THREE ESSAYS ON SUPPLY NETWORK ARCHITECTURE: A NETWORK MULTIPLEXITY APPROACH

By

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ABSTRACT

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This dissertation consists of three essays. The first essay explores the existence of network multiplexity in a supply network context and its association with supply network properties. The primary data collected from a survey of 153 directed valued supply networks at the component level is analyzed to find quantitative and statistically significant evidence on the existence of supply network multiplexity. Empirical results confirm that different types of supply network ties across multiple tiers of supply chain partners shape different supply network architectures. This study further explores the "hidden" dynamics between socio-centric, social network analysis indices used for characterizing multiplex supply networks.

The second essay addresses the unresolved question of the supply network antecedents in a directed valued network setting. Specifically, anchoring on strategic network perspective, it takes into account two major strategic intents (i.e. cost leadership and market responsiveness) of an OEM. Empirical findings based on a network multiplexity approach suggest that a supply network should be viewed as a consciously and purposely designed systematic outcome in accordance with the OEM's strategic goal(s). As a result, this essay attempts to address the theoretical and empirical gap of supply network research by shedding light on the hereto unaddressed strategic antecedents of different supply network architectures.

Extending network competence perspective to the context of supply network, the third essay examines the impact of key indices quantifying supply network architecture on supply

chain performance of an OEM with consideration of the contingent effects of OEM intervention in its immediate suppliers' sourcing decisions. Depending on a key premise underlying network strategy that a firm's inimitable and non-substitutable resources lie outside its boundaries, this essay aims to shed lights on the study of supply network, and consequently, to offer a *supply network competence perspective*. Each essay of this dissertation research is concluded with academic and managerial implications for supply network management.

Dedicated to Young-Shin Angela Park
for her love, prayer, patience and selflessness throughout our marriage

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If I have seen further, it is by standing on the shoulders of giants. — Sir Isaac Newton

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1 INTRODUCTION

Leading-edge companies have realized that the real competition is not company against company, but rather supply chain against supply chain — Martin Christopher, *Logistics and Supply Chain Management: Strategies for Reducing Costs and Improving Services* (1992, p.14).

Individual businesses no longer compete as standalone entities, but rather as collaborative networks. We are now entering the era of 'network competition' where the prizes will go to those organizations who can better structure, coordinate and manage relationships with their partners in a network committed to creating customer and consumer value through collaboration — Martin Christopher, *Logistics and Supply Chain Management: Creating Value-Adding Networks* (2011, p.104).

A firm never exists in isolation. It is nested within other entities, including inter-organizational partnerships, industry associations, international trade agreements; and a firm itself has multiple nested components, including individuals, teams, task forces, business units, geographic markets or offices. Given the highly interdependent and closely interlinked business environment in recent years, even a vertically integrated conglomerate cannot compete alone in that "…nothing happens in isolation …most events and phenomena are connected, caused by, and interacting with a huge number of other pieces of a complex universal puzzle" (Barabási 2003). Weberian social theories have traditionally explained the organizational success and survival in terms of its bureaucratic control such as personal observation or "files or records" that enable behavior prediction and internal error correction (Weber et al. 1946). However, many researchers in various disciplines of business including supply chain management (SCM) have become increasingly inspired to employ a relational approach emphasizing the fact that a firm's

critical resources may lie beyond the boundaries of the focal firm and be embedded in interfirm linkages rather than transactional approach over the years (Dyer and Singh 1998; Koza and Lewin 1998). In recent times, a network perspective of organizations has started to garner attention in the literature. A network perspective primarily depicts the organizational structure in terms of its *multiple* relationships and how they are patterned, whereas the transaction cost economics stresses the appropriate governance structure for transactions between *two* parties (Nohria 1998; Gulati and Gargiulo 1999; Gulati et al. 2000). From a network perspective, the competitiveness of a firm depends vitally on its network architecture, thus neglecting a firm's overall network architecture and attributes can lead to an incomplete understanding of its sources of competitive advantage and ensuing performance. For instance, OEMs heavily relying on their tier-one suppliers are exposed to more risks, such as less control over costs, inability to respond to changes in demand and new technology development, and inability to ensure their suppliers' socially and environmentally responsible conduct (Choi and Linton 2011). A recent global survey supports this view by showing that 40 percent of supply chain disruptions originate below the immediate tier-one suppliers (Business Continuity Institute 2011). Accordingly, there has been ample discussion on the urgency and necessity of adopting a network perspective in SCM research during the past decade (e.g. Choi et al. 2001; Mills et al. 2004; Gupta et al. 2006; Terpend et al. 2008; Nair et al. 2009). The two aforesaid descriptions on key aspects of business competition by the *same* author reflect this radical paradigm shift.

The concept of supply network has evolved through a series of stages from dealing with internal business functions of a firm such as inbound materials and outbound products; to dyadic buyer-supplier relationships between a focal firm and its immediate suppliers; to triadic supply chain which extends the dyad to buyer-supplier-supplier relationships; to supply networks which

investigate a network of interconnected business partners across multiple tiers of a supply network. In spite of these recent conceptual advances, however, supply network research to date suffers from several limitations in providing a more comprehensive understanding and analysis of a supply network. First, most studies still tend to limit their focus on simplistic, linear, and material/information flow control between two supply chain entities, taking less network-based approaches such as buyer-supplier or buyer-supplier-supplier relationships (Harland et al. 2001; Hofbauer and Wenninger 2011). Although useful for investigating a focal firm's transactional or relational exchanges with its immediate supply chain partners, these approaches fall short in grasping the whole picture of complicated network in which manufacturers and their multiple tiers of suppliers are nested (Parkhe et al. 2006; Choi and Kim 2008; Wassmer et al. 2010; Wilhelm 2011). Further, there have been numerous findings in the organizational behavior and strategic management literatures concerning the impact of network on a firm's behavior and performance. For instance, the amount of a firm's market asset and social capital depends on its network position, and consequently, firms can enjoy advantages from their network position by gaining access to the resources and capabilities of their business partners (Burt and Janicik 1996; Gnyawali and Madhavan 2001; Kim et al. 2006). Because of this, firms often build and maintain interfirm relationships not based on potential partners' internal capabilities but their external capabilities to initiate, handle, and utilize multiple external resources (Porter 1980; Anderson et al. 1994).). *Li and Fung*, a Hong Kong-based consumer goods sourcing and logistics company, is a great example of this form of network management capability (Magretta 1998). Previous SCM studies, hence, may be incomplete as they have largely overlooked the entire supply network architecture. Relying upon network studies in sociology, a number of recent studies have regarded supply networks as spontaneously created and informally maintained outcomes,

not as *consciously and purposely designed* organizational architecture on the basis of an OEM's specific strategic objectives to achieve its intended performance outcomes. Studies lacking such considerations – antecedents of supply network formulation – can often give misleading answers to both supply chain academics and practitioners about how different supply networks across various contexts should be managed.

To fill the aforementioned gaps in the SCM literature, this dissertation is organized as three separate essays (Chapters 2, 3, and 4), each of which is focused on specific research questions following this introduction chapter (Chapter 1). The first essay explores how different *directed valued* network ties across *multiple* tiers of supply chain partners shape different supply network architectures. As a result, it aims to offer quantitative and statistically significant evidence on the existence of *supply network multiplexity* and its effects on supply network architecture and further provides meaningful hints to the question of why even firms with outstanding buyer-supplier relationships still (sometimes) fail to maximize the network-wide benefits from their supply chain partners or are vulnerable to external shocks. The second essay investigates the strategic antecedents of different network architectures. More specifically, it looks into the following questions: 1) Are an OEM's strategic intent choices associated with supply network architecture; and 2) If so, what differential effects do those strategic intents have on architectural properties of the supply network. Anchoring on a strategic network perspective emphasizing the importance of network design in achieving a firm's strategic objectives (Gulati et al. 2000), this study attempts to provide a *strategic supply network perspective* which views the supply network architecture as an OEM's strategic choice. The third essay examines the impact of supply network architecture on an OEM's supply chain performance with consideration of the contingent effects of OEM intervention in selecting non-immediate suppliers.

Specifically, it aims to answer the following important questions in supply network research domain: 1) Does the supply network architecture of a firm affect its supply chain performance?; 2) If so, what architectural properties of the supply network will enhance or degrade which supply chain performance outcomes?; and 3) how does an OEM's efforts to exert its influence on its suppliers' sourcing decisions interplay with such causalities? By addressing these questions, this essay endeavors to facilitate further theoretical and empirical development of the network competence perspective in a supply network context. The overall structure of the dissertation is summarized in the Figure 1.1 below.

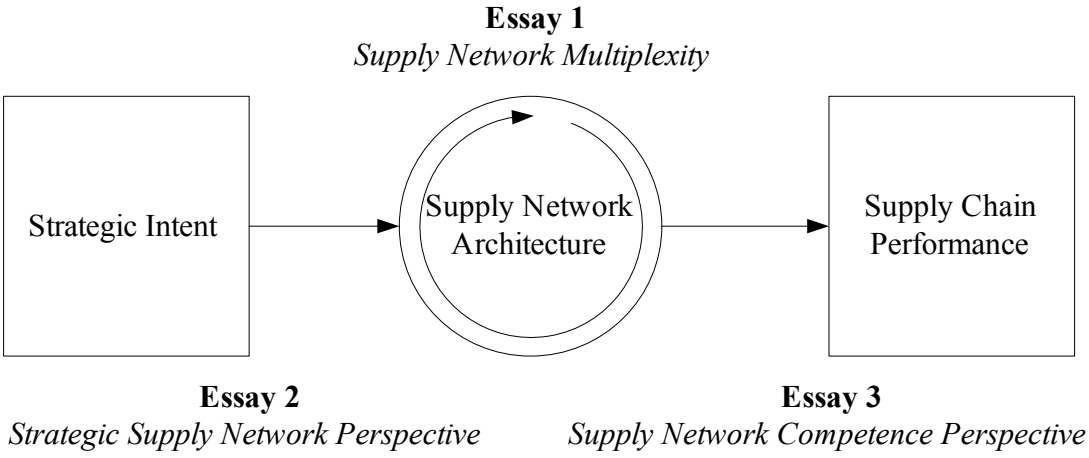


Figure 1.1: Conceptual Links among the Dissertation Essays

2 SAME BOAT, DIFFERENT OCEAN: THE EFFECTS OF NETWORK MULTIPLEXITY ON SUPPLY NETWORK ARCHITECTURE

2.1 Introduction

Analogous to mapping DNA on the human genome, understanding and redesigning a company's capabilities chain also begins with a map, one which identifies the organizations involved in that company's activities … Sometimes that understanding arrives from the most unexpected source imaginable. — Charles H. Fine, *Clockspeed* (1998, p.105)

Previous supply chain management (SCM) studies have investigated the importance of building and managing supply chain dyads between one buyer and its immediate supplier. Regardless of the means by which supply chain dyads are managed, the literature has identified mostly their positive (e.g. Lyons et al. 1990; Autry and Golicic 2010) or negative (e.g. Han et al. 1993; Villena et al. 2011) impacts on firm performance. More recently, this dyadic approach was extended to the triadic case which consists of one focal firm or OEM and two immediate or tier-one suppliers in a single supply chain (e.g. Park and Hartley 2002; Wu and Choi 2005; Dubois and Fredriksson 2008; Mena et al. 2013). While previous dyadic and triadic approaches were useful for investigating interfirm exchanges between a focal firm and its *immediate* supply chain partners, in the era of "network competition" (Christopher 2011), they fall short of grasping the whole picture of a complicated supply network in which a focal firm and its *multiple* tiers of suppliers are nested (Parkhe et al. 2006; Choi and Kim 2008; Wassmer et al. 2010; Wilhelm 2011). In practice, Toyota and Nissan have managed their supply networks by establishing Japanese first-tier suppliers' associations (*Kyohokai* and *Nishiokai*, respectively) since mid-90s (Sako 2004; Dyer and Hatch 2006). When earthquake and tsunami struck Japan's Tohoku region

on March 2011, their entire assembly lines outside the region were completely stopped for over two weeks. Tohoku region has been the biggest parts production base of Japanese automakers; interestingly, most of the affected suppliers were second- or lower-tier suppliers (Fujimoto 2011). Indeed, recent evidence indicates that an over-reliance on first-tier suppliers can present dangerous vulnerabilities to OEMs (Choi and Linton 2011). This underscores the importance of the need to study supply *networks*, consisting of a set of *multiple* supply chain partners connected by a set of *interactive* ties, not just dyadic (or triadic) and unidimensional buyer-supplier relationships. Furthermore, in order to overcome the shortcomings with current approaches to studying supply networks, there have been calls for more detailed investigations of the supply network *architecture*. The "architecture" of supply network is formulated from both exogenous and endogenous sources for linking the members in the entire network, whereas its "structure" is related to a firms better functional outcome or regional (i.e. local) collaboration (Snyder 1991; Swamidass and Snyder 1994). In other words, the architecture of supply network can be interpreted as the collective representation of multiple supply chain dyads or triads. This architectural approach enables SCM researchers to better investigate supply networks which consist of multiple independent entities pursuing their own interests.

Notwithstanding the aforementioned calls, the latest national survey conducted by Firestorm and Genesis Management (2012) still stresses the urgent need for further research in supply network architecture. The survey results show that firms do not fully understand, track, or analyze the inherent risks within their supply network even though suppliers are their largest source of supply chain failures. This unaddressed call for research reveals several limitations of the existing studies in providing a comprehensive understanding and analysis of a supply network architecture. First, current SCM literature has predominantly focused on developing

conceptual frameworks – taxonomies or typologies – to differentiate supply *networks* from supply *chains* or identifying unique attributes of supply networks without empirical substantiation (e.g. Lamming et al. 2000; Mills et al. 2004; Andersen and Christensen 2005). These works have broadened the scope of traditional buyer-supplier relationship studies and have garnered more research attention to the area of understudied supply network architecture by introducing theoretical propositions. However, they lack empirical evidence to show the practical applicability of the propositions developed in them. Second, a few recent empirical studies of supply network architecture fall within the limited domain of descriptive case studies (e.g. Choi and Hong 2002; Srai and Gregory 2008; Kim et al. 2011; Mena et al. 2013). Such exploratory studies have provided some empirical support for the theoretical propositions concerning supply network architecture. At the same time, however, these findings were heavily focused upon one single industry (e.g. automotive, banking, etc.) or firm, and thus lack empirical evidence that can be consistently applied across different supply networks. Last but most important, many studies are still using overly simplified, ambiguous, or non-exclusive measures for different types of network ties (e.g. Samaddar et al. 2006; Mason and Leek 2008; Wilhelm 2011). Granovetter (1973, 1983) distinguishing strong and weak network ties on the basis of reciprocity, frequency, emotional intensity, and intimacy in the relationship. This implies that both the direction and strength of network ties should be taken into account to understand network phenomena. In this vein, the same network can have completely different architectural properties with regard to different kinds and attributes of network ties (commonly referred to as "multiplexity") (Wasserman and Faust 1994; Kenis and Knoke 2002). Prior studies that have overlooked such inherent heterogeneity of a supply network can prevent SCM academics and practitioners from fully grasping the multi-faceted supply network architecture.

To address these theoretical as well as practical issues in the supply network literature, this study investigates how different *directed valued* network ties across *multiple* tiers of supply chain partners shape different supply network architectures. Drawing upon social network analysis (SNA), the primary survey data from 153 component-level supply networks is analyzed to explore the associations between 12 network-level SNA indices for characterizing different supply network architectures. This research offers, to the best of the author's knowledge, the first quantitative and statistically significant evidence on the existence of *supply network multiplexity* and its effects on supply network architecture. This essay is organized as follows: the first section sets out theoretical background and testable propositions on supply network and multiplexity of various network ties in a supply chain context; sections two and three outline methodology, measures, data source/analysis used to describe supply network architecture; section four presents quantitative findings and interpretations examining the propositions, followed by the final section on theoretical/managerial contributions, limitations, and directions for future research.

2.2 Theoretical Background and Proposition

2.2.1 Supply Network

Sociologists described network as a single closed set of actors (or nodes) and one or more types of ties (or edges) between them, and social network research has sought to understand observed dynamics of multiple network entities (i.e. persons). At the firm level, network is the complex organizational outcome that results from multiple strategic alliances that could have governance and performance implications (Webster 1992; Heide 1994). SCM academics have, at least conceptually, understood supply network as a composite entity comprising multiple supply chain

partners and various types of network ties among them (Nassimbeni 2004). Supply chains are often even more complex and multi-faceted than interpersonal network (Cooper et al. 1997; Mentzer et al. 2001; Borgatti and Li 2009; Lindgreen et al. 2013) in that they deal with both inter-organizational and interpersonal factors such as "coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers" (Gibson et al. 2005). The recent incorporation of the term "network" into SCM research represents the urgency and necessity to view supply chains as a multi-level system having a strict architecture (Barabási 2003; Ketchen and Hult 2007; Borgatti and Li 2009; Galaskiewicz 2011). See Table 2.1 for a synopsis of the development of supply network perspective and representative literature.

Table 2.1 Development of Supply Network Perspective and Representative Literature

Stage of Development	Scope of Analysis	Representative Literature
Intra-Firm Chain	The management of internal business functions involved in materials and information flows from inbound to outbound ends of a single supply chain	Goodman et al. (1993); Harland (1996)
Supply Chain Dyad	The management of supply chain dyads between one focal firm and its immediate supplier, downstream distribution channel, or upstream production chain	Bensaou (1999); Angeles and Nath (2001); Grover and Malhotra (2003)
Supply Chain Triad	The management of supply chain triads consisting of one focal firm and two immediate or tier-one suppliers in a single supply chain	Park and Hartley (2002); Wu and Choi (2005); Dubois and Fredriksson (2008); Choi and Wu (2009); Mena et al. (2013)
Supply Network	The management of a network of interconnected business partners across multiple tiers of a single supply chain	Borgatti and Li (2009); Galaskiewicz; (2011); Kim et al. (2011)

Adopted and Revised from Van de Ven and Ferry (1980), Harland (1996), and Varga (2008)

2.2.2 Multiplexity

Pioneering scholars such as Jessop (2003) and Borgatti and Li (2009) have proposed multiplexity in supply networks as a promising area for future research. Multiplexity in social networks is defined as two or more types of exchange (i.e. layering) within the same network ties (Verbrugge 1979; Burt 1980; Feld 1981; Ibarra 1992). Social anthropologists and sociologists introduced the term to denote coexistence of different normative elements in an interpersonal tie. In a family-owned business, for instance, a father-son relationship also can be viewed as an employer-employee relationship. Social ties containing only one such role represent "uniplex" or "single-stranded" ties, whereas those that involve two or more roles are "multiplex" or "many-stranded" ties (Wasserman and Faust 1994; Kenis and Knoke 2002). The practical importance of the concept in social network research was immediately recognized in that it helped to uncover "hidden" network properties and clearly manifested the underlying dynamics of personal ties. For instance, researchers found that multiplex ties were more likely to be intimate, supportive and/or durable, especially during times of need, because: 1) they have multiple bases of interaction (Wellman and Wortley 1990), and 2) there is less chance that one of them will be unavailable (Morin and Seidman 1986).

The concept of network multiplexity can also complement the shortcomings of existing buyer-supplier relationship literature. SCM researchers have stressed the importance of creating trust and reciprocity from repeated transactions with the same supply chain partners. According to the tenets of embeddedness theory (Granovetter 1985), an embedded relationship alleviates information asymmetry and opportunistic behavior in relations between organizations and thus leads to improved performance (Gulati 1995; Uzzi 1996; Rowley et al. 2000). However, growing evidence indicates that repeated interactions do not necessarily result in trust or the expected

benefits; they might even have negative consequences (Sorenson and Waguespack 2006; Poppo et al. 2008); rather, several studies present interdependent contingencies facilitating or restraining the transition from repeated transactions to relational embeddedness in inter-firm networks (Goerzen 2007; Sa Vinhas et al. 2012). The existence of multiplexity in supply networks can provide a theoretical rationale for such inconclusive and equivocal findings by showing that a given supply network with the same set of firms can be perceived differently based on different tie types with different directions and strengths.

In spite of its apparent applicability and research gaps in existing SCM literature, there have been surprisingly few attempts to provide a systematic empirical examination of multiplexity in a supply networks. One imperfect, but notable, exception is Kim et al. (2011) who depicted three supply networks of the center console assembly for Honda Accord, Acura CL/TL, and DaimlerChrysler Grand Cherokee by using SNA indices. This study suffered from the following limitations: 1) as an exploratory case study, it studied only three supply networks all in the automotive industry, 2) their interpretation of results was not drawn from the comparisons between two different network ties (i.e. contract and material flow), but aforementioned three cases, 3) those comparisons were confined to simple description of SNA index scores (e.g. higher or lower) without further statistical verification, 4) network ties were measured on binary (or dichotomous) scales (i.e. "1" if two supply network entities were linked either by contract or non-directional material exchange, "0" otherwise), and 5) other important but invisible supply network ties at the individual level (e.g. professional and personal exchanges) between network entities were overlooked. Despite these limitations, as a pioneering study investigating more than one network tie type within the same network, it hinted at the existence

of multiplexity which remains to be tested. To enrich and generalize this skeletal finding on supply network multiplexity, this essay proposes the following:

> PROPOSITION 1. *A supply network exhibits different architectural properties in terms of different tie types which directly or indirectly link all the members of the network.*

2.2.3 Supply Network Tie Types

The first question that should be considered by a network researcher interested in multiplexity is: what are the different types of network ties that should be considered (Hartman and Johnson 1989)? Supply network entities are interlinked with various types of network ties having different characteristics in accordance with different intentions to achieve different outcomes (Carter et al. 2007; Ketchen and Hult 2007; Borgatti and Li 2009). This study covers four types of supply network ties: contractual, transactional, professional, and personal ties. Table 2.2 offers conceptual definitions of four supply network tie types under consideration and their measurement items used based on the literature. The first two types represent *visible* network ties for exchanging tangible goods and services, whereas the other two capture *invisible* exchanges taking place among supply network entities.

Obviously, multiple supply network members are linked through visible ties such as contract or delivery and receipt of goods and services as consistent with previous supply network studies (e.g. Choi and Hong 2002; Kim et al. 2011). A formal written contract serves as the most fundamental element of economic exchanges but can be differently interpreted by supply chain partners. From a buyer's perspective, a strong contractual tie (i.e. more complete contract) including explicit work-related provisions and prescriptions can safeguard against opportunistic behavior of its counterpart (Williamson 1985). From supplier's perspective, however, an interfirm contract specifying more control and legal rules might reflect distrust between

exchange partners because buyers may opportunistically utilize it by imposing terms and conditions that are unreasonably difficult to comply with on the supplier (Ghoshal and Moran 1996; Woolthuis et al. 2005). In this vein, findings of prior research confirm that contractual and transactional exchanges between supply network partners should be treated as separate network ties, in which complete contract terms between firms do not necessarily imply the actual exchange of goods or services and vice versa. For instance, transactional tie (i.e. the actual exchange of goods and services) can be established without a formal written contract when both parties share relational norms such as reciprocity, solidarity and information sharing (Williamson 1993; Poppo and Zenger 2002; Lazzarini et al. 2004).

Prior network research has pointed out that "much of commitment occurs at a personal rather than organizational level" (Rylander et al. 1997, p.65) and "social capital is at the heart of social network analysis" (Brass and Krackhardt 1999, p.180). Although personal (or social)-level ties are usually invisible and often informal, they are significantly associated with organizational (or network) outcomes such as innovation (Abrahamson and Rosenkopf 1997; Demirkan and Demirkan 2012), knowledge transfer (Abrams et al. 2003; Inkpen and Tsang 2005), and trust (Zaheer et al. 1998; Musteen et al. 2010). While visible and organization-level network ties (i.e. contractual and transactional ties) representing economic exchange are widely discussed in the supply network literature, invisible and personal-level network ties (i.e. professional and personal ties) between supply network partners have received considerably less research attention. However, some researchers have incorporated the personal dimension into organization-level exchanges to uncover the invisible dynamics between network partners. Ulaga and Eggert (2006), for example, found that the extensive interpersonal interaction is a greater differentiator than lower cost for suppliers in achieving key supplier status. More recently, Ahuja

et al. (2012) conceptually argued that different types of personal and organizational network ties can be embedded within the same business network. Grossman et al. (2012) also found the interpersonal similarity between nascent entrepreneurs plays an amplifying role in forming new ventures and their network structures. Extending these ideas from this emerging research stream to the supply network context, this study additionally considers two invisible network ties bridging supply chain personnel in partnering firms. When it is incorporated with social network analysis, this consideration enables the inter- and intra-comparisons of different tie types and comparable network indices, and consequently can provide invaluable insights concerning the underlying network architecture (Borgatti et al. 2009; Borgatti and Li 2009). As will be explained in detail in the following sections, social network analysis offers quantitative indices of network properties. To enrich and extend the findings from the first proposition, therefore, this study investigates the following second proposition.

PROPOSITION 2. *The supply network properties in terms of different tie types exhibit significant positive or negative associations with one another.*

Table 2.2 Conceptual Definitions, Item Measures, and Related Literature for Supply Network Tie Types

Network Tie Type	Conceptual Definition	Item Measure	Related Literature
Contractual tie	The extent to which a supply network entity perceives that it has a 'complete' formal written contract with its immediate counterpart	We have a formal written contract(s) detailing the operational requirements. We have a formal written contract(s) that detail(s) how performance will be monitored. We have a formal written contract(s) detailing warranty policies. We have a formal written contract(s) detailing how to handle complaints and disputes (e.g. penalties for contract violations). We have a formal written contract(s) detailing the level of service expected from this supplier.	Podolny and Page (1998); Liu et al. (2009); Carey et al. (2011)
Transactional tie	A supply network entity's amount of 'monetary' exchange (in percentage points) with its immediate counterpart(s)	For OEMs (i.e. tier-0 firms): A percentage of total spend for each tier-1 supplier of the selected component For tier-(N) (i.e. intermediate) suppliers where N=1 or 2: Percentages of total sales derived from the tier-(N-1) buyer AND total spend for each tier-(N+1) supplier in dealing with the OEM's selected component For tier-3 (i.e. end-tier) suppliers: A percentage of total sales derived from tier-2 suppliers in dealing with the OEM's selected component	Thorelli (1986); Knoke and Yang (2008); Liu et al. (2009)
Professional tie	A supply network entity's perceived strength of the interactions with its immediate counterpart in performing 'work responsibilities'	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters. We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.). The communication between us occurs at different levels of management and cross-functional areas. I (or our executives) receive periodic feedback (via face-to-face, conference calls, e-mail, etc.) on progress, problems, and plans from this supplier's counterparts. I (or our executives) do periodic on-site visits to this supplier's plants.	Liu et al. (2009); Carey et al. (2011); Wilhelm (2011)

Table 2.2 (cont'd)

Network Tie Type	Conceptual Definition	Item Measure	Related Literature
Personal tie	A supply network entity's perceived strength of the interactions 'not directly related to work' with its immediate counterpart	We always invite each other to participate in various activities to socialize. We do personal favors for each other. We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.). We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) during non-working time. We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) outside work places.	Nicholson et al. (2001); Lysons and Gillingham (2003); Burt et al. (2009); Gilgor and Autry (2012)

2.3 Methodology

2.3.1 Social Network Analysis

To demonstrate different supply network architectures dependent upon network ties (i.e. contractual, transactional, professional, and personal ties), this study adopts social network analysis (SNA) which has long been used in analyzing any social network as a set of interrelated actors and ties. This methodology has been widely adopted by business disciplines such as organizational behavior and strategic management to describe inter-firm or interdepartmental network properties and to investigate their performance effects. The field of SCM has stressed the use of SNA methodology in a supply network context. For instance, Carter et al. (2007) proposed SNA as a key approach to advance current knowledge on various relationships existing within and beyond the supply chain by complementing traditional methodologies. This view was echoed by Borgatti and Li (2009) who pointed out that supply chain settings are particularly suitable to adopt SNA indices, which have been proven "highly portable" across other disciplines from economics to physics. Most recently, Galaskiewicz (2011) also noted that SCM theories mostly captured at the local level (e.g. dyad or triad) can be tested by using a supply network as the primary unit of analysis.

In spite of repeated calls for the use of methodology, there are still very few empirical studies that use SNA (e.g. Batallas and Yassine 2006; Schilling and Phelps 2007; Kim et al. 2011). Moreover, to the best of the author's knowledge, *all* existing empirical studies on supply network are case-based research that use SNA measures solely defined for binary (i.e. "1" if a tie is exists between two supply network entities, "0" otherwise) and non-directional ties (i.e. if one supply network entity perceives a tie, its counterpart's perception on the existence of the tie is automatically assumed). This is commonly referred to as *binary network approach*, and most of

the existing SNA indices have been devised solely based on this approach (Wasserman and Faust 1994; Freeman 2004). The binary network approach specified by a symmetric adjacency matrix is conceptually and computationally straightforward and especially appropriate when a researcher focuses on cognitive ties (e.g. who knows whom). An important limitation of this approach, however, is that it involves two counterintuitive and unrealistic premises – all ties are completely homogeneous and symmetrical – which contradict previous findings in the literature. For instance, strong social ties strengthen interpersonal obligations (Coleman 1988), facilitate change in the face of uncertainty (Krackhardt 1992), and help to develop relationship-specific heuristics (Uzzi 1997). Therefore, by using the binary network approach, network researchers can inevitably overlook important information about network properties embedded in network ties, and consequently arrive at limited or even misleading implications on network architecture.

2.3.2 Directed Valued Network Indices

From a methodological standpoint, the present study adopts *directed valued network* approach represented by an asymmetric adjacency matrix to overcome the aforementioned shortcomings of binary network approach (Wasserman and Faust 1994; Freeman 2004). This approach takes into account the direction and strength (or magnitude) of each tie between different network entities. In network terms, a directed valued network consists of a set of actors (or nodes) $\{n_1, n_2, \cdots, n_g\}$, a set of arcs (i.e. directional ties or links) $\{l_1, l_2, \cdots, l_L\}$, and a set of values $\{v_1, v_2, \cdots, v_L\}$ attached to the arcs, subject to $l_k=<n_i,n_j>\neq l_m=<n_j,n_i>$ and v_k is not necessarily equal to v_m. This is a more useful and realistic approach for exploring supply network phenomena since it allows for the possibility that a focal firm may perceive much less strong (or no) tie with its suppliers than those perceived by its suppliers. In this sense, there has

been a growing need for SNA indices that can be used in the directed valued network setting when it is based on a different adjacency matrix.

SNA indices fall into one of two categories: ego-centric and socio-centric approaches (Barnes 1974). The ego-centric approach focuses on a particular actor's position within the network and is particularly useful in dealing with a large network whose boundary cannot be easily specified. In contrast, based on specific criterion of network boundaries, socio-centric approach analyzes the overall pattern of multiple actors within a single, bounded network. This approach can provide a better understanding of the directed valued network in that the network architecture from one ego's viewpoint can be markedly different from those of others linked directly or indirectly (Scott 2000; Marsden 2002). It also fits perfectly with the purpose of this study to explore the existence of supply network multiplexity and its effects on network architecture. Thus, from a measurement perspective, this essay focuses on four socio-centric SNA indices (i.e. betweenness centralization, in-degree centralization, out-degree centralization, and global clustering coefficient) defined only at the network level.

First, betweenness centralization represents whether most network actors are equally central or there are some (i.e. hubs) that are much more central than others. This index can be calculated by the variation in the betweenness centrality divided by the maximum variation in betweenness centrality scores possible in a network of the same size (Freeman 1979). Betweenness centrality is an ego-centric index indicating how often an actor lies on the shortest path between all combinations of pairs of other actors. The more a given actor has a higher betweenness centrality; its immediate actors are more dependent on this actor to reach out to the rest of the network. This index focuses on the role of an actor as an intermediary and posits that this dependence of others makes the actor central in the network. Betweenness centralization, a

socio-centric version of betweenness centrality, ranges from 0 where all network actors have the same betweenness centrality, to 1, where there exists one single actor connecting all the other actors. This study calculates betweenness centralization of a directed valued supply network by adopting the formula suggested by Opsahl et al. (2010) for betweenness centrality ($C_B^{w\alpha}(n_i)$) for network actor n_i, defined as:

$$C_B^{w\alpha}(n_i) = \frac{g_{n_j n_k}^{w\alpha}(n_i)}{g_{n_j n_k}^{w\alpha}}$$

where $g_{n_j n_k}^{w\alpha}$ is the total number of geodesics between two actors (n_j and n_k), $g_{n_j n_k}^{w\alpha}(n_i)$ is the number of geodesics passing through actor n_i, and α is a positive tuning parameter that is set to the benchmark value of 0.5 to equally value both the number of ties and their strengths (w). Thus, betweenness centralization can be formally expressed as:

$$C_B = \frac{\sum_{i \in G}\{C_B^{w\alpha}(n^*) - C_B^{w\alpha}(n_i)\}}{\max \sum_{i \in G}\{C_B^{w\alpha}(n^*) - C_B^{w\alpha}(n_i)\}}$$

where $C_B^{w\alpha}(n^*)$ is the largest value of the betweenness centrality that occurs across the network G; that is $C_B^{w\alpha}(n^*) = \max_i C_B^{w\alpha}(n_i)$.

In the case of directed network, two additional degree indices are defined: in-degree, or the number of links terminating at the actor ($k_{n_i}^{in}$); and out-degree, or the number of ties originating from the actor ($k_{n_i}^{out}$) (Wasserman and Faust 1994). In-degree centralization calculates the dispersion of or variation in in-degree centrality, the extent of individual actor's

influence on other actors, and thus high in-degree centralization indicates the incoming flows of different network resources are focused on a small group of actors in the overall network. In the same sense, high out-degree centralization indicates that a small number of actors send out most of the network resources for the rest of the network actors. This study derives in-degree and out-degree centralization of a supply network from in-degree centrality ($C_{D\text{-}in}^{w\alpha}(n_i)$) and out-degree centrality ($C_{D\text{-}out}^{w\alpha}(n_i)$) for actor n_i of directed valued network by the following equations (Opsahl et al. 2010):

$$C_{D\text{-}in}^{w\alpha}(n_i)=k_{n_i}^{in}\times\left(\frac{s_{n_i}^{in}}{k_{n_i}^{in}}\right)^{\alpha}$$

$$C_{D\text{-}out}^{w\alpha}(n_i)=k_{n_i}^{out}\times\left(\frac{s_{n_i}^{out}}{k_{n_i}^{out}}\right)^{\alpha}$$

where s^{in} and s^{out} are the total strengths attached to the incoming and outgoing ties, respectively. Therefore, the general in-degree and out-degree centralizations ranging from 0 to 1 are respectively defined as:

$$C_{D\text{-}in}=\frac{\sum_{i\in G}\{C_{D\text{-}in}^{w\alpha}(n^*)-C_{D\text{-}in}^{w\alpha}(n_i)\}}{\max\sum_{i\in G}\{C_{D\text{-}in}^{w\alpha}(n^*)-C_{D\text{-}in}^{w\alpha}(n_i)\}}$$

$$C_{D\text{-}out}=\frac{\sum_{i\in G}\{C_{D\text{-}out}^{w\alpha}(n^*)-C_{D\text{-}out}^{w\alpha}(n_i)\}}{\max\sum_{i\in G}\{C_{D\text{-}out}^{w\alpha}(n^*)-C_{D\text{-}out}^{w\alpha}(n_i)\}}$$

where $C_{D\text{-}in}^{w\alpha}(n^*)$ and $C_{D\text{-}out}^{w\alpha}(n^*)$ are the largest in-degree and out-degree centrality values in the network G.

Lastly, this essay uses global clustering coefficient (GCC) varying from 0 to 1 to measure the overall level of cohesion among network actors (Newman 2003; Schank and Wagner 2005). In social network terms, this indicates the probability that network actors n_j and n_k are also connected to each other when n_i is connected to both of them, collectively represented as $(n_i;n_j,n_k)$. In a directed valued network setting, this socio-centric index is defined as the total value of *closed triplets* (i.e. triples of network actors where each actor is connected to the other two; τ_Δ) divided by the total value of *triplets* (i.e. triples where at least one actor is connected to the other two; τ). Triplet value (ω) calculation is based on the geometric mean of the tie values for the nodes comprising the triplet in that it: 1) captures differences between tie strengths, and 2) is robust to extreme tie strength (Opsahl and Panzarasa 2009). Thus, the general GCC (C_g) can be formally stated as:

$$C_g = \frac{1}{N} \sum_{i,j,k \in G} \left\{ \frac{\sum_{(n_i;n_j,n_k) \in \{\tau_\Delta\}} \omega_{\tau_\Delta}(n_i;n_j,n_k)}{\sum_{(n_i;n_j,n_k) \in \{\tau\}} \omega_{\tau}(n_i;n_j,n_k)} \right\}$$

where *N* is the number of possible triplets in network G. Readers can refer to the recent study of Opsahl and Panzarasa (2009) for more details on this technique.

SNA indices have been developed and used within a sociological context, which cannot be directly applied and interpreted within an interfirm supply network context. Table 2.3, consequently, proposes a new framework of the supply network implications of the socio-centric SNA indices for directed valued networks used in this study for each of the four tie types previously defined in Table 2.2.

Table 2.3 Socio-Centric Indices, Conceptual Definitions, and Interpretations by Supply Network Tie Type

Socio-Centric SNA Index	Conceptual Definition	Tie Type	Implications for Directed Valued Supply Network
Betweenness centralization	The extent to which particular network actors serve as hubs relative to the rest of the network	Contractual tie	The extent to which there exist particular focal firms with unequally complete (or specific) contract terms than other supply network members - The lower the index, the more firms there are which have more equally complete contract terms with their supply network counterparts - The higher the index, the more firms there are which have more unequally complete contract terms with their supply network counterparts.
		Transactional tie	The extent to which there exist particular focal firms with unequal percentage of monetary exchanges than other supply network members (i.e. distribution of sales and spending in the network) - The lower the index, the more firms there are which have equal percentage of monetary exchanges with their supply network counterparts. - The higher the index, the more firms there are which have more or less percentage of monetary exchanges with their supply network counterparts.
		Professional tie	The extent to which there exist particular focal firms with unequal amount of work-related interactions than other supply network members - The lower the index, the more firms there are which have equal amount of work-related interactions with their supply network counterparts. - The higher the index, the more firms there are which have more or less work-related interactions with their supply network counterparts.

Table 2.3 (cont'd)

Socio-Centric SNA Index	Conceptual Definition	Tie Type	Implications for Directed Valued Supply Network
Betweenness centralization (cont'd)	The extent to which particular network actors serve as hubs relative to the rest of the network	Personal tie	The extent to which there exist particular focal firms with unequal amount of non-work-related interactions than other supply network members - The lower the index, the more firms there are which have equal amount of non-work-related interactions with their supply network counterparts. - The higher the index, the more firms there are which have more or less non-work-related interactions with their supply network counterparts.
In-degree centralization	The extent to which network resources are converged on particular network actors	Contractual tie	The extent to which particular focal firms have more complete (i.e. less favorable) contract terms from the other supply network members. - The lower the index, the more firms there are which have fair contract terms with their supply network counterparts. - The higher the index, the fewer particular focal firms possess less favorable contract terms with their supply network counterparts.
		Transactional tie	The extent to which particular focal firms take up more percentage of the monetary exchanges occurring inside the supply network than others. - The lower the index, the more firms there are which have equal percentage of monetary exchanges. - The higher the index, the fewer particular focal firms account for more percentage of monetary exchanges than the others.

Table 2.3 (cont'd)

Socio-Centric SNA Index	Conceptual Definition	Tie Type	Implications for Directed Valued Supply Network
In-degree centralization (cont'd)	The extent to which network resources are converged on particular network actors	Professional tie	The extent to which particular focal firms have more incoming work-related interactions from the rest of the supply network members - The lower the index, then each of the supply network members has more equal amount of work-related interactions with one another. - The higher the index, the more work-related interactions among supply network members is focused on fewer particular focal firms.
		Personal tie	The extent to which particular focal firms have more incoming non-work-related interactions from the rest of the supply network members - The lower the index, then each of the supply network members has more equal amount of non-work-related interactions with one another. - The higher the index, the more non-work-related interactions among supply network members is focused on fewer particular focal firms.
Out-degree centralization	The extent to which particular actors disseminate network resources to others	Contractual tie	The extent to which particular focal firms provide more complete (i.e. less favorable) contract terms for the rest of the supply network members. - The lower the index, the more firms there are which have fair contract terms with their supply network counterparts. - The higher the index, the fewer particular focal firms yield less favorable contract terms for their supply network counterparts.

Table 2.3 (cont'd)

Socio-Centric SNA Index	Conceptual Definition	Tie Type	Implications for Directed Valued Supply Network
Out-degree centralization (cont'd)	The extent to which particular actors disseminate network resources to others	Transactional tie	The extent to which particular focal firms generate more percentage of the monetary exchanges occurring inside the supply network than others. - The lower the index, the more firms there are which have equal percentage of monetary exchanges. - The higher the index, the fewer particular focal firms send out most of the percentage of monetary exchanges for the rest of the supply network members.
		Professional tie	The extent to which particular focal firms have more outgoing work-related interactions to the rest of the supply network members - The lower the index, then each of the supply network members has more equal amount of work-related interactions with one another. - The higher the index, the fewer particular focal firms send out most of the work-related interactions to the rest of the supply network members.
		Personal tie	The extent to which particular focal firms generate more outgoing non-work-related interactions for the rest of the supply network members - The lower the index, then each of the supply network members has more equal amount of non-work-related interactions with one another. - The higher the index, the fewer particular focal firms make more non-work-related interactions for the rest of the supply network members.

Table 2.3 (cont'd)

Socio-Centric SNA Index	Conceptual Definition	Tie Type	Implications for Directed Valued Supply Network
Global clustering coefficient	The extent to which how cliquish (or tightly knit) a network is as a whole (i.e. the degree to which all the network actors tend to cluster together)	Contractual tie	The extent to which how the entire supply network members are directly connected by contract relations - The lower the index, the less proportion out of all supply network members are directly connected by contract relations (i.e. the supply network has a more "hierarchical" architecture as a whole). - The higher the index, the more proportion out of all supply network members are directly connected by contract relations (i.e. the supply network has a more "lateral" architecture as a whole).
		Transactional tie	The extent to which how the entire supply network members are directly connected by monetary exchanges - The lower the index, the supply network as a whole has a more "hierarchical" architecture of monetary exchanges among supply network members. - The higher the index, the supply network as a whole has a more "lateral" architecture of monetary exchanges among supply network members.
		Professional tie	The extent to which all the supply network members freely communicate work-related subjects across firm boundaries - The lower the index, the supply network as a whole has a more "hierarchical" architecture of work-related interactions among supply network members. - The higher the index, the supply network as a whole has a more "lateral" architecture of work-related interactions among supply network members.

Table 2.3 (cont'd)

Socio-Centric SNA Index	Conceptual Definition	Tie Type	Implications for Directed Valued Supply Network
Global clustering coefficient (cont'd)	The extent to which how cliquish (or tightly knit) a network is as a whole (i.e. the degree to which all the network actors tend to cluster together)	Personal tie	The extent to which all the supply network members freely communicate non-work-related subjects across firm boundaries - The lower the index, the supply network as a whole has a more "hierarchical" architecture of non-work-related interactions among supply network members. - The higher the index, the supply network as a whole has a more "lateral" architecture of non-work-related interactions among supply network members.

2.4 Data and Analysis

2.4.1 Boundary Specification

Survey is the most common method to collect social network data. Before starting a survey, network researcher should first specify a network boundary around the data to be collected (Laumann et al. 1989; Gulati 1995; Cross and Parker 2004). This is often one of the most challenging task in that: 1) arbitrarily established network boundaries bear more risk of inflated measurement error (Kossinets 2006), 2) SNA indices are sensitive to missing data (Knoke and Yang 2008), and thus 3) a reasonably high response rate over 65% is required (Stork and Richards 1992). Most of all, the overall complexity of a supply network rapidly escalates as more suppliers and tiers (or echelons) are taken into consideration (Beamon 1999). As depicted in Figure 2.1, the number of inter-organizational ties to be examined (N) increases from 1 to 3 when a researcher expands the area of interest from a buyer-supplier dyad to a buyer-supplier-supplier triad by adding one more supplier. If the researcher goes a step further to investigate a tetrad with one buyer and three suppliers, then N grows from 3 to 6, and it rapidly increases as the network boundary extends to pentad (N=9), hexad (N=15), and larger multi-term systems including more suppliers or tiers. The same phenomenon is observed, assuming a purchasing manager deals with only two unrelated suppliers, when the researcher expands the network boundary from two-tier supply networks (N=2) to three-, four-, and five-tier supply network (N=6, 14, and 30, respectively).

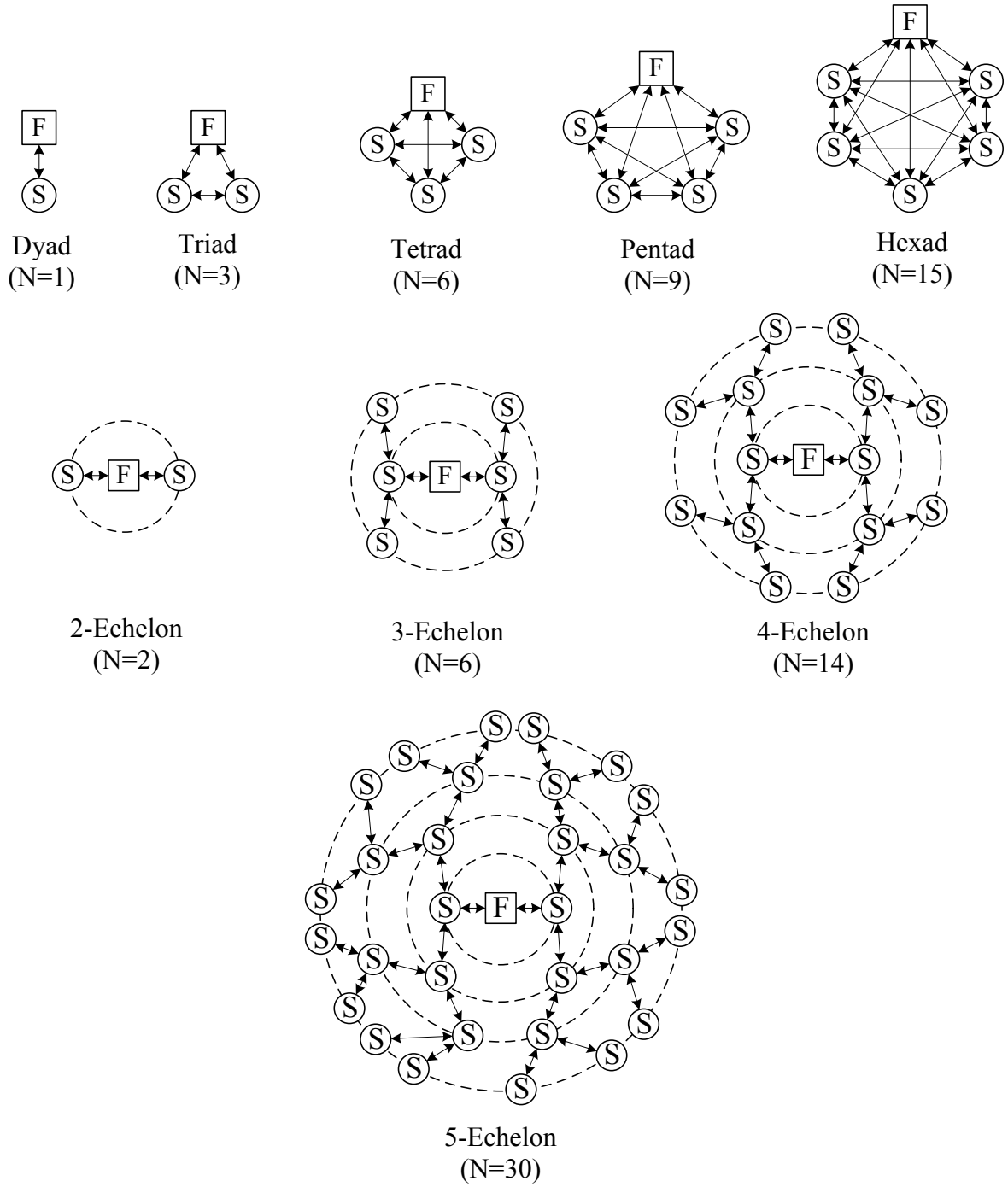


Figure 2.1: Network Complexity with Varying Number of Entities/Tiers

To avoid those pitfalls, previous studies conveniently regarded a social network as an ego network which consists of a focal actor and a set of network actors directly linked to the focal actor. Researchers can save time and effort for data collection by adopting this ego network

approach, but it also has some serious limitations in describing the multiplex architecture of directed valued supply network since: 1) it is prone to distortions as survey responses solely rely on a focal actor's perceptions (i.e. perceptions from its counterparts are not considered) (Mehra et al. 2001; Marsden 2005), and 2) a clear determination of inter-firm network boundaries is almost impossible in that a supply network is a complex system embracing numerous actors linked with various types of ties across multiple tiers (or echelons) (Choi et al. 2001; Borgatti and Halgin 2011). Therefore, for collecting supply network data, the current study takes a *whole network* approach, which collects bidirectional responses stretching from a focal actor to its raw materials suppliers (Wellman 1988; Kilduff and Tsai 2003; Provan et al. 2007), which differentiates this study from prior studies. Although an arduous and time-consuming process is required for collecting whole network data of inter-organizational ties (Scott 2000; Knoke and Yang 2008), it has been repeatedly recommended as the most desirable approach for researchers to investigate the holistic and systemic architecture of a supply network which includes all activities and functions involved to bring a product or service to the market (Ketchen and Hult 2007; Borgatti and Li 2009).

2.4.2 Data Source and Procedure

This study focuses on the individual component-level supply network as the unit of analysis in that a single product is mostly built up by incorporating a mix of functional and innovative components (Huang et al. 2002; Vonderembse et al. 2006). For instance, although Apple's iPad 2 released in March 2011 is regarded as a great example of an innovative product, it consists of a combination of both new (e.g. dual-core Apple A5 system-on-a-chip processor, three-axis gyroscope sensor, etc.) and existing (e.g. lithium-ion polymer battery, 9.7-inch LED-backlit display, etc.) components. In this sense, prior research has examined supply networks by

component-level analysis focusing on a single component or module within a product (e.g. Huang et al. 2005; Kim et al. 2011).

Three major South Korean automobile and consumer electronics manufacturers were contacted to collect the component-level whole network survey data. To lessen the burden of data collection, a combined sampling approach of *fixed list* and *snowball selections* was adopted (Doreian and Woodard 1992; Stevenson and Greenberg 2000; Borgatti and Li 2009). First, to keep the whole network perspective in data collection, initial contacts mostly at the executive level were asked to select a strategically important component with manageable network sizes (i.e. no more than 3 tiers and 5 suppliers per tier) and recommend the most knowledgeable sourcing manager in charge of the selected component. This step also contributed to minimize key informant bias (Kumar et al. 1993). Secondly, sourcing managers were asked to evaluate their perceptions on different types of ties (i.e. contractual, transactional, professional, and personal) with their major immediate suppliers mostly listed as the OEM's preferred supplier. Contractual, professional, and personal ties were evaluated using a five-point scale, anchored by "1" (strongly disagree), "3" (neither disagree not agree), and "5" (strongly agree), and transactional tie was assessed by percentages of total spend (or sales) for each supplier (or buyer) for the selected component. Next, the same questions were given to the OEM's counterparts (i.e. tier one suppliers) based on the contact information provided by the focal firm's sourcing manager. These steps were repeated for the successive tiers of suppliers (i.e. tier two and tier three suppliers) until end-tier suppliers were reached. To check the existence of duplicate respondents (i.e. suppliers), surveys on the successive tiers of suppliers were started after finalizing all the surveys on OEMs or higher tier suppliers. Since all the requested information was extremely confidential and sensitive to both buyers and suppliers, it was promised that all

individual responses would be kept completely confidential, and all analyses would be implemented and presented only at the aggregate level. To reassure respondents regarding the confidentiality of their responses, all completed questionnaires were directly collected by the author instead of being routed through buying firms. As a result of these efforts, a total of 153 component-level (89 electronics and 64 mechanical) networks consisting of 1,852 total network members were collected.

2.4.3 Analysis

As there is no stand-alone software package built on the SNA indices introduced above, all four socio-centric indices (i.e. betweenness centralization, in-degree centralization, out-degree centralization, and global clustering coefficient) of individual directed valued supply network were calculated by using Microsoft Excel, and the codes were verified by two faculty members with experience in the area. UCINET has been one of the most widely accepted SNA tools for conducting the network analysis, but it is not appropriate for analyzing the given valued directed network dataset since it automatically "binarizes" the valued network (Wei et al. 2011). As all network ties of the dataset were valued (i.e. measured on a five-point scale or in percentage), each tie value corresponded to an average value of the item measures assigned to the tie (Wasserman and Faust 1994; Sparrowe et al. 2001; Sykes et al. 2009).

2.5 Results and Interpretations

2.5.1 Descriptive Statistics

Table 2.4 contains basic descriptive statistics and one-way analysis of variance (ANOVA) results for the calculated socio-centric SNA indices based on 153 component-level supply networks by four different tie types. ANOVA implemented to compare the means of tie types with respect to each SNA index showed that they differ statistically. Homogeneity of variances was tested using Levene's test, and planned comparisons between the means assessed using Dunnett's T3 statistic. The mean values were also plotted by network tie type on a radar chart in Figure 2.2 for comparison. A few descriptive observations could be made from the computed indices. First, for all the four SNA indices, transactional network had lower means than contractual network. For instance, the betweenness centralization in transactional network (0.3905) was not as high as that in contractual network (0.5786), which indicates the monetary exchanges are relatively more equally distributed among supply network members. Transactional network with a lower in-degree centralization (0.3246) than contractual network (0.3846) also hinted that more complete contract terms given to a fewer particular focal firms within the supply network were not always associated with more percentage amount of their monetary exchanges. Further, as shown in out-degree values, particular focal firms fell short of generating corresponding percentage amount of monetary exchanges (0.2883) even when they yielded more complete contractual terms for their counterparts (0.4895). These observations collectively suggest the completeness of contract terms is not necessarily associated with more or less monetary exchanges among supply network members. Second, the contractual network showed the highest means for betweenness and out-degree centralizations (0.5786 and 0.4895) compared to those of the other three network types (0.3905 and 0.2883 for transactional network; 0.4840 and 0.4041 for professional network;

0.4922 and 0.3404 for personal network), whereas no such notable difference could be seen in in-degree centralization. This implies that: 1) there exists a relatively smaller group of focal firms mediating other members in contractual networks, and 2) those particular focal firms grant rather more complete (i.e. less favorable) contract terms to their supply network counterparts, which supports the first observation on the lack of relatedness between the completeness of contract terms and the amount of transactions. Another noteworthy point was that the contractual and professional networks exhibited the same pattern in the rank order of indices (i.e. higher out-degree centralization than in-degree centralization), which was contrary to transactional and personal networks following the same pattern (i.e. higher in-degree centralization than out-degree centralization). This suggests that each set (i.e. contractual-professional and transactional-personal) can move in the same general direction with different magnitudes, signifying that the monetary exchanges among supply network members are more associated with their personal ties rather than contractual or professional ties. Perhaps the most interesting observation shown in Table 2.4 is the apparently high GCC in personal network (0.7976) compared to the low values of the other three networks (0.1344, 0.0749, and 0.1709). This demonstrates the personal network has a very loosely knitted architecture as a whole, while the other three are highly clustered together with respect to contractual, transactional, and professional ties. This also clearly shows that supply network members interact very actively with one another on non-work-related matters – creating a lateral (i.e. more egalitarian) personal network architecture – even when they mostly do not share any other network ties with their non-immediate members.

Table 2.4 Descriptive Statistics and ANOVA Results

Socio-Centric SNA Index	Tie	Mean	Stdev	Min	Max	F-Value[a]	Dunnett T3
Betweenness Centralization	Contractual (A)	.5786	.0167	.5505	.6086	759.735**	A > C, D > B
	Transactional (B)	.3905	.0222	.3501	.4300		
	Professional (C)	.4840	.0438	.4102	.5599		
	Personal (D)	.4922	.0455	.4123	.5698		
In-degree Centralization	Contractual (A)	.3846	.0200	.3512	.4185	355.188**	D > A > C > B
	Transactional (B)	.3246	.0191	.2901	.3599		
	Professional (C)	.3424	.0289	.2907	.3894		
	Personal (D)	.4029	.0259	.3628	.4498		
Out-degree Centralization	Contractual (A)	.4895	.0226	.4504	.5299	1,215.549**	A > C > D > B
	Transactional (B)	.2883	.0468	.2115	.3698		
	Professional (C)	.4041	.0150	.3802	.4299		
	Personal (D)	.3404	.0294	.2912	.3898		
Global Clustering Coefficient	Contractual (A)	.1344	.0212	.1003	.1699	45029.104**	D > C > A > B
	Transactional (B)	.0749	.0146	.0503	.0999		
	Professional (C)	.1709	.0121	.1502	.1895		
	Personal (D)	.7976	.0273	.7504	.8497		

Note: N=153 component-level networks

[a] **: Significant at the 0.01 level (2-tailed)

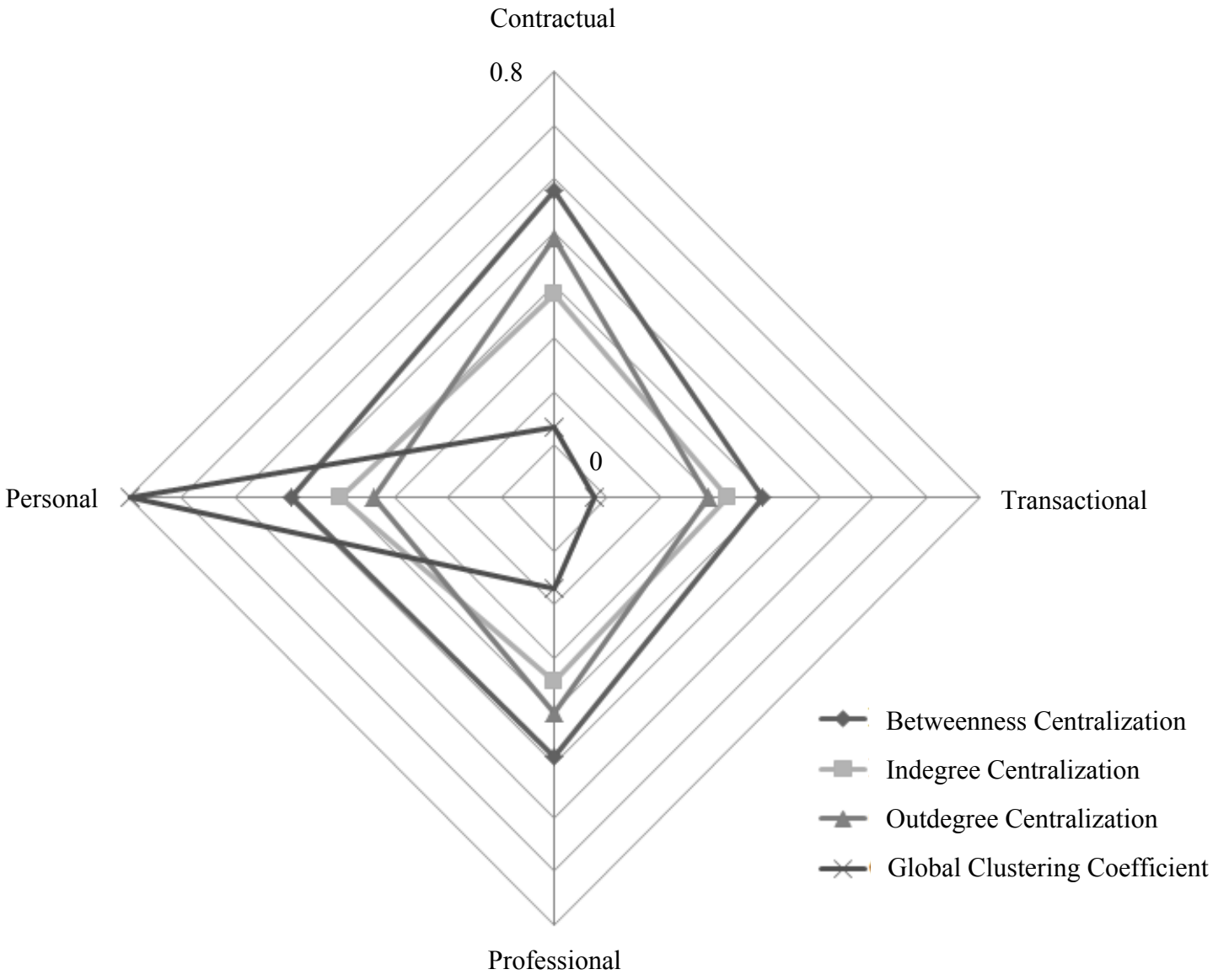


Figure 2.2: Means of Socio-Centric SNA Indices by Network Tie Type

2.5.2 Correlations

To find statistical support for the existence of supply network multiplexity, the bivariate correlation matrix among all four different indices in four different relational dimensions is presented in Table 2.5.

Table 2.5 Bivariate Correlation Matrix

Tie Type	Socio-Centric SNA Index[a]	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Contractual	(a)	1.000							
	(b)	.763**	1.000						
	(c)	.029	.007	1.000					
	(d)	.065	.026	-.201	1.000				
Transactional	(e)	-.127	-.135	.010	-.130	1.000			
	(f)	.759**	.732**	.040	.026	-.100*	1.000		
	(g)	.011	.045	-.080	.026	.056	.023	1.000	
	(h)	.063	.138	.127	-.104	.098	.061	-.068	1.000
Professional	(i)	.063	-.037	-.068	-.069	.061	.042	.045	-.178
	(j)	.177	.139	.036	-.051	-.056	.143*	-.076	-.137
	(k)	.781**	.720**	.043	.016	-.050*	.776**	.143	.001
	(l)	-.765**	-.716**	.057	.043	.129	-.771**	.022	-.091
Personal	(m)	-.759**	-.713**	-.038	-.092	.088	-.717**	-.034	-.079
	(n)	.743**	.764**	.012	.041	-.100*	.737**	.059	.024
	(o)	-.744**	-.736**	-.078	.039	.114*	-.744**	-.053	-.080
	(p)	.733**	.713**	-.024	.045	-.173*	.763**	.127	.067

Note: N = 153 component-level networks; ** : Significant at the .01 level; * : Significant at the 0.05 level (2-tailed)

[a] (a), (e), (i), (m) = Betweenness centralization; (b), (f), (j), (n) = In-degree centralization; (c), (g), (k), (o) = Out-degree centralization; (d), (h), (l), (p) = Global clustering coefficient

Table 2.5 (cont'd)

Tie Type	Socio-Centric SNA Index[a]	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)
Contractual	(a)								
	(b)								
	(c)								
	(d)								
Transactional	(e)								
	(f)								
	(g)								
	(h)								
Professional	(i)	1.000							
	(j)	.163	1.000						
	(k)	.029	.116	1.000					
	(l)	.003	-.182	-.751**	1.000				
Personal	(m)	.013	-.123	-.718**	.683**	1.000			
	(n)	.007	.073	.776**	-.730**	-.750**	1.000		
	(o)	.071	-.122	-.749**	.724**	.671**	-.762**	1.000	
	(p)	-.005	.144	.734**	-.726**	-.717**	.781**	-.712**	1.000

Note: N = 153 component-level networks; **: Significant at the .01 level; *: Significant at the 0.05 level (2-tailed)

[a] (a), (e), (i), (m) = Betweenness centralization; (b), (f), (j), (n) = In-degree centralization; (c), (g), (k), (o) = Out-degree centralization; (d), (h), (l), (p) = Global clustering coefficient

2.5.3 Tests

Before comparing different SNA indices showing significant correlations in Table 2.5, the Shapiro-Wilk test was implemented for normality in them. Seeing all the p-values were less than 0.01 as shown in Table 2.6, the hypothesis that all the indices across different tie types are normally distributed was rejected, which indicates nonparametric tests are called for.

Table 2.6 Normality Test

Socio-Centric SNA Index	Statistic	df	Sig.
(a) Contractual Betweenness Centralization	.957	153	.000
(b) Contractual In-degree Centralization	.947	153	.000
(d) Contractual Global Clustering Coefficient	.943	153	.000
(e) Transactional Betweenness Centralization	.967	153	.001
(f) Transactional In-degree Centralization	.969	153	.001
(j) Professional In-degree Centralization	.956	153	.000
(k) Professional Out-degree Centralization	.932	153	.000
(l) Professional Global Clustering Coefficient	.933	153	.000
(m) Personal Betweenness Centralization	.954	153	.000
(n) Personal In-degree Centralization	.947	153	.000
(o) Personal Out-degree Centralization	.946	153	.000
(p) Personal Global Clustering Coefficient	.965	153	.001

In this regard, Wilcoxon signed-rank test and sign test were used to statistically assess whether there exists any discernible difference within eight sets of highly correlated socio-centric indices. When the distribution is symmetric, the Wilcoxon signed-rank test is used; in other cases, the less powerful sign test can be used when the distribution is highly skewed (Conover 1999). For completeness, both tests were conducted. As shown in the following Table 2.7, the results indicate that there are statistically significant differences between most pairs (except sets 22, 24, and 29) of different socio-centric indices, which validate the first proposition concerning the *different architectural properties of the same supply network with regard to different types of network ties* (i.e. multiplexity).

Table 2.7 Statistical Pairwise Comparisons between Socio-Centric Indices

Inter-Index Relationship Set[a]	p-value (WSR test)[b]	p-value (sign test)[b]	Association (+/−)	R-square (R^2)[c]
Set 1: (b) – (a)	.000**	.000**	+	.621†
Set 2: (f) – (a)	.000**	.000**	+	.558†
Set 3: (f) – (b)	.000**	.000**	+	.511†
Set 4: (f) – (e)	.000**	.000**	−	.029
Set 5: (j) – (d)	.000**	.000**	+	.033
Set 6: (j) – (f)	.000**	.000**	+	.030
Set 7: (k) – (a)	.000**	.000**	+	.565†
Set 8: (k) – (b)	.000**	.000**	+	.567†
Set 9: (k) – (e)	.000**	.000**	−	.026
Set 10: (k) – (f)	.000**	.000**	+	.617†
Set 11: (l) – (a)	.000**	.000**	−	.622†
Set 12: (l) – (b)	.000**	.000**	−	.563†
Set 13: (l) – (f)	.000**	.000**	−	.530†
Set 14: (l) – (k)	.000**	.000**	−	.584†
Set 15: (m) – (a)	.000**	.000**	−	.550†
Set 16: (m) – (b)	.000**	.000**	−	.561†
Set 17: (m) – (f)	.000**	.000**	−	.579†
Set 18: (m) – (k)	.000**	.000**	−	.560†
Set 19: (m) – (l)	.000**	.000**	+	.632†
Set 20: (n) – (a)	.000**	.000**	+	.543†
Set 21: (n) – (b)	.000**	.000**	+	.517†

[a] (a) Contractual Betweenness Centralization; (b) Contractual In-degree Centralization; (d) Contractual Global Clustering Coefficient; (e) Transactional Betweenness Centralization; (f) Transactional In-degree Centralization; (j) Professional In-degree Centralization; (k) Professional Out-degree Centralization; (l) Professional Global Clustering Coefficient; (m) Personal Betweenness Centralization; (n) Personal In-degree Centralization; (o) Personal Out-degree Centralization; (p) Personal Global Clustering Coefficient

[b] **: Significant at the .01 level; *: Significant at the 0.05 level (2-tailed)

[c] †: Coefficient of determination (R^2) ≥ 0.50

Table 2.7 (cont'd)

Inter-Index Relationship Set[a]	p-value (WSR test)[b]	p-value (sign test)[b]	Association (+/−)	R-square (R^2)[c]
Set 22: (n) – (e)	.000**	.015	−	.026
Set 23: (n) – (f)	.000**	.000**	+	.579†
Set 24: (n) – (k)	.260	.518	+	.645†
Set 25: (n) – (l)	.000**	.000**	−	.646†
Set 26: (n) – (m)	.000**	.000**	−	.581†
Set 27: (o) – (a)	.000**	.000**	−	.529†
Set 28: (o) – (b)	.000**	.000**	−	.569†
Set 29: (o) – (f)	.000**	.332	−	.544†
Set 30: (o) – (k)	.000**	.000**	−	.594†
Set 31: (o) – (l)	.000**	.000**	+	.638†
Set 32: (o) – (m)	.000**	.000**	+	.553†
Set 33: (o) – (n)	.000**	.000**	−	.549†
Set 34: (p) – (a)	.000**	.000**	+	.510†
Set 35: (p) – (b)	.000**	.000**	+	.567†
Set 36: (p) – (e)	.000**	.000**	−	.040
Set 37: (p) – (f)	.000**	.000**	+	.591†
Set 38: (p)– (k)	.000**	.000**	+	.575†
Set 39: (p) – (l)	.000**	.000**	−	.520†
Set 40: (p) – (m)	.000**	.000**	−	.595†
Set 41: (p) – (n)	.000**	.000**	+	.527†
Set 42: (p) – (o)	.000**	.000**	−	.592†

[a] (a) Contractual Betweenness Centralization; (b) Contractual In-degree Centralization; (d) Contractual Global Clustering Coefficient; (e) Transactional Betweenness Centralization; (f) Transactional In-degree Centralization; (j) Professional In-degree Centralization; (k) Professional Out-degree Centralization; (l) Professional Global Clustering Coefficient; (m) Personal Betweenness Centralization; (n) Personal In-degree Centralization; (o) Personal Out-degree Centralization; (p) Personal Global Clustering Coefficient

[b] **: Significant at the .01 level; *: Significant at the 0.05 level (2-tailed)

[c] †: Coefficient of determination (R^2) ≥ 0.50

2.5.4 Comparisons

Previous supply network studies using SNA simply compared various SNA indices to interpret the results (e.g. higher or lower). Taking these findings one step further, the present research additionally explores the second proposition on how different socio-centric SNA indices in pairs derived from a directed valued network dataset are related to each other by using scatter plot diagrams with best fit line. The obtained coefficient of determination (R^2) and direction of association of each pairwise set are provided in Table 2.7. A coefficient of determination (i.e. squared correlation coefficient) greater than or equal to 0.50 was considered to indicate a reasonably predictable relationship and the dependence of the paired SNA indices.

First, as shown in Sets 1-3, all three SNA indices (i.e. contractual betweenness centralization, contractual in-degree centralization, and transactional in-degree centralization) are positively associated with one another. These collectively indicate that there exists a particular few firms with more complete contract terms, and specifically, those firms take more of the outside incoming monetary flows (i.e. sales incurred from other network members) than their supply network partners. This observation corresponds well with previous studies which have investigated the effects of information asymmetry on bargaining power. Specifically, it supports the conventional view that more complete contract terms in favor of fewer focal firms provides them with greater leverage to derive more economic benefits from their partners. The next three sets (7, 8, and 10) extend these findings by additionally considering another SNA index, professional out-degree centralization, which measures the extent to which the particular focal firms have more outgoing work-related interactions with other members of the supply network. As commonly observed in all of those three sets, professional out-degree centralization demonstrates positive associations with contractual betweenness, contractual in-degree, and

transactional in-degree centralizations. Taken together these show that the particular focal firms with more complete contract terms and more sales sent out more work-related communications to the rest of the supply network members.

Second, Sets 11-14 describe the interrelationships between the four SNA indices investigated in first six sets (i.e. contractual betweenness, contractual in-degree, transactional in-degree, and professional out-degree centralizations) and professional GCC which measures how freely supply network members communicate with non-adjacent partners about work-related matters. All of the four sets exhibit that there are negative correlations between professional GCC and those four indices. Linking to the previous findings, this shows that the particular focal firms with the more sales and complete contract terms are present only when the supply network has rather hierarchical (i.e. less egalitarian) architecture of work-related interactions with their supply network partners.

Sets 15-19 further extend previous findings by additionally considering another SNA index, betweenness centralization, for non-work-related interactions within the supply network, demonstrating the extent to which there exist particular focal firms with more of those interactions than others. As shown in first four sets (Sets 15-18), the positive interrelationships among contractual betweenness, contractual in-degree, transactional in-degree, and professional out-degree centralizations decrease as the corresponding personal betweenness centralization decreases. This signifies the particular focal firms with positive interplays among more complete contract terms, sales, and outgoing work-related interactions cannot enjoy those synergies when there are more firms which have similarly equal amount of non-work-related interactions with their supply network counterparts. In addition, Set 19 shows that personal betweenness centralization and professional GCC have a positive correlation. This illustrates there can still

exist particular focal firms with more non-work-related interactions even when the supply network as a whole has more lateral (i.e. more egalitarian) architecture of work-related interactions among members. Interestingly, this corroborates the first research proposition by confirming that two invisible network ties (i.e. professional and personal interactions) can be compatibly embedded within the same supply network while holding different network properties.

The next five sets (Sets 20, 21, 23, 25, and 26) show the interrelationships between personal in-degree centralization and the five SNA indices which demonstrated a statistical significance (i.e. contractual betweenness, contractual in-degree, transactional in-degree, personal betweenness centralizations, and contractual GCC). Sets 20, 21, and 23 show the positive relatedness of contractual betweenness, contractual in-degree, transactional in-degree centralizations still holds as personal in-degree centralization increases. This means that the particular focal firms with more complete contract terms and sales also possess more incoming non-work-related interactions than others. However, the more incoming non-work-related interactions those firms have, the less professional GCC and professional betweenness centralization scores they exhibit (See Sets 25 and 26), which collectively implies that: 1) focal firms have more outside incoming non-work-related flows on non-work-related matters when they have more indirect work-related communications with other network members (i.e. under more hierarchical professional network architecture), and 2) focal firms' high control level of work-related interactions may actually discourage their network partners from sending out more non-work-related interactions.

The next six paired sets (Sets 27, 28, 30, 31, 32, and 33) further extend previous findings by considering another index, personal out-degree centralization, which demonstrates the extent

to which particular focal firms have more outgoing non-work-related flows. In line with our previous findings, Sets 27, 28, 30, and 33 illustrate negative associations between personal out-degree centralization and four other SNA indices (i.e. contractual betweenness, contractual in-degree, and professional out-degree, and personal in-degree centralizations). These additional findings collectively signify that: 1) the particular focal firms which already have more complete contract terms and more outgoing work-related interactions are less motivated to generate non-work-related interactions for the rest of the supply network members, and 2) this declining motivation for more outgoing non-work-related flows still holds even when focal firms have more incoming non-work-related flows (i.e. no reciprocal exchange). Sets 31 and 32 do rather stretch the second implication by showing that particular focal firms send out more non-work-related flows when the overall supply network has a more lateral communications architecture of work-related interactions.

Lastly, this study investigated the correlations between personal GCC and other network indices with statistically significant predictabilities. The first four sets (Sets 34, 35, 37, and 38) go on to show positive associations with personal GCC that describes the extent to which all the supply network members freely communicate non-work-related matters across firm boundaries. The sum of these findings highlights the double-edged effects of tightly knitted non-work-related interactions within supply networks which result in that particular focal firms acquire more sales as well as less favorable (i.e. more complete) contract terms as they create more work-related communications. It alludes to an interesting aspect that contractual and transactional inter-firm exchanges are more associated with personal ties between supply network partners, rather than professional ties. This hint is further supported by Set 39 illustrating a negative correlation between the personal and professional GCCs. The previous finding on non-reciprocities of non-

work-related interactions is also reaffirmed by Sets 41 and 42 which denote that the more incoming non-work-related interactions particular focal firms have, the less of them are returned to the remaining network members even when the overall supply network has a more lateral (i.e. more egalitarian) architecture. This may reflect: 1) the non-work-related exchanges are being regarded as one of the most valuable resources within supply networks, and hence 2) firms are not willing to share them with others despite the network as a whole being characterized by relatively limited variations of non-work-related interactions.

2.6 Discussion

2.6.1 Contributions

Previous SCM studies have mainly focused on dyads (i.e. buyer-supplier) or triads (i.e. buyer-supplier-supplier) between supply chain partners. Although those approaches have enhanced our understanding of the exchanges occurring between a buyer and its immediate supplier(s), they have suffered from the restrictive scope to grasp the whole picture of supply network comprising *multiple tiers* of supply chain partners (Choi and Kim 2008; Wilhelm 2011). A few recent works have adopted a network perspective to the SCM context; but they have fallen within limited domains such as conceptual frameworks and descriptive case studies without further empirical substantiation. Drawing upon socio-centric SNA indices, this study collected and analyzed primary data to examine component-level supply network architectures, and consequently it makes important contributions from both theoretical and practical standpoints.

To the best of the author's knowledge, the present work is the first empirical study which discusses how the overall network architecture consisting of same supply chain partners vary depending on different types of supply network ties considered (i.e. *multiplex supply network perspective*). Adding to previously investigated visible interorganizational ties (i.e. contractual

and transactional ties), this study incorporated the invisible dimensions (i.e. professional and personal ties) into supply network analyses to fully explore the invisible dynamics between supply chain partners. All previous supply network studies to this point have investigated the aforementioned ties separately under the untested assumption of uniplex supply network. Nonparametric tests show that there exist statistically significant differences among different network tie types, which supports the multiplex properties of supply networks. Specifically, it is found that more specific or complete contracts between supply chain partners are not necessarily associated with more transactions. The more interesting finding is that interfirm network transactions possess a higher association with personal network ties rather than contractual or professional ties exhibiting the same pattern in the rank order of socio-centric SNA indices. These results collectively confirm interorganizational networks between supply chain partners are *multiplex* and thus call for a multidimensional (rather than uni- or bi-dimensional) approach in trying to analyze and understand supply chain dyads, triads, and/or supply networks.

This essay also provides meaningful hints to the question of why even firms seemingly have outstanding buyer-supplier relationships still (sometimes) fail to maximize the network benefits from their supply chain partners or are vulnerable to external shocks. Social network studies have suggested that multiplex networks are stronger and more durable than uniplex ones as network actors have multiple bases of interaction (Morin and Seidman 1986; Wellman and Wortley 1990). In most of the previous SCM literature, however, different types of interfirm relational ties have either been investigated in separate research models or been lumped together under the same research construct such as buyer-supplier relationship strength or engagement. Either approach can prevent academics from recognizing the existence of network multiplexity and consequently mislead practitioners into believing that they are doing great work in managing

their supply networks. As noted in the introduction, the examples of Japanese automakers after the 2011 earthquake and tsunami offer additional evidence that existing measures of buyer-supplier relationship focus only on a specific tie and thus cannot be directly applied for a supply network which is essentially multiplex in nature. In a practical sense, the findings in this study urge the SCM practitioners to view and manage their supply network not as a simple collection of multiple buyer-supplier relationship but a more complex combination of multiplex interfirm ties.

Managing multiplex networks is considerably more complex in that actors embedded in the same network will perceive the overall network architecture differently (Kim et al. 2006; Shipilov and Li 2012). In a supply network context, this perception discrepancy can give rise to divergent incentives among network partners and consequently hinder the supply network itself from achieving full cooperative outcomes. The current study thus explored the interrelationships between different socio-centric SNA indices in an attempt to provide a foundation for future research about multiplex supply network management. The results of pairwise comparisons generated some interesting observations. For example, showing that particular focal firms can have more incoming flows of professional supply network ties when they give more favorable contract terms to their counterparts; at the same time, they do not have to build stronger professional ties with their supply chain partners if the power across the network is not equally distributed nor concentrated (See Section 2.5.4 for more detailed findings of pairwise comparisons). The empirical findings confirm that no single universal indicator can fully describe the multi-faceted supply network; rather, different network tie types work interdependently in shaping different supply network architectures. This essay offers a draft set of practical guidelines suggesting that SCM practitioners need to consider both the visible

interorganizational and invisible personal exchanges encompassing non-immediate supply chain partners to better understand and design supply network architectures. For instance, some notable invisible network phenomena are brought to light, such as: 1) network members interact with one another on non-work-related matters even when they mostly do not share any other network ties, 2) invisible network ties can be compatibly embedded within the same supply network while holding different network properties, 3) focal firms send out more non-work-related flows when the overall supply network has a more lateral communications architecture of work-related interactions, and 4) non-work-related changes are the most valuable network resource in supply network context.

This study also provides unique methodological contributions. To respond to repetitive calls for applying SNA approach to the SCM context, two more realistic and rigorous network approaches were adopted in the present work: *directed valued network* and *whole network* approaches. First, while the widely-used binary network approach relies on counterintuitive premises that all ties are completely homogeneous and symmetrical, directed valued network approach has definite advantages in grasping network phenomena by considering both directions and strengths of network ties (Wasserman and Faust 1994; Freeman 2004). However, the latest developments in directed valued network indices have, to the author's knowledge, not yet been applied in existing supply network literature. To draw out the fullest grasp of the primary data collected from a survey of 153 component-level supply networks, the present work analyzed and compared socio-centric SNA indices defined for directed valued network. Second, the whole network approach was also used to clarify potential problems related to arbitrary supply network boundaries that depend on a focal firm's perception. Lastly, the current study illustrated supply network phenomena in a statistically testable form by using individual supply network as a unit

of analysis. Existing interfirm network literature has highlighted that system-level analyses employed in this study provide more grounded insights about network phenomena (Mizruchi and Marquis 2006; Galaskiewicz 2011). Our findings show that those analyses can complement or even substitute the previous findings of case-based or local-level supply network research.

2.6.2 Limitations and Directions for Future Research

Given the exploratory nature of empirical supply network research, a few limitations should be noted in ways that represent opportunities for future work. First, four different types of network ties examined in this study are not exhaustive. Although this does not curtail the contributions related to the existence of supply network multiplexity, a few additional tie types can be taken into consideration. One interesting example is knowledge exchange among supply network partners. Based upon the tenets of resource-based view, firms gain access to complementary or synergistic knowledge by forming and managing alliance networks (Inkpen and Tsang 2005; Phelps 2010). Strategic alliance literatures have extensively characterized such knowledge as independent versus systemic (Garud and Nayyar 1994), individual versus collective (Spender 1996), architectural versus component (Matusik and Hill 1998), experiential versus articulated (Simonin 1999), etc. By additionally considering the acquisition or transfer (i.e. tie direction) and effectiveness (i.e. tie strength) of interfirm knowledge, future studies could provide additional evidence that a supply network possesses multiplex architectural properties. Further, it may be valuable for future research to investigate interrelationships among various SNA indices by incorporating different knowledge, resource, market, and/or technology types.

Second, the current study does not utilize all available socio-centric SNA indices in describing network architectures. This limitation comes from the setting of this study: an empirically substantive investigation of directed valued supply networks. For instance, network

density defined as the ratio of the actual number of ties out of the maximum number of ties possible, is useful in describing the connectedness among network members, but at the same time suffers from its dependence on network size (Scott 2000). In general, the bigger the supply network (in which there are more suppliers), the lower the network density. The measure was thus excluded from the analysis to insure rigorous statistical inference. In addition, despite the surging need for directed valued network approach, an overwhelming majority of existing SNA indices is solely defined for non-directional and binary networks. It therefore will be worthwhile for researchers to incorporate future methodological developments in quantifying architectural properties of directed valued supply networks.

Finally, future researchers may find it interesting to expand this perspective to examine antecedents and performance implications of supply network multiplexity. In certain respects, the field of sociology views the emergence of social networks – the collection of interpersonal ties – as social and psychological phenomena occurring among non-predetermined individuals through face-to-face conversations (Tienda and Rajman 2001). In contrast, corporate managers behave as *network architects* by defining the objectives and designating member companies of the network, and their ability to coordinate the complex network of multiple inter-organizational ties is regarded as having a significant impact on the success of a firm (Hinterhuber 2002; Pollock et al. 2004; Fjeldstad et al. 2012). A multiplex supply network, in this regard, can be viewed as an intentionally and strategically designed outcome to enhance network actors' performances. Although no unified framework for network-level performance measurement has yet emerged, such an extension of the current study also could serve as a starting point for future investigations on the role of network multiplexity in maximizing a focal firm's network benefits

from its supply chain partners and for designing a robust network for dealing with supply network risks.

In conclusion, the focus of this essay is to present a multiplex supply network perspective and investigate the corresponding interrelationships between network architectural properties in the way of empirical substantiation. Hopefully, the findings here provide the basics for verifying whether the current knowledge on supply chain dyads/triads still holds in a supply network setting, which will eventually advance understandings of multi-faceted supply network phenomena.

3 MOVING BEYOND SERENDIPITY: HOW SUPPLY NETWORK ARCHITECTURE BECOMES STRATEGIC

3.1 Introduction

The first principle of architectural beauty is that the essential lines of a construction be determined by a perfect appropriateness to its use. — Gustave Eiffel

A firm's network consists of multiple interfirm relationships among two or more partners that voluntarily provide, exchange, or share their value-adding activities or specialized resources to co-develop products, technologies, or services (Gulati 1998; Podolny 2001). Faced with the changes in a business environment where the coordination of complex global networks of a firm's activities is becoming a prime source of competitive advantage (Porter 1998), more supply chain management (SCM) studies have paid increasing attention to the supply network which involves simultaneous interactions among multiple supply chain entities rather than dyadic or triadic ties between one OEM and its immediate supplier(s) (See Table 2.1 for more detail regarding the development stages of supply network research). The term "network" is often regarded as relatively new to SCM researchers, but it has long been associated with the concept of SCM. Cooper and Ellram (1993) called SCM an "integrative philosophy", and Mentzer et al. (2001) acknowledged its objective is "to integrate and manage the sourcing, flow and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers." Therefore, a supply chain is an excellent example of a multi-level complex system which has a strict *architecture* in that it includes "coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers" (Gibson et al. 2005).

Network thinking and analysis were originally regarded as a subtype within the general framework of structural sociology (Wellman 1988). In certain respects, the field of sociology viewed the emergence of networks – the collection of interpersonal ties (e.g. kinship, friendship, communication, co-membership, etc.) – as social and psychological phenomena occurring among non-predetermined individuals through face-to-face conversations, and this view has been widely adopted by other social science disciplines industrial relations. Corporate managers, however, behave as *network architects* by defining the objectives and designating member companies of the network (Hinterhuber 2002; Pollock et al. 2004; Fjeldstad et al. 2012). In this vein, business academics have explored a quite different logic that firms intentionally engage in multiple interfirm alliances, and subsequently formulate networks to achieve their strategic goals. This research stream has been developed into the network strategy which investigates *how* a firm can manage its portfolio of multiple simultaneous alliances (e.g. Parise and Casher 2003; Hoffmann 2007; Wassmer 2010), yet an important question still remains unclear: "*what* determines different network architectures" (Brass 2002); in other words, what are the strategic antecedents of network properties. Anchoring on a strategic network perspective emphasizing the importance of network design in achieving a firm's strategic objectives (Gulati et al. 2000); Doreian (2002) gives a hint towards the existence of antecedents of network architecture by asserting that "networks have instrumental character for network members as these members have structured goals and some goals are achieved through network choices" as the "first principle" of network formulation.

In the above vein, SCM researchers and practitioners have also conjectured the existence of antecedents for heterogeneous supply network architectures. For instance, facing a turbulent business environment, firms need to build and maintain multiple supply bases (Lee 2002) which

are "the portion(s) of the (bigger) supply network that is within the managerial purview of the focal company" (Choi and Krause 2006). While it is obvious that the strategic network perspective should be considered as an integral component of theory in SCM in which researchers should consider multiple entities commonly composed of large numbers of firms from multiple interrelated industries, empirical SCM research has confined itself to simple descriptions on supply network characteristics. The lack of such consideration – antecedents of network formulation – may give misleading answers about how different supply networks across various contexts should be managed. Goal conflicts are also more likely to arise in the supply network setting essentially consisting of multiple tiers of legally separate profit-making organizations with their own strategic goals; in other words, an OEM cannot attain supply chain success without deliberately designing its entire supply network in accordance with different strategic intents. In exploring supply network phenomena, therefore, it is too naïve to rely upon the sociological viewpoint, which characterizes network in terms of spontaneous and informal face-to-face conversations among non-predetermined individuals. Rather, a supply network should be viewed as a *systematic outcome which is intentionally and strategically designed, implemented, and maintained in conformity with the OEM's strategic intent(s)*.

In line with this argument, this essay attempts to address the theoretical and empirical gap of supply network research by exploring the unknown strategic antecedents of different supply network architectures. Specifically, it looks into the following questions: 1) Are an OEM's strategic intent choices associated with supply network architecture; and 2) If so, what differential effects do those strategic intents have on what architectural properties of the supply network. In doing so, Fisher (1997)'s supply chain design considerations (i.e. cost leadership and market responsiveness) are taken into account as OEMs' two major strategic intents. Drawing

upon a unique dataset which allows analyses of multiple directed valued supply networks, this research sheds lights on the unresolved question of the supply network antecedents in a directed valued network setting and, consequently, offers a *strategic supply network perspective*. The remainder of this study is structured as follows. Section 2 provides the theoretical background and develops the hypotheses. Section 3 reviews the data, measures, and research methods used to test the proposed hypotheses. Section 4 provides the key results and interpretations. In section 5, further field investigations were conducted to provide further insights to the quantitative and qualitative findings from the previous section. Section 6 discusses the theoretical and methodological contributions of this research, followed by section 7 which includes limitations as well as directions for future research.

3.2 Theoretical Background and Hypotheses

3.2.1 Network Resource and Strategic Intent

Many sociologists traditionally viewed the emergence of social networks as outcomes of spontaneous and informal face-to-face conversations among non-predetermined individuals (Tienda and Rajman 2001). On the other hand, a stream of strategic alliance literature has adopted a different view that firms *utilize* strategic alliance to access partners' knowledge or skills (Mowery et al. 1996), to hedge their performance risk (Das and Teng 1999), or to enter a certain foreign market (Zahra et al. 2000) within interfirm dyad settings. This view has been anchored in the network resource theory (also known as social resource theory), which is one of the most popular theories in social network research. The theory, mainly developed by Lin et al. (1981), argued that interpersonal contacts enable better access to and mobilization of resources embedded within and outside one's social network such as valuable information and prestigious

others (Bourdieu 1985; Coleman 1988). Combined with interfirm network settings and environments, however, comparatively less is known about what specific motives drive network actors to interact with one another when the consequences of building an interpersonal or interfirm network are widely investigated.

The concept of strategic intent initially suggested by Hamel and Prahalad (1989) has been useful throughout various business disciplines in accounting for managerial motives behind the strategic alliance or joint venture formulation. While a vision is commonly developed and held by top management teams, strategic intent is more than just a vision or ambitious target of top management in that it is shared and implemented at *multiple* levels of the organization that are similar to SCM settings (Hart 1992; Hamel and Prahalad 1994). For instance, Koza and Lewin (1998) proposed a framework emphasizing a firm's strategic partnership structure varied by its strategic intent (exploitation or exploration). DiRomualdo and Gurbaxani (1998) also highlighted the importance of alignment between the strategic intent and supplier relationships to achieve outsourcing success. Ryall (2013) more recently espoused this view by addressing that an OEM should utilize different strategic intent (competitive or persuasive) in garnering the resources and capabilities possessed by non-immediate members of its value network. Extending the aforementioned conceptual arguments to the SCM domain, the OEM's strategic intents may serve as pivotal reference points for managing its supplying partners across multiple tiers which result in different architectural properties of the formed supply network. Very little empirical research, however, has been done to test this conjecture. This essay investigates strategic antecedents of different supply network architecture by incorporating Fisher's (1997) supply chain design considerations (i.e. cost leadership and market responsiveness) as shown in Figure 3.1, and as a result, aims to provide a *strategic supply network perspective*.

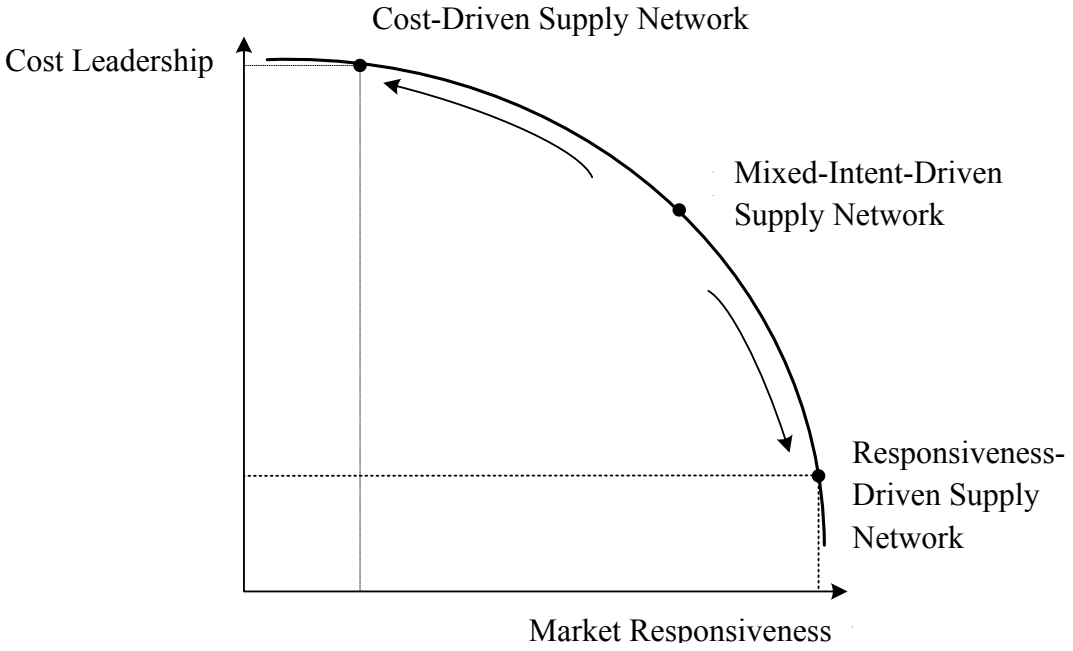


Figure 3.1 Strategic Intents and Corresponding Supply Network Types

3.2.2 Supply Network Tie Types

Ties across interfirm network serve as conduits for network actors to access, transmit, or exchange critical organizational resources (Ahuja 2000a; Adler and Kwon 2002; Zaheer and Bell 2005; Soda and Zaheer 2012). Interestingly, the same supply network can have multiple different architectural properties with regard to types and attributes of network ties (i.e. network resources), which is commonly referred as "multiplexity" (Verbrugge 1979; Burt 1980; Feld 1981; Ibarra 1992). Thus, in accounting for interfirm network phenomena such as supply networks, it is essential to take a network multiplexity approach for finding "hidden" network architectures. This study considers four different supply network tie types – contractual, transactional, professional, and personal ties – which interlink across supply network partners. The first two types represent *visible* network ties for exchanging tangible network resources such

as goods and services, whereas the other two capture *invisible* (and mostly intangible) network resources exchanged between supply network partners.

Obviously, a supply network consists of visible ties such as a contract or delivery and receipt of goods and services (Choi and Hong 2002; Kim et al. 2011). Contractual ties mostly comprise detailed information on interfirm transactions by defining the guidelines for the operational requirements, quality monitoring and control, warranty policies, penalties, and expected service level. Another type of visible network ties considered is a transactional tie reflecting the amount of monetary exchanges which have been regarded as a simple but clear manifestation of the economic transactions occurring within interfirm networks. This tie represents the economic interdependence between network members. In other words, a buying firm gets more dependent on the supplier as the percentage of its total spend to a specific supplier relative to other suppliers increases while the same occurs to the supplier when more percentage of its total sales comes from a specific buying firm relative to others. As the most fundamental element of economic exchanges between supply chain partners, a contractual tie (i.e. a formal written contract between one supply network actor's sourcing partner) has conflicting natures which can foster or hinder commitment between buyers and suppliers (Dyer and Singh 1998; Cannon et al. 2000). For instance, a stronger contractual tie (i.e. more complete contract) including explicit work-related provisions and prescriptions can protect buyers from opportunistic behavior of their counterpart (Williamson 1985). On the contrary, from a supplier's standpoint, a strong contractual tie specifying more control and legal rules can serve as a threat when buyers opportunistically utilize it by imposing terms and conditions that are unreasonably difficult to comply with for the supplier (Ghoshal and Moran 1996; Woolthuis et al. 2005). In this vein, a transactional tie (i.e. the actual exchange of goods and services) can be established

without a formal written contract when both parties share relational norms such as reciprocity, solidarity and information sharing (Williamson 1993; Poppo and Zenger 2002; Lazzarini et al. 2004). This study thus regards the above two visible supply network ties (i.e. contractual and transactional ties) as separate types in which a stronger contractual tie does not necessarily imply more or less economic transactions and vice versa.

Prior network research has pointed out much of interorganizational commitment is often formalized at a personal rather than organizational level and, hence, can offer exclusive access to network resources (Brass and Krackhardt 1999; Gulati 2007; Kleinbaum and Stuart 2014). However, interpersonal and thus invisible ties in supply networks has received relatively less research attention whereas visible network ties representing economic exchange have been actively discussed in the literature. This study thus additionally considers two invisible network ties (i.e. professional and personal ties) bridging the supply chain personnel of partnering firms. Professional ties are normally task-oriented and focus on achieving assigned objectives, while personal ties deal more with the social/emotional side of non-work-related interactions and focus on the interpersonal likeability (Lewicki and Wiethoff 2000; Grayson 2007). In an SCM context, such invisible ties between purchasing and supply managers play a crucial role in facilitating buyer-supplier cooperation, trust, reputation and image and subsequent organizational performance (Zaheer et al. 1998; Stanley and Wisner 2001; Ireland and Webb 2007; Lindgreen et al. 2013). When incorporated with social network analysis, this consideration further enables the inter- and intra-comparisons of different tie types and comparable network indices and consequently can provide invaluable insights concerning the underlying network architecture (Borgatti et al. 2009; Borgatti and Li 2009). Table 2.2 provides conceptual definitions of the four

supply network tie types under consideration and their measurement items used based on the literature.

3.2.3 Indices for Network Characterization

To demonstrate different supply network architectures consisting of the four aforementioned heterogeneous supply network ties (i.e. contractual, transactional, professional, and personal ties), this study adopts social network analysis (SNA) which has long been used in analyzing any social network as a set of interrelated actors and ties. The field of SCM has stressed the potential applicability of SNA in a supply network context. For instance, Carter et al. (2007) proposed SNA as a key approach to advance current knowledge on various relationships existing within and beyond the supply chain by complementing traditional methodologies. This view was echoed by Borgatti and Li (2009) who pointed out that supply chain settings are particularly suitable to adopt SNA indices, which have been proven "highly portable" across other disciplines from economics to physics. More recently, Galaskiewicz (2011) also noted that SCM theories mostly captured at the local level (e.g. dyad or triad) can be tested by using a supply network as the primary unit of analysis. The present study adopts the *directed valued network* approach which considers both direction and strength (or magnitude) of the network tie between different network actors (See section 2.3.2 for more details).

More specifically, this study focuses on four *socio-centric* network indices (i.e. betweenness centralization, in-degree centralization, out-degree centralization, and global clustering coefficient) which analyze the overall pattern of multiple actors within a single, bounded network. While *ego-centric* indices such as centralities deal with a particular actor (i.e. ego)'s position within the network, they provide a better understanding of the directed valued network in that the network architecture from one ego's viewpoint can be markedly different

from those of others linked directly or indirectly (Scott 2000; Marsden 2002). They also perfectly fit with the purpose of this essay to explore the association between an OEM's strategic orientation and its supply network architecture corresponding to different types of supply network ties. Table 2.3 proposes a new framework of supply network implications of the socio-centric SNA indices for directed valued networks used in this study for four types of supply network ties. Please refer to the section 2.3.2 for more details on computing those indices.

3.2.4 Hypotheses

A firm has a power advantage when it is relatively less dependent upon the resources of its counterpart(s), and it often leverages this power over others to achieve intended strategic goals (Pfeffer and Salancik 1978; Dyer and Singh 1998). Social network studies have adopted betweenness centrality to measure an individual actor's power, and the extent to which it controls the resource flows in its network. As a socio-centric measure indicating the variation of the betweenness centralities of all network actors, betweenness centralization characterizes to what extent the overall network is built around a particular group of actors serving as hubs relative to the rest of the network (Freeman 1979; Scott 2000). A low betweenness centralization score represents that the network resources running through various tie types are almost equally distributed across the entire network, whereas a high score indicates that there exist particular focal firms possessing more network resources in it. This measure can be differently interpreted by different supply network tie types. For instance, an OEM pursuing a cost leadership will try to make supply contracts as complete and detailed as possible to reduce any uncertainty, which may translate into cost savings (Lacity and Willcocks 1998; Ghosh and John 2005) and as a result, will induce the unequal completeness of contracts among supply network members. On the other hand, the lack of predictability of market changes prevents OEMs in designing complete supply

contacts when they pursue market responsiveness, and this will result in cooperative but loose contracts containing rather general information (Shrader 2001; Wathne and Heide 2004). Regarding transactional ties, an OEM can exploit economies of scale by focusing on a relatively small number of supply network members when it pursues a cost leadership, whereas it diversifies its supply/purchasing sources as a means of promptly responding to unexpected market changes. This difference is also reflected for the supply networks consisting of professional and personal ties. In other words, the supply network personnel devoted to the low-cost focused strategy may tend to interact with a smaller range of counterparts, while the other leads to professional and personal interactions among a broader array of them. Personal and professional ties in a market responsiveness focused supply network, especially, might be expected to lead to more frequent interactions involving a greater number of actors because it is not a stable environment. Under such environment, information seeking and problem solving behaviors can be expected to dominate leading to greater interactions with more number of network partners. Based on this line of reasoning, the following set of hypotheses is proposed:

HYPOTHESIS 1A. *An OEM's strategic intent of pursuing cost leadership is positively associated with the betweenness centralizations of its supply networks consisting of contractual, transactional, professional and personal ties.*

HYPOTHESIS 1B. *An OEM's strategic intent of pursuing market responsiveness is negatively associated with the betweenness centralizations of its supply networks consisting of contractual, transactional, professional and personal ties.*

A firm with more power over their counterparts also can more easily draw and absorb network resources from the rest of its network by exerting coercive or punitive pressure, and consequently can achieve its strategic goals (Ahuja 2000b; Das and Teng 2000). In social

network research, this power of an individual network actor is commonly measured by in-degree centrality, which represents the total number of ties pointing toward the actor. In-degree centralization, derived by the variation in individual actor's in-degree centrality at the network level, indicates to which extent network resources are concentrated in particular actors (Wasserman and Faust 1994). From a supply network perspective, an OEM trying to achieve cost leadership characterized by pursuing economies of scale will have network architecture with a relatively small group of members which brings in more transactional, professional and personal inflows from the rest of the network. The one seeking market responsiveness, in contrast, will try to hedge against unexpected market changes using diversification strategy, and as a result will have supply network architecture demonstrating relatively equal distributions of transactional, professional and personal inflows across network members. The supply network in-degree centrality accounting for contractual ties may need more cautious interpretation because complete contract terms can impose institutional constraints on interorganizational transactions (Salamon 1987; Lutz 1995; Bassok and Anupindi 1997; Lawrence 1999). The more inflows of complete contracts (i.e. high in-degree centrality) thus indicate that the network actor pulls away the less favorable (or more restrictive) terms and conditions from its counterpart(s). In this sense, OEMs which need tight cost controls may build supply networks where a few focal firms take up more favorable (i.e. less complete) contracts showing low in-degree centralization, whereas their strategic intent of achieving market responsiveness drives the opposite consequence (i.e. supply network members have mutually favorable – that is, equally complete – contracts with others). The preceding discussion leads to the following hypotheses:

HYPOTHESIS 2A. *An OEM's strategic intent of pursuing cost leadership is positively associated with the in-degree centralizations of its supply networks consisting of*

transactional, professional and personal ties, while being negatively associated with the ones consisting of contractual ties.

HYPOTHESIS 2B. *An OEM's strategic intent of pursuing market responsiveness is negatively associated with the in-degree centralizations of its supply networks consisting of transactional, professional and personal ties, while being positively associated with the ones consisting of contractual ties.*

In addition, a firm may relax its own institutional constraints on other exchange partners expecting reciprocal behavior, which eventually helps to achieve its strategic goals (Uzzi 1997; Larsson et al. 1998). This is true especially when both parties have complementary resources to each other or similar sources of uncertainty, and can provide more useful feedbacks to refine their own efforts for their own benefits (Oliver 1991; McEvily et al. 2000). Companies such as Dell and Whirlpool, for example, were transformed to "virtually integrated" organizations by sharing their information and knowledge on inventory level and sales forecasting with other supply network members. A network actor's use of this kind of influence on its exchange partners has been measured by out-degree centrality which denotes the number of network ties originating from the actor. As a socio-centric measure indicating the variation of the out-degree centralities of the entire network actors, out-degree centralization explains the extent to which particular actors distribute transactional or relational network resources to others (Wasserman and Faust 1994). In other words, a high out-degree centralization score indicates that a few particular focal firms disseminate most of the transactional or relational network resources for the rest of the members, whereas a low score represents that each member of the network has a more equal amount of those resources. This measure would be differently interpreted by each type of supply network tie. For instance, when OEMs seek cost leadership, their supply networks

will have the architecture which has small group of firms that send out more complete (i.e. less favorable) contract terms and more amount of monetary exchanges for the rest of the network. They will not be much interested in establishing reciprocal professional and personal ties since those relationship-specific investments can increase switching cost as well as prevent their search for lower cost suppliers (Celly et al. 1999). On the other hand, the ones pursuing market responsiveness will be more willing to initiate more professional and personal interactions with other network partners to detect potential market changes while maintaining a balanced approach for contract completeness and transaction amount. This reasoning leads to the following two hypotheses:

HYPOTHESIS 3A. *An OEM's strategic intent of pursuing cost leadership is positively associated with the out-degree centralizations of its supply networks consisting of contractual and transactional ties, while being negatively associated with the ones consisting of professional and personal ties.*

HYPOTHESIS 3B. *An OEM's strategic intent of pursuing market responsiveness is negatively associated with the out-degree centralizations of its supply networks consisting of contractual and transactional ties, while being positively associated with the ones consisting of professional and personal ties.*

Direct contacts and connections between a firm and its customers/suppliers also facilitate the exchange and distribution of organizational resources, and subsequently contribute to the strategic goals and competitive advantage of the involved actors (Porter 1990; Morgan and Hunt 1999). For instance, Japanese automobile manufacturers such as Toyota and Nissan have endeavored to maintain direct connections with non-immediate suppliers by means of different supplier associations and considerable owner interests in their suppliers (Cusumano 1985; Dyer

1996). Those efforts enabled them to overview the whole supply networks by supplementing the potential shortcomings of hierarchical supply network, characterized by a reliance on a limited number of first-tier suppliers. In social network research, this connectivity among network actors has been measured by global clustering coefficient which means, in plain terms, the probability that the friend of John's friend is also John's friend. More formally, this index indicates the extent to which how cliquish (or tightly knit) a network is as a whole (Newman 2003; Schank and Wagner 2005). A low global clustering coefficient represents that only a few network actors are directly connected to one another which results in hierarchical (i.e. more cliquish) architecture as a whole, whereas a high coefficient value indicates more actors have direct connections with others collectively manifesting lateral (i.e. less cliquish) network architecture. From a supply network perspective, an OEM's intent to acquire cost leadership will drive itself to build a hierarchical supply network which allows for easier and more thorough control on a limited number of major suppliers. The one interested in achieving market responsiveness, on the other hand, will try to establish direct connections as many down-tier suppliers as possible in order to perceive and respond to changing market circumstances, which subsequently leads to lateral supply network architecture. Accordingly, this essay investigates the following set of hypotheses:

> HYPOTHESIS 4A. *An OEM's strategic intent of pursuing cost leadership is negatively associated with the global clustering coefficients of its supply networks consisting of contractual, transactional, professional and personal ties.*
>
> HYPOTHESIS 4B. *An OEM's strategic intent of pursuing market responsiveness is positively associated with the global clustering coefficients of its supply networks consisting of contractual, transactional, professional and personal ties.*

3.3 Methodology

3.3.1 Data

Given the interests of this study, a quantitative method of survey-based questionnaire was employed to collect the data about an OEM's *component-level* strategic intent and the direction and strength of ties among all supply network partners involved to supply the selected component. A single product is mostly built up by incorporating a mix of functional and innovative components (Huang et al. 2002; Vonderembse et al. 2006), and on this account a few but notable studies such as Huang et al. (2005) and Kim et al. (2011) have used the component- (or module-) level supply network investigation. In collecting network data, the boundary of each component-level supply network should be firstly specified in order to avoid potential distortions in describing overall network architecture (Choi et al. 2001; Cross and Parker 2004; Luke and Harris 2007). Initial OEM (i.e. tier-0) contacts mostly at the executive level, were thus asked to select a strategically important component with *manageable* network sizes (i.e. no more than 3 tiers and 5 suppliers per tier) and recommend the most knowledgeable sourcing manager in charge of the selected component. This step also contributed to minimize key informant bias (Kumar et al. 1993). Next, a combined sampling approach of *fixed list* and *snowball selections* was adopted based on the selected components (Doreian and Woodard 1992; Stevenson and Greenberg 2000; Borgatti and Li 2009). The recommended sourcing managers were asked to evaluate their perceptions on different types of ties (i.e. contractual, transactional, professional, and personal) with their major immediate suppliers mostly listed as the OEM's preferred supplier. The same questions were given to the OEM's counterparts (i.e. tier one suppliers) based on the contact information provided by the OEM's sourcing manager, and this dyadic data collection process was repeated for the successive tiers of suppliers (i.e. tier two and tier three suppliers)

until end-tier suppliers were reached. To check the existence of duplicate network partners, surveys on lower-tier suppliers were started after finalizing all the surveys on their immediate upper-tier buyers. The overall data collection process is illustrated in the flow chart in Figure 3.2. As a result of these efforts, a total of 153 component-level networks of three major South Korean automobile and consumer electronics manufacturers consisting of 1,852 total network members were collected. Table 3.1 presents the demographics and descriptive statistics of the study population.

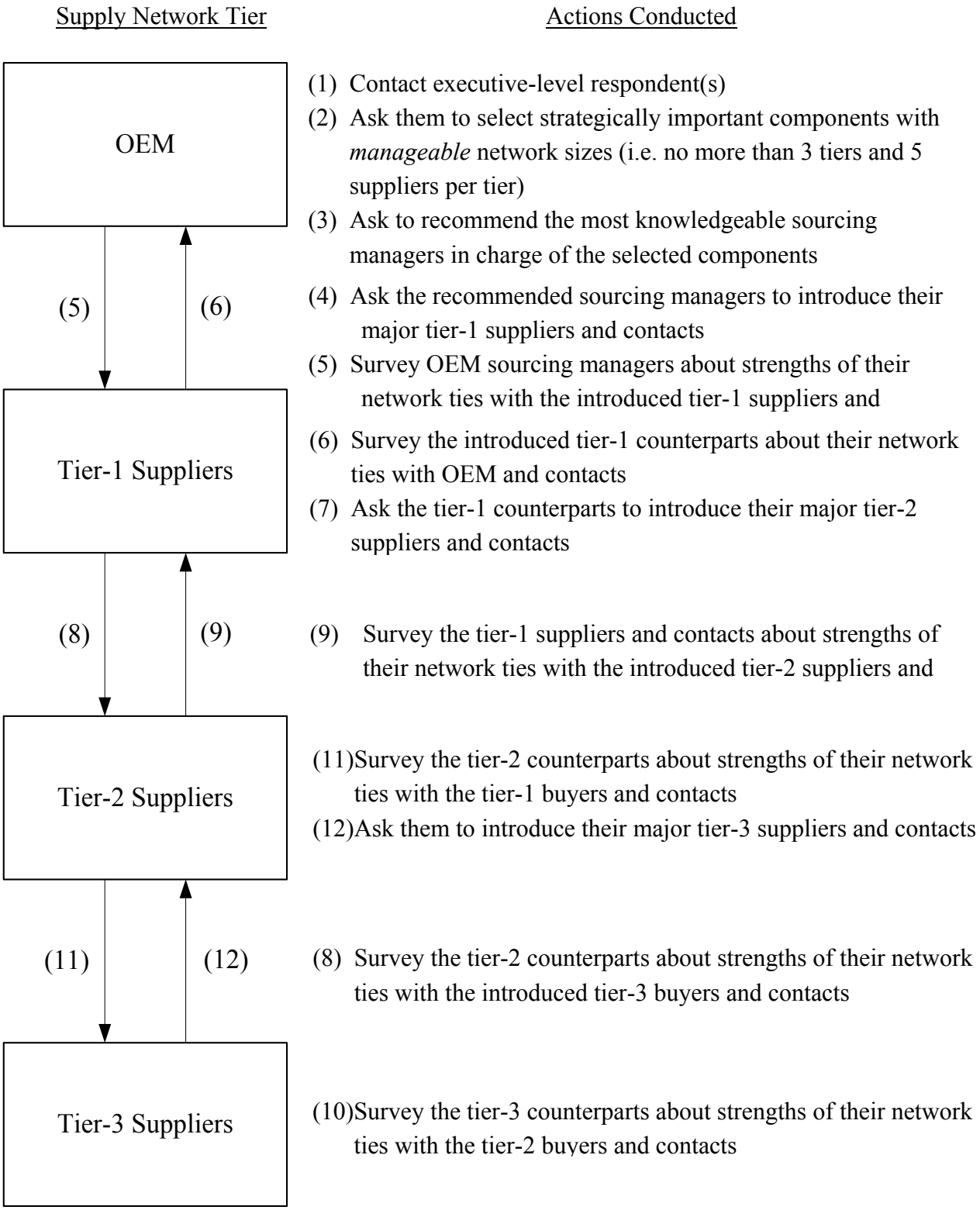


Figure 3.2 Data Collection Process

Table 3.1 Sample Demographics and Descriptive Statistics

Supply Network Tier Level	Number of Employees[a]	N	Average Sales (Million USD)[a]	Respondent's Year of Experience Pertaining to the Selected Component[a]	N	Average Relationship Length with Immediate Suppliers (Yrs.)[a]	Average Relationship Length with Immediate Buyers (Yrs.)[a]
OEMs (i.e. Tier-0s) (N=153)	Less than 100	0	78,726.50	Less than 1 year	9	6.88	N/A
	100-249	0		1-5 years	79		
	250-499	0		6-10 years	57		
	500-999	0		11-20 years	6		
	1000 or more	153		21 years or more	2		
Tier-1 Suppliers (N=308)	Less than 100	0	143.13	Less than 1 year	72	5.36	6.27
	100-249	45		1-5 years	122		
	250-499	219		6-10 years	94		
	500-999	44		11-20 years	12		
	1000 or more	2		21 years or more	8		
Tier-2 Suppliers (N=483)	Less than 100	188	67.26	Less than 1 year	7	3.51	5.84
	100-249	239		1-5 years	227		
	250-499	56		6-10 years	195		
	500-999	0		11-20 years	38		
	1000 or more	0		21 years or more	16		
Tier-3 Suppliers (N=908)	Less than 100	597	13.90	Less than 1 year	13	N/A	3.95
	100-249	311		1-5 years	422		
	250-499	0		6-10 years	323		
	500-999	0		11-20 years	89		
	1000 or more	0		21 years or more	61		

Note: Total Number of Supply Network Members =1,852

[a] All as of 2011 end

3.3.2 Measures

Capturing Strategic Intents

The measures for the component-level strategic intent were adopted from extant studies such as Gunasekaran et al. (2004) and Li et al. (2005). OEM-level respondents, not knowing which item is for what strategic intent, were asked to answer "yes" or "no" for each of eight measure items shown in Table 3.2. A score of +1 was given to "yes" responses to the first four items representing cost leadership, while those to the latter four items for market responsiveness received -1. "No" responses were given a value of "0" for both intents. These response scores were summed up, creating a 9-point scale ranging from -4 to +4, and pre-classified the collected 153 component-level supply networks into three groups based on strategic intent: cost leadership (from +2 to +4; N=42), market responsiveness (from -4 to -2; N=36), and mixed (from -1 to +1; N=75).

Table 3.2 Item Measures for Strategic Intents

Strategic Intent	Item Measure
Cost Leadership	We predominantly implement value analyses with a view to reduce costs.
	We predominantly emphasize whether they offer prices as low or lower than other suppliers.
	We predominantly emphasize whether the supplier offers quantity discounts.
	We predominantly emphasize whether they have lower manufacturing costs compared to other suppliers.
Market Responsiveness	We predominantly emphasize whether they have short production lead time.
	We predominantly emphasize whether they can adapt to fast-changing market/industry.
	We predominantly emphasize the ability to scale up (or down) quickly to changing market demands.
	We predominantly emphasize whether they can rapidly incorporate consumer preferences into the design process.

Validation of this pre-classified group membership was implemented by incorporating K-means clustering and SPSS's Crosstabs procedure. This approach was previously used by Frohlich and Westbrook (2001) to validate their classification of "arcs of integration." As a widely applied method of ordinary cluster analysis, the K-means clustering identifies relatively homogeneous groups of cases for selected variables (Dillon and Goldstein 1984). It seeks elements that have distances from the mean of the own group that are larger than those from another group. The element is then shifted to this group. This process stops if all elements have found 'their' groups. Group memberships for each of the three strategic intent groups were saved and then compared using Crosstabs procedure. Crosstabs was used to count the number of cases that were in common (and different) between the two classifications and to calculate bivariate statistics. The results of this validation approach are shown in Table 3.3. The Pearson's correlation between group membership for the two classification procedures was 0.4620 ($p <$

0.000), which collectively confirms the validity of the employed classification method for component-level strategic intents. Please refer to the section 2.3.2 for more detailed definitions and calculations of SNA indices.

Table 3.3 Classification Results of K-Means Clustering and Accuracy

	Predicted Group[a]	Group 1	Group 2	Group 3	Total
Actual Group[a]	*Summed Score*				
Group 1	+4	**11 (7.2%)**	0 (0%)	0 (0%)	11
	+3	**15 (9.8%)**	0 (0%)	0 (0%)	15
	+2	**16 (10.5%)**	0 (0%)	0 (0%)	16
Group 2	-4	0 (0%)	**6 (3.9%)**	0 (0%)	6
	-3	0 (0%)	**14 (9.2%)**	0 (0%)	14
	-2	0 (0%)	**16 (10.5%)**	0 (0%)	16
Group 3	+1	0 (0%)	0 (0%)	**21 (10.3%)**	21
	0	0 (0%)	0 (0%)	**30 (14.7%)**	30
	-1	0 (0%)	0 (0%)	**24 (11.8%)**	24
Total		42	36	75	**153**

[a] Group 1 = Cost Leadership; Group 2 = Market Responsiveness; Group 3 = Mixed

3.3.3 Methods

Multinomial logit (MNL) analysis was carried out to understand the association between strategic intent groups and supply network tie types for each network index (i.e. Hypotheses 1-4), while controlling for the component type dummy (0 for electronic; 1 for mechanical) of each supply network. Table 3.4 presents descriptive statistics for all variables.

Table 3.4 Descriptive Statistics for Variable

Variable[a]	Mean	Stdev	Min	Max
(a) BC for Contractual Ties	.5786	.0167	.5505	.6086
(b) BC for Transactional Ties	.3905	.0222	.3501	.4300
(c) BC for Professional Ties	.4840	.0438	.4102	.5599
(d) BC for Personal Ties	.4922	.0455	.4123	.5698
(e) IDC for Contractual Ties	.3846	.0200	.3512	.4185
(f) IDC for Transactional Ties	.3246	.0191	.2901	.3599
(g) IDC for Professional Ties	.3424	.0289	.2907	.3894
(h) IDC for Personal Ties	.4029	.0259	.3628	.4498
(i) ODC for Contractual Ties	.4895	.0226	.4504	.5299
(j) ODC for Transactional Ties	.2883	.0468	.2115	.3698
(k) ODC for Professional Ties	.4041	.0150	.3802	.4299
(l) ODC for Personal Ties	.3404	.0294	.2912	.3898
(m) GCC for Contractual Ties	.1344	.0212	.1003	.1699
(n) GCC for Transactional Ties	.0749	.0146	.0503	.0999
(o) GCC for Professional Ties	.1709	.0121	.1502	.1895
(p) GCC for Personal Ties	.7976	.0273	.7504	.8497
(q) Component Type	.4183	.4949	0	1

Note: N=153 component-level networks; Component type was used as a control variable.
[a] BC = Betweenness Centralization; IDC = In-degree Centralization; ODC = Out-degree Centralization; GCC = Global Clustering Coefficient

If X is the vector of network indices explaining the marginal effects of three strategic intents (i.e. cost leadership, market responsiveness and mixed), the general form of the MNL model are expressed as:

$$\text{Prob(y=Cost leadership)} = \frac{e^{X\beta(\text{Cost})}}{(e^{X\beta(\text{Cost})} + e^{X\beta(\text{Resp})} + e^{X\beta(\text{Mix})})}$$

$$\text{Prob(y=Market responsiveness)} = \frac{e^{X\beta(\text{Resp})}}{(e^{X\beta(\text{Cost})} + e^{X\beta(\text{Resp})} + e^{X\beta(\text{Mix})})}$$

$$\text{Prob}(y=\text{Mixed})=\frac{e^{X\beta(\text{Mix})}}{(e^{X\beta(\text{Cost})}+e^{X\beta(\text{Resp})}+e^{X\beta(\text{Mix})})}$$

where β^{Cost}, β^{Resp} and β^{Mix} correspond to each strategic intent. For model identification, in this case, the "mixed" strategic intent was chosen as a reference group (by putting $\beta^{\text{Mix}} = 0$) in that Fisher's (1997) framework presented only two strategic considerations – cost leadership and market responsiveness – in designing supply chains. This is also appropriate as the sampling frame of this study consists of respondents in either electronics or automotive industry. The electronics industry is characterized by rapid changes in technology and shorter lifecycles where competition revolves around better market responsiveness. As a more mature industry, the automotive industry is characterized by relatively slow technological evolution, longer product lifecycles and hard price competition. In these regards, the usage of "mixed" strategic intent group as a reference in the current MNL is a reasonable approach which enables finding a clearer distinction between those two conflicting strategic intents. The above equations therefore can be rephrased as:

$$\text{Prob}(y=\text{Cost leadership})=\frac{e^{X\beta(\text{Cost})}}{(e^{X\beta(\text{Cost})}+e^{X\beta(\text{Resp})}+1)}$$

$$\text{Prob}(y=\text{Market responsiveness})=\frac{e^{X\beta(\text{Resp})}}{(e^{X\beta(\text{Cost})}+e^{X\beta(\text{Resp})}+1)}$$

$$\text{Prob}(y=\text{Mixed})=\frac{1}{(e^{X\beta(\text{Cost})}+e^{X\beta(\text{Resp})}+1)}$$

As a result, it only calculates the relative probability of a strategic intent (either cost leadership – coded as Group 1 – or market responsiveness – coded as Group 2) compared to the mixed intent

(coded as Group 3), not the absolute probability. In other words, the relative probabilities of Groups 1 and 2 to the mixed intent are:

$$\frac{\text{Prob(y=Cost leadership)}}{\text{Prob(y=Mixed)}} = e^{X\beta(\text{Cost})}$$

$$\frac{\text{Prob(y=Market Responsiveness)}}{\text{Prob(y=Mixed)}} = e^{X\beta(\text{Resp})}$$

These ratios are referred to as the relative risk, and its ratio for one-unit change in a network index (x_i) then becomes $e_i^{\beta(\text{Cost})}$ or $e_i^{\beta(\text{Resp})}$. The exponential value of the estimated coefficient is the relative risk for a one-unit change in the corresponding variable. In this sense, the relative risk less (or greater) than one indicates a negative (or positive) association between network index and strategic intent. Therefore, all the other estimated parameters can also be interpreted as the marginal effect (i.e. change in the odds ratio) of a network index associated with the strategic intent as opposed to mixed intent. The parameter vectors (β) are estimated using the maximum likelihood method.

3.4 Results and Interpretations

A series of MNL models were estimated to test the hypotheses. As noted above, analyses focused on the likelihood that supply networks have either cost leadership (Group 1) or market responsiveness (Group 2) intent other than the mixed (Group 3) intent. Table 3.5 summarizes the empirical results on the associations between supply network characteristics and strategic intent. The likelihood ratio (LR) chi-square test statistics with 10 degrees of freedom indicate that all models are significant at the 1% level (94.89 for Model 1; 99.17 for Model 2; 83.19 for Model 3;

103.33 for Model 4). This provides preliminary support for the presented hypotheses by showing that the hypothesized network characteristics account for significant variability in strategic intent. In terms of the control variable, it was found that mechanical components are significantly associated with cost leadership intent, which is generally consistent with previous findings on the impact of product types on the choice of supply chain strategy (e.g. Fisher 1997; Fine 1998; Lamming et al. 2000; McCardle et al. 2007). For the sake of brevity, the estimated coefficients and their significance levels will be mainly used for model interpretations, while other estimates (e.g. standard errors, relative risk, etc.) are also included in Table 3.5 for completeness.

Besides the theoretical and statistical considerations, field investigations were also deemed necessary to interpret supply network phenomena from a more realistic perspective, and consequently, to further support the contention that an OEM's specific strategic intents play a central role in *designing* supply networks with differential characteristics. For verifications of the empirical findings and preliminary interpretations of the models, several component-level supply networks of the sample were revisited and went through follow-up interviews asking about: 1) what supply network management practices are being implemented, 2) how long they have been using those practices, and 3) why and how those practices did (or did not, if applicable) work for achieving specific strategic intents and lead to the revealed network properties. This would provide a more comprehensive and real-world perspective of the association between strategic intent and corresponding network architecture. The exact names of companies, products, components and technologies are replaced with alphabets for anonymity.

Table 3.5 Results of Multinomial Logit Estimation

	Cost Leadership (Group 1) Versus Mixed (Group 3)			Market Responsiveness (Group 2) Versus Mixed		
Variables[a]	B[b,c]	SE[c]	RRR [95% CI][c]	B[b,c]	SE[c]	RRR [95% CI][c]
Model 1 (H1A and H1B) (LR χ^2 (10) = 94.89; Probability > χ^2 = .000)						
(a)	76.710***	23.904	2.06e+33 [9.29e+12, 4.59e+53]	-21.634	20.100	4.02e-10 [3.13e-27, 5.18e+07]
(e)	21.530*	12.451	2.24e+09 [.0564938, 8.89e+19]	.703	9.692	2.019 [1.14e-08, 3.59e+08]
(i)	.446	6.103	1.562 [9.98e-06, 244581.9]	-3.681	5.082	.025 [1.19e-06,533.6256]
(m)	-20.594**	8.668	1.14e-09 [4.77e-17, .0271508]	17.498**	7.866	3.97e+07 [8.006318,1.97e+14]
Component	1.006*	.519	2.735 [.9886056, 7.567924]	-.108	.451	.898 [.3710203, 2.171726]
Intercept	-45.002**	18.181	2.86e-20 [9.56e-36, .0000855]	4.102	14.464	60.452 [2.95e-11, 1.24e+14]
Model 2 (H2A and H2B) (LR χ^2 (10) = 99.17; Probability > χ^2 = .000)						
(b)	10.033	21.109	22761.83 [2.45e-14, 2.11e+22]	-3.517	19.845	0.023 [3.81e-19, 2.31e+15]
(f)	37.792*	21.402	2.59e+16 [.015697, 4.27e+34]	-36.833*	21.472	1.01e-16 [5.33e-35, 190.9992]
(j)	-0.938	8.629	0.391312 [1.77e-08, 8667815]	2.981	8.073	19.70147 [2.65e-06, 1.47e+08]
(n)	41.345**	17.086	9.04e+17 [2586.658, 3.16e+32]	-41.923***	15.227	6.21e-19 [6.79e-32, 5.67e-06]
Component	1.063**	.504	2.893625 [1.077254, 7.772601]	-.174	.475	0.841 [.3311284, 2.133791]
Intercept	-34.559***	7.591	9.80e-16 [3.38e-22, 2.84e-09]	27.460***	8.384	8.43e+11 [61622.66, 1.15e+19]

[a] (a) Contractual Betweenness Centralization; (b) Contractual In-degree Centralization; (d) Contractual Global Clustering Coefficient; (e) Transactional Betweenness Centralization; (f) Transactional In-degree Centralization; (j) Professional In-degree Centralization; (k) Professional Out-degree Centralization; (l) Professional Global Clustering Coefficient; (m) Personal Betweenness Centralization; (n) Personal In-degree Centralization; (o) Personal Out-degree Centralization; (p) Personal Global Clustering Coefficient

[b] *** : Significant at p < .01 level; ** : Significant at p < .05 level; * : Significant at p < .10 level (2-tailed)

[c] B = Estimated Coefficient; SE = Standard Errors; RRR = Relative Risk Ratio; CI = Confidence Interval

Table 3.5 (cont'd)

	Cost Leadership (Group 1) Versus Mixed (Group 3)			Market Responsiveness (Group 2) Versus Mixed		
Variables[a]	B[b,c]	SE[c]	RRR [95% CI][c]	B[b,c]	SE[c]	RRR [95% CI][c]
Model 3 (H3A and H3B) (LR χ^2 (10) = 83.19; Probability > χ^2 = .000)						
(c)	-12.753	9.824	2.89e-06 [1.26e-14, 666.7517]	-1.879	9.075	.153 [2.88e-09, 8094740]
(g)	-2.017	4.925	.133 [8.54e-06, 2071.658]	-.787	5.143	.455 [.0000191, 10858.15]
(k)	73.708***	26.823	1.03e+32 [1.51e+09, 6.97e+54]	-42.428	26.820	3.75e-19 [5.56e-42, 25285.06]
(o)	-27.289**	13.628	1.41e-12 [3.53e-24, .5607792]	27.576**	12.362	9.47e+11 [28.39945, 3.16e+22]
Component	1.076**	.494	2.934 [1.115116, 7.721501]	.172	.456	1.187 [.4853584, 2.904532]
Intercept	-15.353	14.600	2.15e-07 [8.03e-20, 575571.5]	7.305	13.738	1488.243 [3.01e-09, 7.35e+14]
Model 4 (H4A and H4B) (LR χ^2 (10) = 103.33; Probability > χ^2 = .000)						
(d)	45.204***	14.005	4.29e+19 [5.14e+07, 3.57e+31]	-4.344	11.244	.013 [3.49e-12, 4.84e+07]
(h)	-5.136	17.674	.006 [5.31e-18, 6.51e+12]	-15.016	17.233	3.01e-07 [6.45e-22, 1.40e+08]
(l)	-99.201***	34.835	8.27e-44 [1.85e-73, 3.70e-14]	38.369	30.095	4.61e+16 [1.11e-09, 1.91e+42]
(p)	41.407***	15.493	9.61e+17 [62361.18, 1.48e+31]	-39.741***	13.917	5.51e-18 [7.85e-30, 3.86e-06]
Component	1.468***	.555	4.341 [1.46346, 12.87402]	-.479	.478	.619 [.2428988, 1.579997]
Intercept	-24.175	16.119	3.17e-11 [6.03e-25, 1665.899]	25.549*	13.943	1.25e+11 [.1686685, 9.21e+22]

[a] (a) Contractual Betweenness Centralization; (b) Contractual In-degree Centralization; (d) Contractual Global Clustering Coefficient; (e) Transactional Betweenness Centralization; (f) Transactional In-degree Centralization; (j) Professional In-degree Centralization; (k) Professional Out-degree Centralization; (l) Professional Global Clustering Coefficient; (m) Personal Betweenness Centralization; (n) Personal In-degree Centralization; (o) Personal Out-degree Centralization; (p) Personal Global Clustering Coefficient

[b] *** : Significant at p < .01 level; ** : Significant at p < .05 level; * : Significant at p < .10 level (2-tailed)

[c] B = Estimated Coefficient; SE = Standard Errors; RRR = Relative Risk Ratio; CI = Confidence Interval

3.4.1 Model 1: Strategic Intent and Betweenness Centralization

Model 1 testing the associations between strategic intents (either cost leadership or market responsiveness) and betweenness centralizations of different tie types provides four significant results altogether. Specifically, compared to OEMs focusing on mixed intent, the ones pursuing cost leadership are more likely to have supply networks characterized by: 1) unequal completeness of contract terms among network members ($B = 76.710$, $p < .01$), and 2) concentrated transactions (i.e. large proportions with few network members) ($B = 21.530$, $p < .10$). Based on the follow-up interviews, it was confirmed that those observations are based on the logic of cost savings via complete contracts and economies of scale as expected in hypothesis H1A. For instance, one sourcing manager at a large automobile OEM noted: "It can vary case by case, but the baseline strategy for cost and quality control is continuing bulk purchase from a few select vendors who can accommodate every single detail of our proposed terms and conditions."

Interestingly, as opposed to hypothesized, survey results show that supply network personnel of Group 1 are more inclined to have a broader array of personal interactions in relatively equal portions ($B = -20.594$, $p < .05$) while the ones pursuing market responsiveness interact with a smaller range of them in an unequal manner ($B = 17.498$, $p < .05$). These observations can be interpreted as evidence that supply network personnel may be *utilizing their personal contacts for control purpose*, that is, by monitoring whether their counterparts offer the best (lowest) possible cost. One interviewee, the founder and CEO of a tier-1 supplier for an automobile OEM confirmed this conjecture by stating: "Information about cost structure is extremely sensitive for all down-tier suppliers since the buying firm can easily calculate our profit margins, which is not good for us. They (buying firm) already keep asking us to cut down price while maintaining the same quality level as their products are under fierce price

competition. Unfortunately, but inevitably, we are expecting and asking the same thing from and to our suppliers (tier-2)." One senior-level purchasing manager at an OEM commented on this situation: "We already know and understand that they (down-tier suppliers) do not like to share all the information about cost structure. I guess the cost information shared upon our request is 1-2-year-old one or rough numbers only. We cannot simply switch to other alternatives because it raises issues of uncertainty in terms of quality, communication, searching cost, etc. Based on my experience, a quick check whether their profit margins are reasonable is meeting multiple lower-level employees and ask them about how their boss is doing during the casual conversation. If he recently bought a new car or traveled abroad, for instance, it tends to signify there exists a room for additional cuts."

In the market responsiveness versus mixed setting, the only significant result shows that the aforementioned monitoring practice via personal interactions stands in contrast for OEMs focusing on market responsiveness. One of our Group 2 respondents at a large consumer electronics OEM provided the following hint concerning this observation: "I admit that utilizing personal relationships is a key in coping with technological and environmental market uncertainties. At the same time, however, it does not look reasonable putting too much weight on building and maintaining personal relationships with all the existing down-tier suppliers. Although our market environment changes rapidly, a meteoric rise rarely happens in this business. For instance, the current key technology "A" for component "B" was introduced by one of our few but long-time (more than 8-10 years) tier-1 suppliers who have accumulated enough experience and resource to search for the next big thing. We have maintained a short list of the strongest candidates instead of completely predicting what changes will be occurred. This rule has been worked well so far."

3.4.2 Model 2: Strategic Intent and In-degree Centralization

Model 2 yielded four significant associations in hypothesized directions which collectively support the associations between strategic intent choices and out-degree centralizations. The first two results in cost leadership (Group 1) versus mixed intent (Group 3) comparison demonstrate that the supply network in-degree centralizations based on its transactional ($B = 37.792$, $p < .10$) and personal ties ($B = 41.345$, $p < .05$) are higher than the ones focusing on mixed intent if an OEM pursues cost leadership. In other words, compared to Group 3, an OEM's intent to tackle costs seems to be associated with supply networks characterized by fewer particular focal firms which have more incoming amount of transaction percentages and non-work-related interactions than the other network members. Follow-up interviews provided more managerial backgrounds to understand these findings. On the positive coefficient of transactional in-degree centralization under cost leadership, one executive-level respondent of an automobile OEM confirmed the hypothesized logic by stating: "Yes, we try to achieve economies of scale in purchasing to reduce costs. We further encourage our immediate (tier-1) suppliers to keep searching for down-tier suppliers who can provide lower cost for them because that also matters to us. As a result, there must be a relatively small number of firms which draw in more transactions than others. Why don't we simply replace them with Chinese suppliers who can possibly offer lower deals? Considering issues such as quality, security, communication, wage, etc., they can increase total costs while reducing manufacturing costs." Interestingly, the tier-1 counterpart of the above OEM was seeing this business in a very different way which provides hints to explain the positive personal in-degree centralization under cost leadership intent. He replied as follows: "Well, I cannot agree with his argument at all. Who will provide the expected price under cost competition with other OEMs? It is OEM. As they make a bulk purchase for economies of scale,

small and medium-sized suppliers like us are heavily relying on them. By utilizing this bargaining power, they continuously press us to drop our markups by alluding that they can always switch to Chinese alternatives. We also keep searching for cheaper sub-suppliers around the world, but below a certain price, we should often compromise or sacrifice the current quality level which will eventually backfire on ourselves. As a result, we pay special attention to establish the personal relationship to gain their trust. For example, we regularly hire their retiring executives or managers to build and maintain close personal relationships with the OEM."

The next two results in the setting of market responsiveness (Group 2) versus Group 3 also showed predicted patterns for the in-degree centralizations of supply networks based on their transactional ($B = -36.833$, $p < .10$) and personal ($B = -41.923$, $p < .01$) ties. This means that, when an OEM pursues market responsiveness, its supply network is more likely to have network properties that each member has relatively equal amounts of incoming transactional and non-work-related flows from others compared to Group 3. One purchasing manager at a consumer electronics OEM explained about the transactional inflows by stating that: "We build a diversified sourcing portfolio for our component "C" with a short life cycle and uncertain demand. Not surprisingly, most of our immediate (tier-1) suppliers are not dedicated to us either to realize the maximum benefits from the current generation of the component, and they even supply to other OEMs including our competitors. Their sub-suppliers (tier-3s) think and act alike." Regarding the relatively equal inflows of non-work-related (i.e. personal) ties, one tier-1 counterpart personnel of the above OEM noted: "I admit that we have a pretty high level of autonomy, but they (OEMs) still have a position advantage in sensing and responding to market uncertainties such as consumer demand, price and end-consumers' tastes. Unfortunately, OEMs are reluctant to share that information with us because we are doing business with other OEMs

including their suppliers, and thus the opportunities of information sharing through professional seminars, workshops or training are lacking. We try to obtain such information via personal communication. Seeing your result that every network member has almost equal amount of incoming personal ties, it seems our downstream (tier-2 or tier-3) suppliers must be doing the same to our sourcing managers. Well, it is interesting to see everyone got on the same bandwagon."

3.4.3 Model 3: Strategic Intent and Out-degree Centralization

Model 3 tested the associations between strategic intents and out-degree centralizations of four supply network tie types. The results reported partial supports for both hypotheses H3A and H3B. First, in a Group 1 versus Group 3 comparison, it was shown that OEM's cost leadership intent seemed to be positively associated with the out-degree centralization of its supply network composed of professional ties ($B = 73.708$, $p < .01$) whereas it showed a negative association for the same index of personal ties ($B = -27.289$, $p < .05$). The result statistically indicates, compared to Group 3, that the OEMs pursuing cost leadership tend to have a supply network architecture characterized by a few particular focal firms that send out most of the work-related interactions to the rest of the supply network members, and every supply network member has a relatively equal amount of non-work-related interactions with others. On these phenomena, the purchasing manager at a consumer electronics OEM commented as follows: "We emphasize the importance of persistent searching for possible supplier alternatives to achieve our price goal. Regular and frequent interactions such as business meetings, conference calls and other formats of online communication have been useful to ensure our suppliers (tier-1) invest enough efforts to progress." He also added, "Meanwhile, too close personal relationships with suppliers can put us

in awkward situation when we have to lay off the ones that fall short of our expectations. We thus always try to keep personal distance."

On the contrary, in the setting of Group 2 versus Group 3 comparisons, the out-degree centralizations of personal ties showed a positive association with market responsiveness intent ($B = 27.576$, $p < .05$). This observation shows that a fewer particular group of supply network members who initiate more non-work-related interactions with others when the OEM focuses on market responsiveness intent, as conjectured in H3B. One executive-level respondent at a tier-2 automobile component supplier explained this finding as follows: "Our customers (tier-1 suppliers) are closely working with their buyers (OEMs). Considering the technology level of sub-components, unfortunately, they have a relatively wider range of options for finding sub-suppliers like us – they can simply switch to one of our competitors. In order to avoid or at least delay this situation, we try to build and strengthen a close personal relationship with them, and sometimes hire their retiring executives with no manufacturing background for this. This also has been very effective in preventing the retirees with plenty of 'friends' in this business from starting their own, which can be a threat to us."

3.4.4 Model 4: Strategic Intent and Global Clustering Coefficient

The Model 4 demonstrated partial support for hypotheses H4A and H4B examining the associations between strategic intent choices and global clustering coefficients. When an OEM pursues cost leadership, its supply network seemed to be positively related to the global clustering coefficients of contractual ($B = 45.204$, $p < .01$) and personal ($B = 41.407$, $p < .01$) ties on the contrary to expectations. In contrast, the OEM's supply network showed a negative association with the global clustering coefficient based on professional ties under the same intent ($B = -99.201$, $p < .01$). These results collectively indicate that, compared to mixed intent, OEMs

focusing on cost leadership for its component tend to have supply networks where: 1) more network members are connected to one another with complete contract terms and non-work-related interactions, and 2) less of them are connected with work-related interactions. A follow-up interview with one purchasing manager of an automobile OEM provided the rationale to interpret the positive association between cost leadership and global clustering coefficient of contractual ties. The respondent noted: "When we source cost leadership-focused component, the rule of business is quite simple: the supplier who can offer a lower price with reasonable quality wins the deal. Cost part is easy, but it is hard to be sure whether the supplier can meet our expectations on quality. Thus, when discussing and developing contract terms with tier-1 suppliers, we mostly ask them to provide a list of current or potential lower-tier suppliers and to include terms and conditions outlining the quality requirements for sub-components." Regarding the next two findings (i.e. the positive and negative estimated coefficients for personal and professional interactions), he stated: "These two are unexpected, but wholly make sense. Although we try to check sub-suppliers' quality conformance, it is still officially tier-1 supplier's right and responsibility, and hence we cannot directly communicate with lower-tier suppliers on work matters which might lead to the hierarchical network structure of professional interactions. However, we still can indirectly do our part via extensive personal communications, while not directly asking about work-related issues. There are hundreds of possible ways to do this. We also can inquire into the reputation of our original contractor's sub-supplier through another tier-1 supplier's sub-supplier, while not violating the original contract."

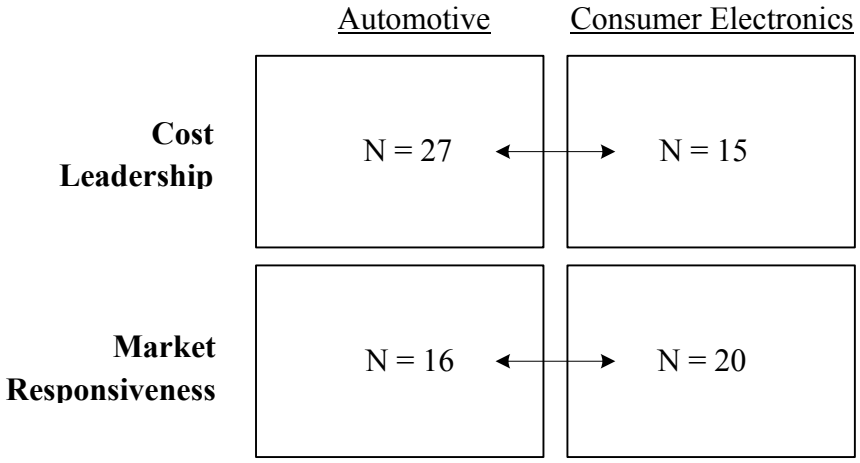
Lastly, it was shown that an OEM's market responsiveness intent seemed to be negatively associated with the global clustering coefficient of its supply network composed of personal ties ($B = -39.741$, $p < .01$) as opposed to hypothesized direction. This observation

indicates that, compared to mixed intent, supply network personnel pursuing market responsiveness are more inclined to have a disconnected network of non-work-related interactions. The founder and CEO of a tier-1 supplier for a consumer electronics OEM explained this phenomenon as follows: "Several government, quasi-governmental, or private organizations hold exhibitions and conferences to help the business entities in dealing with this fast changing market. We regularly participate to those events for socializing. Although participants do not explicitly share sensitive work-related information, those events have been regarded as "must go" events not to be isolated from other supply network members. Good personal relationships do not always bring in new business opportunities, but people may be hesitant to work with a total stranger."

3.5 Further Investigations

The current study utilizes samples from multiple industries and companies. When investigating the supply network design effects of strategic intent, it can be misleading to analyze network data from a single industry or company because of their intrinsic characteristics. Further industry or company wise case comparisons were thus deemed necessary to enrich research findings and yield richer insights. By dividing the sample by industry and firm, this study additionally explored how the supply network properties corresponding to each strategic intent (either cost leadership or market responsiveness) are differently manifested by: 1) industries (consumer electronics and automotive) and 2) different OEMs within the same industry (i.e. consumer electronics OEMs, A and B). Figure 3.3 illustrates this scheme and the sample size for each quadrant. Follow-up interviews on the findings were additionally conducted to offer more practical and meaningful interpretations.

Panel 1: Industry to Industry Comparison by Strategic Intent



Panel 2: Consumer Electronics Firm to Firm Comparison by Strategic Intent

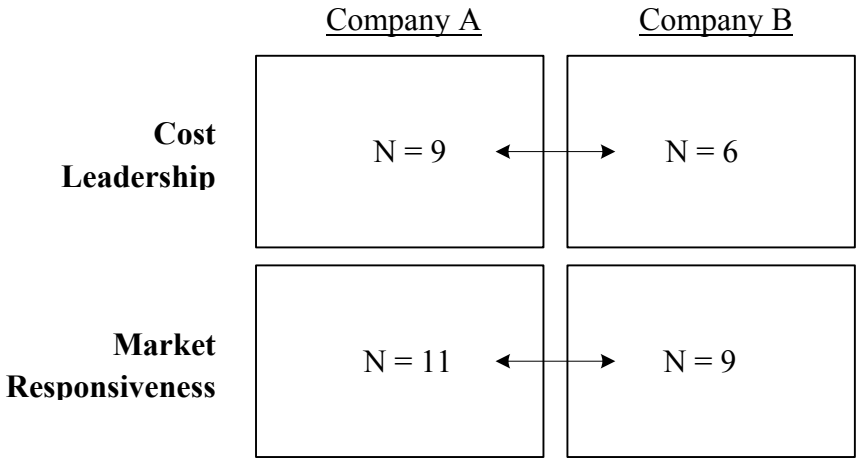


Figure 3.3 Framework for Further Investigations

3.5.1 Industry to Industry Comparison

T-test was employed to analyze each of the four comparison sets in Figure 3.3 for any significant mean differences with respect to supply network properties. One OEM per each industry was also contacted and asked to share their views and experiences which can provide hints for interpreting the test results. As shown in Table 3.6, three SNA indices indicated significant mean differences between industries. Specifically, consumer electronics OEMs showed higher values in professional ODC under cost leadership ($F = .188$, $p < .05$) and in contractual IDC under

market responsiveness ($F = .247$, $p < .05$). These findings indicate that, compared to the automotive industry, consumer electronics OEMs have supply networks where there exist fewer particular focal firms that: 1) send out most of the work-related interactions to others (under cost leadership intent), and 2) have more complete contract terms than others (under market responsiveness intent). One purchasing manager of a consumer electronics OEM explained these findings: "I believe the supplier base plays a role here. Compared to automobile manufacturers, consumer electronics OEMs typically have a broader supplier base; thus we also can more easily probe for potential suppliers who can offer lower prices than the existing ones. Our suppliers may enjoy a similar situation because there are more OEMs in our industry than in the automotive industry. As such, consumer electronics suppliers sometimes behave opportunistically. For instance, one of our former suppliers boasted that they could beat the existing supplier's price and won the deal. They kept their word … by sacrificing quality! Buyers mostly get what they pay for. In this regard, we keep tight controls on the quality of our sub-components while maintaining lower cost by, as found in your results, initiating more work-related interactions with downstream suppliers. We follow a similar logic when sourcing market responsiveness-focused components. We do not know how responsive our suppliers are likely to be until actual market changes take place on the ground, and thus they can be opportunistic. To deal with this concern, we always try to develop extremely complete contacts specifying every single possible market-related contingency. I believe our suppliers may apply the same policy to their suppliers."

Table 3.6 also shows that automotive industry OEMs have a higher value of personal ODC than consumer electronics when they pursue cost leadership ($F = .005$, $p < .05$). In a supply network context, this means that the supply networks of automotive OEMs have fewer particular

focal firms which create more non-work-related interactions for others. In explaining this observation, an executive-level respondent of an automotive OEM also counted the supplier base as the main source of this difference. He noted: "I agree with his view – the supplier base makes a big difference. Let me tell you the reason. Of course, we also try to find a supplier which offers the lowest price when we source cost leadership-focused components. One big difference here is the unit price difference between consumer electronics and automobiles; in other words, this industry has a much more severe consequence for quality problems. This mostly restricts our supplier choice to a shortlist of potential suppliers who previously met our quality requirements or the ones with certain level of quality reputation. Another big difference, I believe, is our understanding on the supply market. We produced most of the components ourselves till about thirty years ago, and our industry change is relatively stable. We therefore do not need to control our suppliers as tightly as consumer electronics OEMs do; rather we try to develop strong personal ties among supply network members. I personally think Toyota has proven that this approach is quite effective for securing cost leadership while maintaining quality."

3.5.2 Firm to Firm Comparison

This study also tested the mean differences of network properties between two consumer electronics OEMs. Pseudonyms ("Company A" and "Company "B") were used for confidentiality. Both companies have well-established brand names and compete neck to neck in the global consumer electronics market. Company A has a strong market position in Latin American, Middle East and South-East Asian consumer electronics markets, while the primary markets of Company B are North American and European countries. The results in Table 3.7 provide some interesting observations on those two companies' differences in supply network properties with respect to strategic intent. Specifically, Company A showed higher values of

contractual IDC ($F = 2.304$, $p < .10$) and professional BC ($F = .155$, $p < .05$) when it pursues cost leadership intent. It also had a higher personal ODC value ($F = .198$, $p < .10$) under the pursuit of market responsiveness. These findings collectively suggest that, compared to Company B, Company A's supply network has these characteristics: 1) a particular group of firms possess less favorable contract terms, 2) those particular firms serve as "hubs" for work-related interactions among network members (both under cost leadership), and 3) particular focal firms initiate more non-work-related interactions for others members (under market responsiveness). One executive-level respondent of Company A provided the following interesting explanation: "Compared to Company B, we are well known for our product localization which provides various product variants in style and features. We have been doing this by slightly modifying the basic product platform. This approach has been quite successful in the fast growing markets of developing countries where there are few domestic alternatives for us but consumers are sensitive to price at the same time. Consumers in those countries expect to get more than they pay for and, thus, are very demanding on our product quality. When we source cost leadership-focused components used for the basic product platform, we should devise complete contracts to perfectly control at less cost than the suppliers' opportunistic behaviors relevant to price and quality (which may lead to our higher contractual IDC). Further, to control whether they abide by those contract terms, we also should become the hub of work-related communications among our supply network members (and that may affect the higher professional BC). Our market responsiveness-focused components are used for localization purposes. As we have a better understanding of the local markets, in this case, we should keep informing our suppliers of potential local market changes to get them prepared for accommodating those changes. I believe this may lead to the finding high professional ODC of us."

Also shown in Table 3.7 is that Company B has significantly higher values of contractual GCC ($F = 2.869$, $p < .05$) under cost leadership intent and professional ODC ($F = .022$, $p < .10$) under market responsiveness intent. These results collectively indicate that: 1) more of its supply network members are directly connected by contract relations when it pursues cost leadership, while 2) there exist particular focal firms who send out most of the work-related interactions to others under the pursuit of market responsiveness. One executive of the company explained these observations by stating that: "Being different from Company A, we mostly launch 'global products' using leading-edge technology, and thus rarely localize our products. As a result, we have had a great success in North America and European continent which are the major battlefields of the global consumer electronics industry. We should gain and protect our technological leadership to keep surviving in those competitive markets because our consumers are ready to pay more for a superior product compared to the ones at emerging markets. I believe all these circumstances may contribute to make the network architectural differences between us and Company A. Even when we source cost leadership-focused components, we focus more on quality-for-money rather than lowest cost per se. Therefore, we should maintain extensive controls via more complete contracts specifying the required quality level over our non-immediate sub-suppliers as well as tier-1 suppliers. This may be leading to our higher contractual GCC. The ones focusing on market responsiveness are the key components with short lifecycles for our final products. When we source those components, we should quickly transfer the technologies we developed to our tier-1 suppliers before they get outdated while preventing any potential leakage or spillover of them. It inevitably creates more of our technical interventions and surveillance activities on tier-1 suppliers, which may be leading to our high professional ODC."

Table 3.6 Panel 1 Comparison Results

Cost Leadership *Market Responsiveness*

SNA Index[a]	Automotive[b]	Consumer Electronics	F-Value[c]	SNA Index[a]	Automotive[b]	Consumer Electronics[b]	F-Value[c]
(a)	.595 (.009)	.599 (.008)	.508	(a)	.565 (.010)	.564 (.008)	.865
(b)	.401 (.010)	.403 (.012)	1.146	(b)	.366 (.009)	.374 (.009)	.247**
(c)	.489 (.025)	.491 (.027)	.028	(c)	.487 (.029)	.493 (.021)	2.752
(d)	.144 (.021)	.137 (.021)	.184	(d)	.133 (.020)	.130 (.021)	.005
(e)	.386 (.022)	.395 (.018)	1.889	(e)	.392 (.024)	.387 (.020)	1.164
(f)	.341 (.009)	.339 (.012)	4.105	(f)	.308 (.008)	.308 (.010)	1.950
(g)	.296 (.049)	.294 (.049)	.024	(g)	.289 (.038)	.284 (.042)	.461
(h)	.075 (.013)	.073 (.017)	2.876	(h)	.071 (.014)	.075 (.015)	.023
(i)	.486 (.038)	.482 (.039)	.008	(i)	.472 (.043)	.483 (.043)	.113
(j)	.345 (.027)	.347 (.030)	.480	(j)	.350 (.029)	.336 (.028)	.135
(k)	.414 (.008)	.420 (.008)	.188**	(k)	.391 (.008)	.395 (.007)	.180
(l)	.162 (.006)	.159 (.006)	.751	(l)	.178 (.007)	.180 (.005)	2.926
(m)	.445 (.026)	.458 (.023)	.908	(m)	.522 (.026)	.536 (.026)	.004
(n)	.431 (.012)	.427 (.013)	.000	(n)	.377 (.012)	.381 (.014)	.821
(o)	.323 (.013)	.315 (.012)	.005**	(o)	.371 (.015)	.364 (.014)	.970
(p)	.823 (.016)	.819 (.012)	4.622	(p)	.777 (.012)	.775 (.017)	6.256

[a] (a) = Contractual BC; (b) = Contractual IDC; (c) = Contractual ODC; (d) Contractual GCC; (e) Transactional BC; (f) Transactional IDC; (g) Transactional ODC; (h) Transactional GCC; (i) Professional BC; (j) Professional IDC; (k) Professional ODC; (l) Professional GCC; (m) Personal BC; (n) Personal IDC; (o) Personal ODC; (p) Personal GCC

[b] Mean (Standard Deviation)

[c] *** : Significant at the 0.01 level; ** : Significant at the 0.05 level; * : Significant at the 0.10 level (2-tailed)

Table 3.7 Panel 2 Comparison Results

Cost Leadership *Market Responsiveness*

SNA Index[a]	Company A[b]	Company B[b]	F-Value[c]	SNA Index[a]	Company A[b]	Company B[b]	F-Value[c]
(a)	.597 (.009)	.602 (.005)	8.069	(a)	.562 (.007)	.567 (.009)	.097
(b)	.407 (.009)	.396 (.013)	2.304*	(b)	.374 (.009)	.373 (.009)	.065
(c)	.488 (.030)	.494 (.024)	.774	(c)	.494 (.024)	.492 (.019)	.561
(d)	.128 (.020)	.151 (.013)	2.869**	(d)	.131 (.020)	.128 (.025)	1.678
(e)	.400 (.012)	.387 (.023)	3.419	(e)	.389 (.021)	.385 (.019)	.839
(f)	.337 (.011)	.342 (.013)	3.062	(f)	.309 (.011)	.306 (.010)	.176
(g)	.307 (.046)	.273 (.051)	.052	(g)	.292 (.047)	.275 (.035)	4.106
(h)	.075 (.017)	.069 (.018)	.031	(h)	.071 (.014)	.079 (.015)	.291
(i)	.464 (.035)	.510 (.028)	.155**	(i)	.470 (.041)	.499 (.044)	.515
(j)	.350 (.032)	.342 (.028)	1.024	(j)	.334 (.025)	.338 (.033)	.720
(k)	.422 (.007)	.416 (.009)	.995	(k)	.392 (.007)	.398 (.007)	.022*
(l)	.158 (.007)	.159 (.007)	.019	(l)	.181 (.005)	.179 (.005)	.087
(m)	.462 (.018)	.451 (.030)	2.837	(m)	.538 (.020)	.533 (.033)	8.309
(n)	.430 (.012)	.422 (.014)	.122	(n)	.383 (.014)	.379 (.013)	.146
(o)	.315 (.012)	.314 (.013)	.090	(o)	.369 (.012)	.358 (.015)	.198*
(p)	.817 (.013)	.822 (.011)	.011	(p)	.775 (.017)	.774 (.018)	.007

[a] (a) = Contractual BC; (b) = Contractual IDC; (c) = Contractual ODC; (d) Contractual GCC; (e) Transactional BC; (f) Transactional IDC; (g) Transactional ODC; (h) Transactional GCC; (i) Professional BC; (j) Professional IDC; (k) Professional ODC; (l) Professional GCC; (m) Personal BC; (n) Personal IDC; (o) Personal ODC; (p) Personal GCC

[b] Mean (Standard Deviation)

[c] ***: Significant at the 0.01 level; **: Significant at the 0.05 level; *: Significant at the 0.10 level (2-tailed)

3.6 Discussion

3.6.1 Contributions

This study makes unique theoretical and methodological contributions to the study of supply networks. While there have been significant conceptual developments, there are only handful of empirical works investigating a multi-tiered supply network setting (e.g. Choi and Hong 2002; Kim et al. 2011; Mena et al. 2013). Even those studies have focused on describing the complexity of supply network while remaining in the domain of case-based investigations that require further empirical substantiation. By analyzing the dataset of 153 supply networks consisting of 1,852 total network members, this study attempted to shed light on the question, "*what* determines different supply network architectures," which has been also recognized by scholars of other disciplines (e.g. Brass 2002; Borgatti and Li 2009; Galaskiewicz 2011). To address this important unresolved question, the current study adopted the strategic intent perspective of organizational formation which has been widely used in strategic supply chain design studies (e.g. Fisher 1997; Huang et al. 2002) that mainly argued different products require different supply chains. The results from social network analyses and MNL models provided significant empirical evidence that supply networks have discernible architectural properties according to a specific strategic intent (either cost leadership or market responsiveness). Further field investigations were conducted to support and interpret the preceding statistical findings. The in-depth follow-up interviews confirmed that supply network members consistently implement certain practices based on their own rational judgments, which consequently lead to the supply network properties found in the study. Taken together, this study suggests that a supply network should be viewed as a *systematic outcome which is intentionally and*

strategically designed, implemented, and maintained in conformity with the OEM's strategic intent(s).

This essay also further develops as well as contradicts the theory of supply network as a complex adaptive system (CAS). In their seminal paper on CAS theory, Choi et al. (2001) conceptually regarded a supply network as an "emerging" form in that: 1) one single network actor cannot completely control the entire supply network, and 2) too much control rather deteriorates innovation and flexibility outcomes. In this vein, the authors defined CAS as "a system that emerges over time into a coherent form, and adapts and organizes itself without any singular entity deliberately managing or controlling it" (Choi et al. 2001, p.352). The current study empirically shows what the "coherent" supply network properties had emerged under the OEM's consideration of a specific strategic intent instead of arguing a deterministic view of supply network architecture. Acknowledging the cross-sectional nature of the data, however, the empirical findings here also cast doubt on the conceptual propositions of CAS theory. As clearly seen in the responses from follow-up interviews, each supply network actor reacted to their immediate customers and suppliers by relying on their own rational assessment of potential costs and benefits of accepting or imposing a strategic intent on their counterparts. The empirical findings of this study thus can be regarded as the architectural outcomes of supply networks resulting from each network actor's continued self-centered perception and behavior reinforced by their counterparts' intents, which is maintained over time. From a managerial standpoint, the current study also provides useful guidance for understanding direct or indirect relationships across multiple tiers in the supply network. Based on the found network properties, supply network managers can infer: 1) how their immediate and non-immediate partners work together (or often against one another) in pursuing common (or sometimes incompatible) interests, and 2)

whether those concordance (or discordance) among network members would help or hinder to achieve the strategic intent of the sourced component. It also can enable open collaboration across firm boundaries by allowing them to freely discuss how much and what kind of network ties should be: 1) orchestrated by hub firms (with betweenness centralization), 2) gained from and disseminated to others (with in-degree and out-degree centralizations), and 3) connecting with one another (with global clustering coefficient) to achieve different strategic intents. All the findings of this study were further corroborated and extended by in-depth follow-up field investigations and interviews with the supply chain professionals.

In addition, this essay is one of few attempts to adopt a concept of network multiplexity by considering multiple types of network ties to examine supply network phenomena. Adding to the traditional visible ties (contractual and transactional ties), invisible dimensions (professional and personal ties) were additionally incorporated in demonstrating supply network architecture. This enabled a more thorough description of supply network architecture, which is essential for drawing more meaningful conclusions about the association between strategic intents and supply network properties. A series of social network analyses confirmed the multiplex traits of supply networks by showing that a given supply network having the same set of firms can be perceived differently based on different tie types with different directions and strengths. This can provide a theoretical foundation to reexamine and confirm that the previous buyer-supplier relationship literature based on uniplex perspective still hold for other types of interfirm ties.

Lastly, the current study adopted *directed valued network* and *whole network* approaches. Directed valued network approach has definite advantages in grasping network phenomena by considering both directions and strengths of network ties, whereas the widely-used binary network approach relies on counterintuitive premises that all ties are completely homogeneous

and symmetrical (Wasserman and Faust 1994; Freeman 2004). In addition, for the sake of saving the time and efforts for network data collection, many social network studies have taken an ego network approach which considers one single network actor and a set of directly linked neighbors. This approach, however, has serious methodological limitations for analyzing supply networks in that: 1) it considers a focal network actor's perceptions only (Mehra et al. 2001; Marsden 2005), and 2) a clear determination of supply network boundary is almost impossible (Choi et al. 2001; Borgatti and Halgin 2011). Therefore, this study adopted a *whole network* approach collecting bidirectional responses stretching from one network actor to its raw materials suppliers, which has been repeatedly recommended as the most desirable approach to investigate supply networks comprising all network entities involved to sourcing activities (Ketchen and Hult 2007; Borgatti and Li 2009). Taken together, this study tried to draw out the fullest grasp of supply network phenomena by adopting more realistic and rigorous network approaches which have not yet been used in existing supply network literature.

3.6.2 Limitations and Future Directions

This essay is not without limitations. First, the strategic intents and supply network tie types considered in this research are not exhaustive. Although Fisher's (1997) considerations are one of the most highly cited paper when discussing supply chain design, future studies may incorporate more component-level strategic intents not represented by Fisher's framework. Innovation-focused components, for instance, can be taken into consideration because it occasionally focuses on both lower cost (in case of incremental innovation) and responsiveness (in case of radical innovation) intents. In this vein, knowledge sharing often proxied by customer- and supplier-specific R&D investments can be considered as an additional supply network tie type.

Second, this study used cross-sectional network data in describing supply network properties because of the non-availability of longitudinal dataset. An access to the secondary data sources could be helpful to provide more generalizable findings on the associations between strategic intents and network properties even though it will still sacrifice sample size to obtain the whole network data. A potential remedy for this challenge is carrying out the same data collection procedure to the original respondents after a certain time period, and conducting an event study analysis on abnormal changes of network properties. It can be another option to targeting industries such as information technology, software or fashion with relatively shorter industry clockspeeds and checking whether the changed network properties remain changed or get restored to the original states.

Lastly, future researchers may find it interesting to examine performance implications of supply network architecture. Prior research in organization theory and strategic management have argued that the interfirm networks consisting of direct and indirect relations with other firms systematically affect a firm's performance such as innovation and financial performance, theoretically termed as "network competence." Depending on a key premise underlying network strategy that a firm's inimitable and non-substitutable resources lie outside its boundaries (Ring and Van de Ven 1994; Mowery et al. 1996; Gulati 1999), it will be an interesting extension to test to see if the existing theories still hold in a supply network context.

In conclusion, this essay provides a strategic supply network perspective by investigating the associations between strategic intents and supply network properties. Hopefully, the findings here provide the basics for developing novel theories of supply network management by testing the applicability of existing knowledge on interfirm networks to a supply network setting, which will eventually advance our understandings on multi-faceted supply network phenomena.

4 SUPPLY NETWORK ARCHITECTURE AND PERFORMANCE: A CONTINGENCY PERSPECTIVE

4.1 Introduction

Individual businesses no longer compete as standalone entities, but rather as collaborative networks. We are now entering the era of 'network competition' where the prizes will go to those organizations who can better structure, coordinate and manage relationships with their partners in a network committed to creating customer and consumer value through collaboration. — Martin Christopher, *Logistics and Supply Chain Management: Creating Value-Adding Networks* (2011, p.104)

A supply chain is a multi-level complex system with a strict *architecture* consisting of a wide range of organizations, people, and activities that are all linked via exchanges of materials, information, and resources in creating a product and then delivering it to the end customer (Cooper et al. 1997; Mentzer et al. 2001; Christopher and Towill 2002; Ketchen et al. 2008). It is also viewed as a set of value-adding activities of separate but well-aligned entities within and across tiers, providing more benefits than the sum of its individual participants could generate, and consequently making those benefits available to all the participants (Lee 2004; Moyaux et al. 2006; Ryall 2013). These notions collectively suggest that a supply chain should be analyzed as a *network* that comprises multiple tiers of network entities such as raw material suppliers, manufacturers, distributors, wholesalers, retailers, and customers.

Although supply chain management (SCM) research has long recognized the importance of building interfirm relationships and their impacts on firm performance, much of this work has been restricted to the investigation of dyadic or triadic relationships between one OEM and its

immediate supplier(s) (Galaskiewicz 2011). In this setting, a buying firm can create influence over its supplier(s) by demonstrating its willingness to jointly improve the earnings and decrease the costs of both parties or by making relationship-specific investments (Hoetker et al. 2007; Ho 2013). While previous dyadic and triadic approaches were useful for investigating interfirm exchanges between a focal firm and its *immediate* supply chain partners, in the era of "network competition" (Christopher 2011), they fall short of grasping the whole picture of a complicated supply network (Parkhe et al. 2006; Choi and Kim 2008; Wassmer et al. 2010; Wilhelm 2011). Frohlich and Westbrook (2001) also acknowledged the pitfalls of those local-level investigations by noting that manufacturers cannot fully utilize their performance potential when they focus on only one side of their supply chains. A few recent works have viewed and explored supply chains as a form of *network* (See Table 2.1 for more detail regarding the development stages of supply network research); but they still have fallen within limited domains such as conceptual frameworks and descriptive case studies without further empirical substantiation on the existence of network competence in the SCM context (Borgatti and Li 2009).

Recent literature, mainly in the domains of organizational behavior and strategic management, has indicated that interfirm networks consisting of multiple direct and indirect relationships play important roles in a firm's competitive strength and performance. As a step to further the resource-based view, those studies utilized various network measures and demonstrated that interfirm networks systematically affect a firm's performance such as organizational learning (Powell et al. 1996; Dyer and Nobeoka 2000), innovation (Hargadon and Sutton 1997; Ahuja 2000a; Tsai 2001), new venture survival (Lee et al. 2001; Hager et al. 2004), team creativity (Uzzi and Spiro 2005), and financial performance (Granovetter 2005; Shipilov 2006). This causality has been termed *network competence* and is defined as the ability of a firm

to develop and utilize interfirm relationships in striving for better performance (Gemünden and Ritter 1997; Ritter 1999). The prevalence of network competence perspective raises the following important questions to supply network researchers. Does the supply network architecture of a firm affect its supply chain performance? If so, what architectural properties of the supply network will enhance or deteriorate which supply chain performance outcomes? Finally, how does an OEM's efforts to exert its influence on its suppliers' sourcing decisions interplay with such causalities?

To address these questions, this study examines the impact of key indices quantifying supply network architecture on supply chain performance measures with consideration of the contingent effects of OEM intervention in selecting non-immediate suppliers. Drawing upon a unique dataset which allows the analyses of directed valued supply networks, this research aims to shed light on the study of supply network, and consequently, to offer a *supply network competence perspective*. The remainder of this piece begins by introducing previous research streams on network competence that will set a stage for developing hypotheses about supply network competence. Section 3 reviews the data, measures, and research methods used to test the proposed hypotheses. Section 4 provides the key results and interpretations. Section 5 presents the results of field investigations to provide further insights to the quantitative and qualitative findings from the previous section. Section 6 discusses the theoretical and methodological contributions, followed by the final section on limitations and directions for future research.

4.2 Theoretical Background and Hypotheses

4.2.1 Network Competence Perspective

Among the studies used to identify the source of network competence, two main research streams can be highlighted: one has tried to find the determinant of network competence at the

ego-centric level focusing on a particular firm's position within the network while another has concentrated on the *socio-centric* level which analyzes the overall pattern of multiple firms (Kilduff and Tsai 2003; Provan et al. 2007). First, a group of researchers has posited that a firm's *position* in interorganizational network shapes network competence and its performance. Podolny (1993), for instance, argued that a bank's network position in terms of centrality is positively associated with its reputation and economic advantages. In the context of the chemical industry, Ahuja (2000a) showed that positional aspects of a firm's ego network – direct/indirect ties and structural holes – influence its subsequent innovation output. More recently, Koka and Prescott (2008) also found the firms in an entrepreneurial position with multiple structural holes are superior than the ones with high centrality in their productivity performance under environmental changes in the steel industry. These representative studies commonly argue that a firm occupying a certain advantageous position within the network may be better able to access and assimilate more resources, and thereby gains better performance. The existing SCM literature examining dyadic or triadic supply chain relationships agrees with this ego-centric view in which it mainly focuses on how a focal firm's interactions with immediate supply chain partner(s) influence its actions and outcomes.

An alternative stream of literature, labeled the socio-centric view, extends the search for a firm's network competence from its position to the overall *architectural properties and characteristics* of the network where it is embedded. This view regards the interfirm network as a governance system which has definite impacts on performance under the presumption that it involves multiple independent entities collaborating toward a common goal to optimize the overall performance of the system (O'Toole 1997; Gulati 1998; Powell et al. 2005). By employing the network as a unit of analysis, it enables researchers to grasp the whole picture of a

complicated interlinked network rather than the individual firms that comprise the network. In adopting the network competence perspective to the SCM context, such view aligns well with the previously mentioned definition of a supply chain as invoked by some pioneering studies (e.g. Cox et al. 2001; Choi and Kim 2008; Srai and Gregory 2008; Kim et al. 2011), and thus is more appropriate to analyze the architecture of supply networks per se and their supply chain performance outcomes. Despite those repeated calls and evident benefits, much of socio-centric network competence research in the field of management as well as SCM has primarily fallen within limited domains such as concept development and descriptive case studies that lack generalizability (e.g. Kogut 2000; Dhanaraj and Parkhe 2006; Koka et al. 2006). The main reason for this dearth of further empirical substantiations is because the data collection is very costly and time-consuming (Scott 2000; Provan et al. 2007; Knoke and Yang 2008). One rare exception is a study by Gibbons (2004) who examined the differential influences of six prototypical inter-regional network architectures on innovation diffusion via the simulation method, but this one example is not sufficient. The current study thus adopts the socio-centric view in examining the performance consequences of supply network properties to further the research on network competence perspective. To the best of the author's knowledge, there has been no other large-scale empirical attempt to explore the associations between an OEM's socio-centric supply network competence and its performance consequences.

4.2.2 Supply Network Tie Types and Characterization Indices

Sociologists illustrated a network as a single closed set of actors (or nodes) and one or more types of ties (or edges) such as friendship, kinship, communication, and co-membership between them, and social network research has sought to understand observed dynamics of multiple network entities (i.e. persons). In business settings, network can be viewed as a complex

organizational outcome of multiple strategic alliances that could have governance and performance implications (Webster 1992; Heide 1994); in this regard, an extensive literatures on corporate governance has addressed that interfirm networks composed of interorganizational and interpersonal ties serve as a firm's inimitable and non-substitutable resources and capabilities (Wiewel and Hunter 1985; Gulati et al. 2000; Håkansson and Ford 2002; Lavie 2006). One aspect that has been neglected in previous studies is the *multiplex* nature of the interorganizational and interpersonal ties embedded in interfirm network, which refers to the multiple different architectural properties with regard to types and attributes of network ties that can be observed from the same network (Verbrugge 1979; Burt 1980; Feld 1981; Ibarra 1992). Considering the various dimensions of supply network ties, it is essential to incorporate this multiplexity approach as a platform for finding the "hidden" properties of supply network architecture. This research thus considers four different supply network tie types – contractual, transactional, professional, and personal ties – which run across multiple partners nested within the supply network. The first two types represent *visible* network ties for exchanging tangible network resources such as goods and services, whereas the other two capture *invisible* (and mostly intangible) resource exchanges taking place among supply network partners. The conceptual definitions of the four supply network tie types under consideration and their measurement items used based on the literature are presented in Table 2.2.

Social network analysis (SNA) indices, which have been widely used by other network researchers in fields of organizational behavior and strategic management, were adopted to quantify the architectural properties of supply networks formed by different tie types. More specifically, this study focuses on four socio-centric network indices (betweenness centralization, in-degree centralization, out-degree centralization, and global clustering coefficient) which

characterize the overall pattern of multiple network actors. Further, unlike the majority of the existing network studies that presumed all ties are completely homogeneous and symmetrical, this research also takes the *directed valued network* approach which considers both direction and strength (or magnitude) of the network tie, which is more useful and realistic approach for exploring network phenomena. Table 2.3 provides a new framework of supply network implications of the socio-centric SNA indices for directed valued networks used in this study for four types of supply network ties.

4.2.3 Hypotheses

The proliferation of network views in interfirm relationship research has raised discussions about how the performance of an interfirm network should be measured (e.g. Dyer 1996; Soda et al. 2004; Villarroel and Taylor 2006; Miller et al. 2013). Thus far, however, they have lacked a consensus as to which measures are appropriate and preferable for describing the outcomes of interfirm networks. This fragmentation arises in that those measures depend upon research context and level of analysis (Park 1996). Supply network research is almost free from this concern in that each supply chain, a basic building block of supply networks, is strategically designed to achieve a set of system-wide objectives through functional differentiation and business process interdependence among its members in offering finished products to end customers (Mentzer et al. 2001; Ketchen and Hult 2007; Chopra and Meindl 2009). A supply network thus is intrinsically built, managed, and coordinated by incorporating micro- and macro-level planning, control, and adjustment that function as integrating mechanisms (Lee and Billington 1995; Chapman et al. 2002; Gibson et al. 2005; Christopher 2011). In this vein, most of the existing literatures dealing with and within a supply network context (or a quasi-supply-network context comprising more than two supply chain members and tiers) have predominantly

viewed an OEM's supply chain performance measures as collective system outcomes of the OEM (or the one closest to end customers) itself and all the rest of the members embedded in its supply network (Beamon 1999; Pathak et al. 2007; Choi and Kim 2008; Schoenherr and Swink 2012). The five most frequently discussed measures of supply network outcomes are: cost (e.g. Lamming et al. 2000; Rusinko 2007), quality (e.g. Taylor 2005; Wang and Du 2007; Choi and Kim 2008), delivery (e.g. Guimaraes et al. 2002; Hallikas et al. 2002; Vachon and Klassen 2002), and flexibility (e.g. Bertrand 2003; Lin 2004; Krajewski et al. 2005), and more recently, innovation (e.g. Rong et al. 2010; Arlbjørn et al. 2011; Corsaro et al. 2012).

Even with the theoretical and empirical underpinnings on the usage of conventional supply chain performance measures in network settings, one distinction should be noted between the cost and the others (i.e. quality, delivery, flexibility, and innovation) due to their different dynamics leading to the OEM's network-wide performance outcomes. More specifically, an OEM's total supply chain cost mostly equals to the sum of those of all supply chain participants (Bowersox and Closs 1996; Lau et al. 2002). From the OEM's standpoint, the benefits of cost reduction generated by direct or indirect partners can be readily transferred to and manifested in its network-wide cost performance outcome (Anderson and Parker 2002; Bajaj et al. 2004; Sarmah et al. 2006). This non path-dependent nature of cost performance can be represented as an additive function of utility gains (i.e. local level cost performance) made by each of its supply network members (i.e. $\mathrm{f(abc)} = f(a) + f(b) + f(c)$ where "f(abc)" denotes an OEM's cost performance) in a network setting. In other words, the OEM that is closest to end-customers can enjoy at least some of the benefits of one upstream supply network member's improved cost performance even when the others do not show comparable outcomes (e.g. $0 < \mathrm{f(abc)} \leq 1$ when $f(a) = 1$, $f(b) = 0$, and $f(c) = 0$). On the other hand, the other four performance measures (i.e.

quality, delivery, flexibility, and innovation) of an OEM are intrinsically path-dependent, and thus system-wide alignment and integration efforts among supply chain members become essential for an individual member's performance improvement to lead to an OEM's (or other downstream members') outcome(s) (Frohlich and Westbrook 2002; Narasimhan and Kim 2002; Flynn et al. 2010; Jin et al. 2013). This collective and systemic nature of the four measures emerges as a multiplicative function of all individual supply network members' performance (i.e. $\mathrm{f(abc)} = f(a) \times f(b) \times f(c)$ where "f(abc)" denotes an OEM's performance). That is, in network settings, one or more supply network members' superior quality, delivery, flexibility, and innovation performance does not always lead to an OEM's network-wide performance but rather is limited by a *bottleneck* not prepared to keep up with such improvement (e.g. $\mathrm{f(abc)} = 0$ when $f(a) = 1$, $f(b) = 0$, and $f(c) = 1$). This study tests the performance consequences of key supply network architecture indices based upon the distinction of supply chain performance measures presented in the preceding chapters.

Social network studies have adopted betweenness centrality to measure an individual actor's power, and the extent to which it controls the resource flows in its network. As a socio-centric measure indicating the variation of the betweenness centralities of all network actors, betweenness centralization characterizes to what extent the overall network is built around a particular group of actors serving as hubs relative to the rest of the network (Freeman 1979; Scott 2000). A low betweenness centralization score represents that the network resources running through various tie types are almost equally distributed across the entire network, whereas a high score indicates that there exist particular firms possessing more or less network resources in it. This measure can differently impact on an OEM's path-dependent (i.e. cost) and non-path-dependent performance measures. When supply network entities are linked through a particular

group of focal firms, those firms will be able to achieve higher cost outcomes by securing more network resources in terms of contract terms, transaction amounts, professional and personal relations, and the OEM can enjoy those benefits achieved by its upstream supply network partner(s). From the OEM's standpoint, in contrast, its quality, delivery, flexibility, and innovation performance outcomes will be realized and observed when network resources are more equally distributed across its supply network entities – collectively characterized as low betweenness centralization – because of their nature as path-dependence. In this setting, an OEM can enjoy a broader range of resource sharing that enables combining its network members' problem solving insights, physical assets, and news of technological breakthroughs (Ahuja 2000a). Based on this line of reasoning, the following set of hypotheses is proposed:

HYPOTHESIS 1A. *The betweenness centralizations of an OEM's supply network consisting of contractual, transactional, professional and personal ties are positively associated with its cost performance.*

HYPOTHESIS 1B. *The betweenness centralizations of an OEM's supply network consisting of contractual, transactional, professional and personal ties are negatively associated with its quality, delivery, flexibility, and innovation performance.*

In network terms, in-degree centrality represents the total number of ties pointing toward one specific network actor. In-degree centralization, a socio-centric version of in-degree centrality, is derived by the variation in individual actor's in-degree centrality at the network level, and this indicates to which extent network resources are converged on particular actors (Wasserman and Faust 1994). A network entity which has more amounts of incoming network resources indicates that the other entities are more dependent upon it. When a firm which is relatively less dependent upon the resources of its counterpart(s), according to Pfeffer and

Salancik (1978) and Dyer and Singh (1998), it often leverages the resource dominance over others to achieve its intended goals. For cost-side effects, the more inflows of network resources towards particular focal firms can enable them to more easily realize cost economies to be reflected in the OEM's cost performance measure. Similarly, when there exists a particular group of network entities possessing more network resources, those entities also can have enough power to serve as coordinators and catalysts in aligning and driving higher levels of network-level objectives to subsequently maximize its own path-dependent performance outcomes. This reasoning leads to the following hypotheses:

HYPOTHESIS 2. *The in-degree centralizations of an OEM's supply network consisting of contractual, transactional, professional and personal ties are positively associated with its cost, quality, delivery, flexibility, and innovation performance.*

As a socio-centric measure indicating the variation of the out-degree centralities of the entire network actors, out-degree centralization explains the extent to which particular actors disseminate network resources to others (Wasserman and Faust 1994). In other words, a high out-degree centralization score indicates that a few particular focal network actors disseminate most of the network interactions for the rest of the members, whereas a low score represents that each actor of the network shares a more equal amount of interactions. In an interfirm network context, high out-degree centralization can be interpreted as that a particular group of focal firms empowers other network entities by sharing its network resources. The majority of the rest of the network receiving network resources from a small group of firms will not be able to, nor seek to, take initiative for aligning and coordinating the network-level objectives. For cost-side effects, the small groups firms disseminating network resources to others themselves will also suffer from the lack of needed resources to achieve their own cost benefits. Based on this reverse logic

from the hypothesized associations between in-degree centralizations and supply chain performance above, the following hypothesis is proposed:

HYPOTHESIS 3. *The out-degree centralizations of an OEM's supply network consisting of contractual, transactional, professional and personal ties are negatively associated with its cost, quality, delivery, flexibility, and innovation performance.*

According to interfirm network literature, direct contacts and connections between a firm and its counterpart (e.g. customer or supplier) facilitate the exchange and distribution of organizational resources, and subsequently contribute to the competitive advantage of involved actors (Porter 1990; Morgan and Hunt 1999). In social network research, this connectivity among network actors has been measured by a global clustering coefficient which indicates the extent to which how cliquish (or tightly knit) a network is as a whole (Newman 2003; Schank and Wagner 2005). A low global clustering coefficient represents that only a few network actors are directly connected to one another which results in hierarchical (i.e. more cliquish) architecture as a whole, whereas a high coefficient value indicates more actors have direct connections with others collectively manifesting lateral (i.e. less cliquish) network architecture. In the context of supply chain performance outcome, more direct connections to one another (i.e. high global clustering coefficient) will be improving path-dependent measures in that those established connections can serve as conduits for better alignment and coordination. From an OEM's standpoint, however, this high connectivity will raise unnecessary costs and efforts which will subsequently deteriorate cost performance because the OEM could enjoy cost benefits without that many direct connections with its network partners. Accordingly, this essay investigates the following set of hypotheses:

HYPOTHESIS 4A. *The global clustering coefficients of an OEM's supply network consisting of contractual, transactional, professional and personal ties are negatively associated with its cost performance.*

HYPOTHESIS 4B. *The global clustering coefficients of an OEM's supply network consisting of contractual, transactional, professional and personal ties are positively associated with its quality, delivery, flexibility, and innovation performance.*

As supply networks usually involve complex interfirm dependencies that require proper coordination, network researchers can improve the completeness, accuracy, and predictability of their findings (Borgatti and Halgin 2011). Considering that supply networks consist of multiple independent entities pursuing their own interests, especially (i.e. not taking account of their reciprocal behaviors), supply network members can behave opportunistically to maximize their own local-level performance (Liu et al. 2009; Danese and Romano 2012; Mahapatra et al. 2012). From an OEM's standpoint, a growing number of outsourcing and offshoring projects have resulted in the increase of indirect supply network members that are invisible and difficult to be monitored. An OEM can prevent the opportunistic behaviors of its indirect upstream supply network members by imposing a strong influence on its immediate (i.e. tier-1) suppliers' sourcing decisions (Williamson 1985). For cost-side effects, this influence will enable the OEM to transfer more non-path-dependent benefits (i.e. cost performance) generated by its indirect as well as immediate supply network members. As discussed in Chapter 3 of this dissertation research, a supply network is viewed as a systematic outcome which is intentionally and strategically designed, implemented, and maintained in conformity with an OEM's strategic intent(s). Therefore, an OEM's influence on its immediate suppliers' sourcing decisions will also be helpful in better defining and spreading its network-level objectives on path-dependent

performance for other supply network members and, subsequently, may amplify the positive performance effects of network resources on its performance. The preceding discussion thus leads to the following hypothesis:

> HYPOTHESIS 5. *An OEM's influence on its immediate suppliers' sourcing decisions positively moderates the associations between the architectural properties of supply network and its supply chain performance.*

4.3 Methodology

4.3.1 Data

Survey is the most common method to collect social network data. Given the interests of this study, a quantitative method of survey-based questionnaire was employed to collect the data about an OEM's *component-level* strategic intent and the direction and strength of ties among all supply network partners involved to supply the selected component. Especially, the current study takes a *whole network* approach, which collects bidirectional responses stretching from a focal actor to its raw materials suppliers (Wellman 1988; Kilduff and Tsai 2003; Provan et al. 2007), which differentiates this study from prior studies. This approach has been repeatedly recommended as the most desirable approach for researchers to investigate the holistic and systemic architecture of a supply network, but according to the exhaustive literature reviews of Provan et al. (2007) on academic articles published between 1985 and 2005 discussing interfirm networks, only 26 articles dealt with interfirm network outcomes based on a whole network approach because of its cost-intensive and time-consuming nature.

To lessen the burden of data collection, three global South Korean automobile and consumer electronics manufacturers were contacted, and then a combined sampling approach of

fixed list and *snowball selections* was adopted (Doreian and Woodard 1992; Stevenson and Greenberg 2000; Borgatti and Li 2009). First, to keep the whole network perspective in data collection, initial contacts mostly at the executive level were asked to select a strategically important component with manageable network sizes (i.e. no more than 3 tiers and 5 suppliers per tier) and recommend the most knowledgeable sourcing manager in charge of the selected component. This step also contributed to minimize key informant bias (Kumar et al. 1993). Secondly, sourcing managers were asked to evaluate their perceptions on different types of ties (i.e. contractual, transactional, professional, and personal) with their major immediate suppliers mostly listed as the OEM's preferred supplier. Contractual, professional, and personal ties were evaluated using a five-point scale, anchored by "1" (strongly disagree), "3" (neither disagree not agree), and "5" (strongly agree), and the transactional tie was assessed by percentages of total spend (or sales) for each supplier (or buyer) for the selected component. Next, the same questions were given to the OEM's counterparts (i.e. tier one suppliers) based on the contact information provided by the focal firm's sourcing manager. These steps were repeated for the successive tiers of suppliers (i.e. tier two and tier three suppliers) until end-tier suppliers were reached. The overall data collection process is summarized in the flow chart in Figure 3.2.

To check the existence of duplicate respondents (i.e. suppliers), surveys on the successive tiers of suppliers were started after finalizing all the surveys on OEMs or higher tier suppliers. Since all the requested information was extremely confidential and sensitive to both buyers and suppliers, it was promised that all individual responses would be kept completely confidential, and all analyses would be implemented and presented only at the aggregate level. To reassure respondents regarding the confidentiality of their responses, all completed questionnaires were directly collected by the author instead of being routed through buying firms. As a result of these

efforts, a unique dataset of 153 component-level (89 electronics and 64 mechanical) whole networks with 1,852 total network members was collected. Table 3.1 provides the demographics and descriptive statistics of the study population.

4.3.2 Variables and Measures

Network Indices

Item measures for each type of supply network ties are shown in Table 2.2. Based on the collected data about the directions and strengths of supply network tie types, the methods in section 2.3.2 were adopted in calculating network indices that characterize overall patterns of relationships among supply network actors (i.e. supply network architecture) in a directed valued network setting. Table 3.4 provides descriptive statistics for all network indices used in this study.

Performance Measures and OEM's Influence on Sourcing Decisions

As discussed earlier, the OEM's performance outcome from its component-level supply network architecture in accordance with the level of its influence on immediate supplier(s) is a main interest of this study. Thus, well-defined and validated scales from the existing literature were adopted for five conventional supply chain performance and one contextual variable (i.e. OEM's influence) measures. All multi-item measures had a five-point Likert scale, anchored by "1" (significantly worse), "3" (neither better nor worse), and "5" (significantly better) for cost, quality, delivery, and flexibility performance, and "1" (strongly disagree), "3" (neither agree nor disagree), and "5" (strongly agree) for innovation performance and OEM's influence. Table 4.1 contains a list of all performance and the OEM's influence measures and corresponding measurement items.

Confirmatory factor analysis (CFA) is used to assess the internal and external consistency of all constructs measured with multi-item *reflective* indicators. Table 4.1 presents the factor

loadings demonstrating significant relationships with their underlying theoretical constructs and the average variance extracted (AVE) values are all well above the criterion of 0.50 (Fornell and Larcker 1981). These results collectively provide evidence of convergent validity. Next, discriminant validity is assessed by comparing the squared correlation between two constructs to their respective AVE (Fornell and Larcker 1981; Chau 1997). None of the squared correlations are equal to or higher than the AVE for each individual construct. Hence, it can be concluded that there is discriminant validity among the theoretical constructs. In addition, reliability by Cronbach's coefficient alpha and composite reliabilities (CR) are assessed. As shown in Table 4.1, all measurement models have high reliabilities with Cronbach's alpha values exceeding 0.80 (Nunnally 1978) and CR values equal to 0.70 or higher (Bagozzi and Yi 1988). Taken together, these results indicate that the theoretical constructs exhibit good psychometric properties.

Table 4.1 Confirmatory Factor Analysis Results

Construct and Measurement Items	Factor Loadings	AVE	Composite Reliability	Cronbach's Alpha
Cost Performance		0.734	0.776	0.932
Acquisition costs	0.782			
Cost reduction performance	0.911			
Designing cost out of the component	0.886			
Ability to meet target costs	0.894			
Supplier's ability to engage in strategic cost modeling	0.795			
Quality Performance		0.792	0.876	0.951
Technical capability	0.831			
Conformance quality	0.903			
Internal process quality	0.925			
Component durability	0.907			
Component reliability	0.894			
Delivery Performance		0.648	0.892	0.813
On-time delivery	0.731			
Manufacturing lead time	0.875			
Customer lead time	0.802			
Shipping accuracy	0.543			
Flexibility Performance		0.752	0.924	0.891
Volume flexibility	0.854			
Delivery flexibility	0.906			
Design flexibility	0.868			
Launch flexibility	0.840			

Note: N=153 component-level networks

Table 4.1 (cont'd)

Construct and Measurement Items	Factor Loadings	AVE	Composite Reliability	Cronbach's Alpha
Innovation Performance		0.506	0.754	0.807
By sourcing this component, our firm could significantly increase the number of new products to the market.	0.796			
By sourcing this component, our firm could add much more new features to existing product(s).	0.759			
By sourcing this component, our firm could add unique features to existing product(s).	0.667			
By sourcing this component, our firm could have significantly higher new product success rate.	0.704			
By sourcing this component, our firm could develop new product or features much faster.	0.679			
OEM's Influence		0.847	0.965	0.960
Our firm maintains active communication of our sourcing strategy with all supply network partners.	0.924			
Our firm and immediate (i.e. tier-1) suppliers always make joint decisions on selecting tier-2 or 3 suppliers.	0.981			
Our immediate (i.e. tier-1) suppliers must get our firm's approval on their selection of tier-2 or 3 suppliers.	0.976			
Our firm puts significant efforts to align suppliers across the whole supply network to our sourcing strategy.	0.746			
Our firm has well-established guidelines to support our immediate (i.e. tier-1) suppliers' selection of suppliers.	0.973			

Note: N=153 component-level networks

Cronbach's alpha ≥ 0.80; Average variance extracted [AVE] ≥ 0.50; Composite reliability ≥ 0.70; Factor loading ≥ 0.50

4.3.3 Methods

Hierarchical multiple regression analyses were adopted to test the main effect and interactional models (i.e. H1-H5) while controlling for the component type and network size of each component-level supply network. Before running the regressions, the responses on OEM's supply chain performance were converted into new weighted scores weighted by factor loadings generated by factor analyses. This was because responses based on rankings (e.g. 5-point Likert scale) often cannot provide meaningful statistical results. For example, on such a scale, let 50% of the total responses show marked as "1" while the other half signed "5" for a particular question. The mean value of the item is represented as "3" in interpretation even though none of the respondents chose that score. The response scores on supply chain performance thus were converted into new weighted scores weighted by factor loadings generated by factor analyses. In other words, for $i = 1, 2, \dots, n$, where n is the number of respondents (i.e. component-level supply networks); $t = 1, 2, \dots, m$, m is the number of factors, and w_j is the factor loading of jth item, $j = 1, 2, \dots, k$, k is the number of items included in the tth factor, where x_{ji} is the ith respondent's score for jth item, the score for each factor (Ft_i) is:

$$Ft_i = w_1 \times x_{1i} + w_2 \times x_{2i} + \cdots + w_k \times x_{ki} = \sum_{j=1}^{k} w_j \times x_{ji}$$

By following the procedures described by Cohen et al. (2003), next, only control variables were entered in the first step. In the second step, the main indices characterizing supply network architecture were added to the regression. In the third and final step, the interaction terms, the cross-products of supply network indices and OEM's influence on its immediate suppliers' sourcing decisions (OFI) were introduced into the regression. The change in R^2 from step 2 to

step 3 provides a test of whether the interaction term makes a statistically significant contribution to the equation. This three-step procedure was repeated in 20 separate regressions, 4 with network indices (i.e. betweenness centralization, in-degree centralization, out-degree centralization, and global clustering coefficient) and 5 with supply chain performance (i.e. cost, quality, delivery, flexibility, and innovation) as the dependent variable. The regression equation of this approach using 10 variables (including 2 control variables) per each performance measure is represented as follows:

$$\text{Performance} = b0 + b1\times BC + b2\times IDC + b3\times ODC + b4\times GCC + b5\times BC\times OFI + b6\times IDC\times OFI + b7\times ODC\times OFI + b8\times GCC\times OFI + e$$

The key variables were mean-centered to simplify the interpretation of the results and to control the multicollinearity in moderated multiple regressions with continuous variables (Cronbach 1987; Aiken and West 1991; Hox 2010). Variance inflation factors (VIF) were also checked to see if there was a multicollinearity problem. Based on the all the regression models, the highest VIF was 3.173, which suggests no strong multicollinearity concern.

4.4 Results and Interpretations

A series of hierarchical multiple regression models were estimated to test the hypotheses. The empirical results on the associations between architectural characteristics of component-level supply networks and the OEM's supply chain performance are summarized in Tables 4.2 (Hypotheses 1A and 1B), 4.3 (Hypothesis 2), 4.4 (Hypothesis 3), and 4.5 (Hypotheses 4A and 4B). Moderating effects of an OEM's influence on its tier-1 suppliers' sourcing decisions (H5) were tested in each of the previous four hypotheses. For the sake of brevity, the estimated coefficients (B) and their significance levels will be mainly used for model interpretations, while

other estimates such as F and R^2 values are reported in those tables for completeness. In interpreting the results, field investigations were deemed necessary to interpret supply network phenomena from a more realistic perspective. Several component-level supply networks of the sample were thus revisited for verifications of the empirical findings and their preliminary interpretations. This provided a more complete and real-world perspective of the associations between an OEM's supply network architecture and its performance consequences. The exact names of companies, products, components were replaced with alphabets for anonymity.

Table 4.2 Results of Hierarchical Regression Analyses: Performance Effects of Betweenness Centralizations

	Dependent Variables														
	Cost			Quality			Delivery			Flexibility			Innovation		
	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2
Step 1: Controls (Comp = Component Type; Size = Network Size)															
Compo	-.020	.276	.004	.009	.050	.001	.008	.016	.000	.045	.286	.004	-.074	.688	.009
Size	.012			.005			-.002			.004			.001		
Step 2: Main Effects[b]															
Compo	-.019	.182	.007	.011	.861	.034	.019	*2.79*	.103	.039	.629	.025	-.082	1.867	.071
Size	.011			.005			-.002			.004			.001		
(a)	1.347			1.339			1.662			-.994			-2.358		
(e)	-.420			-3.048			.364			1.305			-2.068		
(i)	-.138			.234			-1.223			.817			.671		
(m)	.132			.211			-2.090			-1.036			.747		

Note: N=153 component-level networks

Bold: Significant at p < .01 level; *Underlined and Italic*: Significant at p < .05 level; Underlined Only: Significant at p < .10 level

[a] B = Unstandardized Coefficient

[b] (a) Contractual Betweenness Centralization; (e) Transactional Betweenness Centralization; (i) Professional Betweenness Centralization; (m) Personal Betweenness Centralization

Table 4.2 (cont'd)

	Dependent Variables														
	Cost			Quality			Delivery			Flexibility			Innovation		
	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2
Step 3: Interactions[b] (OFI = OEM's Influence on Tier-1 Suppliers' Sourcing Decisions)															
Compo	-.017	.375	.026	.006	1.01	.066	.024	*2.33*	.141	.039	.723	.048	-.088	1.801	.113
Size	.010			.005			-.004			.004			-.001		
(a)	1.496			2.228			.752			-.148			-2.515		
(e)	-.705			-3.359			.621			1.225			-2.163		
(i)	.034			.262			-1.064			.818			.709		
(m)	.315			.427			*-2.312*			-.811			.493		
(a) × OFI	-6.606			-7.926			9.437			-1.374			4.756		
(e) × OFI	-.434			4.945			-4.352			6.653			.024		
(i) × OFI	.875			-1.103			-.917			-.136			**-4.674**		
(m) × OFI	.505			-1.932			*-5.612*			-.530			2.803		

Note: N=153 component-level networks

Bold: Significant at p < .01 level; *Underlined and Italic*: Significant at p < .05 level; Underlined Only: Significant at p < .10 level

[a] B = Unstandardized Coefficient

[b] (a) Contractual Betweenness Centralization; (e) Transactional Betweenness Centralization; (i) Professional Betweenness Centralization; (m) Personal Betweenness Centralization

Table 4.3 Results of Hierarchical Regression Analyses: Performance Effects of In-degree Centralizations

	Dependent Variables														
	Cost			Quality			Delivery			Flexibility			Innovation		
	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2
Step 1: Controls (Comp = Component Type; Size = Network Size)															
Compo	-.020	.276	.004	.009	.050	.001	.008	.016	.000	.045	.286	.004	.012	.688	.009
Size	.012			.005			-.002			.004			.009		
Step 2: Main Effects[b]															
Compo	-.022	.457	.018	.004	.222	.009	.009	**3.093**	.113	.025	1.681	.065	-.084	1.558	.060
Size	.017			.001			-.009			.004			.003		
(b)	2.858			-2.110			.758			-1.693			-2.456		
(f)	.852			1.462			*5.793*			**8.142**			.558		
(j)	-1.117			-.411			1.804			-.836			-.461		
(n)	-1.879			1.294			.085			-3.044			-1.800		

Note: N=153 component-level networks

Bold: Significant at p < .01 level; *Underlined and Italic*: Significant at p < .05 level; Underlined Only: Significant at p < .10 level

[a] B = Unstandardized Coefficient

[b] (b) Contractual In-degree Centralization; (f) Transactional In-degree Centralization; (j) Professional In-degree Centralization; (n) Personal In-degree Centralization

Table 4.3 (cont'd)

	Dependent Variables														
	Cost			Quality			Delivery			Flexibility			Innovation		
	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2
Step 3: Interactions[b] (OFI = OEM's Influence on Tier-1 Suppliers' Sourcing Decisions)															
Compo	-.034	.637	.043	-.006	.384	.026	.005	*1.934*	.120	.012	1.758	.110	-.087	1.387	.089
Size	.022			.004			-.009			.009			.001		
(b)	3.411			-1.492			1.089			-.651			-1.788		
(f)	.177			.686			5.261			**7.214**			-.263		
(j)	-1.320			-.437			2.015			-.740			-.052		
(n)	-1.988			1.338			.298			-2.862			-1.513		
(b) × OFI	4.332			.223			-5.014			-3.313			-.743		
(f) × OFI	-11.225			-6.449			1.421			1.888			7.701		
(j) × OFI	-2.222			-3.235			-2.270			*-7.379*			-3.371		
(n) × OFI	1.599			1.900			1.102			3.819			-7.623		

Note: N=153 component-level networks

Bold: Significant at $p < .01$ level; *Underlined and Italic*: Significant at $p < .05$ level; Underlined Only: Significant at $p < .10$ level

[a] B = Unstandardized Coefficient

[b] (b) Contractual In-degree Centralization; (f) Transactional In-degree Centralization; (j) Professional In-degree Centralization; (n) Personal In-degree Centralization

Table 4.4 Results of Hierarchical Regression Analyses: Performance Effects of Out-degree Centralizations

	Dependent Variables														
	Cost			Quality			Delivery			Flexibility			Innovation		
	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2
Step 1: Controls (Comp = Component Type; Size = Network Size)															
Compo	-.020	.276	.004	.009	.050	.001	.008	.016	.000	.045	.286	.004	-.074	.668	.009
Size	.012			.005			-.002			.004			.001		
Step 2: Main Effects[b]															
Compo	-.013	.986	.039	.007	.622	.025	.008	*2.331*	.087	.045	.361	.015	-.071	1.374	.053
Size	.016			.000			-.009			.003			.005		
(c)	-.311			.785			1.813			-.995			-.607		
(g)	-1.312			-.011			-.743			-.228			.059		
(k)	5.566			-2.963			2.427			-1.889			-3.853		
(o)	2.455			-2.854			-2.797			-1.680			1.073		

Note: N=153 component-level networks

Bold: Significant at p < .01 level; *Underlined and Italic*: Significant at p < .05 level; Underlined Only: Significant at p < .10 level

[a] B = Unstandardized Coefficient

[b] (c) Contractual Out-degree Centralization; (g) Transactional Out-degree Centralization; (k) Professional Out-degree Centralization; (o) Personal Out-degree Centralization

Table 4.4 (cont'd)

	Dependent Variables														
	Cost			Quality			Delivery			Flexibility			Innovation		
	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2
Step 3: Interactions[b] (OFI = OEM's Influence on Tier-1 Suppliers' Sourcing Decisions)															
Compo	-.027	1.258	.081	.010	1.297	.084	-.004	1.656	.104	.046	.685	.046	-.051	1.248	.081
Size	.014			-.003			-.008			.002			.004		
(c)	-.251			1.023			1.680			-.887			-.428		
(g)	-1.399			-.051			-.771			-.283			.092		
(k)	5.906			-2.636			2.422			-1.870			-3.974		
(o)	2.863			-2.327			-2.861			-1.747			1.130		
(c) × OFI	-.586			4.002			-3.982			4.619			4.218		
(g) × OFI	.259			-2.023			1.177			2.701			-1.654		
(k) × OFI	10.74			14.26			-6.200			7.350			-9.250		
(o) × OFI	*10.78*			**11.80**			-1.529			2.201			-2.968		

Note: N=153 component-level networks

Bold: Significant at p < .01 level; *Underlined and Italic*: Significant at p < .05 level; Underlined Only: Significant at p < .10 level

[a] B = Unstandardized Coefficient

[b] (c) Contractual Out-degree Centralization; (g) Transactional Out-degree Centralization; (k) Professional Out-degree Centralization; (o) Personal Out-degree Centralization

Table 4.5 Results of Hierarchical Regression Analyses: Performance Effects of Global Clustering Coefficients

	Dependent Variables														
	Cost			Quality			Delivery			Flexibility			Innovation		
	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2
Step 1: Controls (Comp = Component Type; Size = Network Size)															
Compo	-.020	.276	.004	.009	.050	.001	.008	.016	.000	.045	.286	.004	-.074	.688	.009
Size	.012			.005			-.002			.004			.001		
Step 2: Main Effects[b]															
Compo	-.027	.716	.029	.015	.291	.012	.033	1.298	.051	.047	.397	.016	-.100	*2.524*	.094
Size	.006			.000			-.006			-.001			.012		
(d)	-2.655			-.525			.306			-.158			1.144		
(h)	-1.900			.327			3.202			-.551			-3.606		
(l)	1.924			1.468			-3.544			3.847			-1.945		
(p)	1.572			1.980			1.631			2.427			*-4.261*		

Note: N=153 component-level networks

Bold: Significant at p < .01 level; *Underlined and Italic*: Significant at p < .05 level; Underlined Only: Significant at p < .10 level

[a] B = Unstandardized Coefficient

[b] (d) Contractual Global Clustering Coefficient; (h) Transactional Global Clustering Coefficient; (l) Professional Global Clustering Coefficient; (p) Personal Global Clustering Coefficient

Table 4.5 (cont'd)

	Dependent Variables														
	Cost			Quality			Delivery			Flexibility			Innovation		
	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2	B[a]	F	R^2
Step 3: Interactions[b] (OFI = OEM's Influence on Tier-1 Suppliers' Sourcing Decisions)															
Compo	-.033	1.009	.066	.012	.292	.020	.036	1.097	.072	.049	.573	.039	-.104	1.897	.118
Size	.002			-.002			-.003			.000			.007		
(d)	*-3.341*			-.832			.091			-.685			.992		
(h)	-2.232			.140			3.457			-.502			-3.721		
(l)	2.773			1.863			-3.774			3.948			-.932		
(p)	1.652			1.999			1.711			2.641			*-4.028*		
(c) × OFI	1.207			.092			5.216			6.336			-1.579		
(g) × OFI	-5.441			-2.091			-6.366			-2.165			2.691		
(k) × OFI	-1.987			-.713			1.927			-2.295			-9.968		
(o) × OFI	-6.713			-3.203			2.024			-3.465			-6.888		

Note: N=153 component-level networks

Bold: Significant at $p < .01$ level; *Underlined and Italic*: Significant at $p < .05$ level; Underlined Only: Significant at $p < .10$ level

[a] B = Unstandardized Coefficient

[b] (d) Contractual Global Clustering Coefficient; (h) Transactional Global Clustering Coefficient; (l) Professional Global Clustering Coefficient; (p) Personal Global Clustering Coefficient

4.4.1 Cost Performance Effects of Supply Network Architecture

First, no significant result was found regarding the cost performance consequences of all supply network characteristics; that is, an OEM's supply network architecture in terms of contractual, transactional, professional, personal ties do not affect its cost performance in hypothesized directions. Some significant coefficients were found. For instance, transactional out-degree centralization showed a negative impact on the OEM's cost performance, which is in the hypothesized direction. However, interpretations were not warranted as the overall model was not statistically significant. Those results collectively suggest network-wide cost benefits are not conveyed via the interfirm ties among supply network members in terms of contractual, transactional, professional, or personal interactions. This finding contradicts previous literatures (e.g. Anderson and Parker 2002; Bajaj et al. 2004; Sarmah et al. 2006) which argued the transferability of cost benefits across supply network. Going a step further, this might also imply the possibility that cost performance is intrinsically *local*, and thus can be shared within a narrower scope such as supply chain dyads or triads. One senior-level purchasing manager at an automobile OEM commented: "They (cost benefits generated by downstream suppliers) should be theoretically transferable. In an automobile industry, based on my experience so far, most of the cost benefits are coming from manufacturing processes rationalization, capacity management, and/or manpower coordination (e.g. efficient work shifts) which are very internal. Further, suppliers will never want to announce it to their counterparts to keep all those benefits inside their own. We (i.e. an OEM) thus cannot realize what cost improvements were made (or not) by our suppliers, and this invisibility gets worse when dealing with non-immediate suppliers. This is one of main reasons why we set up cost reduction goals every 2-3 years and often offer incentives to encourage them achieving those goals."

4.4.2 Quality Performance Effects of Supply Network Architecture

Similar to cost performance, no model on the association between quality performance supply network index in terms of contractual, transactional, professional, personal ties was found statistically significant. Some significant coefficients supported the hypothesized direction. The interaction terms of an OEM's influence with professional and personal network ties among supply network members especially showed significantly positive impacts on quality performance; however, the overall model was not statistically significant. These results were hard to interpret and lack of intuitive meaning considering that numerous studies on total quality management have highlighted the positive impacts of close interfirm and interpersonal relationships. One purchasing manager of a consumer electronics OEM said: "I believe it is coming from the measure, quality. The qualities of sourced components are continuously traced and tested along the entire supply chain, from raw material supplier to our tier-1 suppliers. Therefore, you would not be able to find any notable quality increase or decrease within sourced components if you measure our (OEM's) performance only – those aspects will be more visible at a more downstream level. Most of our quality problems rather occur in assembly lines where all components are gathered."

4.4.3 Delivery Performance Effects of Supply Network Architecture

The results demonstrated partial support for hypotheses H1B and H2 examining the associations between delivery performance and supply network architecture in terms of betweenness centralization and in-degree centralization. First, the betweenness centralization regarding supply network entities' personal ties showed a negative coefficient ($B = -2.312$, $p < 0.05$) on an OEM's delivery performance. This indicates that an OEM's delivery performance gets worse as fewer focal firms serve as powerful and dominating hubs for exchanging non-work-related interactions

among supply chain personnel within the supply network. From a practitioner's perspective, however, personal relationships are invisible and thus are hard to control by the management. The significant negative interaction coefficient ($B = -5.612$, $p < 0.05$) gives a useful hint for mitigating the risk of personal interactions overly dominated by a few supply network entities. The result shows that the detrimental effects of personal ties on delivery performance get weaker when an OEM has a strong influence on its suppliers' sub-supplier selections. In other words, an OEM may mitigate the negative impact of high betweenness centralization of personal ties by increasing the influence on its counterpart's (i.e. first-tier supplier's) selection of sub-suppliers. Although there is only one significant dependent variable, it is a meaningful result in that it shows the role of personal ties among supply chain personnel in managing a traditional supply chain performance measure. Second, the in-degree centralization of transactional ties among supply network entities positively affects the focal firm's delivery performance ($B = 5.261$, $p < 0.05$). This shows that an OEM's delivery performance was improved when there are only a few particular focal firms which take up more percentage amounts of monetary exchanges within its supply network. This can be interpreted as: 1) other supply network entities are more dependent on fewer focal firms with regard to their sales, 2) those focal firms can consolidate and coordinate orders from multiple tiers of suppliers, and 3) this consequently improves the delivery performance of an OEM who is the end-customer of the supply network. Further, it implies that OEMs can reduce the upstream amplification (or bullwhip) effects in their supply networks by encouraging a few key down-tier suppliers to purchase a larger amount from the rest of the supply network. Third, the in-degree and out-degree centralizations regarding supply network entities' professional ties ($B = 2.015$ and 2.422 respectively, $p < 0.1$) are shown positive and significant. This collectively means that an OEM's delivery performance gets improved as the

more work-related interactions are focused on (in-degree) or disseminated by (out-degree) particular focal firms. This fits with the well-accepted delivery performance benefits of more centralized supply chain control (e.g., van der Vaart and van Donk 2004; Lockamy 2008). These results collectively suggest that an OEM can improve its delivery performance by encouraging a particular group of suppliers to collect and/or send out work-related interactions from and/or to the rest of the suppliers.

4.4.4 Flexibility Performance Effects of Supply Network Architecture

It was also found that the out-degree centralization of transactional ties among supply network entities positively affects the OEM's delivery performance ($B = 7.214$, $p < 0.01$), which provides partial support for H2. This illustrates that an OEM's flexibility performance in terms of volume, delivery, design, and launch is improved as fewer focal firms account for more percentage amount of monetary exchanges than the others within the supply network. Taken together with the positive association between in-degree centralization of transactional ties and delivery performance, this can be interpreted as evidence that: 1) those focal firms may be *utilizing* the financial resources assured by more incoming monetary transactions, and 2) the generated benefits are conveyed to the OEM's improved flexibility outcomes and possibly to other supply network members.

4.4.5 Innovation Performance Effects of Supply Network Architecture

The first notable finding is the detrimental effects of in-degree centralization of transactional ties among supply network entities on OEM's innovation performance. This SNA measure showed a positive effect on an OEM's delivery performance above. This collectively indicates that an OEM's over-empowerment for its down-tier suppliers' consolidated purchasing may hurt its

innovation performance. This also might indicate that relying on a few key suppliers is not enough for innovation performance since knowledge assets/resources are much more dispersed in today's supply networks (e.g. crowd sourcing). At the same time, however, the positive impact of the betweenness centralization with regard to supply network entities' transactional ties on an OEM's innovation performance highlights that there should be particular focal firms which have more percentage amount of monetary exchanges than others to gain better innovation performance. This implies that a small group of supply network entities with more transactional interests (in both sales and purchasing) may take the initiative to improve their end-customer's (i.e. OEM's) innovation performance. In other words, it is a situation in which "the more you have, the more you worry." This conjecture can be partially verified by the positive impact of the in-degree centralization with regard to network members' transactional ties on the OEM's innovation performance. Lastly, the negative coefficient of the global clustering coefficient with regard to network members' transactional ties indicates that the OEM's innovation performance deteriorates as its supply network as a whole has a more 'lateral' architecture of monetary exchanges among supply network members. It also supports the above observation (i.e. innovation by a small group of firms) by showing that the OEM's innovation performance becomes worse as more supply network entities have direct transactional connections with others on the supply network. Interestingly, this result contradicts those of Ahuja (2000a) who found the positive impact of an OEM's direct ties on its innovation performance. This might imply that an OEM's direct tie benefits such as knowledge transfer, knowledge spill-overs, and information sharing could be offset or even outweighed by transaction costs incurred in establishing and maintaining more direct interfirm ties. Given that Ahuja's (2000a) study utilized binary and ego-centric SNA index (i.e. degree centrality), furthermore, this finding also shows the usefulness

directed valued and socio-centric network analyses adopted by this study in addressing interfirm network architecture questions that pertain to its performance consequences.

4.5 Discussion

What makes one supply chain more successful than another under the era of supply-chain-to-supply-chain competition? A promising body of research claims that the answer lies within the orchestration of interfirm relationships, but it has suffered from the restrictive scope to grasp the whole picture of supply network comprising *multiple tiers* of supply chain partners (Choi and Kim 2008; Wilhelm 2011). A few recent works have adopted a network perspective to the SCM context; but they have fallen within limited domains such as conceptual frameworks and descriptive case studies without further empirical substantiation. This study draws on an innovative setting and data to overcome the limitations of previous dyadic/triadic studies. By analyzing the dataset of 153 supply networks consisting of 1,852 total network members, this study attempted to shed light on the question, "what architectural properties of supply networks drive the OEM's performance?" To address this question, this essay adopted the network competence perspective which has been widely used in organization behavior and strategic management literatures. The results from social network analyses and hierarchical regression analyses provided significant empirical evidence that certain architectural properties of supply networks improve or sometimes deteriorate OEMs' performance consequences in accordance with its influence on immediate suppliers' sourcing decisions. Further field investigations were conducted to support and extend the preceding statistical findings.

To the best of the author's knowledge, the present work is the first empirical study which discusses how the overall network architecture consisting of same supply chain partners vary depending on different types of supply network ties considered (i.e. multiplex supply network

perspective). Adding to previously investigated visible inter-organizational ties (i.e. contractual and transactional ties), this study incorporated the invisible dimensions (i.e. professional and personal ties) into supply network analyses to fully explore the invisible dynamics between supply chain partners. Most other previous supply network studies to this point have investigated the aforementioned ties separately under the untested assumption of uniplex supply network. A series of social network analyses confirmed the multiplex traits of supply networks by showing that a given supply network having the same set of firms can be perceived differently based on different tie types with different directions and strengths. This can provide a theoretical foundation to reexamine and confirm that the previous buyer-supplier relationship literature based on uniplex perspective still hold for other types of interfirm ties.

Given the exploratory nature of empirical supply network research, a few limitations should be noted in ways that represent opportunities for future work. First, four different types of network ties examined in this study are not exhaustive. Second, the current study does not utilize all available socio-centric SNA indices in describing network architectures. This limitation comes from the setting of this study: as an empirically substantive investigation of directed valued supply networks. Second, this study used cross-sectional network data in describing supply network properties because of the non-availability of longitudinal dataset. An access to the secondary data sources could be helpful to provide more generalizable findings on the associations between strategic intents and network properties even though it will still sacrifice sample size to obtain the whole network data. A potential remedy for this challenge is carrying out the same data collection procedure to the original respondents after a certain time period, and conducting an event study analysis on abnormal changes of network properties. It can be another option to targeting industries such as information technology, software or fashion with relatively

shorter industry clockspeeds and checking whether the changed network properties remain changed or are restored to the original states. Lastly, this study also utilized OEMs' supply chain performance as a proxy of its overall network performance. Although anchored by theoretical and empirical foundations on the usage of supply chain performance, it will be an interesting extension to compare the performance consequences of two different scopes (i.e. existing OEM-level measures vs. new measures) for the future research.

5 CONCLUSIONS

This dissertation is a theory-building endeavor and has resulted in many useful insights in understanding supply network phenomena. The overarching objective of this dissertation research is to shed light on supply network management by delving into the internal architecture of supply networks and its strategic antecedents and performance consequence. Given the shortcomings and limitations in extant SCM literature, this dissertation asks the following meaningful but understudied questions: 1) how can the multidimensional and complex architecture of whole supply network be collectively described; 2) what antecedent forces drive firms to adopt certain types of supply network architecture; 3) how does an OEM's supply network architectures affect its ensuing supply chain performance. More specifically, the first essay investigated how different *directed valued* network ties across *multiple* tiers of supply chain partners shape different supply network architectures. Managing multiplex networks is considerably more complex in that actors embedded in the same network will perceive the overall network architecture differently (Kim et al. 2006; Shipilov and Li 2012). In a supply network context, this perception discrepancy can give rise to divergent incentives among network partners and consequently hinder the supply network itself from achieving full cooperative outcomes. Drawing upon social network analysis, the primary survey data from 153 component-level supply networks was analyzed to explore the "hidden" dynamics between 12 network-level social network analysis indices for characterizing different supply network architectures. This research offered, to the best of the author's knowledge, the first quantitative and statistically significant evidence on the existence of *supply network multiplexity* and its effects on supply network architecture.

Anchored by the multiplex nature of supply networks found in the previous study, the second essay attempted to shed light on the question, "what determines different supply network architectures," which has been also recognized by scholars of other disciplines (e.g. Brass 2002; Borgatti and Li 2009; Galaskiewicz 2011). To tackle this important but unresolved question, I adopted the strategic intent perspective of organizational formation which has been widely used in strategic supply chain design studies (e.g. Fisher 1997; Huang et al. 2002) that mainly argued different products require different supply chains. The results from social network analyses and multinomial logit models provided significant empirical evidence that supply networks have discernible architectural properties according to the strategic intent that is pursued. Further field investigations were conducted to support and extend the preceding statistical findings. The in-depth follow-up interviews confirmed that supply network members consistently implement certain practices based on their own rational judgments, which impact supply network properties. Taken together, this study suggests that a supply network should be viewed as a *systematic outcome which is intentionally and strategically designed, implemented, and maintained in conformity with the OEM's strategic intent(s)*. From a managerial standpoint, the findings from this essay also provided useful guidance for understanding direct or indirect relationships across multiple tiers in the supply network. Based on the found network properties, supply network managers can infer: 1) how their immediate and non-immediate partners work together (or often against one another) in pursuing common (or sometimes incompatible) interests, and 2) whether the concordance (or discordance) among network members would help or hinder the achievement of the strategic intent of the sourced component. It also can enable open collaboration across firm boundaries by allowing them to freely discuss how much and what kind of network ties should be: 1) orchestrated by hub firms (with betweenness centralization), 2)

gained from and disseminated to others (with in-degree and out-degree centralizations), and 3) connecting with one another (with global clustering coefficient) to achieve different strategic intents. All the findings of this study were further corroborated and extended by in-depth follow-up field investigations and interviews with the supply chain professionals.

The third essay examined the performance implications of supply network architecture. Prior research in organization theory and strategic management have argued that the interfirm networks consisting of direct and indirect relations with other firms systematically affect a firm's performance such as innovation and financial performance, theoretically termed as "network competence." Depending on a key premise underlying network strategy that a firm's inimitable and non-substitutable resources lie outside its boundaries (Ring and Van de Ven 1994; Mowery et al. 1996; Gulati 1999), this research aimed to shed light on the study of supply network, and consequently, to offer a *supply network competence perspective*. By analyzing the unique dataset consisting of 1,852 total network members with social network analyses and hierarchical regression analyses, this study provided significant empirical evidence that certain architectural properties of supply networks improve or sometimes deteriorate OEMs' performance consequences in accordance with its influence on immediate suppliers' sourcing decisions. Further field investigations were conducted to support and extend the preceding statistical findings.

To conclude, the primary objective of this research was to provide a deeper understanding of how interfirm network architecture can be structured, viewed, and affect firms in the context of supply chain management. This dissertation contributes to theory development in supply chain management in several ways. The first contribution of this dissertation is that it extends the theory of buyer-supplier relationship beyond the models found in organizational

behavior and strategic management literature. Specifically, an investigation of network multiplexity provides a setting for re-evaluating existing SCM practices and theories pertaining to supply chain configuration. This conceptualization aids future theory-building activities in supply *network* management to consider a multi-faceted framework incorporating multiple types of interfirm ties (i.e., contractual, transactional, professional, and personal ties). The second contribution is that this research reveals the importance of an OEM's strategic initiative by investigating the differential impacts of cost leadership and market responsiveness intents, which poses a doubt to the extant propositional view on the emergence of supply networks. In order to support the empirical findings, further field investigations (industry-to-industry and firm-to-firm comparisons) were conducted. As a result, this research asserts that the competitive strategy based on a focal firm's intent could potentially permeate into its supply network architecture. The existing supply network literature has not conceptually or empirically considered the implications of cost leadership and market responsiveness focused competitive strategies in a collaborative supply network context. The findings of this research allow a deeper understanding of the implications of strategic intent which has been regarded as important determinants in many supply chain strategy studies. The third contribution of this dissertation is that it presents the competitive role of supply network architecture comprising multiple network entities across multiple tiers. This study provides reasoning for building and managing supply networks characterized in terms of various architectural traits (i.e., betweenness centralization, in-degree centralization, out-degree centralization, and global clustering coefficient) in drawing supply chain performance. The performance incentive for an OEM to strategically maneuver its overall supply network architecture is highlighted. Finally, from a methodological standpoint, this dissertation provides motivation to use the directed valued and socio-centric SNA approach to

address some of the interesting questions about supply network phenomena. By employing up-to-date techniques to analyze a large-scale network-level dataset, this research enhances the existing methodological foundations for supply network studies. By theorizing, analyzing, and synthesizing the pursued research questions and data, the author endeavors to extend our knowledge of supply networks and to provide a clear roadmap for scholars exploring the links between network studies and supply chain management.

APPENDIX

APPENDIX

MICHIGAN STATE UNIVERSITY | Broad Graduate School of Management

Determinants of Supply Network Architecture and Ensuing Performance

PART 1

June 4, 2012

To Whom It May Concern,

We would like to invite your participation in a research being conducted by researchers at the Eli Broad Graduate School of Management, Michigan State University (MSU). I, a project investigator, Ram Narasimhan is serving as a John H. McConnel Chaired Professor and University Distinguished Professor here at MSU. MSU has been one of the top-notched research universities in accordance with the U.S. News' Best Business Schools rankings in Supply Chain Management/Logistics specification over last decade. I have been impressed by Korean manufacturers' supply chain management capabilities whilst teaching MBA classes at Seoul National University Business School as a part of the Global Scholars Invitation Fellowship Program and having a featured interview with Chosun Ilbo (http://news.chosun.com/site/data/html_dir/2008/04/04/200804040099 3.html).

Given the highly interdependent and closely interlinked business environment in recent years, individual businesses no longer compete as standalone entities, but rather as collaborative networks. In this era of 'network-based competition,' the purpose of this study is to investigate how firms' supply network architectures are formed via various types of interactions with their buyers and suppliers. We hypothesize that differences in strategic intents of firms for individual component will induce different supply network architectures and affect the ensuing performance, depending on the contextual features in their buyer-supplier relationships. Knowledge from this study will help supply chain managers in different situations design an appropriate supply network architecture which coordinates multiple supply chain entities involved in global sourcing. The survey will take approximately 30-40 minutes.

All of your answers will be kept strictly confidential. Your firm name will NOT appear in any future reports without your permission, and your individual responses will NOT be disclosed to any outside agencies. Only summary data and aggregate results from statistical analysis of the data will be published. We request you to answer all questions to the best of your ability and knowledge, as incomplete surveys can create serious problems during data analysis and reduce

the sample size available for meaningful analysis of data. If you are not sure of an answer to a question, please provide your best estimate.

Upon your request, a copy of the research findings will be sent to you, allowing you to benchmark your supply network management practices with those of other companies. Simply indicate your interest at the end of this survey and provide your contact information. In the report, individual responses will be kept confidential and only the summary data and aggregate results will be used.

If you have any questions about your rights as a participant in this research, or if you feel you have been placed at risk, you can contact the MSU's Research Integrity Officer through the MSU Social Science/Behavioral/ Education Institutional Review Board (SIRB) at 1-517-355-2180. Return of the questionnaire will be considered your consent to participate.

Thank you very much for helping with this important study. We will be happy to answer any questions or concerns you may have on this study. Please contact Myung Kyo Kim.

Sincerely,

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MICHIGAN STATE UNIVERSITY | Broad Graduate School of Management

Determinants of Supply Network Architecture and Ensuing Performance

PART 2

June 4, 2012

To Whom It May Concerned,

We deeply appreciate your participation in this research. This executive brief is intended to help you understand the concepts on which your response is sought in this survey and to provide you several important guidelines before starting to answer the questions in the survey.

To pursue the research objectives, we need to collect detailed data on a whole 'supply network' consisting of multiple suppliers in multiple tiers. The simplified supply network of a focal firm (FF) illustrated below consists of 7 suppliers in 2 tiers. Supply chain management academics and practitioners call firms supplying components to your firm (FF) such as S11, S12, and S13, 'tier-1 suppliers' and firms SS21, SS22, SS23, and SS24 supplying sub-components to tier-1 suppliers, 'tier-2 suppliers.' The lead dictionary1 definition of component refers to 'a part of a mechanical or electrical system.' By following this definition, in the setting of this survey, the 'components' mean subsystems that go into your finished (i.e. final) product to be sold to customers. Also, in Figure 1 below, the depth of a focal firm's supply network is 2 (= the number of tiers to reach end-item suppliers) and the width (= the greatest number of suppliers existing in the same tier) of the focal firm's network is 4.

[1] http://dictionary.reference.com/browse/component

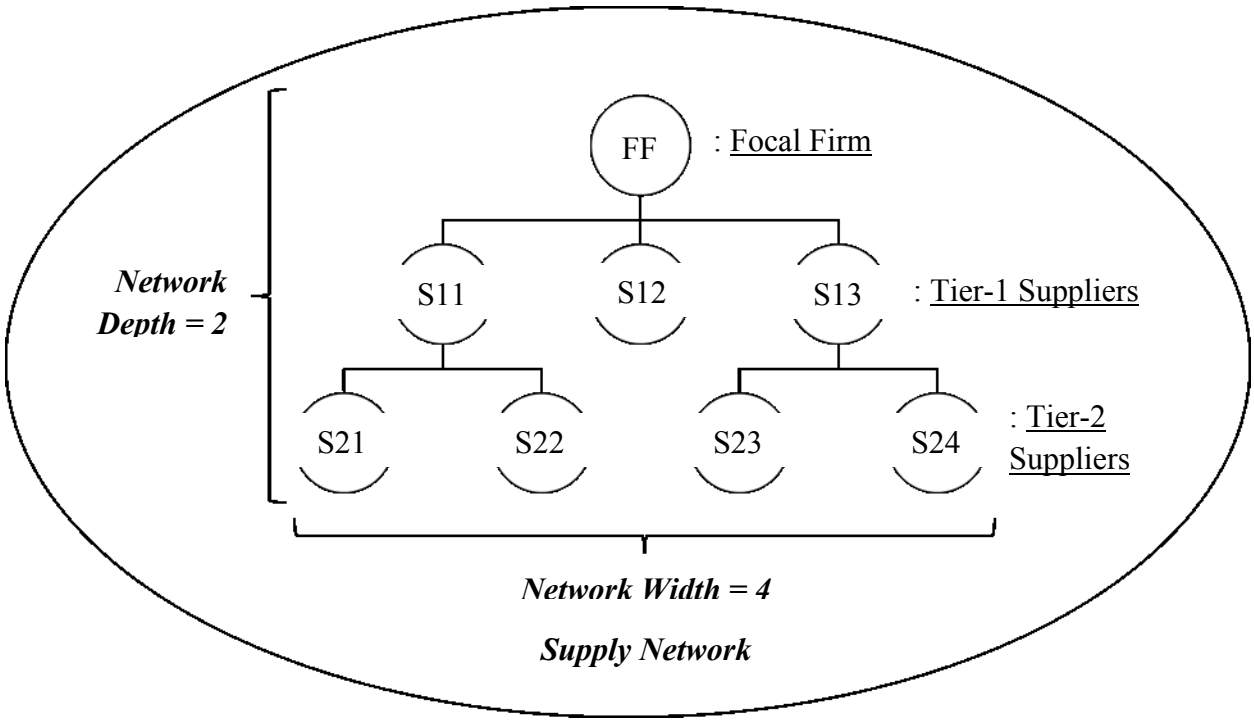

Figure 5.1 Simplified Example of the Supply Network

Questions in this survey will ask you only about your (i.e. focal firm's) finished (i.e. final) product(s), one of its components, and relationships with major immediate (i.e. tier-1) suppliers of the component (not about your tier-2 suppliers). Based on your responses, we will: 1) contact your tier-1 suppliers, 2) give them almost the same questions relative to their position in the supply network, 3) contact their immediate suppliers (i.e. your tier-2 suppliers), and continue this procedure until we reach the end-tier supplier(s) of your whole supply network.

However, to successfully complete these data collection processes, we need your help to set up the 'boundaries' of your supply network. As you might have already noticed, our data collection processes can be excessively time-consuming and labor intensive without manageable depth and width of a network. For instance, too big network size (e.g. more than 5 suppliers per each tier or more than 4 tiers in a network) or a complex network can significantly delay data collection processes and completion of our research. In contrast, too small (e.g. only 2 tiers per network) or simplistic (e.g. only 1 supplier per tier) can diminish theoretical/practical contributions of this research. Therefore, we request you to select a strategically important component with a "manageable" network sizes (i.e. 'no more than 3 tiers and 5 suppliers per tier') before starting this survey on the next page.

If you have any questions about this executive brief, please contact M.K. Kim at myungkyo@bus.msu.edu or 1-517-432-6446. Again, thank you very much for your participation.

Sincerely,

Ram Narasimhan, Ph.D.
Professor of Supply Chain Management
University Distinguished Professor
John H. McConnel Endowed Chair of Business Administration
narasimh@bus.msu.edu
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MICHIGAN STATE UNIVERSITY | Broad Graduate School of Management

Determinants of Supply Network Architecture and Ensuing Performance

PART 3

Section 1: General Information Please answer ALL questions.

Your organization's name:

Your position or title in your organization:

How many years has it been since you started to work in this organization?
- Less than 1 year
- 1-5 years
- 6-10 years
- 11-20 years
- 21 or more years

Your organization's approximate number of employees:
- Less than 100
- 100-249
- 250-499
- 500-999
- 1000 or more

Section 2: Component and Supplier Information Please answer ALL questions.

In answering the questions below, please consider a specific component with strategic importance of your product and its major immediate suppliers (may be listed in your firm's preferred supplier list).

Name of component:

Function of component:

Finished (i.e. final) product in which this component is used:

For how many years have you been involved in decisions (e.g. design, development, quality, procurement, etc.) pertaining to this component?

Less than 1 year
1-5 years
6-10 years
11-20 years
21 or more years

On each of the following statements, please check (√) only ONE answer (either "Yes" or "No") which best describes your firm's emphasis in selecting immediate (i.e. tier-1) suppliers of the specific component you selected. Please answer questions to the best of your ability and knowledge.

When our firm selects an immediate (i.e. tier-1) supplier(s) for this component:

		Y	N
1	We predominantly implement value analyses with a view to reduce costs.		
2	We predominantly emphasize whether they offer prices as low or lower than other suppliers.		
3	We predominantly emphasize whether the supplier offers quantity discounts.		
4	We predominantly emphasize whether they have lower manufacturing costs compared to other suppliers.		
5	We predominantly emphasize whether they have short production lead time.		
6	We predominantly emphasize whether they can adapt to fast-changing market/industry.		
7	We predominantly emphasize the ability to scale up (or down) quickly to changing market demands.		
8	We predominantly emphasize whether they can rapidly incorporate consumer preferences into the design process.		

This question pertains to your operational information sharing with immediate (i.e. tier-1) suppliers of the specific component you selected. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	Our firm provides immediate suppliers with demand forecast information.	1	2	3	4	5
2	Our firm and immediate suppliers share capacity planning information.	1	2	3	4	5
3	Our firm shares its inventory level information with immediate suppliers.	1	2	3	4	5
4	Our firm shares its production plans with immediate suppliers.	1	2	3	4	5
5	Our firm can easily monitor the status of its orders.	1	2	3	4	5

This question pertains to your influence on supply network partners related to the specific component you selected. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	Our firm maintains active communication of our sourcing strategy with all supply network partners.	1	2	3	4	5
2	Our firm and immediate (i.e. tier-1) suppliers always make joint decisions on selecting tier-2 or 3 suppliers.	1	2	3	4	5
3	Our immediate (i.e. tier-1) suppliers must get our firm's approval on their selection of tier-2 or 3 suppliers.	1	2	3	4	5
4	Our firm puts significant efforts to align suppliers across the whole supply network to our sourcing strategy.	1	2	3	4	5
5	Our firm has well-established guidelines to support our immediate (i.e. tier-1) suppliers' selection of suppliers.	1	2	3	4	5

Please name ALL major immediate (i.e. tier-1) suppliers of the component, percentage of total spend for this component's supplier, and contact information. We will contact them and send a survey. They will not see your responses. The information you provide below will not be identifiable in any published results generated from this study.

Supplier 1 (Name):
Length of relationship (yrs):
Percentages of total spend for this component's supplier (%):
Contact person name:
Phone number:
E-mail:

Supplier 2 (Name):
Length of relationship (yrs):
Percentages of total spend for this component's supplier (%):
Contact person name:
Phone number:
E-mail:

Supplier 3 (Name):
Length of relationship (yrs):
Percentages of total spend for this component's supplier (%):
Contact person name:
Phone number:
E-mail:

Supplier 4 (Name):
Length of relationship (yrs):
Percentages of total spend for this component's supplier (%):
Contact person name:
Phone number:
E-mail:

Supplier 5 (Name):
Length of relationship (yrs):
Percentages of total spend for this component's supplier (%):
Contact person name:
Phone number:
E-mail:

Section 3: Supplier Relationship & Contextual Information Please answer ALL questions.

In this section, you will be asked about your relationship with EACH of the above suppliers listed in Q8 of the previous section. Specifically, this section seeks details about your personal and your firm's contractual, professional, personal, and contextual aspects of your relationship with individual immediate supplier regarding the specific component selected in the previous section.

Thus, this section of the survey should be completed multiple times for EACH supplier you listed in Q8 of the previous section. If you listed three suppliers there, for instance, please answer the questions for ALL those three suppliers ONE BY ONE). We understand that it may be time consuming to provide answers to this section. However, your input is vital to our analyses to figure out your firm's overall supply network architecture built through various types of interactions with all of your major suppliers. Thank you again for your participation.

1. Your Relationship with Supplier 1

Do you have a formal contractual relationship with Supplier 1? Yes No

If "Yes," please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions. If "No" please proceed to Q2.

Contractual Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We have a formal written contract(s) detailing the operational requirements.	1	2	3	4	5
2	We have a formal written contract(s) that detail(s) how performance will be monitored.	1	2	3	4	5
3	We have a formal written contract(s) detailing warranty policies.	1	2	3	4	5

4	We have a formal written contract(s) detailing how to handle complaints and disputes (e.g. penalties for contract violations).	1	2	3	4	5
5	We have a formal written contract(s) detailing the level of service expected from this supplier.	1	2	3	4	5

The following question (Q2) pertains to your firm's business (or professional) relationship with Supplier 1's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Business/Professional Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters.	1	2	3	4	5
2	We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.).	1	2	3	4	5
3	The communication between us occurs at different levels of management and cross-functional areas.	1	2	3	4	5
4	I (or our executives) receive periodic feedback (via face-to-face, conference calls, e-mail, etc.) on progress, problems, and plans from this supplier's counterparts.	1	2	3	4	5

5	I (or our executives) do periodic on-site visits to this supplier's plants.	1	2	3	4	5

The following question (Q3) pertains to your or other executives' personal relationship (or friendship) with Supplier 1's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Personal Relationship/Friendship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We always invite each other to participate in various activities to socialize.	1	2	3	4	5
2	We do personal favors for each other.	1	2	3	4	5
3	We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.).	1	2	3	4	5
4	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) during non-working time.	1	2	3	4	5
5	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) outside work places.	1	2	3	4	5

2. Your Relationship with Supplier 2

Do you have a formal contractual relationship with Supplier 2? Yes No

If "Yes," please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions. If "No" please proceed to Q2.

Contractual Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We have a formal written contract(s) detailing the operational requirements.	1	2	3	4	5
2	We have a formal written contract(s) that detail(s) how performance will be monitored.	1	2	3	4	5
3	We have a formal written contract(s) detailing warranty policies.	1	2	3	4	5
4	We have a formal written contract(s) detailing how to handle complaints and disputes (e.g. penalties for contract violations).	1	2	3	4	5
5	We have a formal written contract(s) detailing the level of service expected from this supplier.	1	2	3	4	5

The following question (Q2) pertains to your firm's business (or professional) relationship with Supplier 2's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Business/Professional Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters.	1	2	3	4	5
2	We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.).	1	2	3	4	5
3	The communication between us occurs at different levels of management and cross-functional areas.	1	2	3	4	5
4	I (or our executives) receive periodic feedback (via face-to-face, conference calls, e-mail, etc.) on progress, problems, and plans from this supplier's counterparts.	1	2	3	4	5
5	I (or our executives) do periodic on-site visits to this supplier's plants.	1	2	3	4	5

The following question (Q3) pertains to your or other executives' personal relationship (or friendship) with Supplier 2's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Personal Relationship/Friendship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We always invite each other to participate in various activities to socialize.	1	2	3	4	5
2	We do personal favors for each other.	1	2	3	4	5
3	We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.).	1	2	3	4	5
4	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) during non-working time.	1	2	3	4	5
5	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) outside work places.	1	2	3	4	5

3. Your Relationship with Supplier 3

Do you have a formal contractual relationship with Supplier 3? Yes No

If "Yes," please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions. If "No" please proceed to Q2.

Contractual Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We have a formal written contract(s) detailing the operational requirements.	1	2	3	4	5
2	We have a formal written contract(s) that detail(s) how performance will be monitored.	1	2	3	4	5
3	We have a formal written contract(s) detailing warranty policies.	1	2	3	4	5
4	We have a formal written contract(s) detailing how to handle complaints and disputes (e.g. penalties for contract violations).	1	2	3	4	5
5	We have a formal written contract(s) detailing the level of service expected from this supplier.	1	2	3	4	5

The following question (Q2) pertains to your firm's business (or professional) relationship with Supplier 3's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Business/Professional Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters.	1	2	3	4	5
2	We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.).	1	2	3	4	5
3	The communication between us occurs at different levels of management and cross-functional areas.	1	2	3	4	5
4	I (or our executives) receive periodic feedback (via face-to-face, conference calls, e-mail, etc.) on progress, problems, and plans from this supplier's counterparts.	1	2	3	4	5
5	I (or our executives) do periodic on-site visits to this supplier's plants.	1	2	3	4	5

The following question (Q3) pertains to your or other executives' personal relationship (or friendship) with Supplier 3's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Personal Relationship/Friendship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We always invite each other to participate in various activities to socialize.	1	2	3	4	5
2	We do personal favors for each other.	1	2	3	4	5
3	We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.).	1	2	3	4	5
4	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) during non-working time.	1	2	3	4	5
5	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) outside work places.	1	2	3	4	5

4. Your Relationship with Supplier 4

Do you have a formal contractual relationship with Supplier 4? Yes No

If "Yes," please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions. If "No" please proceed to Q2.

Contractual Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We have a formal written contract(s) detailing the operational requirements.	1	2	3	4	5
2	We have a formal written contract(s) that detail(s) how performance will be monitored.	1	2	3	4	5
3	We have a formal written contract(s) detailing warranty policies.	1	2	3	4	5
4	We have a formal written contract(s) detailing how to handle complaints and disputes (e.g. penalties for contract violations).	1	2	3	4	5
5	We have a formal written contract(s) detailing the level of service expected from this supplier.	1	2	3	4	5

The following question (Q2) pertains to your firm's business (or professional) relationship with Supplier 4's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Business/Professional Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters.	1	2	3	4	5
2	We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.).	1	2	3	4	5
3	The communication between us occurs at different levels of management and cross-functional areas.	1	2	3	4	5
4	I (or our executives) receive periodic feedback (via face-to-face, conference calls, e-mail, etc.) on progress, problems, and plans from this supplier's counterparts.	1	2	3	4	5
5	I (or our executives) do periodic on-site visits to this supplier's plants.	1	2	3	4	5

The following question (Q3) pertains to your or other executives' personal relationship (or friendship) with Supplier 4's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Personal Relationship/Friendship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We always invite each other to participate in various activities to socialize.	1	2	3	4	5
2	We do personal favors for each other.	1	2	3	4	5
3	We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.).	1	2	3	4	5
4	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) during non-working time.	1	2	3	4	5
5	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) outside work places.	1	2	3	4	5

4. Your Relationship with Supplier 5

Do you have a formal contractual relationship with Supplier 5? Yes No

If "Yes," please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions. If "No" please proceed to Q2.

Contractual Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We have a formal written contract(s) detailing the operational requirements.	1	2	3	4	5
2	We have a formal written contract(s) that detail(s) how performance will be monitored.	1	2	3	4	5
3	We have a formal written contract(s) detailing warranty policies.	1	2	3	4	5
4	We have a formal written contract(s) detailing how to handle complaints and disputes (e.g. penalties for contract violations).	1	2	3	4	5
5	We have a formal written contract(s) detailing the level of service expected from this supplier.	1	2	3	4	5

The following question (Q2) pertains to your firm's business (or professional) relationship with Supplier 5's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Business/Professional Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters.	1	2	3	4	5
2	We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.).	1	2	3	4	5
3	The communication between us occurs at different levels of management and cross-functional areas.	1	2	3	4	5
4	I (or our executives) receive periodic feedback (via face-to-face, conference calls, e-mail, etc.) on progress, problems, and plans from this supplier's counterparts.	1	2	3	4	5
5	I (or our executives) do periodic on-site visits to this supplier's plants.	1	2	3	4	5

The following question (Q3) pertains to your or other executives' personal relationship (or friendship) with Supplier 5's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Personal Relationship/Friendship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We always invite each other to participate in various activities to socialize.	1	2	3	4	5
2	We do personal favors for each other.	1	2	3	4	5
3	We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.).	1	2	3	4	5
4	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) during non-working time.	1	2	3	4	5
5	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) outside work places.	1	2	3	4	5

Section 4: Component-Level Supply Chain Performance Information Please answer ALL questions.

In this section, you will be asked about your firm's supply chain performance for the specific component you selected in Section 2. All of your responses should refer to the relative performance compared to the industry average or major competitors. Please make check only ONE answer based on a scale of 5.

How would you judge your QUALITY performance for the COMPONENT compared to industry average (or your major competitors)?

		Significantly worse	Worse	Neither better nor worse	Better	Significantly better
1	Technical capability: Ability of component capable of performing desired functions	1	2	3	4	5
2	Conformance quality: Ability to meet targets for component quality and/or to conform to given component specifications and perceptions of quality	1	2	3	4	5
3	Internal process quality: Ability to produce high-quality (or low-defect-rate) finished products (e.g. in-plant defect/fallout rate, finished-product first-pass rate, etc.)	1	2	3	4	5
4	Component durability: Ability to maximize the amount of time before the component deteriorates or needs to be replaced	1	2	3	4	5

5	Component reliability: Ability to maximize the amount of time before component's failure or malfunction	1	2	3	4	5

How would you judge your FLEXIBILITY performance for the COMPONENT compared to industry average (or your major competitors)?

		Significantly worse	Worse	Neither better nor worse	Better	Significantly better
1	Volume flexibility: Ability to change the level of production volumes for the component in order to accommodate demand variations	1	2	3	4	5
2	Delivery flexibility: Ability to change planned delivery dates and/or to respond to changes in delivery requirements	1	2	3	4	5
3	Design flexibility: Ability to change product mix (i.e. variety of products) or customize components to meet customers' requests	1	2	3	4	5
4	Launch flexibility: Ability to quickly introduce new versions of components	1	2	3	4	5

How would you judge your DELIVERY performance for the COMPONENT compared to industry average (or your major competitors)?

		Significantly worse	Worse	Neither better nor worse	Better	Significantly better
1	On-time delivery: Ability to meet quoted or anticipated delivery dates on a consistent basis	1	2	3	4	5
2	Manufacturing lead time: Ability to reduce the time which elapses between the start of production and the completion of the products	1	2	3	4	5
3	Customer lead time: Ability to reduce the time which elapses between the receipt of our firm's order and the delivery of the components	1	2	3	4	5
4	Shipping accuracy: Ability to deliver the right amount of the right component to the right place on a consistent basis	1	2	3	4	5

How would you judge your suppliers' COST performance with regard to the COMPONENT compared to industry average (or your major competitors)?

		Significantly worse	Worse	Neither better nor worse	Better	Significantly better
1	Acquisition costs	1	2	3	4	5
2	Cost reduction performance	1	2	3	4	5
3	Designing cost out of the component	1	2	3	4	5
4	Ability to meet target costs	1	2	3	4	5
5	Supplier's ability to engage in strategic cost modeling	1	2	3	4	5

How would you judge the INNOVATION performance of your firm's PRODUCT that uses this component compared to industry average (or your major competitors) over the last 3 years? Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	By sourcing this component, our firm could significantly increase the number of new products to the market.	1	2	3	4	5
2	By sourcing this component, our firm could add much more new features to existing product(s).	1	2	3	4	5
3	By sourcing this component, our firm could add unique features to existing product(s).	1	2	3	4	5
4	By sourcing this component, our firm could have significantly higher new product success rate.	1	2	3	4	5
5	By sourcing this component, our firm could develop new product or features much faster.	1	2	3	4	5

Summary

Thank you very much for your help with this research study. Your participation will contribute to a better understanding of the increasingly complex supply network architectures and their performance outcomes. Are there any important issues that you feel have been left out? If so, please comment in the space provided on this page.

Please let us know if there are other areas that we should consider for future study.

Comments and additional remarks:

Please return the completed questionnaire by June 30, 2012

If you want us to send you a summary of our findings, please provide your mailing address or contact information. Your personal contact information will be kept strictly confidential.

Name	
Job Title	
Business Unit (if applicable)	
Company	
Postal Address	
Phone	
E-mail	

THANK YOU FOR YOUR TIME AND PARTICIPATION!

MICHIGAN STATE UNIVERSITY | Broad Graduate School of Management

Determinants of Supply Network Architecture and Ensuing Performance (for TIER-1 SUPPLIERS)

PART 1

June 4, 2012

To Whom It May Concern,

In collaboration with O O O, we would like to invite your participation in a research being conducted by researchers at the Eli Broad Graduate School of Management, Michigan State University (MSU). I, a project investigator, Ram Narasimhan is serving as a John H. McConnel Chaired Professor and University Distinguished Professor here at MSU. MSU has been one of the top-notched research universities in accordance with the U.S. News' Best Business Schools rankings in Supply Chain Management/Logistics specification over last decade. I have been impressed by Korean manufacturers' supply chain management capabilities whilst teaching MBA classes at Seoul National University Business School as a part of the Global Scholars Invitation Fellowship Program and having a featured interview with Chosun Ilbo (http://news.chosun.com/site/data/html_dir/2008/04/04/200804040099 3.html).

Given the highly interdependent and closely interlinked business environment in recent years, individual businesses no longer compete as standalone entities, but rather as collaborative networks. In this era of 'network-based competition,' the purpose of this study is to investigate how firms' supply network architectures are formed via various types of interactions with their buyers and suppliers. We hypothesize that differences in strategic intents of firms for individual component will induce different supply network architectures and affect the ensuing performance, depending on the contextual features in their buyer-supplier relationships. Knowledge from this study will help supply chain managers in different situations design an appropriate supply network architecture which coordinates multiple supply chain entities involved in global sourcing. The survey will take approximately 25-30 minutes.

All of your answers will be kept strictly confidential. Your firm name will NOT appear in any future reports without your permission, and your individual responses will NOT be disclosed to any outside agencies. Only summary data and aggregate results from statistical analysis of the data will be published. We request you to answer all questions to the best of your ability and knowledge, as incomplete surveys can create serious problems during data analysis and reduce

the sample size available for meaningful analysis of data. If you are not sure of an answer to a question, please provide your best estimate.

Upon your request, a copy of the research findings will be sent to you, allowing you to benchmark your supply network management practices with those of other companies. Simply indicate your interest at the end of this survey and provide your contact information. In the report, individual responses will be kept confidential and only the summary data and aggregate results will be used.

If you have any questions about your rights as a participant in this research, or if you feel you have been placed at risk, you can contact the MSU's Research Integrity Officer through the MSU Social Science/Behavioral/ Education Institutional Review Board (SIRB) at 1-517-355-2180. Return of the questionnaire will be considered your consent to participate.

Thank you very much for helping with this important study. We will be happy to answer any questions or concerns you may have on this study. Please contact Myung Kyo Kim.

Sincerely,

Ram Narasimhan, Ph.D.
Professor of Supply Chain Management
University Distinguished Professor
John H. McConnel Endowed Chair of Business Administration
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1-517-432-6426

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MICHIGAN STATE UNIVERSITY | Broad Graduate School of Management

Determinants of Supply Network Architecture and Ensuing Performance (for TIER-1 SUPPLIERS)

PART 2

Section 1: General Information Please answer ALL questions.

Your organization's name:

Your position or title in your organization:

How many years has it been since you started to work in this organization?

Less than 1 year
1-5 years
6-10 years
11-20 years
21 or more years

Your organization's approximate number of employees:

Less than 100
100-249
250-499
500-999
1000 or more

Section 2: Component and Supplier Information Please answer ALL questions.

In answering the questions below, please consider the component your firm supplies to (focal firm's name), all of its sub-components, and their major immediate suppliers (may be listed in your firm's preferred supplier list).

Questions about the component your firm supplies to O O O:

For how many years have you been involved in decisions (e.g. design, development, quality, procurement, etc.) pertaining to the component?

Less than 1 year
1-5 years
6-10 years
11-20 years
21 or more years

This component share (in percentage) of total sales (i.e. O O O) (%) (= sales of component to O O O /your firm's total sales):

Please indicate the production technology used for manufacturing the component your firm supplies to O O O.

Customized production technology
Small batch production technology
Large batch production technology
Assembly line production technology
Other (Please specify:)

The next set of questions pertains to the changes of the component your firm supplies to O O O. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions.

Compared with other components manufactured by our firm:

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	The production technology used in manufacturing this component changes much more rapidly.	1	2	3	4	5
2	It is much more important for this component to adapt to changing technological trends.	1	2	3	4	5
3	New versions of this component are introduced much more frequently.	1	2	3	4	5
4	Technological changes provide much bigger opportunities for this component.	1	2	3	4	5
5	It is much more difficult to forecast where the technology used in this component will be in the next 2-3 years.	1	2	3	4	5

Questions about the sub-components your firm sources from immediate suppliers to produce the component your firm supplies to O O O:

Names of sub-components:

Functions of each sub-component:

Please name ALL major immediate suppliers of the component, percentage of total spend for this component's supplier, and contact information per each sub-component. We will contact them and send a survey. They will not see your responses. The information you provide below will not be identifiable in any published results generated from this study.

(Sub-component 1)

Supplier 1 (Name):
Length of relationship (yrs):
Percentages of total spend for this component's supplier (%):
Contact person name:
Phone number:
E-mail:

Supplier 2 (Name):
Length of relationship (yrs):
Percentages of total spend for this component's supplier (%):
Contact person name:
Phone number:
E-mail:

(Sub-component 2)

Supplier 1 (Name):
Length of relationship (yrs):
Percentages of total spend for this component's supplier (%):
Contact person name:
Phone number:
E-mail:

Supplier 2 (Name):
Length of relationship (yrs):
Percentages of total spend for this component's supplier (%):
Contact person name:
Phone number:
E-mail:

Section 3: Buyer/Supplier Relationship Information Please answer ALL questions.

In this section, you will be asked about your relationship with your immediate buyer and EACH of the above immediate suppliers listed in Q7 of the previous section. Specifically, this section seeks details about your personal and your firm's contractual, professional, and personal relationships with (focal firm) and individual immediate supplier regarding the each sub-component selected at Q5 of the previous section.

Thus, this section of the survey should be completed multiple times for (O O O) and EACH supplier of EACH sub-component you listed at Q7 of the previous section. If you listed two suppliers per each three sub-components there, for instance, please answer ALL those seven (= O O O + 2*3 suppliers) firms ONE BY ONE. We understand that this may prove difficult and time consuming to provide answers to this section. However, your input is vital to our analyses to figure out a firm's overall supply network architecture built through various types of interactions with your focal firm (i.e. O O O) and all of your major suppliers. Thank you again for your participation.

1. Your Relationship with O O O

Do you have a formal contractual relationship with O O O? Yes No

If "Yes," please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions.

Contractual Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We have a formal written contract(s) detailing the operational requirements.	1	2	3	4	5
2	We have a formal written contract(s) that detail(s) how our performance will be monitored.	1	2	3	4	5
3	We have a formal written contract(s) detailing our warranty policies.	1	2	3	4	5

4	We have a formal written contract(s) detailing how we will handle their complaints and disputes (e.g. penalties for contract violations).	1	2	3	4	5
5	We have a formal written contract(s) detailing the level of their service expected from us.	1	2	3	4	5

The following question (Q2) pertains to your or executives' business (or professional) relationship with (O O O)'s counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Business/Professional Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters.	1	2	3	4	5
2	We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.).	1	2	3	4	5
3	The communication between us occurs at different levels of management and cross-functional areas.	1	2	3	4	5
4	I (or our executives) give periodic feedback (via face-to-face, conference calls, e-mail, etc.) on our progress, problems, and plans to O O O's counterparts.	1	2	3	4	5

5	O O O's executives (or other employees) do periodic on-site visits to our plants.	1	2	3	4	5

The following question (Q3) pertains to your or executives' personal relationship (or friendship) with O O O's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Personal Relationship/Friendship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We always invite each other to participate in various activities for socialization.	1	2	3	4	5
2	We do personal favors to each other.	1	2	3	4	5
3	We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.).	1	2	3	4	5
4	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) during non-working time.	1	2	3	4	5
5	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) outside work places.	1	2	3	4	5

2. Your Relationship with Supplier 1 of Sub-Component 1

Do you have a formal contractual relationship with Supplier 1 of Sub-Component 1?

Yes No

If "Yes," please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions.

Contractual Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We have a formal written contract(s) detailing the operational requirements.	1	2	3	4	5
2	We have a formal written contract(s) that detail(s) how performance will be monitored.	1	2	3	4	5
3	We have a formal written contract(s) detailing warranty policies.	1	2	3	4	5
4	We have a formal written contract(s) detailing how to handle complaints and disputes (e.g. penalties for contract violations).	1	2	3	4	5
5	We have a formal written contract(s) detailing the level of service expected from this supplier.	1	2	3	4	5

The following question (Q2) pertains to your or executives' business (or professional) relationship with Supplier 1 of Sub-Component 1's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Business/Professional Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters.	1	2	3	4	5
2	We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.).	1	2	3	4	5
3	The communication between us occurs at different levels of management and cross-functional areas.	1	2	3	4	5
4	I (or our executives) receive periodic feedback (via face-to-face, conference calls, e-mail, etc.) on progress, problems, and plans from (Supplier 1 of Sub-Component 1)'s counterparts.	1	2	3	4	5
5	I (or our executives) do periodic on-site visits to (Supplier 1 of Sub-Component 1)'s plants.	1	2	3	4	5

The following question (Q3) pertains to your or executives' personal relationship (or friendship) with Supplier 1 of Sub-Component 1's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Personal Relationship/Friendship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We always invite each other to participate in various activities for socialization.	1	2	3	4	5
2	We do personal favors to each other.	1	2	3	4	5
3	We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.).	1	2	3	4	5
4	We often communicate (via face-to-face, phone calls, e-mails, etc.) during non-working time.	1	2	3	4	5
5	We often communicate (via face-to-face, phone calls, e-mails, etc.) outside work places.	1	2	3	4	5

3. Your Relationship with Supplier 2 of Sub-Component 1

Do you have a formal contractual relationship with Supplier 2 of Sub-Component 1?

Yes No

If "Yes," please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions.

Contractual Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We have a formal written contract(s) detailing the operational requirements.	1	2	3	4	5
2	We have a formal written contract(s) that detail(s) how performance will be monitored.	1	2	3	4	5
3	We have a formal written contract(s) detailing warranty policies.	1	2	3	4	5
4	We have a formal written contract(s) detailing how to handle complaints and disputes (e.g. penalties for contract violations).	1	2	3	4	5
5	We have a formal written contract(s) detailing the level of service expected from this supplier.	1	2	3	4	5

The following question (Q2) pertains to your or executives' business (or professional) relationship with Supplier 2 of Sub-Component 1's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Business/Professional Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters.	1	2	3	4	5
2	We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.).	1	2	3	4	5
3	The communication between us occurs at different levels of management and cross-functional areas.	1	2	3	4	5
4	I (or our executives) receive periodic feedback (via face-to-face, conference calls, e-mail, etc.) on progress, problems, and plans from (Supplier 2 of Sub-Component 1)'s counterparts.	1	2	3	4	5
5	I (or our executives) do periodic on-site visits to (Supplier 2 of Sub-Component 1)'s plants.	1	2	3	4	5

The following question (Q3) pertains to your or executives' personal relationship (or friendship) with Supplier 2 of Sub-Component 1's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Personal Relationship/Friendship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We always invite each other to participate in various activities for socialization.	1	2	3	4	5
2	We do personal favors to each other.	1	2	3	4	5
3	We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.).	1	2	3	4	5
4	We often communicate (via face-to-face, phone calls, e-mails, etc.) during non-working time.	1	2	3	4	5
5	We often communicate (via face-to-face, phone calls, e-mails, etc.) outside work places.	1	2	3	4	5

4. Your Relationship with Supplier 1 of Sub-Component 2

Do you have a formal contractual relationship with Supplier 1 of Sub-Component 2?

Yes No

If "Yes," please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions.

Contractual Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We have a formal written contract(s) detailing the operational requirements.	1	2	3	4	5
2	We have a formal written contract(s) that detail(s) how performance will be monitored.	1	2	3	4	5
3	We have a formal written contract(s) detailing warranty policies.	1	2	3	4	5
4	We have a formal written contract(s) detailing how to handle complaints and disputes (e.g. penalties for contract violations).	1	2	3	4	5
5	We have a formal written contract(s) detailing the level of service expected from this supplier.	1	2	3	4	5

The following question (Q2) pertains to your or executives' business (or professional) relationship with Supplier 1 of Sub-Component 2's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Business/Professional Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters.	1	2	3	4	5
2	We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.).	1	2	3	4	5
3	The communication between us occurs at different levels of management and cross-functional areas.	1	2	3	4	5
4	I (or our executives) receive periodic feedback (via face-to-face, conference calls, e-mail, etc.) on progress, problems, and plans from (Supplier 1 of Sub-Component 2)'s counterparts.	1	2	3	4	5
5	I (or our executives) do periodic on-site visits to (Supplier 1 of Sub-Component 2)'s plants.	1	2	3	4	5

The following question (Q3) pertains to your or executives' personal relationship (or friendship) with Supplier 1 of Sub-Component 2's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Personal Relationship/Friendship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We always invite each other to participate in various activities for socialization.	1	2	3	4	5
2	We do personal favors to each other.	1	2	3	4	5
3	We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.).	1	2	3	4	5
4	We often communicate (via face-to-face, phone calls, e-mails, etc.) during non-working time.	1	2	3	4	5
5	We often communicate (via face-to-face, phone calls, e-mails, etc.) outside work places.	1	2	3	4	5

5. Your Relationship with Supplier 2 of Sub-Component 2

Do you have a formal contractual relationship with Supplier 2 of Sub-Component 2?

Yes No

If "Yes," please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions.

Contractual Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We have a formal written contract(s) detailing the operational requirements.	1	2	3	4	5
2	We have a formal written contract(s) that detail(s) how performance will be monitored.	1	2	3	4	5
3	We have a formal written contract(s) detailing warranty policies.	1	2	3	4	5
4	We have a formal written contract(s) detailing how to handle complaints and disputes (e.g. penalties for contract violations).	1	2	3	4	5
5	We have a formal written contract(s) detailing the level of service expected from this supplier.	1	2	3	4	5

The following question (Q2) pertains to your or executives' business (or professional) relationship with Supplier 2 of Sub-Component 2's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Business/Professional Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters.	1	2	3	4	5
2	We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.).	1	2	3	4	5
3	The communication between us occurs at different levels of management and cross-functional areas.	1	2	3	4	5
4	I (or our executives) receive periodic feedback (via face-to-face, conference calls, e-mail, etc.) on progress, problems, and plans from (Supplier 2 of Sub-Component 2)'s counterparts.	1	2	3	4	5
5	I (or our executives) do periodic on-site visits to (Supplier 2 of Sub-Component 2)'s plants.	1	2	3	4	5

The following question (Q3) pertains to your or executives' personal relationship (or friendship) with Supplier 2 of Sub-Component 2's counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Personal Relationship/Friendship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We always invite each other to participate in various activities for socialization.	1	2	3	4	5
2	We do personal favors to each other.	1	2	3	4	5
3	We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.).	1	2	3	4	5
4	We often communicate (via face-to-face, phone calls, e-mails, etc.) during non-working time.	1	2	3	4	5
5	We often communicate (via face-to-face, phone calls, e-mails, etc.) outside work places.	1	2	3	4	5

Summary

Thank you very much for your help with this research study. Your participation will contribute to a better understanding of the increasingly complex supply network architectures and their performance outcomes. Are there any important issues that you feel have been left out? If so, please comment in the space provided on this page.

Please let us know if there are other areas that we should consider for future study.

Comments and additional remarks:

Please return the completed questionnaire by June 30, 2012

If you want us to send you a summary of our findings, please provide your mailing address or contact information. Your personal contact information will be kept strictly confidential.

Name	
Job Title	
Business Unit (if applicable)	
Company	
Postal Address	
Phone	
E-mail	

THANK YOU FOR YOUR TIME AND PARTICIPATION!

MICHIGAN STATE UNIVERSITY | Broad Graduate School of Management

Determinants of Supply Network Architecture and Ensuing Performance (for SECOND-TIER SUPPLIERS)

PART 1

June 4, 2012

To Whom It May Concern,

In collaboration with O O O and ◇ ◇ ◇, we would like to invite your participation in a research being conducted by researchers at the Eli Broad Graduate School of Management, Michigan State University (MSU). I, a project investigator, Ram Narasimhan is serving as a John H. McConnel Chaired Professor and University Distinguished Professor here at MSU. MSU has been one of the top-notched research universities in accordance with the U.S. News' Best Business Schools rankings in Supply Chain Management/Logistics specification over last decade. I have been impressed by Korean manufacturers' supply chain management capabilities whilst teaching MBA classes at Seoul National University Business School as a part of the Global Scholars Invitation Fellowship Program and having a featured interview with Chosun Ilbo (http://news.chosun.com/site/data/html_dir/2008/04/04/200804040099.3.html).

Given the highly interdependent and closely interlinked business environment in recent years, individual businesses no longer compete as standalone entities, but rather as collaborative networks. In this era of 'network-based competition,' the purpose of this study is to investigate how firms' supply network architectures are formed via various types of interactions with their buyers and suppliers. We hypothesize that differences in strategic intents of firms for individual component will induce different supply network architectures and affect the ensuing performance, depending on the contextual features in their buyer-supplier relationships. Knowledge from this study will help supply chain managers in different situations design an appropriate supply network architecture which coordinates multiple supply chain entities involved in global sourcing. The survey will take approximately 10 minutes.

All of your answers will be kept strictly confidential. Your firm name will NOT appear in any future reports without your permission, and your individual responses will NOT be disclosed to any outside agencies. Only summary data and aggregate results from statistical analysis of the data will be published. We request you to answer all questions to the best of your ability and knowledge, as incomplete surveys can create serious problems during data analysis and reduce

the sample size available for meaningful analysis of data. If you are not sure of an answer to a question, please provide your best estimate.

Upon your request, a copy of the research findings will be sent to you, allowing you to benchmark your supply network management practices with those of other companies. Simply indicate your interest at the end of this survey and provide your contact information. In the report, individual responses will be kept confidential and only the summary data and aggregate results will be used.

If you have any questions about your rights as a participant in this research, or if you feel you have been placed at risk, you can contact the MSU's Research Integrity Officer through the MSU Social Science/Behavioral/ Education Institutional Review Board (SIRB) at 1-517-355-2180. Return of the questionnaire will be considered your consent to participate.

Thank you very much for helping with this important study. We will be happy to answer any questions or concerns you may have on this study. Please contact Myung Kyo Kim.

Sincerely,

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John H. McConnel Endowed Chair of Business Administration
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MICHIGAN STATE UNIVERSITY | Broad Graduate School of Management

Determinants of Supply Network Architecture and Ensuing Performance (for SECOND-TIER SUPPLIERS)

PART 2

Section 1: General Information Please answer ALL questions.

Your organization's name:

Your position or title in your organization:

How many years has it been since you started to work in this organization?

Less than 1 year
1-5 years
6-10 years
11-20 years
21 or more years

Your organization's approximate number of employees:

Less than 100
100-249
250-499
500-999
1000 or more

Section 2: Component Information Please answer ALL questions.

In answering the questions below, please consider the component your organization supplies to ◇ ◇ ◇.

For how many years have you been involved in decisions (e.g. design, development, quality, procurement, etc.) pertaining to the component?

Less than 1 year
1-5 years
6-10 years
11-20 years
21 or more years

This component share (in percentage) of total sales (i.e. ◇ ◇ ◇) (%) (= sales of component to ◇ ◇ ◇/your firm's total sales):

Section 3: Buyer Relationship Information **Please answer ALL questions.**

In this section, you will be asked about your relationship with your immediate buying firm (i.e. ◇ ◇ ◇). Specifically, this section seeks details about your personal and your firm's contractual, professional, and interpersonal relationships with ◇ ◇ ◇.

Do you have a formal contractual relationship with ◇ ◇ ◇? Yes No

If "Yes," please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree" for the following questions.

Contractual Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We have a formal written contract(s) detailing the operational requirements.	1	2	3	4	5
2	We have a formal written contract(s) that detail(s) how our performance will be monitored.	1	2	3	4	5
3	We have a formal written contract(s) detailing our warranty policies.	1	2	3	4	5
4	We have a formal written contract(s) detailing how we will handle their complaints and disputes (e.g. penalties for contract violations).	1	2	3	4	5
5	We have a formal written contract(s) detailing the level of their service expected from us.	1	2	3	4	5

The following question (Q2) pertains to your or executives' business (or professional) relationship with ◇ ◇ ◇'s counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Business/Professional Relationship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We regularly communicate (via face-to-face, conference calls, e-mails, etc.) on work matters.	1	2	3	4	5
2	We widely share and welcome each other's ideas or initiatives via open communication (e.g. joint workshops, etc.).	1	2	3	4	5
3	The communication between us occurs at different levels of management and cross-functional areas.	1	2	3	4	5
4	I (or our executives) give periodic feedback (via face-to-face, conference calls, e-mail, etc.) on our progress, problems, and plans to this ◇ ◇ ◇'s counterparts.	1	2	3	4	5
5	◇ ◇ ◇'s executives (or other employees) do periodic on-site visits to our plants.	1	2	3	4	5

The following question (Q3) pertains to your or executives' personal relationship (or friendship) with ◇ ◇ ◇'s counterparts. Please indicate the extent to which you agree or disagree with the following statements by checking (√) ONE answer based on a scale of 5 where 1 represents "Strongly disagree" and 5 represents "Strongly agree."

Personal Relationship/Friendship

		Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
1	We always invite each other to participate in various activities for socialization.	1	2	3	4	5
2	We do personal favors to each other.	1	2	3	4	5
3	We voluntarily exchange something of a personal nature to each other on appropriate occasions (e.g. birthday cards, congratulations, condolences, etc.).	1	2	3	4	5
4	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) during non-working time.	1	2	3	4	5
5	We often communicate (via face-to-face, phone calls, e-mails, social network services, etc.) outside work places.	1	2	3	4	5

Summary

Thank you very much for your help with this research study. Your participation will contribute to a better understanding of the increasingly complex supply network architectures and their performance outcomes. Are there any important issues that you feel have been left out? If so, please comment in the space provided on this page.

Please let us know if there are other areas that we should consider for future study.

Comments and additional remarks:

Please return the completed questionnaire by June 30, 2012

If you want us to send you a summary of our findings, please provide your mailing address or contact information. Your personal contact information will be kept strictly confidential.

Name	
Job Title	
Business Unit (if applicable)	
Company	
Postal Address	
Phone	
E-mail	

THANK YOU FOR YOUR TIME AND PARTICIPATION!

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