# CIFE CENTER FOR INTEGRATED FACILITY ENGINEERING

# Modeling Systemic Innovation in Design and Construction Networks

By

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*Bridging the Innovation Gap in Project-based Industries*
*2004-2005 CIFE Seed Project 2nd Year Report*

# "Modeling Systemic Innovation in Design and Construction Networks"

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## SUMMARY OF RESEARCH WORK COMPLETED

The AEC (architecture, engineering and construction) industry is the largest industry in the world and is often described as a laggard industry in adopting new products and processes. Research on this topic has almost exclusively focused on the behavior of firms. This second year CIFE Seed Grant project report presents the research completed to date on the mechanisms that impact the diffusion and implementation of systemic innovations in design and construction networks. Our research focuses primarily on product and process innovations of a systemic nature (i.e., those that require multiple specialist firms to change their process in a coordinated fashion) though we also investigated localized innovations (i.e., those that imply change only within a specific specialty type). Systemic innovations researched include integrated supply chain management, the prefabrication of building systems, and the evolution to 3D CAD virtual design and construction tools. By gaining insight into the mechanisms that impact the diffusion and implementation of systemic innovations in the AEC industry, we can hope to bridge the innovation gap. In doing so we can begin to capture the productivity gains that manufacturing industries earned in adopting systemic innovations.

*During the course of the first two years of this seed project, we have:*

- Completed a comprehensive review of the AEC innovation literature, the project-based industry innovation literature, and the literature on interorganizational networks. We identified a significant gap in existing theory to explain the diffusion and implementation of innovations in interorganizational networks and the project-based industries which they populate.
- Collected case histories of innovations from an international sample of contractors, architects, engineers, facility owners, and technology vendors. In the first year of the

research we collected data from a small pool of home building organizations implementing a supply chain innovation and a prefabricated wall system innovation. However, in the second year of the study we focused our data collection on innovations in object-based 3D CAD. We expanded our data collection effort to investigate 82 firms.

- Established a point of departure framework and conceptual model for understanding the innovation gap phenomenon. We then tested those findings in a much larger international sample of firms in the second year. We extended our theoretical constructs and developed a model for systemic innovation in interorganizational networks.
- Opened an international, intercollegiate dialogue on the ideas contained in the research with Professor Ikujiro Nonaka (Hitotsubashi Business School), Professor Peter Morris (University College London), Professor Antti Ainamo and Risto Tainio (Helsinki School of Economics), and Professor Karlos Artto (Helsinki University of Technology).
- Published our findings at numerous conferences; including, the ASCE Specialty Conference on Leadership and Management (Levitt et al. 2004), the Project Management Institute International Research Conference (Taylor and Levitt 2004a), the NordNet International Conference on Project Management (Taylor and Levitt 2004b), the Hawaii International Conference on Systems Science (Taylor and Levitt 2005a), the Academy of Management Annual Conference (Taylor and Levitt 2005b). A paper based on this research has also been accepted for presentation at the Organization Science Winter Conference to take place in 2006 (Taylor and Levitt 2006).
- Published the findings from the first year as a chapter in a book on innovations in project management edited by Dennis Slevin, David Cleland, and Jeffrey Pinto and published by the Project Management Institute (Taylor and Levitt 2004c). We also submitted a journal article entitled "Aligning Innovations and Networks: Toward a Theory of Innovation in Interorganizational Networks" to a leading management journal.
- Submitted proposals for funding which were accepted by CIFE members Tekes, VTT and Autodesk, by the CIFE Seed Grant program itself for a new project that extends from the findings in this second year project (project entitled, “Organizing to Exploit Integrated Information Technologies”), and a Stanford Lieberman Graduate Research Fellowship.

- John Taylor successfully defended his dissertation in June 2005 based on the work conducted in the first two years of this CIFE Seed Research Grant.

## 1. INTRODUCTION TO BRIDGING THE INNOVATION GAP RESEARCH PROJECT

Project-based industries are among the largest industries in the global economy and the construction industry is the largest among these. Innovation research to date, however, has largely focused on traditional, hierarchical industries. When project-based industries are included in innovation studies, the analyses rarely explore the implications of organizational and industry structure on diffusion. A review of the literature on innovation in the project-based construction, motion picture, pharmaceutical, biotechnology, and healthcare industries suggests that organizing around projects creates difficulties for innovation. The extra effort required to diffuse some innovations leads to an innovation gap for project-based industries. We explored these issues through cases of component prefabrication, supply chain integration, and the evolution to virtual design and construction.

In the first year report for the “Bridging the Innovation Gap” CIFE Seed Grant Project we discussed the findings from the component prefabrication and supply chain integration innovations (Taylor and Levitt 2004d). In this second year project report we will focus on the findings from an international investigation of 82 firms implementing object-based 3D CAD innovations. We begin by describing the background academic work that provides a point of departure for this research. In previous reports we gave detailed descriptions for previous research on innovation in project-based industries and, in particular, the building industry. For this second year project update we will focus the literature review on the interorganizational networks which populate project-based industries. We then present the findings from our investigation of innovations in 3D CAD diffusing through and being implemented by design and construction networks in the United States and Finland. Based on constructs identified in the case, we develop a grounded theoretical model for systemic innovation in interorganizational networks.

## 2. INNOVATION AND INTERORGANIZATIONAL NETWORKS

Few would dispute the linkage between innovation and a firm's ability to maintain competitive advantage over time. Innovation has been shown to be critical to the renewal of industries (Schumpeter 1942) and to be a central mechanism by which firms secure a place in the competitive future (Van de Ven 1986). Surviving the waves of "creative destruction" theorized by Schumpeter (1942) and developing inimitable resource endowments (Amit and Schoemaker 1993) requires firms to move beyond re-investment in existing technologies to the implementation of new, innovative alternatives. Research on how firms implement new innovations has received considerable attention in the literature (Abernathy and Utterback 1978, Afuah 2001, Barley 1986, Henderson and Clark 1990, Mansfield 1968, Tushman and Anderson 1986). However, research on the implementation of innovations has predominantly focused on firms (Afuah 2001). Researchers have called for more innovation studies focused on the interorganizational networks which populate project-based industries (Gann and Salter 2000).

Over the last two decades a burgeoning stream of literature has emerged on the topic of interorganizational networks (Borgatti and Foster 2003). In interorganizational networks, groups of two or more firms work together in the interdependent production of goods or services (Powell 1990). In the past, adoption of the multidivisional form of organization was shown to lead to competitive advantage (Chandler 1962). Notwithstanding difficulties in collecting data on across-firm performance, researchers describe networks of firms as achieving different levels of competitive advantage when competing with other interorganizational networks (Dyer and Ouchi 1993). If interorganizational networks are to achieve and maintain competitive advantage, then they must understand how to implement innovations within their network.

Researchers find that the introduction of innovations in networks can positively impact competitive advantage in networks (Cash and Konsyniski 1985) while reducing the competitive advantage of other interorganizational networks (Jacobides and Winter 2005). However, for all of its received importance to the renewal of industries and the competitive advantage of firms, there is scant attention in the literature on the implementation of innovations in interorganizational networks. Given the growth in the use of interorganizational networks both within (Barley et al. 1992) and across (Kanter 1991) industries, researchers must explore the implementation of innovations in interorganizational networks. We need to develop new theories if innovation research is to remain relevant to firms in these proliferating networks.

### 2.1. Interorganizational Networks

Building on Coase's (1937) and Williamson’s (1975) concepts of markets and hierarchies, Eccles (1981) identified *quasi-firms* in the Massachusetts construction industry. Unlike the market transactions described in the transaction cost framework, in *quasi-firms* “relations between the general contractor and his subcontractors are stable and continuous over fairly long periods of time and only infrequently established through competitive bidding" (Eccles 1981, pp. 339-340). Eccles postulated that the transactions in *quasi-firm* networks represented a new mode of exchange. He described *quasi-firms* as existing between hierarchy and market modes of exchange. Stinchcombe (1985) also contributed to this debate suggesting that, in construction, contracts acted as a proxy for hierarchy in this mid-range mode of economic exchange. Williamson (1985) later extended the transaction cost economics framework to include the concept of *hybrid* organizational arrangements. Arguments for *quasi-firm* and *hybrid* organizational arrangements were rooted principally in terms of economic exchanges containing aspects of both market and within-firm hierarchical exchanges.

Since the discovery of the quasi-firm interorganizational networks (Eccles 1981), researchers have argued both the economic (Eccles 1981, 1988; Stinchcombe 1985, Williamson 1985) and sociological (Granovetter 1992, Miles and Snow 1986, Powell, 1987, 1990, Uzzi 1997) foundations of the interorganizational network form of organization. A recent definition of interorganizational networks describes them as "any collection of actors ($N \geq 2$) that pursue repeated, enduring exchange relations with one another and, at the same time, lack legitimate organizational authority to arbitrate and resolve disputes that may arise during the exchange" (Podolny and Page 1998, p. 59). Economists explore the role of transaction costs to explicate the form of organization. However, researchers adopting a sociological perspective of interorganizational networks expand the scope of interorganizational research by exploring why firms would pursue repeated and enduring exchanges and how, in the absence of legitimate organizational authority, firms resolve disputes.

Powell (1990) argues that interorganizational networks are a new form of organization. He contends that a social interaction structure exists for interorganizational network exchanges. In networks, he argues, complementary strengths are the normative basis of exchange and norms of reciprocity govern dispute resolutions. Though arguments over the form of organization continue, recent investigations of interorganizational networks have predominantly focused on exploring the role interactions between firms in an interorganizational network to elaborate on the social interaction arguments by Powell and others (Miles and Snow 1986, Powell 1987, 1990).

Researchers explore the formation process of role interactions in networks to understand how firms choose other firms with which to interact (Beckman et al. 2004; Gulati and Gargiulo

1999) and what strategies (Luke et al. 1989) and motivations (Galaskiewicz 1985) underpin partner selection. The stability of those interactions over time has received attention from researchers seeking to understand the dynamics of affiliation (Powell et al. 2005), the antecedents for the dissolution of network interactions (Baker et al. 1998), and the returns to continued interaction experience (Gulati 1995). A large body of researchers has explored the impact of interaction experience in networks on the flow (Appleyard 1996), transfer (Mowery et al. 1996), and sharing (Faulkner and Anderson 1987) of knowledge across network role interactions.

Moving beyond understanding formation, durability, and learning in interorganizational networks, a number of researchers have explored the processes by which interactions between firms in networks are governed. Researchers ascribe the endurance of networks to historical context of interactions (Scott 1987) and to relational embeddedness (Granovetter 1992). These investigations are then used develop theories of interorganizational network governance (Larson 1992). Sociologically-driven theories explaining why firms "pursue repeated, enduring exchange relations" (Podolny and Page 1998, p. 59) and the processes by which firms in networks "resolve disputes that may arise" (Podolny and Page 1998, p. 59) contribute to a more complete understanding of the interorganizational network form of organization than economic theories alone. However, in focusing on the formation, durability, learning and governance of interorganizational network role interactions, they largely fail to explore how the role interactions in a network may impact the creation, adoption and implementation of innovations.

### 2.2. Innovation in Interorganizational Networks

It is striking given the scope and scale of research on interorganizational networks, that very few articles address the topic of innovation in interorganizational networks. Researchers have long hailed innovation as being central to the renewal of firms (Mansfield 1968) and industries (Schumpeter 1942). However, the question of how this form of organization impacts the innovation process remains to a large extent unexplored. The few interorganizational network researchers addressing innovation tend to focus on the innovativeness of a network of firms. In other words, researchers explore the production of novelty endogenously within networks as opposed to the adoption and implementation of innovations produced exogenously. Studies of the innovativeness of interorganizational networks have resulted in conflicting findings.

Powell and colleagues (1996) identified networks within the biotechnology industry as the loci for innovation. Their arguments were rooted in the fact that organizations do not contain all the knowledge that they need. Interorganizational networks provide access to relevant knowledge not available internally or externally for purchase. Therefore, organizing into interorganizational networks enables firms to share and exploit asymmetries in knowledge. Building and leveraging an inter-firm sharing of knowledge enabled firms in networks to build new capabilities and outperform firms that were not connected in networks. Ahuja (2000) confirmed the findings of Powell and his colleagues in the chemicals industry. He found that connectedness through direct and indirect ties into networks increased organizations' performance and, hence, he posited, their innovativeness.

In two later papers about learning in biotechnology and pharmaceutical networks, Powell and his colleagues (Powell 1998, Powell et al. 1999) caution about the difficulty of making learning portable in interorganizational networks. Zeller (2002) investigated the impact of developing research and development interorganizational networks in the Swiss pharmaceutical industry and observed a slow down in the innovativeness of the firms. In other industries, the impact on learning and innovativeness of adopting the interorganizational network form of organization has also been found to have negative effects. Lampel and Shamsie (2003) found an evolutionary stagnation in the ability for firms in the motion picture industry to innovate. Gann and Salter (2000) describe broken learning and feedback loops in construction industry networks that negatively impact their ability to innovate.

There is clearly some question as to whether interorganizational networks enable firms to become more innovative or whether they are a liability to innovativeness. Gulati (1998) suggests that it is exceedingly difficult to attribute the performance of an interorganizational network to any single factor. Perhaps the range in outcomes regarding the innovativeness of interorganizational networks lay in using performance as the indicator of innovativeness. A surprising finding in a paper by Powell and his colleagues (1999) may suggest a mediating factor. They indicate that "perhaps the most interesting finding is that there are decreasing returns to network experience" (p. 151). A more complete exploration of the question of innovativeness in interorganizational networks may lay in exploring the impact of the maturity of role interactions on performance. Lampel and Shamsie (2003) explore this question investigating longitudinal data on the evolution from hierarchy to interorganizational networks in the Hollywood motion picture industry. Their finding that "the dark side of new organizational forms in Hollywood is an evolutionary stagnation in the craft of making movies" (p. 2206) would seem to imply rather strongly that innovativeness is negatively correlated with the maturity of role interactions.

These findings are interesting and have clear implications for understanding and leveraging interorganizational networks as a form of organization. However, they do not address the adoption and implementation of an innovation developed outside of the network. Previous research finds that the introduction of a new technological innovation within an organization can restructure role interactions (Barley 1986, Dougherty 1992), alter work patterns (Barley and Kunda 2001, Orlikowski 1992, Orlikowski et al. 1995), and, in doing so, cause a restructuring of the technology (Orlikowski 1992, Orlikowski et al. 1995). If the implementation of a technology propagates far-reaching changes across an organization, its work, and the implemented technology, then surely the propagated changes will intensify as they attempt to cross organizational boundaries within networks. Some researchers argue that innovation studies must look beyond focal firms (Afuah 2001). Afuah (2001) identified disruptions across buyer-supplier relationships as a consequence of innovations in the reduced instruction set computing industry. Waves of change that propagate across organizational boundaries in interdependent interorganizational networks may require multiple iterations of mutual adjustment at the interfaces that bridge role interactions.

In this CIFE Seed Project we explore innovation in design and construction networks to fill the gap in understanding in this area. In the second year of this project we conduct a cross-national comparison of systemic innovation outcomes and implementation processes in design and construction networks in the United States and Finland. We use the findings to build a theory for systemic innovation in interorganizational networks.

## 3. CONSTRUCTION INDUSTRY NETWORKS INVESTIGATED

In most cases, the construction networks we researched consisted of an owner, an architect, an engineer, a general contractor, numerous subcontractors (e.g., plumbing, HVAC, electrical, framing), and fabricators. We define the network as the group of specialist firms contracted to work together on specific construction projects. We view projects as instances of work for the network. Examples of projects in the context of this paper include the design and construction of a building, the design and fabrication of a structural system for a building, or the design and construction of a home.

We introduced variation into the research design by focusing on networks in two distinct markets. Glaser and Strauss (1967) suggest that maximizing variances in research designs enables researchers to develop dense categories and identify fundamental uniformities. Because we lack a foundation of research and constructs at the intersection between innovation and interorganizational network research, we designed a cross-national investigation to capitalize on national variances in identifying the relevant constructs and dimensions. In the Hall and Soskice (2001) work on varieties of capitalism, Finland was identified as a coordinated market economy (e.g., particularistic, with long term relationships) and the United States as a liberal market economy (e.g., universalistic, arms-length relationships, and one-off contracting).

The "varieties of capitalism" approach is a relevant dimension upon which to introduce variance. The definition of liberal *vs.* coordinated market economies implies some variation in inter-firm relationships across countries. Consequently, we chose to concentrate the data collection efforts on construction industry networks in the United States and Finland on the basis that they provided "polar" contrasting cases (Pettigrew 1990). Networks selected for inclusion in the study were selected on the basis of their ability to support analytic generalization (Yin 1989), in other words, we selected specific networks that were in the process of implementing 3D CAD building information modeling tools.

## 4. DATA COLLECTION AND ANALYSIS

Researchers suggest that grounded theory building research include multiple case studies (Eisenhardt 1991) and multiple data collection methods (Eisenhardt 1989) in order to increase the validity of the constructs identified. In this paper we investigate innovations in object-based 3D CAD diffusing through construction networks in the United States and Europe. We employ multiple data collection methods; including, ethnographic interviews, direct observation, and review of primary and secondary documentation. By triangulating the findings across these different data collection methods we strengthen the validity of our findings (Eisenhardt 1989).

The data collection effort for this paper took place from spring 2004 through winter 2005. Three months were spent based in Finland collecting data in Europe from summer 2004 through autumn 2004. We conducted multiple interviews with employees from the three building information modeling application vendors included in the study and collected primary documentation from each. However, the bulk of our data was collected from the United States and

Finnish construction networks included in the study. We conducted over 200 hours of interviews in 82 discussions with owners, architects, engineers, general contractors, subcontractors and fabricators. Of the interview discussions, 31 were with construction network specialist firms in Finland and the remaining 51 were within the United States. In most cases we interviewed the individual in the organization most involved in managing the company's utilization of CAD products. This individual was typically referred to as the "CAD Manager" or the "CAD Director." In some instances we spoke to more senior managers. In all cases we focused the interview discussion on specific project experiences where transitions to building information modeling applications occurred.

In addition to interview discussions, direct observations were made within and across specialist firms to observe the changes in process associated with implementing 3D CAD building information modeling applications. We were invited to attend company meetings and project discussions, to visit project sites both under construction and recently completed, and to generally observe the interactions between specialists in the network relating to the implementation of 3D CAD. We took extensive notes during this process and took digital photographs for use in the data analysis. Interview discussions and observations were recorded in a numbered set of field research notebooks. Interview discussions were also recorded using a digital voice recorder.

Whenever possible, we requested hard copies of materials discussed during interviews and observations. Data collected included contract documents, process flow diagrams, construction schedules, building information models, bills of materials, project decision schedules, animations of building information models, and any other information that might lend insight into the internal and interorganizational practices of the network in adopting building information modeling applications. This primary documentation was attached to the field notebooks and often elucidated concepts that were not entirely clear when reviewing the notes from an interview or observation.

The research project also benefited from many informal discussions with informants who had an overall perspective of the use of CAD in both the United States and Finnish construction networks. We were able to attend a conference related to building information modeling applications in the United States and in Finland and were able to speak to many users. In the interactions with the informants and the conference users, we were able to review our findings and thereby further increase the validity of the constructs. Overall, we were able to manage the reliability of our findings by keeping an indexed, organized database of the field notebooks, audio interview files, photographs, and documents collected.

The data collected in this project were entered into a qualitative data analysis software package. Data from the interviews, observation, documentation, and photographs were coded and systematically analyzed for patterns. Memo notations were used to develop concepts and constructs. Constructs were grouped into propositions that could contribute to an explanation for market acceptance of innovations in interorganizational networks. Finally, a set of propositions was developed to provide the foundation for a grounded theoretical model for innovation in networks.

## 5. IMPLEMENTING 3D CAD IN CONSTRUCTION NETWORKS

A set of four constructs were identified which impact the implementation and diffusion of the 3D CAD systemic innovation in design and construction networks. These are described in the following sections:

### 5.1. Relational Stability

In Eccles' (1981) 25-year old study of the construction industry, he identified that construction firms operated in networks with long-term relationships and only contracted with one to two specialists of each type. These longer-term relationships were not based on choosing partners offering the lowest price. Interestingly, in this study, we found that Finnish construction networks currently contract very much along the lines described by Eccles, with firms engaging in tight partnership relationships with one to three firms for each specialist type in the network. In contrast, construction networks in the United States currently tend to adopt shorter-term relationships than those identified in Eccles' study. Interviewees in United States construction firm networks disclosed that they contract with five to six different firms for each specialist firm type. Many firms cited cost pressure as a rationale for adopting a more arms-length approach to contracting. In the 25 years since the Eccles' investigation of the quasi-firm, the construction network has evolved to shorter-term relationships with a larger set of partner firms in the United States.

We describe the degree of stability in network role relations as *relational stability*. Networks in the Finnish construction industry exhibited strong *relational stability* by choosing to work with only one to three firms for each specialist type. As predicted by the Hall and Soskice (2001) work on varieties of capitalism, members of networks in this coordinated economy tended to choose partners based on previous working relations. In contrast, construction networks in the United States exhibited weak *relational stability* due to the fact that members tended to choose from among five or six firms for each specialist type. Firms in the United States networks were more concerned with getting a low price than working with the same set of firms from project to project.

The *relational stability* construct relates to several other constructs explored in organizational research. For example, Stinchcombe (1968) described the process of having to socialize new members in a group as the rate of social reconstruction. Interorganizational network researchers describe the phenomenon where firms are socialized into networks as embeddedness (Granovetter 1985, Uzzi 1997). Though embeddedness is a multifaceted term, Granovetter describes it in terms of on-going patterns of relations in economic exchange. This is consistent with the Eccles (1981) conceptualization of the *quasi-firm* in construction.

Weak *relational stability* in networks created difficulties for firms implementing object-based 3D CAD innovations because learning from one project failed to carry forward to the next project when membership in the project networks shifted significantly from project to project. Learning occurred more slowly within firms because the weak *relational stability* limited the number of times they would be exposed to the innovation. However, much more insidious is the fact that inter-firm learning — the development of interorganizational routines — failed to accumulate as a result of the limited opportunities for specific specialist firm pairs to work together. Since each of these innovations required firm networks to shift the allocation of work and to resolve new kinds of interdependencies, the weak *relational stability* exacerbated problems associated with implementing the systemic innovation in the network and led to much slower diffusion than expected. In contrast, the strong *relational stability* in the Finnish networks mitigated the impact of shifting allocations of work associated with the systemic innovation.

**PROPOSITION 1a.** *The weaker the relational stability in an interorganizational network, the greater the difficulty to achieve network-level learning. This contributes to slower systemic innovation diffusion rates.*

**PROPOSITION 1b.** *The stronger the relational stability in an interorganizational network, the lesser the difficulty to achieve network level learning. This contributes to faster systemic innovation diffusion rates.*

### 5.2. Interests

A second contrasting construct between the Finnish and United States network implementation processes related to firm-level versus network-level *interests*. In the United States, firms in construction networks were focused on the *interests* of their own firm. In one illustrative case, an architecture firm in the United States opted not to inform its customers or network partners that it was using object-based 3D CAD even though its managers acknowledged that sharing such information and files would greatly reduce downstream workload and reduce errors. They stated clearly that they wanted the benefits of the new technology to accrue only within their own firm. Firms in U.S. networks also expressed concerns over other firms exhibiting strategic, self-interested behavior. In other words, they were concerned that their trading partners would use the change required by shifting allocations of work to increase the pricing for their work.

In the Finnish case, firms were much more apt to share the benefits of building information modeling with their network partners. Structural designers in construction networks in Finland chose to share models with downstream fabricators to obviate the fabricator's need to produce its own electronic CAD files for manufacturing. One Finnish contractor described how it brought all of its impacted network partners to sit around a table and discuss how the change would impact each firm, so that the costs and benefits of the innovation could be equitably distributed across the network.

Williamson (1985) discusses *interests* in his work on transaction cost economics and economic exchange. He describes hybrid forms of organization (essentially interorganizational networks) as relying on "mutual interests" (Williamson 1985, p. 155) to minimize transaction costs by limiting the impact of opportunism and mistakes. The concept of *interests* also relates to the embeddedness construct described by Granovetter (1992) and related to the *relational stability* construct. Granovetter argues that the deeper the embededdness, the more likely firms in a network are to see their *interests* as aligned rather than opposed. This is consistent with what we observed in the U.S. and Finnish networks.

When *interests* accumulated at the level of the firm, as was the case for the U.S. networks studied, the effect was to exacerbate the diffusion rate of systemic innovation. By considering only their firm's *interests* and not attempting to share the benefits of the innovation with their trading partners, firms in U.S. networks were restricting the rate of diffusion of the innovation. In contrast, in the Finnish networks the *interests* were defined at the network level, alleviating fears of opportunism and increasing firms' willingness to share the benefits of innovation with their partners. In these networks, the network level accrual of *interests* expedited diffusion.

> **PROPOSITION 2a.** *If interests are centered on the firm in an interorganizational network, the network will adopt systemic innovations more slowly. This contributes to slower systemic innovation diffusion rates.*

> **PROPOSITION 2b.** *If interests extend to the network in an interorganizational network, the network will adopt systemic innovations more quickly. This contributes to faster systemic innovation diffusion rates.*

### 5.3. Boundary Strength

Another construct that helped to explain the contrasts between U.S. and Finnish interorganizational networks was *boundary strength*. The strength of organizational boundaries played a critical role in how networks adapted to systemic innovations. In the United States the *boundary strength* between firms in a network was comparatively rigid. In the United States several firms vertically integrated into a single firm when attempts at redistributing work in the network failed. Object-based 3D CAD innovations require the designer to increase his or her knowledge of the objects they were designing. An example observed many times in the data collection was the situation where the wall of a room meets the ceiling. In 2D CAD it sufficed for the architect to just draw a line where the wall meets the ceiling. However, with building information modeling, the designer has to define the way in which the wall object is connected to the ceiling object. This requires greater knowledge of how the structure will be constructed in the field. In U.S. networks architects generally resisted taking on this additional responsibility since it did not fit with a standard interpretation of their role in the network. In contrast, Finnish firms adopting 3D CAD redrew the organizational boundaries separating the firms in the network without losing their firm identity. The architect took on aspects of the work that had previously been completed by the builder so that the network of firms was quickly able to garner the benefits of the systemic innovation.

Researchers are beginning to explore the role of organizational boundaries in interorganizational networks. Jacobides and Winter (2005) investigate integration and disintegration in Swiss watch making as a function of organizational capabilities. Likewise, Afuah (2001) explores the role of vertical integration in the face of technological change in the RISC industry. Both of these studies explore organizational boundaries from the perspective of where they should be circumscribed. Should firms integrate to eliminate boundaries in the face of technological change, as was the case on one of the U.S. networks we investigated? Or, should firms in the network remain independent?

In the case of the networks we investigated, the *boundary strength* in the U.S. networks was rigid. Because they continued to work with so many different network partners across projects, firms in the United States found it more difficult to negotiate changes in their organizational boundaries with other firms in the network to accommodate the systemic innovation. This contributed to a reduction in the rate of diffusion. Interestingly, in the case of one network, the rigid boundaries separating firms in the network were removed when the contractor in the network decided to vertically integrate a set of specialist firms from the network into its own organization. This led to tremendous productivity improvements as it reduced the impact of the weak *relational stability* and the firm level *interests*. However, it did not positively influence the diffusion outcome because not many others in the industry followed the same strategy of integration. In the case of the Finnish networks, the *boundary strength* was fluid. Firms in the coordinated market economy in which Finnish networks form and operate were able to reallocate work across fluid boundaries as necessary to accommodate a systemic innovation.

**PROPOSITION 3a.** *If the boundary strength between firms in a network is rigid, networks will have significant difficulty adapting to systemic innovations. This contributes to slower systemic innovation diffusion rates.*

**PROPOSITION 3b.** *If the boundary strength between firms in a network is fluid, networks will have little difficulty adapting to systemic innovations. This contributes to faster systemic innovation diffusion rates.*

### 5.4. Agent for Network-level Change

A final construct identified in comparing Finnish and United States construction networks was the presence of an *agent for network-level change*. In the liberal market economy context of the United States, firm networks must self-organize in the face of pressures for network-level change. The knowledge of an innovation among firms in the network can be distributed unevenly across multiple firms in networks. Moreover, discussions among groups of firms to assess needed changes can easily contravene tough U.S. anti-trust laws and be viewed internally or externally as illegal collusion. Thus, rational self-organization among firms in the United States firm networks may not lead to the most rational solution for the entire network.

Van de Ven (1986) argues that in instances such as this, impeccable micro-logic can lead to macro-nonsense.

In Finland, TEKES, the national technology funding agency, promotes network-level productivity enhancing changes by organizing firms into partnership networks to adopt innovations it regards as promising, and by directly subsidizing the costs such a change may have on individual firms in the network. It subsidizes these costs by funding the applied research on issues associated with early adoption of the innovations. In doing so, the national technology funding agency fulfills the role of an *agent for network-level change*.

**PROPOSITION 4a.** *In the absence of an agent for network-level change, networks will have difficulty self-organizing to adopt systemic innovations. This contributes to slower systemic innovation diffusion rates.*

**PROPOSITION 4b.** *In the presence of an agent for network-level change, networks will benefit from orchestrated change. This contributes to faster systemic innovation diffusion rates.*

## 6. MODELING SYSTEMIC INNOVATION IN INTERORGANIZATIONAL NETWORKS

We summarize the constructs (*relational stability*, *interests*, *boundary strength,* and *agent for network-level change*) identified in comparing United States and Finnish construction networks and their related dimensions in Table 6.1. Taken together, this set of constructs and related propositions provide the foundation for a new theoretical framework for understanding systemic innovations being implemented by and diffusing through networks of firms.

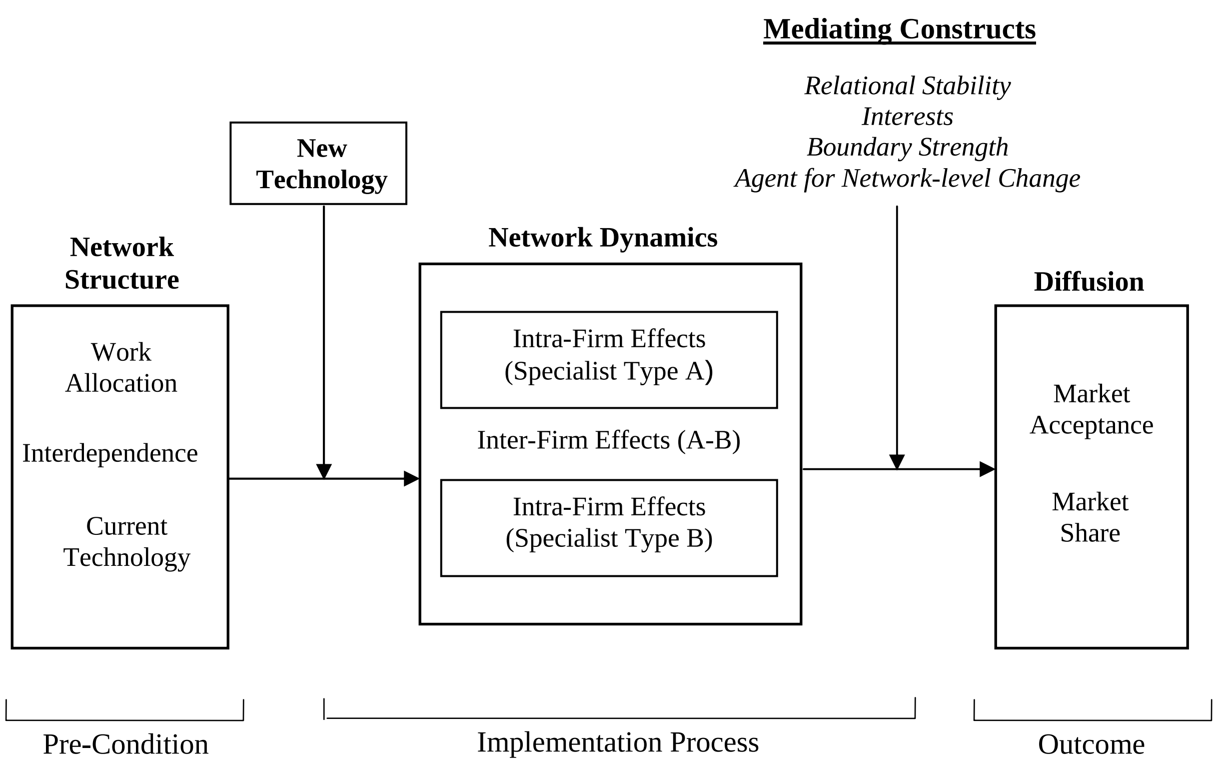
**Table 6.1 - Comparing Construction Networks in Finland and the United States**

| | **Country in which Construction Network Exists** | |
|---|---|---|
| **Construct** | United States | Finland |
| *Relational Stability* | Weak<br>(Tendency to contract from 5-6 firms per specialist type) | Strong<br>(Tendency to contract from 1-3 firms per specialist type) |
| *Interests* | Firm | Network |
| *Boundary Strength* | Rigid | Fluid |
| *Agent for network-level change* | None<br>(Network is self-organizing) | National Technology Funding Agencies |

### 6.1. Network Structure

Before we can understand the impact and outcomes of technological innovation on a network or a population of networks, we must understand the pre-existing network structure. One key aspect of the network structure identified in this research is the *allocation of work* to specialists in the network. Because firms in the network must work together to complete some overarching task (e.g., the design and construction of a building, the production and distribution of a motion picture, or the testing and development of a new drug) certain task *interdependencies* exist that structure the flow of work between firms in the network (Thompson 1967). Sharma and Yetton (2003) demonstrated the importance of understanding these task interdependencies in relation to the successful implementation of information systems. The *current technology* used by firms in the network is also an important element of the network structure.

**Figure 6.1 - Model for Innovation in Interorganizational Networks**



### 6.2. Network Dynamics and Diffusion Outcomes

Systemic innovations require multiple, interdependent types of specialist firms to mutually adapt to changes introduced by the innovation. Therefore, there is a set of firm effects that can be understood using existing innovation theory. However, in the case of systemic innovations such as object-based 3D CAD, more than one type of specialist firm population must adapt to the change. This impacts the rate at which the network can adapt to the change. Network dynamics caused by the inter-firm effects, however, have a far greater impact on the diffusion outcomes. The inter-firm effects invoke a set of mediating constructs (see Figure 6.1). The degree to which diffusion outcomes are impacted by a systemic innovation is determined by the values for the four mediating constructs. Strong *relational stability*, network-level *interests*, fluid *boundary strength*, and the existence of an *agent for network-level change* will mitigate difficulties of mutual adjusting to a systemic innovation. Conversely, weak *relational stability*, firm-level *interests*, rigid *boundary strength*, and the absence of an *agent for network-level change* will exacerbate difficulties of mutual adjustment and slow the diffusion rate for a systemic innovation.

## 7. CONCLUSIONS AND IMPLICATIONS

This research addresses the call in the innovation literature for fieldwork and theoretical research to better understand project-based forms of organizations. It contributes to a more complete understanding of innovation by extending previous organizational innovation theories to include systemic innovation in interorganizational networks. Because the model incorporates how one network can be more successful with innovation than another, it addresses the current tension in the interorganizational network literature about the impact of networks on innovation. Networks adopting systemic innovations that exhibit strong *relational stability*, network-level *interests*, fluid *boundaries*, and the existence of an *agent for network level change* when faced with a systemic innovation will perform comparatively better than other networks. In the studies by Powell and his colleagues (1996, 1998), which viewed networks as a locus for innovation, they described biotechnology networks as developing tight, knowledge sharing partnerships (strong *relational stability*) and discussed the important role of the National Institutes of Health (*agent for network-level change*). Also because the interdependencies were more resource than task based, *allocations of work* would play a diminished role in determining innovation outcomes. The model we presented in this report on systemic innovation in interorganizational networks would predict that these biotechnology networks would be successful innovators.

In contrast, the motion picture industry networks investigated by Lampel and Shamsie (2003) and the construction industry networks investigated by Gann and Salter (2000) exhibited no clear *agent for network-level change*. The authors describe the move to networks as disturbing the value orientation of individuals and firms toward changes to the network as a whole. This suggests both a lack of an *agent for network-level change* and a firm-level accrual of *interests*. The model would predict that these motion picture industry and construction industry networks would have some difficulty with innovation. Therefore, the model can simultaneously accommodate the 'locus of innovation' findings of Powell and his colleagues (1996, 1998) and the network 'stagnation' findings of Lampel and Shamsie (2003) and Gann and Salter (2000). This model then provides a first step toward resolving divergent views on innovation in interorganizational networks.

## 8. RELATION TO CIFE RESEARCH & GOALS

This work supports the "Value of Innovative Design-Construction Processes" thrust area which points out that "in comparison to sister fields, the AEC industry continues to lag behind in its adoption of innovative methods." This research directly addresses this issue. Furthermore, as the CIFE 2004 Call for Seed Research Proposals stated, "integration [is] the 'middle name' of CIFE." Improving our understanding of how integrated solutions (which imply systemic changes) can be successfully diffused across the AEC industry is critical to CIFE's mission. This research directly addresses this issue and builds a theoretical framework to understand and remedy it.

## 9. INDUSTRY INVOLVEMENT

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