in the study, and final products. The lists below should give a good overview of the somewhat chaotic timeline that this study followed.

Data Collection
- 2011: Pilot study social network surveys
- 2011: Pilot study interviews
- 2012: PI CoP social network survey
- 2013: PI CoP interviews
- 2012: CAD social network survey
- 2013/14: CAD interviews
- 2012: Trans. CoP social network survey
- 2013/14: Trans. CoP interviews

Analysis
- Individual reports (descriptive stats w/ preliminary results)
- Aggregate quantitative data mining
    - General network measures, density, centrality
    - Blockmodels
    - Visualizations
    - Visualization mining (different colors//layouts)
- Focus on boundary analysis, RCT
- Creation and use of boundary analysis tool
- Transcription
- Coding
- Regression of usefulness

Papers
- 2012: PI quant. Report (network based, descriptive statistics)
- 2012: Trans quant. Report (network based, descriptive statistics)
- 2012: CAD quant. Report (network based, descriptive statistics)
- CRC 2012 – Used relative frequencies for boundary spanning
- EPOC 2012 – Used relative frequencies for boundary spanning
- EPOC 2013 – Refined visualization, org boundaries
- JME 2013 – Submitted RCT paper on geog. Boundaries, (rejected).
- 2013: Quantitative analysis course paper – Usefulness regression
- CRC 2014 – Usefulness regression
- EPOC 2014 – qualitative, types analysis (CH 5)
- Physical boundaries paper 2014 – Boundary analysis and qual. Analysis (CH 3)
- Organizational boundaries paper 2014 – Boundary analysis and (small amount) qualitative analysis (CH 2)
- 2014: PI qualitative report
- 2014: Trans qualitative report
- 2014: CAD qualitative report

CROSS POLLINATION OF QUALITATIVE AND QUANTITATIVE THOUGHT

While it would be nearly impossible to track all of the ways in which qualitative and quantitative methods intersect with one another, the key value of a mixed methods study is the active cross-pollination of ideas and conceptual validation (see Appendix H). In this study, the quantitative social network analysis provided an overview of patterns that spanned the entire CoP, while the qualitative interviews specified how and why these patterns occur. As I bounced between quantitative and qualitative data collection and analysis, clues gained from each method informed and helped develop our findings. Once again, I will provide an illustration of what this looked like.

To stay consistent with the example given above, Chapter 3 benefited significantly from the cross pollination and validation of quantitative and qualitative data. When I originally began to analyze the social network data, it was exceedingly difficult to find patterns of connection that were interesting or useful to talk about. When we started using RCT analysis, it would show us when there were fewer or more connections than expected between geographic groups, but the analysis method did not account for group size. When I began conducting interviews, it became apparent that many of the variations in numbers of connections were not perceived by the network participants. Basically there was a misalignment between our quantitative methods, and the reality that these methods were trying to portray. As a result, we developed a new analysis methodology that had a built in statistical mechanism to account for group size, and as a result we detected larger differences between observed and expected values. This brought new network patterns to light that corresponded with the narrative of the CoP. Within the Process Improvement CoP, quantitative patterns linking Chile, Canada, and Australia were initially confusing. One interviewee briefly mentioned that they traveled between these three countries overseeing the mining and metals division of the company. Also, we discovered that many of the connections within the PI CoP were initiated through organizational control and organizational opportunity. This led to the hypothesis that the network patterns were driven by reporting structures and opportunities created by working together. We were able to return to the quantitative data to verify assumptions made from qualitative data, and calculate a relative frequency of connections made between these three countries that occurred within the mining and metals business unit. Next, using the social network dataset, I tracked all of the interviewees and connections that we had targeted in interviews, and was able to conduct a specific effort to code interviews within the mining and metals business unit, and between these various countries.

The end result was an understanding that of unique network patterns caused by geographically integrated training, mutual work tasks, and employee mobility within the mining and metals business unit.

Without having both qualitative and quantitative data, this type of in-depth analysis would not be possible. Furthermore, with a large and complex dataset, multiple, varied accounts of a phenomena can provide rich, nuanced views that lead to high quality conclusions.

LESSONS LEARNED

My tendency as an engineer was to desire a more linear, phase oriented approach to mixed methods research, although such an approach would have limited the robustness and richness of our analysis. Rather than the process oriented approach dictated in Figure F-1, I think that mixed methods study is more like making stew. As I went along we threw in more and more components, and then let them cook together over time and soak up the flavors of the other "ingredients." At first, our analysis and conclusions were fairly weak, because we had not gathered enough data to grasp the more complex phenomenon of knowledge sharing within multi-lateral CoPs. Once everything had cooked together for a while, the ideas that developed were a result of many different pieces of data that were gathered in different ways, and helped to compensate for the weaknesses of other areas.

If I had the opportunity to go back and change anything about the research design, I would have spent more time on the front end to understand the context of the CoPs that we chose to study. In every case, the richest ideas came from mixed qualitative and quantitative knowledge. When we began the study, I saw phase 1 as fully quantitative, and hence not subject to issues of context. Unfortunately, with very little guidance from the populations we sought to understand, I think that more than half of our survey data is not very useful. With 5 or 6 brief interviews at the beginning of each study, I could have established a much better connection with the individuals that we were studying, and designed a far better survey to meet both our needs and theirs. Unfortunately, I did not initiate these conversations with community members until the surveys were complete. Within each of the companies, we had a series of kickoff meetings, although I would prefer to have interviews from all levels.

Despite some of the shortcomings of the study, there were a number of things that we did very well. I put together a validation plan (see Appendix H) to triangulate between qualitative and quantitative data-sets, which led to a very robust research design. Specifically, we were able to validate connections from the survey through interviews, which greatly enhanced our construct validity. Furthermore, between the survey and interviews, we generated a fairly complete view of each CoP, which is a uniquely strong data set. Finally, I believe that during analysis, we did an excellent job of refining our methods, which were initially very exploratory. During this study, we have progressed from using relative frequencies to creating the boundary analysis program, and accompanied our findings with rich, contextual data from the interviews. Typically, mixed methods studies ask separate research questions, or progress in phases. This study however, has fully integrated both qualitative and quantitative analysis to generate rich conclusions and embrace the complexity of CoPs as a phenomenon.

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Appendix G - Evaluating the Usefulness of Knowledge Sharing Connections in Multinational Construction Companies[1]

ABSTRACT

Although knowledge is a vital resource for construction companies, most organizations do not take full advantage of their knowledge resources. In many cases, knowledge management is a game of extremes; either managers take a hands off approach and employees fail to initiate connections that would otherwise be useful, or they embrace a spirit of collaboration that saturates employees with relationships and information flows that are redundant, time intensive, and distracting. To better understand what drives effectiveness in knowledge sharing networks, this study examines the relationship between structural and relational factors and the perceived usefulness of knowledge sharing connections. Results indicate that there is no association between usefulness and communication frequency, media richness, or geographic and disciplinary boundary spanning. These results and their implications are discussed in depth.

KNOWLEDGE TRANSFER AND CONSTRUCTION ORGANIZATIONS

Understanding the value of knowledge sharing in any organization is a unique challenge. In construction organizations, most managers struggle to facilitate value adding knowledge transfer without overloading their workers and distracting them from the high intensity project tasks which are typical of the industry. Although each project represents a discreet opportunity to learn and grow for construction companies, we often find that the same problems repeatedly plague both projects and organizations. For example, past research has demonstrated lackluster performance in the construction industry's adherence to budget, schedule, and quality measures

[1] This work was submitted to the CRC 2014 conference, and should be cited as: Wanberg, J. and Javernick-Will, A. (2014). Evaluating the Usefulness of Knowledge Sharing Connections in Multinational Construction Companies. 2014 Construction Research Congress, Atlanta, GA, May 2014.

(Flyvbjerg et al. 2002) and stagnant productivity and safety statistics (Hallowell 2011). At the same time, knowledge sharing can reduce repeated mistakes, focus organizational resources on providing a quality product, and foster an innovative environment which will advance the construction industry (Javernick-Will and Levitt 2009).

Even though knowledge is one of the most important resources of a firm (Grant 1996), it is difficult to track or measure. This is because most knowledge is not written down, but exists in the "mental maps, beliefs, paradigms, and viewpoints" of an individual combined with their "concrete know how, crafts, and skills that apply to a specific context" (Alavi and Leidner 2001). When it is embedded within individuals, knowledge is referred to as "tacit" in nature (Nonaka 1994), and it is this characteristic that differentiates it from other resources in the firm (Liebeskind 1996). Because of this, there are unique challenges associated with mobilizing tacit knowledge because exchange occurs predominately in the context of individual relationships (Javernick-Will and Hartmann 2011), which makes it difficult to transfer, even within the boundaries of the organization (Szulanski 1996).

In multinational construction companies, managers are aware that learning from projects around the world can give them a competitive advantage if global expertise is transferred and applied to localized settings (Javernick-Will and Levitt 2009). Because most organizational knowledge is tacit in nature, the interpersonal networks made up of individual relationships are the only way that tacit knowledge can be transferred on a global level (March 1991). As a result, many multinational organizations create knowledge management programs to create knowledge sharing connections (KSC) to transfer this valuable tacit knowledge. However, while these KSC can provide employees with useful knowledge, they can also saturate employees with inapplicable information or unproductive, yet time intensive relationships. Thus, we must determine if there are consistent factors that contribute to the practical value of individual knowledge sharing connections (KSC).

USEFULNESS AND KNOWLEDGE SHARING

While there are a number of different ways to establish the practical value of a knowledge sharing connection, one of the most direct methods is to determine if those engaged in the relationship find it to be useful. Although it is difficult to theoretically claim that usefulness is an objective measure, it offers some distinct advantages. Usefulness transcends the content shared and relational dynamics to give a more holistic perception of a connection. Prior studies have discussed the importance or utility of certain types of knowledge content (Javernick-Will and Levitt 2009), and defined outcomes such as creativity (Sosa 2011) and individual performance (Cross and Cummings 2004). Other studies have examined individual and social motivations for sharing knowledge (Javernick-Will 2012; Quigley et al. 2007), with the hope that management can capitalize on these motivations to influence knowledge sharing activities. Furthermore, knowledge sharing connections can serve a variety of different roles, each of which provide different, but valuable knowledge content (Cross and Sproull 2004). Interestingly, however, few scholars have asked employees engaged in a KSC if their connection is useful. Usefulness can help differentiate between connections which add value, and those which overload employees with redundant or difficult relationships, leading to a deeper understanding of the characteristics of a connection that give it practical value.

This study investigates the perceived usefulness of KSCs from several different perspectives. Thus far, there are two strains of research which we have labeled “network structure” and “connection dynamics,” which explain why knowledge sharing connections are valuable. Both approaches are used in our analysis. First, we account for each employee’s position within the structure of the knowledge sharing network to analyze whether inter-disciplinary connections or those that link different geographies are perceived as more useful than those that do not. Next, we determine if the connection dynamics of frequency of interaction and method of communication used affect the efficacy of a relationship in transferring knowledge, and therefore the perceived usefulness of the connection.

NETWORK STRUCTURE

One potential source of value for a knowledge sharing connections is that they provide a bridge to knowledge resources that would otherwise be inaccessible. According to structural holes theory (Burt 1992), non-redundant connections to unique knowledge bases provide individuals with new perspectives and more up to date knowledge that they would not otherwise see in a localized context. Furthermore, these benefits put an individual in a position of power due to their network position as a gatekeeper of knowledge. Knowledge sharing networks act to distribute best practices and lessons learned throughout the network such that well connected employees benefit from the best possible knowledge that the organization has to offer.

Practically speaking, construction companies have geographically distributed employees engaged in multi-disciplinary work, which requires a high degree of coordination between different groups defined within these attributes. Geographic work location provides a convenient boundary condition characterized by different projects, different cultural patterns of thinking, and differing contextual knowledge. Connections that link individuals in different countries are well placed to take advantage of the best knowledge from varying geographic knowledge bases.

Similarly, the technical expertise of various disciplines varies widely, and inter-disciplinary knowledge sharing connections are well placed to access the knowledge unique to each discipline. Cummings (2004) studied multi-lateral work groups that were geographically distributed and multi-disciplinary. He found that the "structural diversity" of spanning multiple knowledge bases led to increased work group performance (Cummings 2004). Thus, structural holes theory would indicate that inter-geographical and inter-disciplinary connections would provide access to unique knowledge bases that would enhance the knowledge sharing potential of the network as a whole, and increase the individual usefulness of that particular connection.

CONNECTION DYNAMICS

Another potential source of value in knowledge sharing connections comes from relational characteristics such as frequency of interaction and method of exchange. Indeed we would expect that without the proper connection dynamics to accurately and easily transfer knowledge, a KSC would not be very useful. Granovetter (1973) drew attention to this idea in his seminal paper on the "strength of weak ties" in which he argued that the dynamics of individual ties have resounding effects on relational and network outcomes. Weak ties, which are characterized by lower time investment, lower emotional intensity, and lower degrees of intimacy, are ill suited for conveying complex tacit knowledge, and may fail to meet the needs of individuals who maintain them.

Although there has been widespread application of the term "strong tie," there is inconsistency in the metrics that define tie strength. Two of the most consistent metrics are the frequency of exchange, with higher frequencies indicating stronger ties (Granovetter 1973; Lin et al. 1978), and the method of exchange, where more social forms of communication are better able to convey complex knowledge (Cummings et al. 2002; Javernick-Will and Hartmann 2011). This assumption comes from media richness theory, which examines the strengths and shortcomings of various communication media in accurately transferring knowledge between people. A study examining the role of computer mediated communication on a number of important relational outcomes defines richer communication as that which properly communicates more subtle communicative cues such as facial expressions and body language (Dennis and Kinney 1998). Using media richness theory, further studies have empirically demonstrated that media richness has a positive impact on decision quality (Kahai and Cooper 2003). It follows that richer methods of communication would create an environment in which complex knowledge can be transferred between individuals, potentially leading to an increase in the perceived degree of usefulness.

POINT OF DEPARTURE

This paper seeks to unite these two strains of research through an empirical investigation into the usefulness of dyadic connections. If the theories above hold true, then connections to different knowledge bases will provide individuals with access to unique ideas, leading to more useful connections. Furthermore, strong ties characterized by increased frequency of exchange and more social methods of communication should be associated with more useful connections. Both lines of inquiry have deepened our knowledge regarding the effectiveness of knowledge sharing, though very few studies have examined both structural and connection level factors in the same analysis. Furthermore, most studies have attempted to quantify the benefits of knowledge sharing in terms of team level performance outcomes rather than individual perceptions. This gap in current research is concerning, as a fundamental outcome of a knowledge sharing connection is whether or not it is useful to the participating individuals. This study will unite these two strains of research into a single quantitative study that examines a potential relationship between the usefulness of knowledge sharing connections, network structure, and connection dynamics.

HYPOTHESIS DEVELOPMENT

To start, we will define usefulness as a connection that provides an individual with *"knowledge that they would otherwise not have figured out on their own."* This definition allows us to establish a degree of objectivity in our assessment because it filters out connections that may be considered useful simply because they are pleasant. From this definition, we develop a number of hypotheses related to the usefulness of a connection based on dyadic and network level variables.

To begin, we examine the relationship between the usefulness of a connection, and the frequency and method of communication. We would expect that with more frequent communication, connections have a higher probability of being useful. This is because a shortened feedback loop between the knowledge provider and knowledge recipient that results from frequent communication allows the personal instruction or "socialization" required to transfer tacit knowledge (Javernick-Will and Hartmann 2011). Furthermore, socialization requires rich methods of communication that give both the provider and recipient access to a social atmosphere. The methods of communication are therefore limited to face to face interactions and meetings, whether virtual or otherwise.

H1: Increased frequency of communication is associated with more useful connections

H2: Richer methods of communication are associated with more useful connections

The next two hypotheses address the structural research that elucidates the benefits of accessing differing knowledge bases. From previous research, scholars have examined the benefits of connecting with different geographic locations and disciplines (Cummings 2004). Similarly, organizational theory and network structures posit numerous benefits to connecting with others who interact with different networks (Burt 1992). Because of the natural silos that tend to occur due to geographic and disciplinary differences, this theory is especially relevant to construction companies. Our hypotheses therefore propose that connections to different disciplines and geographic locations will provide access to new knowledge, therefore producing connections with a higher degree of usefulness.

H3: Geographic boundary spanning is associated with more useful connections

H4: Disciplinary boundary spanning is associated with more useful connections

RESEARCH SETTING

We selected three communities of practice (CoPs) housed within two multinational construction and engineering organizations. CoPs have been adopted in the commercial environment as a mechanism for sharing knowledge, and have been defined as:

"a group of professionals informally bound to one another through exposure to a common class of problems, common pursuit of solutions, and thereby themselves embodying a store of knowledge" (Manville and Foote 1996 p. 80)

To this definition we add several qualifying observations regarding the communities that we have selected. First, within CoPs, employees have the ability to share knowledge between disciplines and geographic locations, as well as the freedom to choose their methods and frequency of communication. These CoPs often involve members who share knowledge because of workflows, but also capture interactions between employees that are not a result of workflows. Because of this, each community offers a diverse and complete view into the informal knowledge sharing that happens within a company to complete work.

As a strategy to increase the external validity of this study, we have used three CoPs within two multiple companies to determine if these effects span multiple CoP and organizational contexts. The three CoPs are profiled briefly below:

Process Improvement CoP: Housed within company A, this CoP consists of 273 individuals spread across 19 countries and 20 disciplines. The members of this CoP serve as internal consultants that provide process improvement expertise for projects. Members share knowledge through an online reporting system, but maintain strong interpersonal relationships as they are relocated to new assignments. Within this CoP, we studied 640 connections, of which 133 were considered useful.

Transportation CoP: Housed within company B, this CoP has 365 members across 10 countries and 16 disciplines. The members all participate in transportation related projects around the world. Members primarily share knowledge through an online forum and knowledge repository, which allows them to do a content-based search of documents and employee profiles. Within this CoP, we studied 352 connections, of which 131 were considered useful.

CAD CoP: Also housed within Company B, this CoP boasts 1152 members in 17 countries and 20 disciplines. Worldwide, the CoP members provide drawings, support, and management for all drafting related activities. Members share knowledge using the same online platform as the Transportation CoP, though there is also extensive sharing of documents such as CAD blocks and standards. Often, individuals post questions to a forum that are answered by others around the world. Within this CoP, we studied 1083 connections, of which 249 were considered useful.

METHOD

Each of the CoPs has membership lists that served as the defining parameters of the study population. We obtained this list, in addition to employee location data, from each organization's HR department. To collect the social knowledge sharing network, we used online survey methods. Using an online survey tool called NetworkGenie, we deployed social network surveys that asked participants three types of questions. The first type of question asked participants about individual preferences and demographic characteristics such as their educational discipline. The next asked each individual with whom they had shared knowledge with in the past six months, allowing them to search the membership list for other employees. The last asked questions of each identified connection to determine the perceived usefulness, frequency of interaction, and method of communication.

Respondents evaluated the usefulness of each of their connections based upon four outcomes: (1) the connection provides the reporting party with knowledge that they would otherwise not have figured out on their own; (2) the connection provided the recipient with knowledge that saved them time, but they could have figured out on their own; (3) the connection provided the recipient with knowledge that was basic or somewhat incorrect or (4) the connection provided information that was incorrect or made the issue worse. Rather than use a likert scale, these four categories help specify the outcome of a connection in terms of value added to the company. Respondents also provided information on the frequency of interaction, which used a simple ordinal scale. Options included: (1) at least once per day, (2) several times per week, (3) at least once per week, (4) at least once per month, and (5) every six months. Lastly, the media richness variable was derived after asking respondents to identify the two forms of communication used most frequently to share knowledge. These included reports, meetings, intranet, email, personal discussion, and instant messaging. We divided these choices into three categories according to the media richness hierarchy presented by Daft (1987). The categories were (1) face-to-face (virtual or personal, but allows individuals to read facial cues), (2) written and addressed documents, and (3) unaddressed documents.

Using the social network analysis software NetMiner, we created a list of all identified connections within each community, and then assigned dummy variables to geographic and disciplinary boundaries. When a connection spanned a geographical or disciplinary boundary, it was assigned a value of '1', and when a connection did not span a geographical or disciplinary boundary, a value of '0' was assigned.

Due to the categorical nature of our variables, we dichotomized the usefulness variable and conducted a logistic regression. Unlike conventional linear regression, the coefficients in a logistic regression report the change in the log of the odds ratio relative to a unit of change in the independent variables. Because our independent variables are also categorical, our regression evaluates the log of a change in probability of attaining the outcome (usefulness) if a connection has reported a given frequency/media richness, or if boundary spanning is present relative to a base case. Further interpretation follows in the results section.

RESULTS

We present the regression results for all three communities in a single table. Due to space limitations, we only include odds ratios, standard errors, and p values. As an aid to interpretation, frequency of communication decreases as the response number increases, and the richness of communication decreases as the richness score increases. For both of these variables, the first response is omitted from Table 1 as it serves as a base case. The odds ratios can therefore be interpreted as the change in the log probability of a connection being useful relative to the base response of 1. Both geographic and disciplinary boundary spanning were analyzed as dummy variables, so the odds ratios are not presented in categorical form. As a final note, there was a lack of data for the middle category (2) of media richness for the Transportation CoP, so these values were omitted from Table 1.

Table G-1 –Regression Results

	Process Imp. (n=365)			CAD (n=471)			Trans (n=145)		
Usefulness	Odds Ratio	Std. Err.	p-value	Odds Ratio	Std. Err.	p-value	Odds Ratio	Std. Err.	p-value
Frequency									
2	0.656	0.373	0.459	1.091	0.532	0.858	2.753	3.411	0.414
3	0.375	0.233	0.115	2.377	1.061	0.052	2.641	3.276	0.434
4	0.689	0.38	0.510	2.406	1.039	0.042**	3.371	4.094	0.413
5	0.897	0.495	0.845	3.668	1.658	0.004**	2.651	3.155	0.413
Media Richness									
2	1.107	0.842	0.894	0.653	0.604	0.645	na	na	na
3	1.35	0.964	0.674	1.216	1.080	0.826	0.861	0.359	0.720
Geo.BS	1.183	0.3	0.508	0.927	0.221	0.751	2.083	1.063	0.149
Disc. BS	0.823	0.212	0.453	0.943	0.208	0.791	0.866	0.305	0.149
Constant	0.659	0.594	0.644	0.197	0.195	0.102	0.399	0.482	0.447

*** significant at α = 0.05*

Beginning with hypothesis 1 and 2, which address the dyadic level variables of frequency and media richness, we do not find support in the Process Improvement or Transportation CoPs that increased frequency of communication or richer forms of communication lead to more useful connections. The odds ratios are all positive and non significant, indicating the lack of a cohesive trend. However, the CAD CoP displays odds ratios that are positive and highly significant for responses 4 (once per month) and 5 (once every six months. This indicates that there is an increase in the log probability that a connection is useful if there is less frequent interaction. With this evidence, we do not accept hypothesis 1 and 2.

In regards to structural factors, geographic and disciplinary boundary spanning variables also yielded odds ratios which were positive and non-significant in each CoP. This shows that knowledge sharing connections which span geographic or disciplinary boundaries do not significantly increase the probability that a knowledge sharing connection is perceived as useful. On this basis we similarly do not accept hypothesis 3 and 4.

DISCUSSION & LIMITATIONS

Although there has been extensive discussion regarding the efficacy of knowledge sharing within communities of practice, there is a dearth of scholarship that empirically ties outcomes to both relational and structural factors. Interestingly enough, we did not find support for any of our hypothesis, which suggests that the usefulness of a knowledge sharing connection may not be explicitly tied to a certain set of characteristics such as frequency, method of communication, or boundary spanning.

To begin, hypothesis 1 and 2 speculated that more frequent interaction through richer communication media would lead to more useful knowledge sharing connections. Our results led us to reject hypothesis 1 and 2. Interestingly enough, we discovered evidence that less frequent interaction can potentially lead to more useful connections, as the odds ratio for the less frequent interaction rates of (4) once per month and (5) once every six months, was both positive and significant. The literal interpretation is that the likelihood that a connection is useful increases when the frequency of interaction changes from more than once per month to less than once per month. At first, this is a puzzling finding, however Granovetter (1973) argued that weak ties can be the ones which provide the greatest benefit to the individual who holds them. Granovetter spoke specifically about the willingness of weak ties to endorse one another, although it may have a more subtle application to knowledge sharing. In our case, we may be observing latent knowledge sharing connections which are in a state of dormancy until one of the parties requires something. Our expectation is that this would lead to infrequent, needs-based knowledge sharing interactions. These latent ties may provide participants with highly useful relationships at a relatively low cost in terms of time and effort. This would also explain why less frequent ties may be seen as more useful than a more time intensive relationship that does not provide meaningful knowledge with every interaction.

Even more surprising is the lack of association between media richness and the usefulness of a knowledge sharing connection. With the advent of so many IT platforms that facilitate virtual communication, many managers are concerned that virtual interactions are not able to provide the same quality of interaction and produce an individualistic culture that severely limits collaborative knowledge sharing. Our results do not indicate that this concern is validated, but rather show that there is no association between more social modes of communication and the perceived usefulness of the connection.

Furthermore, our results did not show that inter-disciplinary connections or connections spanning geographic boundaries were perceived as more useful. There are a number of reasons why this may be so, but the most plausible is that there is simply less need to seek knowledge from someone with a different disciplinary background or contextual experience. In construction organizations, most employees are focused on discipline specific tasks and projects which occur within a fixed region. We can reasonably expect the size of most multinational construction organizations makes it so that, most employees can find the knowledge that they need without leaving their region. It is important to realize however, that there are still theoretical performance benefits to sharing knowledge across disciplinary and geographic boundaries. Just because it is not perceived as useful by individuals does not mean that it is not aligned with the strategic goals of the company. This reveals an important rift between the perceptions of individuals and the direction of the firm that is rooted in bounded rationality. Even if individuals desire to tap in to the global expertise of the company, they cannot know what everyone else knows. They are therefore limited in their ability to know where to go within the company for knowledge resources, access global knowledge, and perceive its benefits.

One theory which has been researched more extensively is the power of interpersonal relationships to either encourage or impede knowledge sharing. Prior work has theorized that knowledge is difficult to transfer within organizations due to the "arduousness of the relationship" (Szulanski 1996), and many other works have examined the importance of trust in knowledge transfer (Abrams et al. 2003; Handy 1995; Szulanski et al. 2004). If someone is not trusted, knowledge sharing is less likely to be effective and useful regardless of the frequency of communication, method of exchange, or advantageous connection to different knowledge bases. On the other hand, with a fully trusting relationship, it is still possible that one party or the other lacks the knowledge required to make an exchange useful. Future work would do well to consider the relational dynamics, knowledge content, and the connection dynamics together to determine what makes a connection useful.

Although it is not within the scope of this study, the authors are also conducting interviews with select members of each of the three CoPs. During these interviews, participants are asked about specific connections that they have within the network, the types of knowledge that they share, and what makes particular connections useful. Most commonly, respondents indicate that they have an existing relationship, and that the person has the expertise they need and is willing to take the time to share it. On the other hand, non-useful connections occur when the respondent indicates that their connection does not have the expertise to provide them with what they really need.

With this study, there are several limitations which must be considered. To begin, our unit of analysis is the individual connection. While we use structural holes theory as a basis to claim the benefits of inter-geographic and inter-disciplinary knowledge sharing, we have not accounted for the lack of redundancy which creates a power differential between individuals with many structural holes in their networks, and those without such holes. Next, because we dichotomized our usefulness variable, we lost resolution that could lead to a more continuous measure of the value of individual connections. Future research would do well to determine a more continuous scale upon which to measure the outcome of a knowledge sharing connection.

CONCLUSION

Despite the limitations of this study, we have taken a tangible step forward into evaluating the efficacy of knowledge sharing at an individual level. By combining relational and structural measures, we have opened the door for future research to incorporate the theorized benefits of social network analysis into more conventional empirical investigations. This study explored the potential relationship between the usefulness of a knowledge sharing connection and the frequency of interaction, method of communication, geographic boundary spanning, and disciplinary boundary spanning. Our results indicated that none of these four factors can significantly predict whether or not a knowledge sharing connection is perceived as being useful by the participants. These findings open the door to future research that further investigates factors which contribute to the practical value of knowledge sharing connections.

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Appendix H – Validity Plan

Throughout this study, we have worked to ensure that the conclusions drawn have internal, external, and construct validity. This section outlines particular threats to the validity of this study, and how we have worked to address each one. When applicable, we have included a "result" that outlines a tangible check on validity that is not merely process oriented, but required some secondary analysis or comparison.

INTERNAL VALIDITY

Internal validity refers to the degree to which our conclusions are warranted given the evidence presented within the study. The primary threat to internal validity is systematic error due to our research design. Currently, there are several threats to internal validity which must be addressed. This section outlines each one, and operationalizes the actions which have taken, and the criteria by which I have established internal validity.

Self Selection Bias

Threat: Individuals who took the survey could be qualitatively different from those who did not. This could occur due to observable demographic categories, or could be due to more subtle attitude differences.

Actions to take: Each CoP will be split in to survey takers and non-survey takers. When the data is available, groups will be compared to ensure proportional representation along geographies and business units. These two categories were selected because data are typically provided for 100% of community members through HR departments, and both are relevant for our analysis.

Criteria for validity: Because we have data for our entire populations, proportions tests do not yield theoretically valuable outputs. For this reason, a qualitative comparison to ensure representation from the largest groups is sufficient. We did this through an examination of the proportions of survey takers and non-survey takers, and then discussed with CoP leaders whether the samples were representative.

RESULT: For each CoP, the compared proportions of survey takers and non-survey takers are acceptably similar. The results appear in tables below. Note that there is not GBU data for the Transportation CoP, but also that this CoP was excluded from Chapter 2 on this basis.

CAD CoP:

Table H-1- CAD CoP by Country

	Yes (n=387)	***No (n=765)***
Australia	17%	20%
Canada	19%	14%
China	3%	2%
Hong Kong	1%	1%
Ireland	1%	2%
New Zealand	4%	2%
Qatar	4%	5%
UAE	8%	12%
UK	12%	16%
USA	28%	25%

Table H-2 - CAD by Business Unit

	Yes (n=387)	***No (n=765)***
Building Engineering	15%	17%
Corporate	1%	1%
Energy	2%	3%
Environment	3%	4%
Minerals and Industry	4%	3%
Multiple	5%	6%
PDD	17%	16%
Transportation	35%	32%
Water	19%	18%

Transportation CoP

Table H-3 - Transportation CoP by Country

	Yes (n=131)	***No (n=234)***
Australia	10%	10%
Canada	17%	14%
New Zealand	5%	1%
Qatar	1%	2%

UAE	2%	2%
UK	3%	3%
USA	61%	68%

Process Improvement CoP

Table H-4 - Process Improvement CoP by Country

	Yes (n=119)	*No (n=149)*
Angola	1%	1%
Australia	9%	8%
Canada	4%	5%
Chile	6%	6%
England	9%	10%
India	1%	1%
Oman	1%	1%
Peru	1%	1%
Qatar	2%	3%
Saudi Arabia	2%	1%
UAE	3%	3%
USA	61%	60%

Table H-5 - Process Improvement CoP by Business Unit

	Yes (n=119)	*No (n=153)*
BSII	29%	29%
Civil	16%	14%
Corporate Services	1%	3%
M&M	15%	8%
OG&C	13%	20%
Power	25%	25%

Original Hypothesis

Threat: When this research was initiated, there were original intuitions and beliefs about the outcomes.

The conclusions that we are currently drawing should be based on prior intuition, otherwise they may just reflect our current attitudes and biases now that we have been involved in the study over time.

Actions to take: There are 7 original hypotheses from a working meeting in mid 2012 which apply to the work we are currently doing. Each hypothesis should be evaluated on the basis of our quantitative data to determine its explanatory power. This should be used as input for future explanatory models based on qualitative data.

*Criteria for validity***:** If our hypotheses are correct, they need to be considered in future explanatory models. If our models do not align with these hypotheses, they will not be valid. If, however the original hypothesis are not accepted, future explanatory models should consider them to be an alternative explanation that has been ruled out.

RESULT: Of the 6 hypothesis relevant to this work, only 2 were completely aligned with our results. Each hypothesis, where it appears in this work, as well as its alignment with our results are outlined below.

1. ***Intra-disciplinary* KSC are more frequent than inter-disciplinary KSC in a global CoP**

    Results in Chapter 2 were inconsistent. Thus, our original model that assumed discipline as a stable boundary that always limits connection is incorrect, and is considered an alternative explanation that is ruled out. Our current theories do not consider disciplinary homophily as a consistent driver of network patterns, and introduced contextual and management forces as a more likely explanation.

2. ***Intra-group/business practice* KSC are more frequent than inter-group/business practice KSC in a global CoP**

    Results in Chapter 2 were also inconsistent for business practice. Once again, we modified our explanatory models and considered intrinsic characteristics of business units as an alternative explanation that has been ruled out. Current theory sees contextual and management forces as a more likely explanation.

3. ***Intra-cultural* KSC are more frequent than inter-cultural KSC in a global CoP**

   Results from Chapter 3 confirmed this hypothesis, but showed that these forces can be overcome through expatriate workers. This is consistent with work presented by (Haas 2006)*, and was validated by both qualitative and quantitative data from this dissertation.*

4. ***Intra-country* KSC are more frequent than inter-country KSC in a global CoP**

   Results from Chapter 3 showed that almost every country displayed higher levels of intra country KSC than inter-country KSC. This is consistent with prior work (Javernick-Will 2011b; Kleinbaum et al. 2013)*.*

5. **Inter-attribute KSC are more useful than intra-attribute KSC [weak ties argument]**

   The conference paper presented in Appendix G does not support this hypothesis. Thus, the assumption that inter-attribute KSC are intrinsically more useful is considered an alternative explanation that is ruled out.

6. **Less frequent knowledge exchange within a KSC is more useful than more frequent knowledge exchange (noise)**

   The conference paper presented in Appendix G supports this hypothesis.

Explanatory Models

Threat: We can dream up explanations for what we are seeing that are completely incorrect, and only exist as a figment of our imagination.

Actions to take: To ensure internal validity of our explanatory models, we need to follow a rationalistic process which provides a roadmap for repeatability. This process follows the steps to explanation building presented in Yin (2008). We will work to develop two models, presented in their current form below as research questions and key statements:

Model 1:

Question 1: How do knowledge sharing connections form in multinational CoPs?

> *Key Statement 1-1: Knowledge sharing connections form via five mechanisms: organizational control, organizational opportunity, social networks, non-person based searching, and serendipity*

Model 2:

Question 2: What is the role of CoPs in coordinating knowledge within the firm?

> *Key statement 2-1: Knowledge sharing connections can be classified into four categories: overlapping, complimentary, growth, and non-overlapping connections. Each one is determined by the degree of overlap between participants' knowledge bases.*
>
> *Key statement 2-2: CoPs partially address the bounded rationality of managers by allowing members to choose with whom they connect.*

Criteria for validity: To ensure the validity of these models, we will follow the process outlined by Yin (2008) for explanatory model building, while keeping a research journal that details each part of the process. We began by constructing the initial explanatory models using the data from the Supplier Quality and Expediting pilot study. From there, we compared these findings to the Process Improvement CoP, the CAD CoP, and the Transportation CoP. This constitutes a total of three iterations for building our explanatory models. During the comparison between cases, we will entertain rival explanations through a "devil's advocate" type discussion with committee members, and we will ask community leaders for rival explanations during our monthly updates. Our models are valid if they apply across all three cases, and if we are unable to describe the three cases with viable rival explanations.

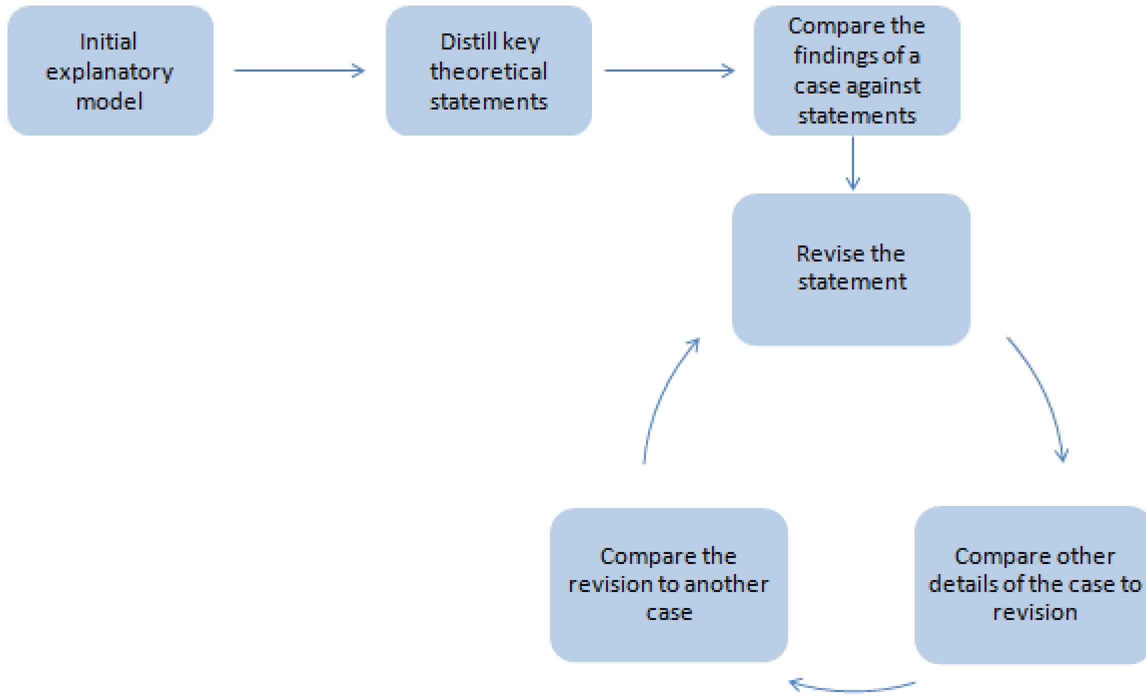

Figure H-1- Process of building explanatory models

RESULT: *We followed the process above, which increases the internal validity of our model findings.*

Response Rates

Threat: Social network studies usually demand close to 100% response rates to be considered valid. We have obtained 30-40% response rates to our online based social network surveys. If these response rates are not sufficient to demonstrate phenomena within the CoP, the conclusions we draw from our quantitative data may not reflect the true population of the CoP.

Actions to take: Establish and justify criteria, match to analysis methods.

Criteria for validity: These criteria come from network theory and statistics.

1. Networks need near or close to 1 connection per person (on average). It is at this point that there become enough connections to link everyone in to a giant connected component. If we cannot reasonably assume from the collected data that individuals are connected to the network, then the grouping as a CoP is essentially a phantom population. Even though they are

grouped together, they cannot be considered a cohesive community. Thus the first criterion is that survey respondents indicate an average of at least 1 connection/person.

2. Statistically speaking, there are a number of network measures that are traditionally used in studies as comparative statistics. Among these are density, centrality, and betweeness scores for the entire community. These are not valid with less than a 100% response rate, and thus are not used in this study. Given our lower response rates, we chose analysis methods that were not dependent on response rates. Using statistical re-sampling, our conclusions are just as valid for part of the network as they are for the whole network, assuming there is no self selection bias in respondents and non-respondents.

EXTERNAL VALIDITY

External validity refers to the degree to which our conclusions can reasonably apply to different contexts in which the same phenomena occur. The primary threat to external validity is a study site that is not reflective of a larger population. It is therefore essential to understand how our study is designed to represent a broader context than the individual communities which were studied.

CoP Selection

Threat: Because we require a high degree of company participation in our research, and CoPs can be very heterogeneous, it is not possible to randomly sample from all multinational CoPs housed within construction and engineering organizations. Without a careful definition of the contexts in which we expect our conclusions to apply, our study will not be generalizable to other contexts.

Actions to take: Based on the original CoP selection, provide theoretical and practical rationale for where this work will apply (see below).

Criteria for validity: For those who read this dissertation work, it is externally valid only if:

1. Members are engaged in knowledge intensive work

2. The group is an explicitly identified knowledge sharing community in which participation is voluntary
3. The community has a readily identifiable formal membership
4. Community members are distributed geographically and organizationally to at least 3 countries and 3 different organizational affiliations (either business unit, grade level, or function)
5. The size of the community is greater than 90 people (upper edge of banding concept in at least 3 locations (Chinowsky et al. 2009))
6. On average, each community member is connected to at least 1 other community member
7. The community is supplementary to the existing organizational structure; that is, members function within the same geographic locations and organizational divisions as those who do not belong to the CoP. Members are therefore subject to the greater organizational structure, not outside of it due to their membership.

RESULT: These criteria were included in the conclusion as a limitation of the study.

Study Scope

Threat: At some point, the scope of the study can become so small that our findings would only apply to a very narrow range of situations. If we were only to look at one community, we cannot be sure that our findings apply to anything outside of that one community.

Actions to take: Justify the external validity of our study given our site selection of 3 CoPs within 2 multinational companies.

Criteria for validity: Given the criteria of evaluation provided in the "CoP Selection" section above, there can still be contextual variation in two ways. One is due to community level contextual differences, which would occur between CoPs within the same company. The second contextual variation is due to the community association with a particular company, such that differences would occur between CoPs that are housed in different companies. Due to the high cost of gathering social network data, we attempted to minimize the data collection cost of this study while capturing both types of variation. To do so, we selected three communities in two different companies. Using this scope, we have two cross-company comparisons which we can make, and one within company comparison. Findings which use data from all three communities are therefore robust to community level and company level contextual differences, and have a high level of external validity.

Interviewee Selection

Threat: We have selected 5-10% of each CoP to participate in 30-40 minute semi-structured interviews. If our selection is not balanced, we may not be receiving opinions that are reflective of the CoP as a whole.

*Actions to take***:** Select interviewees based on individual demographics, network roles, and connection diversity. Track these selections to verify that they represent potential differences of opinion in the population.

*Criteria for validity***:** Although we cannot explicitly observe and track differences in opinion within each CoP, we can ensure that each major geographic location and demographic group is represented. During the interview selection process, we will compare the demographic relative frequencies of our selected interviewees to the entire CoP population. Each geographic, business unit, generational, functional, and grade level group which represents a significant (equivalent to 1 interviewee out of the number of potential interviewees) proportion of the CoP population will be represented. Furthermore, we will explicitly select balanced numbers of individuals with core and periphery network positions relative to other actors in the CoP. Finally, we will ensure our interviewees collectively participate in connections which span each different potential demographic boundary. This study will be considered externally valid if we can demonstrate that our interviewee selection included individuals and connections from each of these major classifications.

CONSTRUCT VALIDITY

The study has achieved construct validity when we can demonstrate that what we have measured reflects the concepts we discuss. Because much of our analysis and process models are predicated on assumptions that we can accurately measure the network structure of a given community, the primary threat to construct validity is our measurement of community membership, connections between members, and knowledge sharing within those connections.

Establishing Community Membership and Identity

Threat: During the formulation of our research design, we assumed a definition of our communities of practice that was based upon formal membership lists. If however, these lists actually reflect a formal classification of employees, and members do not understand themselves as belonging to a larger community, then we have no basis for claiming that these are communities of practice.

Actions to take: Use multiple sources of data, to supplement and verify original lists.

Criteria for validity: Community membership is evaluated in two ways. The first is inclusion on the membership list, and the second is by asking 5-10% of community members to identify where they fit within the community in terms of their individual area of expertise. Membership is validated if interviewees confirm that they belong to the community.

RESULT: *100% of interviewees confirmed their membership to the CoP.*

Existence of a Connection

Threat: An integral element of the research is quantitatively graphing the knowledge sharing connections within each CoP. Connections are self reported, and are therefore subject to a degree of individual opinion. If there is a high instance of one sided reporting, so that two people report differently on the same connection, it would be difficult to claim that we are actually measuring knowledge sharing connections.

Actions to take: Use multiple measures to verify 10-15% of the connections in the network through interviews. Although it would be more ideal to have each connection confirmed through two way reporting, response rates do not allow us to do this. Furthermore, individuals can forget to make selections, which is realistic given the number of potential alters presented on the survey. For each interviewee, we will ask about three connections that they supposedly have within the community. Some interviewees (10%) will not have taken the survey, but will still be asked about connections that others have reported.

Criteria for validity: Connections are valid if the interviewees confirm that the connection exists, and are able to recount relevant details of that connection. If fewer than 90% of connections are validated, there will be reason to question the dataset.

RESULT

Of the connections asked about during interviews, 92.2% were validated as knowledge sharing connections. Of the 7.8% that were not confirmed 1.5% indicated that they were aware of the other person, but did not consider their interactions to be knowledge exchange. We consider the survey construct of a "knowledge sharing connection" to be validated.

Knowledge Flows

Threat: In Chapters 2 and 3, we draw comparisons between connections that cross disciplinary and geographic boundaries respectively, and make claims about network capacity using quantitative numbers of connections. In many cases, we see that there are far more intra-boundary connections than intra-boundary connections. One alternative explanation for this phenomenon is that this occurs because inter-boundary connections are more useful, and hence fewer of them are needed. When we make claims about network capacity however, it requires the assumption that inter and intra-boundary connections are qualitatively similar.

Actions to take: Appendix G presents a conference paper in which inter-boundary and intra-boundary connections are quantitatively compared to examine if one group was more useful.

Criteria for validity: Inter-boundary knowledge sharing connections and intra-boundary knowledge sharing connections have the same perceived usefulness.

RESULT: *As it appears in Appendix G, there is no statistical difference in usefulness between inter and intra-disciplinary or geographic connections. This validates the assumption in Chapters 2 and 3 that the number of connections is a reasonable proxy for network capacity.*

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