A Dissertation

entitled

The Effects of Product Complexity and Supply Base Complexity on Supply Chain Performance

by

Prashanth Anekal

Submitted to the Graduate Faculty as partial fulfillment of the requirements

for the Doctor of Philosophy Degree in Manufacturing and Technology Management

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An Abstract of

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Over the years, we have seen that products manufactured and the supply base of many manufacturers have become more complex. The reasons for the increase in complexity are many. Prominent ones are (a) advances in manufacturing technology; (b) customers' demand for new and improved product functionality; and (c) manufacturers' need to differentiate themselves from their competitors. The resulting increase in complexity can however have negative implications on the performance of the supply chain. As products and supply bases become more complex, the task of managing these complexities and achieving the desired results becomes more challenging. Inability to manage these complexities results in lower performance throughout the supply chain. Thus, we can say that product complexity and supply base complexity are both "necessary evils".

Manufacturing literature has recognized that product complexity can have negative effects on plant performance. Emerging studies have explored the negative impacts of product complexity and supply base complexity. However, most of these

studies are either conceptual or address narrow aspects of performance, such as delivery performance. In order to bridge this gap, the first aim of this study is to examine the impact of product complexity and supply base complexity on efficiency and responsiveness of the supply chain. Secondly, the study examines the mediating impact of coordination mechanism on the relationship between product complexity / supply base complexity on supply chain performance. Operational coordination and strategic coordination are proposed to be the mediating variables. Thirdly, recognizing the fact that complexity is unavoidable and inevitable in certain circumstances, the study proposes a set of mechanisms that help supply chains improve coordination and thus reduce the negative effects of complexity on supply chain performance.

The proposed research model was tested using data collected by a large scale survey of manufacturing firms. The survey was answered by 270 respondents in various managerial roles in purchasing, operations and supply chain functional areas. The study developed and tested measurement instruments for the constructs proposed in the research model. Instruments were tested for reliability and validity using the collected data. The proposed research model was analyzed using Structural Equations Modeling (SEM).

The results of the study suggest a negative impact of product complexity and supply base complexity on supply chain performance. The data however shows that product complexity does not have a direct impact on supply chain performance, but rather has an indirect impact through supply base complexity. This indicates that product complexity has an effect on the nature and structure of the supply base. The role of coordination mechanisms (operational and strategic) as a mediator between complexity and supply chain performance was not supported by the data. This indicates a possible moderating role for coordinating mechanisms in this relationship. However, the extent of coordination between supply chain partners was found to be a key determinant of supply chain performance. The role of IT based and non-IT based mechanisms in mitigating the negative impact of complexity on supply chain performance was found to be effective in general.

This study thus makes contributions to theory by: (a) developing a research framework that draws from multiple theories to identify the relationships between product complexity, supply base complexity and supply chain performance; (b) identifying the various components of product and supply base complexity in a supply chain system; (c) identifying the strategic and operational roles of coordination mechanisms; and (d) developing and validating measurement instruments that can be employed in future studies. This study can be of interest to supply chain practitioners since it identifies the effects of complexity in the supply chain and identifies mechanisms to manage the effects of complexity in the system. Insights from this study are expected to improve managerial effectiveness in the supply chain.

To my wife and my mother

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Chapter 1

Introduction

The dictionary definition describes complexity as something that is complicated, intricate, involved and made of many varied interrelated parts. These dimensions of complexity hold good in the context of the supply chain. When we consider the focal company and its upstream supply chain, two kinds of complexities assume importance - Product complexity (PC) and Supply base complexity (SBC). Manufacturing and supply chain literature has recognized the fact that both these complexities are on this rise in organizations and supply chains. The rise in product complexity can be attributed to three core reasons – (1) advances in manufacturing technology; (2) customers demand for new and improved products; and (3) need to differentiate itself from its competitors. The rise in supply base complexity can be attributed to many reasons. The prominent reasons being: (a) practice of employing multiple sources of supply (b) global sourcing practices. At one level, we can say that an increase in both kinds of complexity is inevitable. But increase in complexity can affect performance of the entire supply chain in ways that are not desirable. Manufacturing literature has examined the effect of increased product complexity on manufacturing performance outcomes at the plant level. Bozarth et al

(2009) examined the impact of increased product complexity on performance at the plant level. Novak and Eppinger (2001) discuss the effect of product complexity on the decision to integrate vertically in organizations. Supply chain literature has examined the impact of product complexity on limited aspects of supply chain performance. Conceptual studies have proposed negative relationships between supply base complexity and certain aspects of performance like transaction cost, supplier innovativeness, supply risk etc (Ex: Choi and Krause, 2006). However, the effect of complexity on supply chain performance has not yet been examined in detail. In particular, efficiency and responsiveness aspects of supply chain performance have not been examined through rigorous empirical work. Academic researchers and practitioners have started recognizing the problems with increasing complexity. Thus, there is substantial potential for studying how and why complexity might impact supply chain performance.

In order to understand why complexity affects performance in the supply chain, this study proposes the use of the information processing view proposed by Galbraith (1974). This study contends that increase in product complexity and supply base complexity increases the information processing requirement throughout the supply chain. The inability to handle increased information processing load leads to inferior performance in the supply chain. The use of the information processing view is expected to provide answers as to “why” and “how” product complexity and supply base complexity affect supply chain performance.

To provide answer as to “how” product complexity and supply base complexity affect supply chain performance, this study examines the role of coordination between supply chain partners. The success of any supply chain depends on the extent to which supply chain partners are successful in achieving coordination. As requirements in the supply chain become more complex, increase in information processing requirements hamper the ability of supply chain partners to achieve coordination. Thus we examine coordination as the mediating variable in the relationship between product complexity / supply base complexity and supply chain performance. An examination of the various aspects of coordination is expected to provide answers to the "how" part of our question. Thus we examine both direct and indirect paths between product complexity / supply base complexity and supply chain performance.

This study further goes on to explore ways to manage the effects of product complexity and supply base complexity. We recognize the fact that to a large extent, product complexity and supply base complexity are inevitable and can be seen as a "necessary evil". So, we examine the role of information processing mechanisms in boosting coordination, thus leading to improved management of the effects of complexity.

This study addresses the following research questions:

Research question 1: What is the effect of product complexity and supply base complexity on supply chain performance?

Research question 2: What is the role of coordination mechanisms in the relationship between complexity and supply chain performance?

Research question 3: How can organizations increase information processing capability in the quest to improve coordination?

This study begins by identifying the various dimensions of product complexity and supply base complexity. Based on a comprehensive review of literature, Product complexity is identified as a function of number of components, interaction between components, product decomposability, technological intricacy and technological novelty. Supply base complexity is identified as a function of the number of suppliers in the supply base, differentiation among suppliers and interrelationships between suppliers. These dimensions of product complexity and supply base complexity are used to identify how an increase in these complexity dimensions affect supply chain efficiency and responsiveness.

In order to examine the indirect relationship between complexity and supply chain performance, this study proposes two coordination constructs. The study argues that coordination between supply chain partners can be examined at two levels – Operational and Strategic. Both types of coordination look at the extent to which supply chain partners are able to manage interdependencies. Three dimensions of coordination are identified as part of the study. Information sharing, Decision synchronization and Collective learning are the three focal aspects of coordination proposed in this study.

Finally, this study identifies a set of practices that are employed by organizations to deal with the negative effects of increasing complexity. According to Galbraith's information processing view, one way to deal with uncertainty and complexity is by increasing the capability to process information. The use of information technology in organizations is a means to improve information processing capabilities. In the context of supply chains, the use of inter-organizational information systems or Inter-organizational systems (IOS) is a means to increase the ability to process information within a supply chain. In addition to the use of information technology, this study also identifies other practices that enable supply chains to deal with information processing requirements that accompany complexity. These practices are essentially seen as enablers of improved coordination between supply chain partners.

Chapter 2 provides a detailed review of literature related to the constructs and sub-constructs. The theoretical framework for this study and the hypothesized relationships are described in Chapter 3.

Chapter 2

Theoretical Framework and Construct Development

2.1 Theory

This study examines the issue of complexity and performance in the supply chain from the information processing perspective. The main idea here is that an increase in complexity within the supply chain will make the task of processing information required to accomplish tasks more difficult. Thus, information processing theory is used as the main theoretical base to explain the effects of complexity within the supply chain. In order to understand the impact of complexity within the supply chain, the study also draws from Complexity theory, Coordination theory, Interdependence theory and Social Capital theory.

2.1.1 Information Processing Theory

The organizational information processing model was proposed by Galbraith (1974) to explain the design of complex organizations under conditions of uncertainty. The basic proposition of the information processing theory is that under conditions of uncertainty, greater amount of information has to be processed to accomplish a task or to achieve a certain level of performance. A mechanistic model was proposed by Galbraith to successfully achieve coordination in large organizations. The model consisted of the following 7 design strategies: (1) the use of rules or programs to achieve coordination (2) the use of hierarchy to deal with problems for which no specific rules have been specified (3) coordination by specifying outputs, goals and targets (4) creation of slack resources (5) creation of self-contained tasks (6) investment in vertical information systems (7) creation of lateral relations. Galbraith further goes on to identify strategies 4 and 5 as ways to reduce the information processing need. Strategies 6 and 7 are identified as ways to increase the capacity to process information.

Information processing theory has been previously used to explain the effect of manufacturing environment complexity on manufacturing performance. Flynn and Flynn (1999) identify manufacturing diversity, goal diversity, supplier diversity, customer diversity and labor diversity as sources of uncertainty and thus complexity of a manufacturing environment. Flynn and Flynn (1999) also examine some of the strategies (5, 6 and 7) proposed by Galbraith (1974).

The applicability of Galbraith's information processing theory is not limited to the organizational context. It is equally applicable in inter-organizational contexts. Grover and Saeed (2007) look at the issue of coordination between organizations from the lens of information processing. Accordingly, increased uncertainty and complexity resulting from product and market characteristics are said to drive the need for coordination, which in turn has to be matched by having appropriate coordination mechanisms and information processing capabilities. Zhou (2011) examines data from North American manufacturing firms to show the relevance of information processing theory in the supply chain environment. Supply chain and information systems literature has relied on Galbraith's views to explain the emergence of supply chain information technologies, inter-organizational systems, supply chain integration and collaboration mechanisms (e.g. Premkumar et al 2005; Zhou and Benton, 2007; Forster (2000); Kim and Umanath, 1999; Gattiker and Goodhue, 2004; Kim et al. 2006; Bensaou, 1997; Bensaou and Venkatraman, 1995).

2.1.2 Complexity Theory

The issue of complexity has been discussed extensively by organization scientists. A system is said to be complex when the system consists of a large number of parts and there are many interactions between the individual parts (Simon, 1996). In the context of organization science, the organization is the system in question. Thompson (1967, p. 6) describes a complex organization as a set of interdependent parts, which together make up a whole that is interdependent with some larger environment. Another view of organizational complexity is in terms of the number of activities or subsystems within the organization (Daft, 1992, p. 15). Complex systems are complex because of the fact that the behavior of these systems can be hard to predict (Casti, 1994; Anderson, 1999). The relationship between cause and effect in a complex system tends to be non-linear in nature (Casti, 1994).

In recent years, Complexity theory and Chaos theory have found increasing acceptance in the area of supply chain research (Pathak et al 2007). Choi et al (2001) proposed the idea of looking at supply networks as Complex Adaptive Systems (CAS), rather than simply as systems. The complex and dynamic nature of these supply networks has led to identifying these systems as CAS. A CAS is said to emerge over time into a coherent form, and organize itself without any deliberate control (Holland, 1995; Choi et al, 2001). Choi et al (2001) have identified three foci of CAS - an internal mechanism, an environment, and co-evolution. Internal mechanism refers to (a) the agents that make up the system, (b) self-organizing behavior and emergence of structures and patterns, and (c) agents' degree of freedom. The environment refers to the existing dynamism and complex landscapes. Co-evolution refers to the emergence and development of new agents within the system, which results in disequilibrium within the system. The CAS perspective in the context of supply chains can contribute to increased realism of research models and improved understanding of organizational relationships (Pathak et al 2007). This perspective is especially useful in examining buyer-supplier relationships, supplier-supplier relationships, supplier differentiation and supply network issues regarding competition, cooperation and coopetition (Pathak et al 2007; Choi et al 2006).

2.1.3 Coordination Theory and Interdependence Theory

Supply chain research has been greatly influenced by organizational, economic and behavioral theories. Two such theories from the stream of organization science are Coordination theory and Interdependence theory. The main reason for the acceptance of these theories in supply chain research is because of the inherent nature of supply chains. The supply chain system, like any other system, is essentially made of interrelated components (Scott, 1981; Skipper et al 2008). Between each of these components, we can see different levels of interdependence. This interdependence creates the need for coordination among the various components of the supply chain. Coordination theory, initially developed by Malone and Crowston (1994) addresses various issues related to the management of these interdependencies. Malone and Crowston (1994) thus define coordination as “managing dependencies among activities”. Since the need for coordination is driven by the existence of dependencies, Interdependence theory is used to throw light on various aspects of coordination. Thompson (1967) explores the issue of interdependency and proposes three levels of interdependencies within systems. Accordingly, the weakest level of interdependence (Level 1) is called as Pooled interdependence. An illustration of pooled interdependence is when two suppliers are supplying to an OEM, but have no impact (dependence) on each other (Skipper et al 2008). The second level of interdependence is called Sequential interdependence (Level 2), where dependence is such that the output of one is the input to another. Level 3 of interdependence is called Reciprocal Interdependence. This is similar to Sequential interdependence. The only difference being that the “input-output exchange can move in both directions” (Skipper et al 2008). According to Thompson (1967), different coordination strategies are required for each of these three levels of interdependence. Coordination by Standardization, Coordination by Plan and Coordination by Mutual Adjustment are suggested coordination strategies or mechanisms for levels 1, 2 and 3 of interdependence respectively.

Coordination theory proposed by Malone and Crowston (1994) also discusses coordination processes to manage shared resources, producer/customer relations, simultaneity constraints and task/sub-task relationships. The use of information technology, standardization of outputs, customer participation, group decision making are some of the issues addressed to enable coordination Malone and Crowston (1994).

2.1.4 Social Capital Theory

Social capital theory is focused on the social relationships between individuals or groups and possible outcomes as a result of these relationships (Granovetter, 1992). Social capital studies recognize relationships to be a "resource of social action" (Nahapiet and Ghoshal, 1998). Social capital is said to have an influence on human capital, productivity and productivity of firms, geographic regions and counties (Coleman, 1988; Baker, 1990; Putnam, 1993; Fukuyama, 1995). Access to resources and economic rents are possible through social relationships. Social capital is embedded in networks of acquaintances and these network members can be sources of valuable information and opportunities (Granovetter, 1973). Being an integral part of a network contributes to social status and reputation (Bourdieu, 1986). Nahapiet and Ghoshal (1998) propose three dimensions of social capital - Structural capital, Cognitive capital and Relational capital. Structural capital refers to the structural linkages or the patterns of connections between actors in a network. Diversity, centrality and boundary spanning roles of actors in the network contribute to the growth in capital (Krause et al 2007). Relational capital refers to the personal relationships between individuals that develop through a series of repeated interactions. Respect, trust and friendship are key elements of relational capital. The assets created through these relationships contribute to the relational dimension of social capital. Cognitive capital refers to resources that provide "shared representations, interpretations and systems of meaning" (Nahapiet and Ghoshal, 1998). Shared languages, codes and narratives contribute to shared understanding among network members (Weick, 1995).

Social capital and its dimensions have performance implications at an organizational and inter-organizational level. Nahapiet and Ghoshal (1998) propose that social capital facilitates the creation of intellectual capital in organizations. Tsai and Ghoshal (1998) propose social interactions and trust to be manifestations of the structural and relational dimensions respectively of social capital. These two dimensions were shown to have an impact on resource sharing and product innovation. Social capital is said to play a more prominent role in the context of strategic alliances (Krause et al 2007). Research has shown that the three dimensions of social capital improve alliance outcomes by enabling resourcing sharing in the form of knowledge, technology and values (e.g. Dyer and Singh, 1998; Kogut and Zander, 1992; Szulanski, 1996; Inkpen and Tsang, 2005).

2.1.5 Research framework

In this study, concepts and ideas are drawn from the four theories describe above to come up with a theoretical framework that examines the relationships between complexity and supply chain performance. The theories throw light on important issues related to complexity, information processing and coordination in organizational and inter-organizational contexts. However, it is important to integrate the ideas discussed in these theories to gain a clear understanding about how complexity affects performance in supply chains.

The information processing theory forms the crux of this study by providing the conceptual base for proposed relationships. Core concepts of this theory explain the effects of complexity in the supply chain and provide ways to manage the effects of complexity. Complexity theory is used to identify the various dimensions of product complexity and supply base complexity. It is useful in identifying how these individual dimensions contribute to the complexity of the system as a whole. Coordination theory and inter-dependence theory explain the interactions between entities when there is a certain level of dependency between them. It also throws light on strategies to manage these interdependencies. Social capital theory is used to identify factors that create closer relational ties between supply chain members and thereby increase information processing capability. The proposed research framework shown in figure 1 addresses the following: (1) Impact of complexity on supply chain performance; (2) Mediating role of coordination; (3) Impact of information processing capability on coordination and (4) Supply chain performance impact on firm performance.

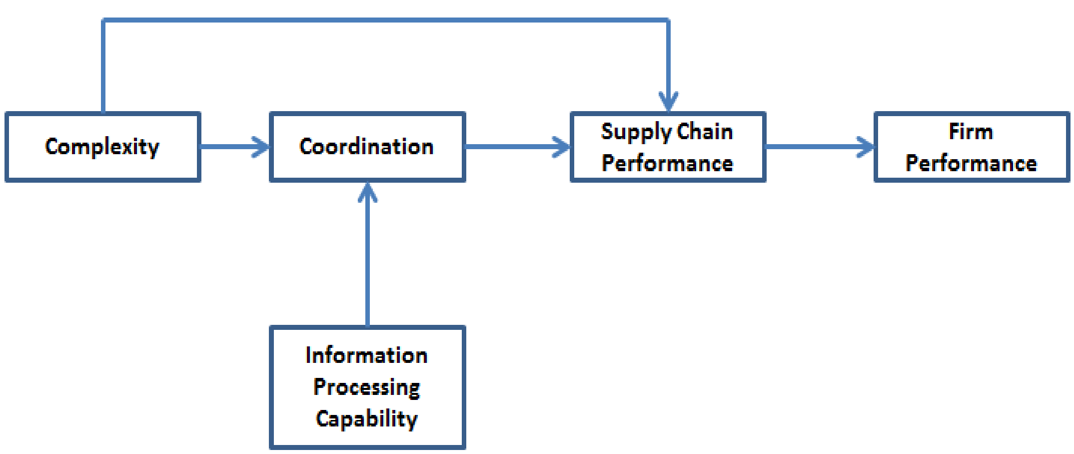

Figure 2-1: Research framework

2.2 Literature Review and Construct Development

This part of the study identifies the main constructs that constitute the detailed research model. A detailed review of literature is presented to develop construct definitions and identify sub-constructs.

2.2.1 Product Complexity

The complexity of a supply chain is determined from the perspective of the focal firm by the firm's internal characteristics. It is also determined by the characteristics of the upstream and downstream parts of the firm's value chain. In academic literature, Wilding (1998) was one of the first researchers to explore the construct of supply chain complexity. Wilding (1998) explored supply chain complexity in terms of deterministic chaos, parallel interactions and amplifications. Vachon and Klassen (2002), on the other hand, conceptualized supply chain complexity in terms of numerousness, interconnectivity and systems unpredictability. A more recent conceptualization of supply chain complexity by Bozarth et al (2009) looks at it in terms of internal manufacturing complexity, upstream complexity and downstream complexity. One common element among all these conceptualizations of supply chain complexity is the inclusion of product complexity as a key element or determinant of supply chain complexity. Thus, this study examines product complexity in detail.

Simon (1962) was one of the early researchers who defined a complex system as "one made up of a large number of parts that interact in a nonsimple way'' (p. 468). This definition of a complex system essentially identifies two different things – numerousness and interactions. Numerousness refers to the number of sub-systems that make up the part. Interaction refers to the relationship between the sub-systems or the way individual components are connected to form the system (Casti, 1979). Yates (1978) has identified five important components of a complex system - interactions, number of component parts, nonlinearity, broken symmetry, and non-holonomic constraints. Complexity in a system can also arise out of the level of detail within the system and also the extent of dynamism inherent in the system (Bozarth et al 2009). The level of detail is generally determined by number of parts or components that make up the system. Dynamism refers to the unpredictability of the system in response to any input (Waldrop 1992; Bozarth et al 2009). Based on literature identified above, we can say that researchers unanimously agree that increasing the number of parts in the system (product) adds to the complexity of the system (product).

Increasing the number of parts or components has implications both at the internal manufacturing level as well as at the inter-organizational level. The number of unique parts is said to drive detail complexity (Bozarth et al 2009) and in turn affects manufacturing performance at the plant level (Fisher et al., 1999; Krishnan and Gupta, 2001; Ramdas and Sawhney, 2001). At the supply chain level, multiplicity of parts or components will increase the need for greater coordination with supply chain partners, thus affecting performance (Vachon and Klassen, 2002).

Close interaction between individual components also increase complexity of the system as a whole. For instance, the interaction between individual components and physical closeness between individual components is greater in a front wheel drive vehicle than a rear wheel drive vehicle. Thus, designing and making changes to existing designs requires a greater coordinated effort under circumstances of increased interaction (Novak and Eppinger, 2001).

Another aspect of the product that adds to the complexity is the decomposability. Decomposability refers to the ease with which a product can be separated into its components without affecting performance (Khurana, 1999). The extent to which a product can be easily decomposed is said to have an effect on the agility of the manufacturing operation and thus performance outcomes (Jacobs et al 2011). Modular product design makes products easily decomposable, thus making it easier to achieve various product configurations and also improve lead time, delivery speed and responsiveness (Jacobs et al 2011).

Product novelty refers to the newness of the product itself, its architecture or the technology associated with the product (Novak and Eppinger 2001; Tatikonda and Rosenthal 2000; Hobday 1998). When the product is new and the associated technology is new, learning and mastering the various issues associated with the product takes more time and effort. Many of the problems and issues associated with it usually emerge over time. Managing problems and solving issues will then become an arduous task till managers and other organizational members understand the product and technology. The issue of product and technology novelty has been addressed in new product development literature. Product and technology novelty are seen as factors that affect the performance of NPD projects in terms of speed and learning effort (Kim and Wilemon, 2003).

Complexity of a product is also driven by the number of functions it is designed for. Jacobs and Swink (2011) recognize this as a multiplicity dimension of product complexity. The number of functions quantifies the complexity of the set of services the product delivers (Griffin, 1997). An increase in the number of functions designed into the product increases the effort required to plan, source and make the product. Increased complexity resulting from the number of functions also affects the development cycle time of new products (Griffin, 1997). A greater number of functions also results in increased interactions between individual components of the product. As many of the processes involved in planning, sourcing and making the product cross organizational boundaries, managing such processes involves increased effort and coordination.

Table 2.1: Dimensions of Product Complexity

Dimensions of product complexity	References
Number of components / Number of parts – the number parts or components that go into making a product.	Novak and Eppinger, 2001; Vachon and Klassen, 2002; Cooper et al., 1992; Fisher et al., 1999; Krishnan and Gupta, 2001; Ramdas and Sawhney, 2001; Bozarth et al., 2009; Senge, 1990; Murmann, 1994;
Interaction between components – the extent of close coupling and interconnection between individual parts or components of a product.	Novak and Eppinger, 2001; Vachon and Klassen, 2002; Khurana, 1999; Singh, 1997; Kaski and Heikkila, 2002.
Product novelty – the newness of the product, its architecture and associated technology.	Novak and Eppinger 2001; Tatikonda and Rosenthal, 2000; Hobday, 1998
Technological intricacy – the complexity of the embedded technologies in the product.	Singh, 1997; Milgate, 2001; Corso et al., 2001.
Product decomposability – the extent to which a product can be separated into individual components.	Khurana, 1999; Vachon and Klassen, 2002

Product functions – the number of functions designed into the product.	Griffin, 1997; Jacobs and Swink, 2011

In this study, *Product complexity* is defined as a function of (a) number of components (b) interaction between components (c) product decomposability (d) technological intricacy and (e) technological novelty.

Table 2.2: Product complexity – Definition and References

Construct	Definition	References
Product complexity	A function of (a) number of components (b) interaction between components (c) product decomposability (d) technological intricacy (e) technological novelty	Novak and Eppinger, 2001; Vachon and Klassen, 2002; Cooper et al., 1992; Fisher et al., 1999; Krishnan and Gupta, 2001; Ramdas and Sawhney, 2001; Bozarth et al., 2009; Khurana, 1999; Singh, 1997.

2.2.2 Supply Base Complexity

The upstream of a supply chain is made up of the focal firm's suppliers and the suppliers' suppliers. The set of companies that are located upstream of the focal company is generally referred to as supply network (Porter 1985). The supply base on the other hand, is seen as a sub-set of the supply network. Choi and Krause (2006) define a supply base as made up of "suppliers that are actively managed through contracts and the purchase of parts, materials and services". The issue of complexity arises when the structure and composition of the supply base is such that management and coordination of the suppliers within the base becomes extremely difficult. Supply base complexity is generally explained in terms of the three dimensions of multiplicity, diversity and functional inter-relatedness. These three dimensions are used to identify various sources of complexity in an organizational or inter-organizational context (Jacobs and Swink, 2011). Multiplicity refers to the existence of a large number of elements (Jacobs and Swink, 2011). In the context of a supply base, multiplicity refers to the existence of a large number of suppliers. Multiplicity of suppliers in the supply base has been a source of concern for most large organizations. In order to address this issue, many organizations have embarked on supply base rationalization or supply base reduction. A large number of suppliers in the supply base contribute to increased transaction and coordination costs. Choi and Krause (2006) identify the number of suppliers as one of the three dimensions of supply base complexity. They propose a decrease in supplier responsiveness as the number of suppliers increase. However, the debate between single sourcing and multiple (or dual) sourcing has been an ongoing one in supply chain research. This stream of literature can be divided into two groups – the first group looks at the effect of order splitting on lead time and the second group examines the total inventory cost of a multiple sourcing strategy (Sarkar and Mohapatra, 2009). Supply chain risk literature recommends the use of multiple suppliers for the same product as a way to reduce supplier risk and also safeguard against unforeseen events (Tang and Tomlin, 2008). Multiple sourcing practices and risk reduction practices have thus resulted in increased supply base complexity.

The diversity dimension of complexity in the context of the supply base refers to the existence of differences among suppliers in the supply base. These differences may be in terms of capabilities or/and practices. Choi and Krause (2006) define differentiation of suppliers as “the degree of different characteristics such as organizational cultures, operational practices, technical capabilities, and geographical separation that exist among the suppliers in the supply base”. Organization culture here refers to shared norms and beliefs. Sharing common norms and practices enables more efficient work and process flow between partners in a supply chain (Choi and Krause, 2006). Similar operational practices also help establish smoother flow between operating partners. Supplier diversity, on the other hand is said to make it much more difficult to ensure JIT deliveries from suppliers (Srinivasan et al 1994). Organizations also expect their suppliers to be technically capable. Adequate technical capability ensures that buyers are not spending their efforts on bridging the technical gap between them and their suppliers. In current times, where buyers depend on their suppliers for both designing and developing new products, supplier selection is to a large extent dependent on technical capability. For instance, supplier selection based on technical capability is seen as a key antecedent for black box and grey box supplier integration in product development (Koufteros et al 2007). A survey of suppliers in the US auto industry shows that design capability and technical capability are key criteria for supplier selection (Choi and Hartley, 1996). Geographic location of suppliers is another key issue when organizations are concerned about effective supply chain management (Tan 2002). Buyers prefer suppliers to be closely located. The emergence of supplier parks especially in the auto industry is because of the preference of OEMs to have their suppliers located close to their manufacturing plants. Cost reduction, increased efficiency and lower labor costs are seen as some of the benefits of having co-located suppliers (Morris et al 2004). Co-located suppliers are also preferable for JIT delivery of component parts and sub-assemblies. In the computer industry, Dell is known to keep its suppliers in close physical proximity to ensure JIT delivery and thus keep inventory levels to a minimum. Suppliers' physical proximity becomes even more important under conditions of high uncertainty (Hakansson and Wootz, 1975). Thus, higher differentiation leads to greater complexity.

Inter-relationships between suppliers refer to the working relationships among suppliers in the supply base (Choi and Krause, 2006). In a supply base, it is not uncommon to find suppliers who supply to or buy from each other. These working relationships between suppliers sometimes emerge over time and are also directed by a powerful focal company in the supply chain. Focal companies sometimes require their suppliers to have working relationships with each other for reasons of efficiency and quality. This kind of relationship between suppliers can be seen as collaborative or cooperative relationships. However, cooperative relationships may not always be desirable as they can lead to collusion and thus work against the interest of the focal company (Brandenburger and Nalebuff, 1996; Choi et al., 2002; Hill, 1990; Choi and Krause 2006). In certain cases, focal companies try to foster a sense of competition between suppliers by pitting them against each other.

Table 2.3: Dimensions of supply base complexity

Dimensions of Supply Base Complexity	**References**
Number of suppliers	Choi and Krause, 2006; Bozarth et al., 2009; Handfield and Nichols, 1999; Ogden, 2006; Koufteros et al., 2007; Tully, 1995; Bakos and Brynjolfsson, 1993;
Differentiation between suppliers	Choi and Krause, 2006; Dooley, 2001; Choi and Hartley, 1996
Inter-relationship between suppliers	Choi and Krause, 2006; Choi and Hong, 2002; Dooley, 2001; Choi et al., 2002; Wu, 2003; Kamath and Liker, 1994; Wu and Choi, 2005; Smith and Laage-Hellman, 1992; Brandenburger and Nalebuff, 1996; Hill 1990

These three dimensions are said to be the main drivers of complexity in a supply base. Thus in this research, we define supply base complexity as a function of (a) number of suppliers (b) differentiation among suppliers (c) interrelationships between suppliers.

Table 2.4: Supply base complexity – Definition and References

Construct	Definition	References
Supply Base Complexity	A function of (a) number of suppliers (b) differentiation among suppliers (c) interrelationships between suppliers	Choi and Krause, 2006; Bozarth et al., 2009; Handfield and Nichols, 1999; Ogden, 2006; Koufteros et al., 2007; Choi and Hartley, 1996; Choi and Hong, 2002; Choi et al., 2002; Wu and Choi, 2005.

2.2.3 Operational Coordination and Strategic Coordination

The issue of coordination has garnered more attention as systems have become more complex over time (Malone and Crowston, 1994). Coordination is seen as the task of managing dependencies between activities. The need for coordination arises when there is any form of interdependency. For instance, consider a manufacturing setup where the output of machine A serves as the input for machine B. This creates a direct dependency and thus a need for coordination between the two. Thus, to a large extent, the level of interdependency dictates the extent of coordination necessary. Interdependence between tasks has been divided by Thompson (1967) as pooled, sequential and reciprocal. Thompson (1967) has also provided three generic strategies or coordination mechanisms – coordination by standardization, coordination by plans and coordination by mutual adjustment. The importance of interdependence and coordination is highlighted in the context of supply chains. A supply chain is said to be made up of interdependent units within the firm and a set of interdependent units both upstream and downstream of the firm (Ballou et al., 2000). Thus coordination is crucial in a supply chain and this is reflected in supply chain literature. Cooper et al (1997) regard supply chain management as integration and coordination of a set of activities that span the supply chain from the initial supplier of raw materials to the end customer. Ballou et al (2000) identify three dimensions of supply chain management as (1) intra-functional coordination (2) inter-functional coordination and (3) inter-organizational coordination. In all these three dimensions of coordination, coordination can be with respect to either physical flows or information flow.

Supply chain coordination as such has been defined in a variety of ways. For instance, Kaur et al (2006) take a graph theoretic perspective of supply chain coordination and describe it as a way to attain mutually defined goals through joint efforts of supply chain members. Kanda and Deshmukh (2008) describe supply chain coordination as management of dependencies between supply chain members. In the field of engineering, supply chain coordination has been conceptualized as a way by which decisions of all members of the system is orchestrated to achieve a systematic target (Shi, 2011). Supply chain coordination has also been defined in terms of collaborative efforts of supply chain partners (Hong et al 2009). Lee (2000) describe supply chain coordination as a means to redesign decision rights, resources and work flows between supply chain members to achieve better performance. Simatupang et al (2002) explore supply chain coordination in terms of four modes of coordination, namely information sharing, logistics synchronization, incentive alignment and collective learning. Simatupang et al (2004) define supply chain coordination as the extent to which supply chain partners are actively involved in information sharing and decision synchronization. Information sharing generally refers to exchange of relevant, accurate, complete and confidential information between supply chain partners in order to increase information visibility in the supply chain (Cao, 2007). Decision synchronization is a means to achieve coordination by organizing and aligning decisions and activities with supply chain partners in a timely manner (Cao, 2007; Simatupang et al 2002). Based on the nature of information shared and decisions synchronized, coordination can be divided into Operational Strategic. For instance, Madlberger (2009) make a clear distinction between inter-organizational operational information sharing and inter-organizational strategic information sharing. Li et al (2006) propose three levels of information sharing between organizations – operational, tactical and strategic. Similarly, management literature related to decision making has identified decision making in terms of operational decision making and strategic decision making. Thus it makes logical sense to look at the issue of supply chain coordination in terms of operational coordination and strategic coordination. This is in line with Sanders (2008), where coordination between buyers and suppliers is divided into operational coordination and strategic coordination.

Thus, in this study *we define Operational coordination as the extent to which the focal firm manages interdependent processes for day-to-day activities with its supply chain partners*. We define *Strategic coordination as the extent to which the focal firm manages interdependent processes for long-term planning with its supply chain partners*.

Both operational and strategic coordination consist of three components – Information sharing, Decision synchronization and Collective learning. These three components of coordination are discussed in the following section.

2.2.3.1 Information sharing:

Information is considered to be a valuable resource for any organization or supply chain. Access to timely and accurate information can be very critical and tends to determine the extent to which supply chains are able to achieve high levels of performance. Supply chain researchers have stressed on the importance of information and information visibility throughout the supply chain (Lee et al 2000; Lee and Whang, 1998; Frohlich and Westbrook, 2001; Metters, 1997; Stank et al 1997). For instance, in the seminal article by Lee et al (1997), the lack of information visibility is identified as the main reason for the existence of the bullwhip effect in supply chains. Demand variability increases as one moves up along the supply chain when supply chain partners do not share information. Amplification of demand variability results in either stock outs or excess inventory at various points in the supply chain. This eventually affects service levels and other aspects of operational performance. In the context of supply chain coordination, information sharing and information visibility thus play a critical role. Information sharing is seen as an enabler of improved planning and coordination in the supply chain (Lee et al 2000), and is identified as one of the five building blocks of a successful supply chain relationship (Lalonde, 1998; Li and Lin, 2006). Information sharing is considered to be a "generic cure for supply chain ailments" (Sahin and Robinson, 2002). Yu et al (2001) examine the impact of information sharing on supply chain partnerships and conclude that all members of the supply chain are better off when information is shared. Inventory reductions and cost savings are the specific benefits identified by Yu et al (2001). Many of the popular supply chain practices like vendor managed inventory (VMI), continuous replenishment, collaborative planning forecasting and replenishment (CPFR) will cease to exist without effective information sharing (Chen and Chen, 1997; Lummus and Vokurka, 1999; Chen, 2002; Lee and Whang, 2000). These supply chain practices are essentially mechanisms created to achieve coordination within the supply chain. The lack of coordination in the supply chain occurs when decision makers have incomplete information or no information at all (Sahin and Robinson, 2002). In order to address the lack of information, researchers have examined information sharing in terms of information content, information quality and the use of technology to enable information sharing (ex: Zhou and Benton, 2007). Information content refers to the nature of information being shared. On the basis of the source of the information, information content can be classified into manufacturer information, supplier information, distributor information, retailer information and customer information (Handfield and Nichols, 1999; Chopra and Meindl, 2001; Zhou and Benton, 2007). Information quality refers to the extent to which information is useful and meets the needs of the supply chain (Peterson, 1999). Information quality is determined on the basis of accuracy, completeness, recency, credibility, frequency, relevance, timeliness (Neumann and Segev, 1979; McCormack, 1998; Petersen, 1999; Zhou and Benton, 2007).

Supply chain literature has recognized information sharing as a fundamental component of supply chain management. Information sharing is a way to ensure common understanding between supply chain partners (Simatupang et al 2002). In this study, we propose that information sharing is a vital component of both operational coordination and strategic coordination. Thus we define *information sharing (operational) as the e*xtent to which the focal firm exchanges information about day-to-day activities with its supply chain partners. *Information sharing (strategic) is defined as the extent to which the focal firm exchanges information about planning and positioning activities with its supply chain partners.*

2.2.3.2 Decision synchronization:

Decision synchronization is a key aspect of any kind of coordination. It is similar to the market mediation function of the supply chain (Simatupang et al 2002). Decision synchronization is necessary for balancing supply according to demand (Fisher, 1997). In order to balance supply and demand, it is essential to coordinate decisions of all supply chain members to meet the goal. Inability to coordinate these decisions will result in a mismatch between supply and demand. Synchronizing decisions of various supply chain members is not an easy task. This is mainly because of conflicting objectives and complex allocation of decision rights among supply chain partners (Anand and Mendelson, 1997). Synchronized decision making thus calls for appropriate allocation of decision rights in order to enable joint decision making in the supply chain. Recognizing the importance of joint decision making, Simatupang et al (2004) describe decision synchronization as the extent to which participating actors become involved in joint decision making in matters such as resolving conflicting objectives, mitigating uncertainty, redesigning workflow, and allocating resources. Joint decision making is an enabler of decision synchronization and thus supply chain coordination. Joint decision making can be seen at each of the decision areas identified by SCOR. These decision areas are Plan, Source, Make, Deliver and Return. Lockamy and McCormak (2004) identify planning practices in the SCOR decision areas and joint decision making aspect is seen in all the SCOR decision areas. Joint decision making in the planning area is highlighted by the widespread application of Collaborative Planning Forecasting and Replenishment (CPFR) practices. Inventory management, logistics management and production management literature have also emphasized the benefits of joint decision making. Moses and Seshadri (2002) discuss joint decision making as a mechanism to minimize cost and optimize inventory level in the supply chain. Joint system cost consideration and joint pricing are also some of the ways to minimize supply chain costs and maximize supply chain profits (Gurnani, 2001; Boyaci and Gallego, 2002; Wu and Ouyang, 2003; Chen and Chen, 2005). Joint decision making in terms of pricing can also minimize inventory carrying and distribution costs (Haq and Kannan, 2006). Joint product planning is another way to achieve coordination and reduce overall production cost (Jayaraman and Pirkul, 2001; Pyke and Cohen, 1993). Coordinated production scheduling and vehicle routing can also minimize associated costs (Chandra and Fisher, 1994). Decision synchronization is thus seen as a means to improve supply chain responsiveness, efficiency and overall profitability (Corbett et al 1999).

In this study, we define decision synchronization in the context of operational coordination and strategic coordination. *Decision synchronization (operational) is defined as the extent to which the focal firm makes joint decisions for day-to-day interface activities with its supply chain partners. Decision synchronization (strategic) is* *defined as the extent to which the focal firm makes joint decisions for planning and positioning activities with its supply chain partners*.

2.2.3.3 Collective Learning:

Organizational learning and inter-organizational learning are two forms of learning that have been explored and examined in various streams of literature. The same is true in the context of supply chain literature. In a supply chain where various supply chain partners are constantly interacting and collaborating, the context of learning is inter-organizational and collective. Supply chain partners learn with and from each other through their actions and interactions. Collective learning or joint learning thus becomes a key component of coordination within the supply chain (Simatupag et al 2002). This view is reflected in the way numerous researchers have defined collective learning and joint learning. For instance, Keeble and Wilkinson (1999) define collective learning in regions as " the creation and further development of a base of common and shared knowledge among individuals making up a productive system which allows them to co-ordinate their actions in the resolution of the technological and organizational problems they confront " (p. 296). Gambarotto and Solari (2004) describe collective learning as a coordinated change of competencies. Collective learning is also seen as a process of creating shared procedures and processes which enables action coordination and problem resolution (Lazaric and Lorenze, 1998). From the perspective of knowledge, collective learning is described as an interactive process of generating and accumulating knowledge (Cotic-Svetina et al., 2008). Zhou et al. (2001) describe collective learning as a learning strategy. An integral part of this strategy would be coordinating the knowledge available to individual actors or organizations to meet a common goal. One way to achieve knowledge coordination is by allowing for joint creation of knowledge via collective learning (Cohendet et al 1999). Coordination through collective learning helps address the problems of knowledge initiation and diffusion across organizations (Simatupang et al 2002; Sawhney and Prandelli, 2000). Since coordination is divided into strategic and operational, collective learning should address both aspects of coordination. Thus, in this study we define *collective learning (operational) as the extent to which the focal firm develops understanding and competencies about day-to-day activities jointly with its supply chain partners. Collective learning (strategic) is defined as the extent to which the focal firm develops understanding and competencies about planning and positioning activities jointly with its supply chain partners.*

Table 2.5: Operational and Strategic Coordination – Definition and References

Construct	**Construct Definition**	**Construct Details & References**
Operational Coordination	Extent to which the focal firm manages interdependent processes for day-to-day activities with its supply chain partners.	Operational coordination includes Information sharing, Decision synchronization and Collective learning. Information sharing is the extent to which the focal firm exchanges information about day-to-day activities with its supply chain partners. Decision synchronization is the extent to which the focal firm makes joint decisions for day-to-day interface activities with its supply chain partners.

		Collective learning is the extent to which the focal firm develops understanding and competencies about day-to-day activities jointly with its supply chain partners. *Malone and Crowston, 1994; Thompson, 1967; Ballou et al., 2000; Simatupang et al, 2002; Simatupang et al., 2004; Cao, 2007; Sanders, 2008; Lee et al., 2000; Keeble and Wilkinson, 1999; Gambarotto and Solari, 2004; Cotic-Svetina et al., 2008.*
Strategic Coordination	Extent to which the focal firm manages interdependent processes for long-term planning with its supply chain partners.	Strategic coordination includes Information sharing, Decision synchronization and Collective learning. Information sharing is the extent to which the focal firm exchanges information about planning and positioning activities with its supply chain partners. Decision synchronization is the extent to which the focal firm makes joint decisions for planning and positioning activities with its supply chain partners Collective learning is the extent to which the focal firm develops understanding and competencies about planning and positioning activities jointly with its supply chain partners. *Malone and Crowston, 1994; Thompson, 1967; Ballou et al., 2000; Simatupang et al., 2002; Simatupang et al., 2004; Cao, 2007; Sanders, 2008; Lee et al., 2000; Keeble and Wilkinson, 1999; Gambarotto and Solari, 2004; Cotic-Svetina et al., 2008.*

2.2.4 Inter-Organizational Systems (IOS)

Information and communication technology systems that generally span organizational boundaries are referred to as Inter-organizational systems (Subramani, 2004). In a supply chain inter-organizational systems enable connections between various supply chain partners. In a broad way, IOS have been defined as information systems shared by multiple organizations (Cash and Konsynski, 1985). IOS in general includes any kind of information and communication technology that helps manage interdependencies between firms (Chi and Holsapple, 2005). A wide range of inter-organizational systems are in use today. Approximately 30,000 or more inter-organizational systems are operational in industry (Subramani, 2004). IOS literature reveals how researchers have categorized IOS based on usage, functionality and various other contextual factors. This effort of IOS researchers highlights the concept of appropriation proposed by DeSanctis and Poole (1994). Appropriation refers to the way a certain tool or application is used. Subramani (2004) refers to appropriation as patterns of use. Appropriation of any information system is contextual and situated. To a very large extent, appropriation depends on the intended outcomes. Additionally, different appropriations lead to different outcomes. Subramani (2004) thus describes two patterns of information technology (IT) use as IT for exploration and IT for exploitation. The concepts of exploration and exploitation used here are drawn from learning theory (March, 1991). Exploration refers to the pursuit of new alternatives and possibilities. Exploitation refers to refining and optimization of existing certainties. Subramani (2004) discusses how the use of supply chain management information systems by suppliers can be classified into patterns of exploration and exploitation. Vickery et al., (2003) divides supply chain information technologies into (a) computerized production systems (b) integrated information systems; and (c) integrated electronic data interchange. Meier and Sprague (1991) classify IOS into three categories: (a) ordering systems (b) electronic markets and (c) online information dissemination systems. Hong (2002) classifies IOS into four categories: resource pooling, operational cooperation, operational coordination, and complementary cooperation. Resource pooling IOS enables participating partners to pool resources, share cost and risk. Operational cooperation IOS enables common value creation by providing access to information. An operational coordination IOS is used to manage dependencies and increase operational efficiency. Complementary cooperation IOS refers to the ability of the IOS to enable cooperation between members of the supply chain who assume complementary roles. Cao (2007) proposes a broad classification of IOS into (a) IOS for integration (b) IOS for communication and (c) IOS for intelligence. Integration here refers to effective coupling of various processes. Communication refers to the facilitation of information flows. Intelligence refers to learning and knowledge creation among supply chain partners. Another widely accepted classification of information system distinguishes between transactional information technology and analytical information technology. According to this classification, transactional systems enable automated handling, processing and transfer of information or data. Analytical systems process transactional data to generate analytical information that helps in managerial decision making.

These various classifications of IOS appropriations have generated important and interesting insights for theory and practice. However, a classification that captures the nature of supply chain transaction enabled by IOS can provide some more interesting insights. Supply chain literature has classified supply chain transactions into pure transactions and relational transactions. Pure transactions are market based transactions which are more arms'-length in nature. On the other hand, relational transactions depend on closer relational ties between transacting members. On this basis, this study proposes two patterns of IOS use, namely Transactional IOS and Relational IOS. A discussion of these two patterns of IOS use is followed.

2.2.4.1 Transactional IOS

The use of IOS for pure transactional purposes with supply chain members is referred to in this study as Transactional IOS. This has many similarities to the IT appropriation identified as "IT for exploitation" in the MIS stream of research (Subramani, 2004; Sanders, 2008). Literature identifies two broad motives for the use of information systems – automating and informating (Subramani, 2004). IT use for exploitation is also along the lines of "automating". Transactional IOS enables automation of structured tasks between supply chain members. Structured information refers to data that is contextually and semantically well defined. Processing procedures and protocols for structured information is generally well defined and there is no deviation from procedure. Structured information can be transferred and processed from one information system to the other with zero or minimal human intervention. Examples of automation of structured information include automated billing, electronic transfer of request for quotation (RFQ)/purchase orders/advanced shipping notice/order status reports/payments, exchange of inventory related information. The advantages of IOS use for transactional purposes range from reduced time of operations, reduced errors, reduced human effort, improved quality of transaction, and finally improved bottom lines (Riggins and Mukhopadhyay, 1994; Mukhopadhyay and Kekre 2002; Subramani, 2004; Clemons and Row, 1992; Clemons et al., 1993). One of the most widely used applications of transactional IOS is Electronic Data Interchange (EDI). EDI refers to a set of automated and standardized computer based transfer or exchange of data. The basic premise of EDI is the standardization of information exchanges. There are various EDI standards used in industry as of today. For example, the automotive industry in the US depends on the standards prescribed by COVISINT. Thus, the main characteristics of information systems classified as transactional are – automation and standardization. On the basis of these characteristics, in this study we define *Transactional IOS as the extent to which the focal firm uses IOS for the exchange of structured information with its supply chain partners*. It includes the use of IOS for automating and standardizing information flows with supply chain partners.

2.2.4.2 Relational IOS

In the supply chain, inter-organizational systems are employed as a means of enabling relational ties between supply chain members and for the processing of unstructured information. Relational ties refer to relationships that go beyond mere transactional exchanges. Relational transactions or relational exchanges in a supply chain are in contrast with arm's-length transactions. Relational transactions move beyond the use of markets as an exchange mechanism. They rely on informal exchange mechanisms that are based on social exchange mechanisms, mutual trust and values (Zhou and Peng, 2010; Granovetter, 1985). Relational transactions are more common when exchanging partners are focused on working together with intent to explore new possibilities. In this sense, use of IOS for relational purposes is similar to the use of IT for exploration as proposed by Subramani (2004).

Along with the ability of IOS to connect supply chain partners, they are also used to enable supply chain partners to work together and collaborate. The use of collaborative design tools and collaborative planning, forecasting and replenishment (CPFR) are examples of IOS that enable relational exchanges. Collaborative information technology tools are useful when the nature of information calls for partners to work closely and make joint decisions to achieve objectives. Shen et al (2008) describe a process of product design called Computer Supported Collaborative Design (CSCD). This is a product design process that involves supply chain partners such as suppliers and customers in the design of new products. Information technology tools such as CAD/CAM and semantic web technologies are employed for this purpose. Shen and Wang (2003) provide a comprehensive list of information technology tools used in collaborative design. Gordon et al (2008) describe the use of information technology at the “fuzzy front end” of the innovation process. They propose that the use of information systems enable collaboration, knowledge sharing and competitive intelligence gathering and thus contribute to innovation. Shafiei et al., (2012) discuss the growing reliance of collaborative decision support systems (CDSS) in supply chain management. These systems facilitate collaboration between partners and provide access to a range of decision tools. Decision simulation and what-if analysis are made possible through CDSS.

Based on these thoughts, *Relational IOS is defined as the extent to which the focal firm uses IOS to enable long term relationships with its supply chain partners*. It includes the use of IOS for enabling collaboration and exchange of non-standardized information with supply chain partners.

Table 2.6: Transactional IOS and Relational IOS – Definition and References

Construct	**Construct definition**	**Construct details & References**
Transactional IOS	The extent to which the focal firm uses IOS for the exchange of structured information with its supply chain partners.	It includes the use of IOS for automating and standardizing information flows with supply chain partners. *Subramani, 2004; Sanders, 2008; Cao, 2007; Riggins and Mukhopadhyay, 1994; Mukhopadhyay and Kekre, 2002.*
Relational IOS	The extent to which the focal firm uses IOS to enable long term relationships with its supply chain partners.	It includes the use of IOS for enabling collaboration and exchange of non-standardized information with supply chain partners. *Subramani, 2004; Sanders, 2008; Cao, 2007; Gordon et al., 2008; Shen et al., 2008; Shafiei et al., 2012.*

2.2.5 Boundary Spanning Capability (BSC)

In a supply chain, the flow of processes, materials and information often cross organizational boundaries. When this happens, it becomes a question of effectively managing boundary spanning activities. Boundary spanning activities are generally managed by individuals situated at the organizational interface. These individuals are referred to as boundary spanners and the ability of an organization to effectively manage boundary spanning activity is seen as the boundary spanning capability (Zhang et al 2011). Boundary spanning capability allows an organization to manage its interaction with supply chain partners and facilitate coordination and collaborations (Stock, 2006; MacDuffie and Helper, 2006). The ability to span organizational boundaries is seen as a key organizational competence (Grant, 1996; Kogut and Zander, 1992; Nonaka, 1994; von Hippel, 1988).Boundary spanning capability depends on the ability to perform and manage a variety of boundary spanning functions. Some of the most common boundary spanning functions are processing information, transferring ideas between boundaries, acting as a medium of knowledge dissemination, influencing external entities about perceptions regarding the organization, being the face of the organization (e.g. Aldrich and Herker, 1977; Friedman and Podolny, 1992; Ireland and Webb, 2007). Zhang et al (2011) broadly divide boundary spanning functions into three categories – (a) enable communications from within the organization to external entities (b) influence external entities by the use of knowledge and influence and (c) facilitate deals and compromises between the organization and external entities. Zhang et al (2011) define boundary spanning capability in terms of the performance of purchasing agents who are entrusted with boundary spanning activities. In this study, *Boundary spanning capability is defined as the extent to which the focal firm creates effective interfaces and connections with its supply chain partners.*

The advantages and need for boundary spanning capability has been discussed in various streams of literature. Innovation literature is of the view that boundary spanning capability is critical for organizational renewal (Lindgren et al 2008). The seminal paper by Cohen and Levinthal (1990) on absorptive capacity directly points to the importance of the ability to span organizational boundaries. They describe absorptive capacity as the ability to recognize the importance of information existing outside the firm, assimilate it within the organization and use it commercially. Work practice literature identifies boundary spanning as an integral element of learning (Lindgren et al 2008). MIS literature examines the issue of boundary spanning in terms of the applicability of information technology tools to span organizational boundaries (Levina and Vaast, 2005). Other streams of literature such as decision science (Choudhury & Sampler, 1997), human relations (Russ et al., 1998), logistics (Morash et al., 1997), psychology (Voydanoff, 2005) have examined boundary spanning.

Naturally, the benefits of boundary spanning activities and capability have been discussed in these streams of literature. Absorptive capacity, which is seen as a form of boundary spanning capability is said to have positive impacts on firms' innovative capability (Cohen and Levinthal, 1990), firm performance in a joint venture (Lane et al 2001), supply chain collaboration (Zacharia et al 2011), manufacturing flexibility (Patel et al 2012), time based manufacturing practices and value to customer (Tu et al 2006). Boundary spanning capability achieved through the use of boundary spanning information technologies impacts performance in terms of reduced ordering cost, reduced inventory and improved customer satisfaction (Yao et al., 2009).

Table 2.7: Boundary spanning capability – Definition and References

Construct	Construct definition	References
Boundary Spanning Capability	The extent to which the focal firm creates effective interfaces and connections with its supply chain partners.	Zhang et al 2011; Levina and Vaast, 2005; Lindgren et al., 2008; Cohen & Levinthal, 1990; von Hippel, 1988.

2.2.6 Supply Chain Relational Capital (SCRC):

Transactions within a supply chain are not merely dependent on the availability and existence of hard resources such as capital, labor, technology or intellectual capital. Supply chain transactions are also dependent on the extent to which there are social relationships among supply chain partners. According to the Social Capital Theory, social relationships and the resulting resource called social capital can be seen as a valuable resource or asset. According to Nahapiet and Ghoshal (1998), social capital is a multidimensional concept made up of structural capital, cognitive capital and relational capital. Structural capital refers to the capital resulting from structural configuration of the supply chain and also from boundary spanning activities of peripheral entities (Krause et al 2007). Cognitive capital refers to shared meanings and interpretations of supply chain members. Relational capital refers to the personal relationships and social ties that exist between multiple parties (Krause et al 2007; Cousins et al 2006). Relational capital is a function of trust and mutual respect between transacting partners (Nahapiet and Ghoshal, 1998). Relational capital is also function of time as it gradually builds over time. Socialization processes are generally responsible for increases in relational capital

(Cousins et al 2006). Relational capital stems from a strong sense of belonging and cooperation between partner firms (Capello and Faggian, 2005). Relational capital is also defined as the extent of trust, reciprocity and strength of ties among members of a team. Kale et al. (2000) refer to relational capital as trust, respect and friendship that is a result of close interactions between alliance partners. Cousins et al. (2006) define supply chain relational capital "as the configuration and social structure of the group through which resources are accessed". They determine the extent of supply chain relational capital by the degree of mutual trust, respect and close interactions between supply chain partners. In this study, *Supply chain relational capital is defined as the extent to which the focal firm has mutual trust, respect and social interactions with its supply chain partners*.

Relational capital has performance implications at many levels. In the supply chain, mutual trust and respect is seen as one of the ways to reduce transactions costs. Lack of trust between transacting partners will mean that more resources have to be allocated to monitor the actions of the partners. The fear of opportunism is also triggered by the lack of trust between supply chain partners. One of the main factors for the failure of supply chain partnerships is the lack of trust (Forrest and Martin, 1990). Trust is seen as an important ingredient of success in many of the high technology industries where supply chain collaboration is very evident (Sahay, 2003). Trust related benefits include the willingness to share information, reduced cost of transactions, reduced time for transactions, improved responsiveness and also increased innovativeness. Social interactions between members of a supply chain contribute to the growth of relational capital and goodwill between partners (Liker and Choi, 2004). Social interaction between supply chain members also improves extent of integration between supply chain partners

(Wu et al., 2004). In the area of knowledge management, social interaction is seen as a means to acquire and disseminate tacit knowledge between members (Lang, 2004).

Table 2.8: Supply chain relational capital – Definition and References

Construct	Construct definition	References
Supply Chain Relational Capital	The extent to which the focal firm has mutual trust, respect and social interactions with its supply chain partners	Cousins et al., 2006; Nahapiet and Ghoshal, 1998; Krause et al., 2007; Kale et al., 2000.

2.2.7 Collaborative Knowledge Management (CKM):

The resource based view of organizations proposes that resources that valuable, rare, inimitable and non-substitutable can be sources of competitive advantage. One such resource in the context of the supply chain is knowledge. In a supply chain, knowledge is constantly generated, transferred, assimilated and used due to the actions of various supply chain entities. However, in many cases this process is not carefully orchestrated or managed. On many occasions, the lack of effective management results in a collective loss to the entire supply chain. Organizations have now recognized the importance of managing knowledge as a key resource and thus have systems and processes in place to take care of this. When these systems and processes are collectively devised and managed, it is known as collaborative knowledge management.

Knowledge in a supply chain is not a stand-alone entity. Supply chain knowledge is referred to as "a reservoir of collective insights, understandings, beliefs, behavioral routines, procedures and policies drawn from hard data as well as on viewpoints, beliefs, values and intuitions, and owned by the supply chain regarding mutually interested issues such as markets, products, technologies and processes" (Li et al., 2012). Supply chain knowledge management is the ability to capture knowledge from various domains and store it in a way that makes it accessible for use, reuse and sharing (Smirnov and Chandra, 2000; Gunasekaran and Ngai, 2006). Supply chain knowledge management has its roots in organizational knowledge management research. Knowledge management was initially studied at the organizational level, where there have been various conceptualizations of the concept. King (2001) defined knowledge management in terms of acquisition, explication and communication of individual expertise in a way that is relevant to organizational members. Another view of knowledge management looks at it as a way to harness intellectual capital (Marshall, 1997). However, most researchers conceptualize knowledge management to be consisting of some or all of the following – creation, assimilation, dissemination, storage, use and leverage of organizational knowledge. The focus of knowledge management has over the years expanded to the domain of the supply chain. The role of supply chain participants has evolved from being mere suppliers or customers. Supply chain participants are now collaborative partners entrusted with more responsibilities. This has created the necessity to share knowledge with supply chain partners and thus manage it together. Collaborative knowledge management practice thus refers to processes that enable firms to generate, store, access, disseminate and apply supply chain knowledge across organizational boundaries to achieve supply chain objectives (Li et al., 2012).

Collaborative knowledge management starts with the collaborative creation of knowledge. The basis for the creation of knowledge in an organizational or inter-organizational context is through interaction (Dave and Koskela, 2009). Interaction between supply chain partners may be in the form of face-to-face meetings or information system enabled interaction. Information system enabled interaction may be achieved by the integration of information systems used by two or more organizations. Formation of strategic alliances is seen as an effective way to collaboratively create knowledge (Grant and Baden-Fuller, 2004). Strategic alliance formed for the purpose of new product development is seen as an exploratory form of knowledge generation (Rothaermel and Deeds, 2004). Collaborative knowledge creation in the long term can lead to economic rents and competitive advantage (Samaddar and Kadiyala, 2006).

Collaborative knowledge storage refers to the co-ownership of knowledge resources in a centralized location that is managed by all parties involved, thus leading to improved access (Nielsen, 2006). Knowledge from various sources can be pooled and stored thereby creating a knowledge warehouse or a centralized database. Collaborative knowledge storage involves three tasks – (a) collecting knowledge resources from various sources; (b) codifying the knowledge to make it comprehendible and (c) specifying ownership rights and instituting governance mechanisms (Li et al., 2012).

Providing access to the stored knowledge is an important aspect of collaborative knowledge management. Managing access to knowledge can be crucial when dealing with proprietary organizational or inter-organizational information. Provision or restriction of access ensures safety of information. However, stored knowledge becomes useful only when it is accessible to the right people at the right time (Davenport and Prusak, 1998).

Collaborative knowledge dissemination refers to the distribution of stored knowledge to all parties involved in a usable form. Dissemination of knowledge depends on knowledge sharing processes. Knowledge can be shared in several ways. Knowledge dissemination is largely dependent on whether the knowledge being shared is tacit or explicit in nature. Tacit knowledge is knowledge that is hard to codify. Explicit knowledge can be codified and transferred easily. Socialization and interaction processes are useful for the exchange of tacit knowledge.

Collaborative knowledge application refers to the act of knowledge utilization for purposes of decision making, problem solving and goal attainment (Li et al 2012). Collaborative knowledge application is a way for partners involved in strategic alliances to take advantage of complementary knowledge (Meier, 2011).

Effective knowledge management depends on the existence of well-established knowledge management routines. Routines have been described as the "capability for repeated performance that has been learned by an organization" (Feldman 2000, p. 612). Routines have also been described to be an important source of inertia for organizations (Ashforth and Fried 1988; Collinson and Wilson, 2006). In this study, we thus *define Collaborative knowledge management as the extent to which the focal firm collectively creates, stores and accesses knowledge with its supply chain partners*.

Table 2.9: Collaborative knowledge management – Definition and References

Construct	Construct definition	References
Collaborative Knowledge Management	The extent to which the focal firm collectively creates, stores and accesses knowledge with its supply chain partners	Li et al., 2012; Smirnov and Chandra, 2000; Gunasekaran and Ngai, 2006; Dave and Koskela, 2009; Samaddar and Kadiyala, 2006;

2.2.8 Supplier Development (SD):

Organizations rely extensively on external entities for supply of materials and services. Suppliers are thus considered to be an important resource and asset for an organization. An organizations' performance is greatly dependent on the performance of its core suppliers. Because of this reason, firms prefer to nurture and manage their suppliers. Apart from managing the activities of its suppliers, firms also engage in improving the capabilities and performance of its suppliers. Improving and managing supplier capabilities involves a set of activities and practices. This endeavor is commonly recognized as supplier development. Supplier development is seen as an effort on the part of the buyer to increase the performance and capabilities of the supplier in order to meet both long term and short term supply needs (Krause, 1997; Krause and Ellram, 1997; Humphreys et al 2004). Supplier development is a way by which buyers ensure that they have a competent set of suppliers. It is also a way to facilitate continuous improvement efforts at the end of the suppliers (Liao et al 2010). Supplier development is thus defined in this study as a set of practices employed by the buying firm to improve capabilities of suppliers within a firm's supply base (Krause, 1997; Krause and Ellram, 1997; Humphreys et al 2004).

Supplier development has performance implications for both the supplier as well as the buyer. The benefits of supplier development efforts are seen in terms of reduced cycle time, reduced defects, improved delivery performance and improved cost performance (Krause, 1997). Apart from improving supplier capabilities, supplier development programs are responsible for improved communication and trust between buyer and supplier (Humphreys et al 2004).

Supply chain researchers have identified various practices that are grouped under Supplier development. One of the earlier studies identified supplier development in terms of identifying and developing new sources of supply (Leenders, 1966). Hahn et al. (1989) discussed development of new supply sources as a part of Hyundai's supplier development effort. Evolution of supply chain practices and literature over the years has identified a set of common practices. Krause et al (2000) has identified the following four strategies for supplier development – Competitive pressure, Supplier evaluation and certification, Supplier incentives and direct involvement.

The use of multiple suppliers for the same product is employed to create competitive pressure among suppliers. The idea behind this strategy is to create a sense of competition among suppliers and push them to outperform each other (Dyer and Ouchi, 1993; Tezuka, 1997). Better performing suppliers are rewarded by allocating increased share of the business.

Periodic evaluation of supplier performance is a way to monitor supplier performance over time. Supplier evaluation is an important criterion for supplier selection and continuation. Evaluation of supplier performance helps identify areas of weakness among suppliers (Hahn et al. 1989). However, supplier evaluation alone is not sufficient. The existence of a communication mechanism is important to ensure feedback is provided to the suppliers (Krause and Ellram, 1997). Supplier certification can be seen as a formal recognition and communication mechanism. Certification is another way to identify suppliers that meet the requirements of the buyers. Certification of suppliers is also seen as a supplier motivational mechanism (Carr and Pearson, 1999; Krause et al., 2000). Supplier evaluation and certification are thus essential elements of strategic sourcing (Araz and Ozkarahan, 2007).

Instituting mechanisms for providing incentives to suppliers is also a part of supplier development. Incentives are generally given based on performance over a period of time. This is a mechanism to share the benefits of cost savings and increased profit with deserving suppliers (Monczka et al., 1993; Gunipero, 1990; Modi and Mabert, 2007). Supplier incentives are also given in the form of increased volume of business and extension of future contracts (Krause et al 2000).

Direct involvement is yet another way to achieve supplier development. Direct involvement refers an active role of the buying firm in the activities of the supplier. It involves a range of initiatives such as providing financial assistance, technical assistance, training, capital equipment and process improvement (Dyer and Ouchi, 1993; Monczka et al., 1993; Krause et al 2000; Modi and Mabert, 2007). Direct involvement is undertaken by many of the Japanese automotive manufacturers. For example, Honda is known to provide technical assistance to improve supplier quality and identify areas of improvement (MacDuffie and Helper, 1997). Toyota provides training and guidance to its suppliers in implementing the Toyota Production System (Dyer and Nobeoka, 2000).

Among the four practices identified above, the use of competitive pressure as a supplier development strategy is not always desirable (Modi and Mabert, 2007). This strategy signifies an arm's length relationship and is not advocated in long term supply chain relationships. Use of competitive pressure is acceptable when the transactions are one off market transactions. Fostering competition among suppliers by having many suppliers for the same product can have negative implications for supply risk, responsiveness and innovation (Choi and Krause, 2006). In the context of this study, use of competitive pressure is thus not considered as a supplier development activity. Based on the discussion above, *Supplier development is defined as the extent to which the focal firm employs practices to improve capabilities of its supply chain partners*. The set of practices include – Supplier evaluation, Supplier Incentives and Direct Involvement. Supplier evaluation is defined as the process of quantifying the efficiency and effectiveness of suppliers in the supply base (Neely et al 1995). Supplier incentives are defined as enablers of supplier performance improvement (Modi and Mabert, 2007). Direct involvement refers to a proactive role of the buyer in the activities of the supplier (Monczka et al., 1993; Krause et al., 2000).

Table 2.10: Supplier development – Definition and References

Construct	Construct definition	References
Supplier Development	The extent to which the focal firm employs practices to improve capabilities of its supply chain partners.	Krause, 1997; Krause and Ellram, 1997; Humphreys et al., 2004; Modi and Mabert, 2007; Krause et al., 2000; Hanh et al., 1989; Carr and Pearson, 1999.

2.2.9 Supply Chain Efficiency:

Efficiency and effectiveness are the two most commonly discussed performance metrics in management studies. Efficiency refers to "doing things right". In a general sense, efficiency focuses on deriving outputs by using minimal inputs. Supply chain literature has discussed extensively about efficiency and the design of efficient supply chains. The seminal paper by Fisher (1997) makes a clear distinction between efficient supply chains and responsive supply chains. According to Fisher (1997), the focus of efficient supply chains is to minimize cost and inventory build-up all along the supply chain. Lean literature is also heavily focused on efficiency. The lean philosophy is based on the principle of minimizing wastage. It addresses multiple aspects such as wastage of time, labor, raw materials and other key resources. Lean literature addresses the issue of cost reduction by targeting the various sources of waste (Shah and Ward, 2003). Cost based efficiency measures are a common feature of most supply chain performance measurement systems (Ex: Beamon, 1999; Cohen and Lee, 1988; Cohen and Lee, 1989; Cohen and Moon 1990; Lee and Feitzinger, 1995; Pyke and Cohen, 1993; Pyke and Cohen, 1994; Tzafestas and Kapsiotis, 1994).

The lean supply chain literature has addressed the issue of minimizing inventories throughout the supply chain. Supply chains try to overcome problems by having excess inventory. Excess inventory however does not solve problems, but temporarily hides them. The use of Just In Time (JIT) principles and JIT supply is one way to minimize inventory. The most efficient supply chains optimize inventory levels at multiple echelons of the supply chain. Inventory based measures provide a good indication of supply chain efficiency (Modi and Mabert, 2010). Another aspect of efficient supply chains is the ability to ensure prompt delivery of goods and services. Delivery reliability and reduction of lead time are two important determinants of supply chain efficiency (Yeung et al.,2008; Li andO'Brien,1999).

In this study, *Supply chain efficiency refers to the extent to which the supply chain optimizes cost, inventory and delivery performance*.

Table 2.11: Supply chain efficiency – Definition and References

Construct	Construct definition	References
Supply Chain Efficiency	The extent to which the supply chain optimizes cost, inventory and delivery performance	Fisher, 1997; Vonderembse et al., 2006; Shah and Ward, 2003; Beamon, 1999; Cohen and Lee, 1988; Modi and Mabert, 2010; Schroeder and Flynn, 2001.

2.2.10 Supply Chain Responsiveness:

The origin of the concept of responsiveness can be traced back to the times of "time based competition" (Stalk, 1988; Bower and Hout, 1988). Other trends and initiatives such as Quick Response Programs (QRP), Effective Customer Response (ECR) and Mass Customization are closely related to responsiveness (Holweg, 2005). The common factor in all these is the ability to change based on external factors. Supply chain responsiveness refers to the ability of the supply chain to respond quickly to changes in demand (Lee, 1997). The need for responsiveness is generated by product and market characteristics. For instance, innovative products are characterized by uncertain demand. The ability to match demand and supply thus assumes more importance for such products. Responsiveness is not merely a question of responding to changes in demand. It is a question of how fast a supply chain is able to respond to those changes (Swafford et al., 2006). The changes here may be in terms of volumes, variety, customization or new products (Christopher, 2000).

A review of literature reveals that responsiveness and flexibility are inter-related (Fisher 1997; Holweg 2005; Prater et al 2001; Christopher 2000; Gunasekaran and Yusuf, 2002). The main difference between the two is that while flexibility has an internal focus, responsiveness has an external focus. Flexibility is the ability to make changes to operating states and switch between tasks (Vokurka et al., 2002). These changes in operating states are recognized in terms of volume flexibility, mix flexibility, machine flexibility, routing flexibility, process flexibility and new product flexibility (Slack, 1983; Browne et al., 1984; Sethi and Sethi, 1990; Gerwin, 1993; Parker and Wirth, 1999). Responsiveness focuses on the ability to respond to marketplace changes. Thus, this study addresses two aspects of responsiveness – the ability to change based on customer requirement (or market changes) and the speed of response. Based on these thoughts, *supply chain responsiveness is defined as the extent to which the supply chain responds quickly to changes in demand and external environment*.

Table 2.12: Supply chain responsiveness – Definition and References

Construct	Construct definition	References
Supply Chain Responsiveness	The extent to which the supply chain responds quickly to changes in demand and external environment.	Lee, 1997; Swafford et al., 2006; Christopher, 2000; Prater et al 2001; Gunasekaran and Yusuf, 2002; Fisher 1997.

2.2.11 Firm Performance:

Firm performance or organizational performance is the most widely used outcome variable in operations management literature. It is essentially a measure of how well the firm is performing in relation to a set of metrics. A widely employed practice in academic literature is using operational indicators such as cost, quality, delivery reliability and flexibility as firm performance metrics (Li et al 2005; Li et al 2006; Koufteros 1995; Koufteros et al 1997; Krause et al 2007; Klassen and Whybark, 1999). Financial and market based indicators are also employed to assess firm performance (e.g. Holmberg, 2000; Tan et al 1999; Huselid et al 1997; Baker and Sinkula, 2005). Assessment of firm performance in terms of its ability to create competitive advantage is widely accepted (e.g. Li et al 2006). Successful organizations achieve competitive advantage by creating a defensible position over competitors (Li et al 2006). Thus, the achievement of competitive goals is a good indicator of a firm's performance. In this study, firm performance is thus defined as *the extent to which the firm meets its competitive goals*.

Competitive goals are described in terms of the ability of the firm to provide value to the customer (Tu et al 2001) and value to the firm itself to ensure growth and financial sustainability (Tracey and Tan, 2001).

Table 2.13: Firm performance – Definition and References

Construct	Construct definition	References
Firm Performance	The extent to which the firm meets its competitive goals.	Yamin et al., 1999; Li et al., 2005; Li et al., 2006; Koufteros, 1995; Koufteros et al., 1997; Krause et al., 2007; Baker and Sinkula, 2005.

The next chapter describes hypothesized relationships and arguments based on logical reasoning, literature and practice.

Chapter 3

Hypotheses Development

This chapter identifies the relationships between the constructs identified in Chapter 2 and provides the logic for the proposed relationships.

3.1 Research hypotheses:

In this study, the proposed hypotheses indicate (1) a direct relationship between product complexity/supply base complexity and supply chain performance; (2) indirect relationship between product complexity/supply base complexity and supply chain performance mediated by Operational and Strategic Coordination; and (3) effect of mitigating variables on Operational and Strategic Coordination. Table 3.1 outlines the proposed relationships. Figure 3-1 shows the detailed research model with the hypotheses identified.

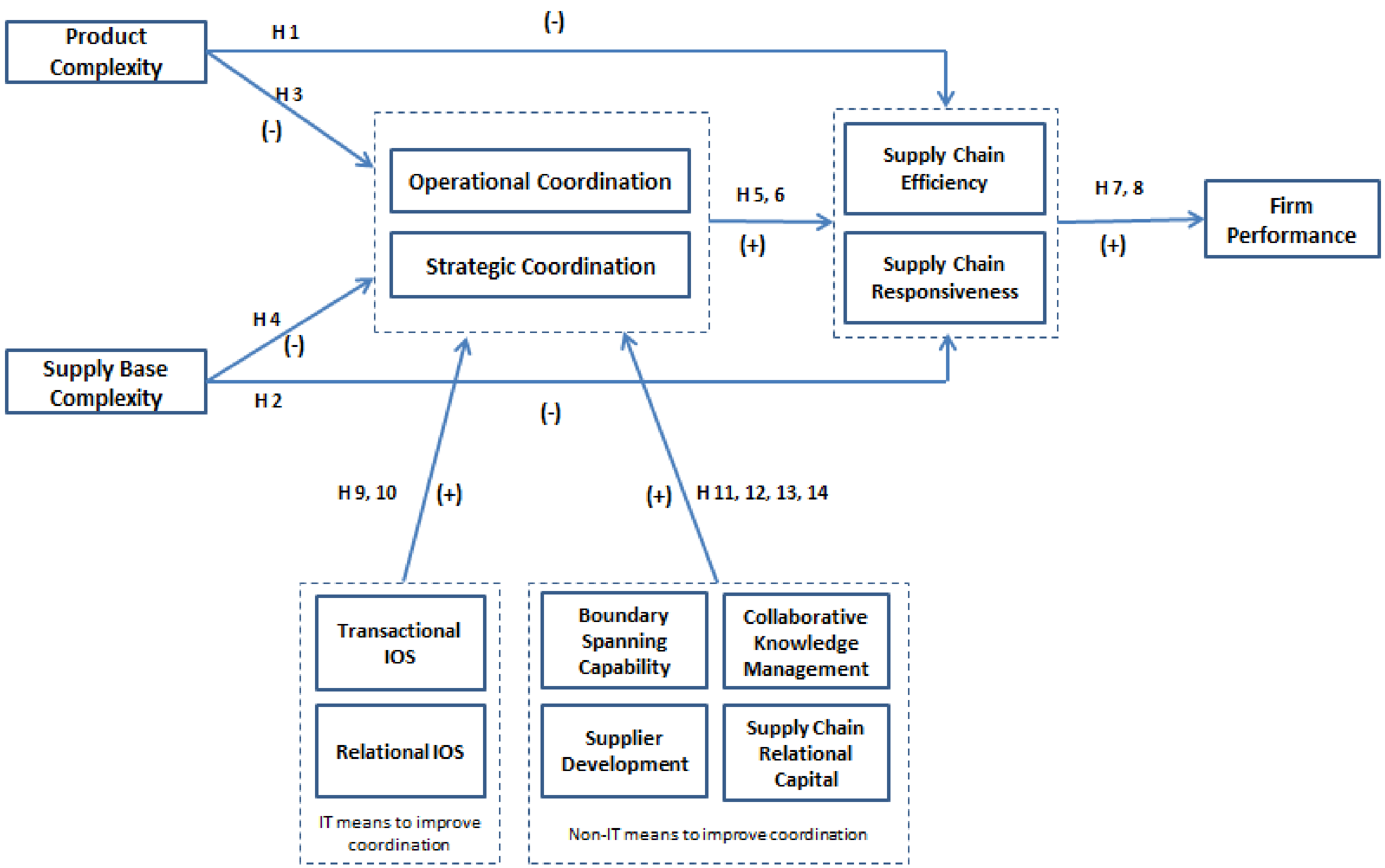

Figure 3-1: Research model

Table 3.1: Hypothesized Relationships

H 1a	Product complexity has a negative relationship with Supply chain efficiency
H 1b	Product complexity has a negative relationship with Supply chain responsiveness
H 2a	Supply base complexity has a negative relationship with Supply chain efficiency
H 2b	Supply base complexity has a negative relationship with Supply chain responsiveness
H 3a	Product complexity has a negative relationship with Operational Coordination
H 3b	Product complexity has a negative relationship with Strategic Coordination
H 4a	Supply base complexity has a negative relationship with Operational Coordination
H 4b	Supply base complexity has a negative relationship with Strategic Coordination
H 5a	Operational Coordination has a positive relationship with Supply chain efficiency
H 5b	Operational Coordination has a positive relationship with Supply chain responsiveness
H 6a	Strategic Coordination has a positive relationship with Supply chain efficiency
H 6b	Strategic Coordination has a positive relationship with Supply chain responsiveness
H7	Supply chain efficiency has a positive relationship with firm performance
H 8	Supply chain responsiveness has a positive relationship with firm performance
H 9a	Transactional IOS has a positive relationship with Operational Coordination
H 9b	Transactional IOS has a positive relationship with Strategic Coordination
H 10a	Relational IOS has a positive relationship with Operational Coordination
H 10b	Relational IOS has a positive relationship with Strategic Coordination
H 11a	Boundary spanning capability has a positive relationship with Operational Coordination
H 11b	Boundary spanning capability has a positive relationship with Strategic

	Coordination
H 12a	Collaborative Knowledge management has a positive relationship with Operational Coordination
H 12b	Collaborative Knowledge management has a positive relationship with Strategic Coordination
H 13a	Supply Chain Relational Capital has a positive relationship with Operational Coordination
H 13b	Supply Chain Relational Capital has a positive relationship with Strategic Coordination
H 14a	Supplier Development has a positive relationship with Operational Coordination
H 14b	Supplier Development has a positive relationship with Strategic Coordination

3.1.1 Research hypotheses 1a and 1b (Impact of Product Complexity on Supply Chain Performance):

Researchers have discussed the impact of complexity on various aspects of performance. Operations management literature has explored the effects of manufacturing complexity at the plant level. For instance, Flynn and Flynn (1999) propose a negative relationship between manufacturing environment complexity and plant performance. Bozarth et al (2009) propose a negative relationship between internal manufacturing complexity and plant level performance. At the supply chain level there have been conceptual studies that indicate a negative effect between complexity and supply chain performance. Christopher (2000) identifies complexity to be one of the barriers to achieving a truly agile supply chain. Prater et al (2001) discuss the negative effect of complexity and uncertainty on supply chain agility. However, very few empirical studies have addressed relationship between complexity and supply chain performance. This section describes the proposed relationship between product complexity and two dimensions of supply chain performance, namely efficiency and responsiveness.

According to a Bain survey of over 900 global executives, close to 70% of the respondents agree that complexity is affecting the cost and profit of their organizations (Gottfredson and Aspinall, 2005). The implications of product complexity are not just limited to the focal firm, but affect the operations of the entire supply chain. An increase in product complexity will have adverse effects on the cost efficiency of the supply chain. The basic reason for this being the increase in transaction costs that accompanies increasing complexity. Novak and Eppinger (2001) propose a relationship between product complexity and the tendency to adopt vertical integration. They identify product complexity in terms of number of components, component interactions and product novelty. These dimensions of product complexity are said to drive the choice between make or buy. Transaction costs tend to be higher when a complex product is sourced externally. They also suggest that sourcing from external entities is optimal when product complexity is at the lower end. Product complexity has been shown to increase inventory holding costs (Johnson and Anderson, 2000; Alfaro and Corbett, 2003). Procurement costs increase as number of components increases (Meyer and Mugge, 2001). Firms generally employ the use of component commonality to reduce complexity and achieve lower costs through improved economies of scale (Meyer and Mugge, 2001; Closs et al., 2010). Product complexity tends to increase inventory throughout the supply chain. The variability and component variation associated with complex products tends to be high (Closs et al., 2010). In order to cope with this variability, firms in the supply chain tend to hold more inventories. Complex products tend to have longer lead times as manufacturing and sourcing operations are more tedious and time consuming. Longer lead times are again associated with increased variability. Firms are forced to carry more inventories to meet expected demand and changes in demand during lead time. Previous studies have shown that an increase in product complexity increase inventory levels and decreases service levels, delivery reliability, unit fill rate and order fill rate (Lee and Tang, 1997; Alfaro and Corbett, 2003; Closs et al 2010). Supply chain cost efficiency thus tends to be lower when product complexity is high.

Hypothesis 1a: *Product complexity has a negative relationship with supply chain efficiency.*

Apart from being efficient, the best supply chains are said to be those that are responsive to changes. A responsive supply chain is one that is able to cater to changing demand, market, competitor, environment and technology changes in a timely manner. However, product complexity makes it difficult for supply chains to achieve responsiveness. Inherent complexity of a product makes it enough of a challenge to achieve responsiveness internally. In such a case, achieving responsiveness throughout the supply chain can be an arduous task.

Christopher (2000) identifies increasing complexity to be one of the impediments to achieving agility in the system. Firms operating in complex environments find it increasingly difficult to react to changes in demand (Prater et al., 2001). All aspects of product complexity contribute to the difficulty in achieving customer responsiveness (Sharifi et al., 2006). Manufacturing literature addresses the issue of reducing product complexity in order to achieve mass customization (Blecker and Abdelkafi, 2006). The main strategies employed to achieve mass customization are the use of modular product design and component commonality. Both these strategies essentially reduce product complexity. Modular product designs are employed to achieve higher levels of product decomposability and reduced interactions. Component commonality reduces the number of different components being used and reduced part count can contribute to improved customer responsiveness (Lang and Hugge, 1995). These two strategies reduce complexity of internal operations and sourcing operations. Responding to changes from the external environment is easier when product complexity is reduced by employing these strategies. Responsiveness also depends on the extent to which a firm and its supply chain are able to make changes to product designs based on external requirements. These external changes may arise from customers, competitors or other environmental sources. In such a situation, the ability to reduce lead time and product development cycle time can be very useful. Product complexity however contributes to an increase in product development cycle time thereby reducing the extent to which the supply chain can be responsive (Griffin, 1997). Technological novelty and product novelty have a similar effect on product development cycle time (Griffin, 1997) and thus leading to slower response to changes.

Hypothesis 1b: *Product complexity has a negative relationship with supply chain responsiveness.*

3.1.2 Research hypotheses 2a and 2b (Impact of Supply Base Complexity on Supply Chain Performance):

The supply base of a firm refers to a portion of the firm's supply network that is actively managed by it. The supply base is a sub-set of the supply network. In this study, Supply base complexity is seen as a function of the number of suppliers, differentiation among suppliers and inter-relationships between suppliers in the supply base (Choi and Krause, 2006). Complexity of the supply base is determined to a large extent by the supply management policies of the focal firm. Supply base complexity is inevitable under certain circumstances. However, supply base complexity has performance implications in the supply chain.

An increase in the number of suppliers in the supply base contributes to an increase in overall transaction costs (Choi and Krause, 2006). The costs incurred as part of transaction costs include search cost, bargaining cost and monitoring cost. Search cost and bargaining cost are incurred mainly at the initial stages of a transactional relationship. Monitoring cost is incurred throughout the duration of the relationship, but decreases over time. In any case, costs incurred in managing a larger supply base are always high. Due to this reason, most firms employ supply base reduction or rationalization as a cost reduction strategy (e.g. Ballew and Schnorbus, 1994; Bamford, 1994; Handfield and Nichols, 1999; Trent and Monczka, 1998; Raia, 1992). Multiple suppliers for the same product can also drive inventory levels in the supply chain. Having multiple sources of supply reduces the ability to pool risk and demand variability. As a result, higher levels of buffer inventory or safety stock are carried in the supply chain.

Increased differentiation among suppliers in the supply base can drive up costs. This is because the focal company will have to dedicate time, effort and other tangible resources to extract the required output from less qualified suppliers. Supplier differentiation created by global sourcing strategies contributes to increased inventory because of longer lead times. Variability increases with increase in lead time, thus forcing supply chain participants to carry more inventories. Global sourcing can have an adverse effect on delivery reliability.

Supplier inter-relationships refer to working relationships among suppliers in the supply base. These relationships are sometimes orchestrated by the focal firm to ensure stricter control over quality and availability. However, inter-relationships among suppliers can sometimes lead to collusion (Brandenburger and Nalebuff, 1996; Choi et al., 2002; Hill, 1990), which may work against the interests of the focal firm. Increased cost and lower reliability are some of the implications of supplier collusion.

Hypothesis 2a: Supply base *complexity has a negative relationship with supply chain efficiency.*

There is a tendency to presume that having multiple sources of supply can lead to a higher responsiveness to changes. However, practice and literature suggests otherwise. Responsive supply chains or firms that desire responsiveness are known to work closely with limited suppliers by reducing their supply base (Liker and Choi, 2004). Reducing the supply base to improve responsiveness is a widely followed practice in the automotive industry. Single sourcing strategies are employed in many industries where responsiveness in critical (Treleven and Schweikhart, 1988). Differentiation among suppliers in the supply base works against achieving responsiveness. Differentiation in terms of geographic dispersion makes it difficult to achieve changes in response to customer, environmental or other external demands. This is precisely the reason why many US firms have started relying on suppliers close to home. For instance, Lee (2004) illustrates the examples of Flextronics (manufacturer of Xbox) and Gap. Both these companies moved manufacturing operations closer to the home market in order to achieve speed, flexibility and responsiveness. Differentiation among suppliers in terms of operational culture and practices also works against responsiveness. Cultural alignment is a key determinant of partnership success (Brensen and Marshall, 2000). Similarities in organizational culture helps supply chain partners in building healthy working relationships. Similarly, alignment of processes and operational practices ensures smooth flow of supply chain processes (Sanders, 2005). Choi et al (2002) describe inter-relationships between suppliers in terms of competitive, cooperative and co-opetitive. They propose that excess competition or cooperation can both be detrimental from the buyer's perspective in the long term. A move to create a sense of competition may backfire as suppliers may perceive it to be selfish behavior. Cooperation may lead to instances where suppliers collude to derive benefits at the expense of the buyer. On the whole, intensity of supplier inter-relationships affects the responsiveness of the entire supply chain.

Hypothesis 2b: Supply base *complexity has a negative relationship with supply chain responsiveness.*

3.1.3 Research hypotheses 3a and 3b (Impact of Product Complexity on Coordination):

According to the information processing view, complexity and uncertainty is accompanied by an increased information processing load (Galbraith, 1973). Inherent complexity of tasks and situations increases the amount of information that has to be processed to complete a given task or achieve the required objective (Grover and Saeed, 2007). The inability to respond to the increased information processing load requirements affects performance negatively. When activities are internalized in a firm, information processing occurs within the firm boundaries. However, in the context of a supply chain, activities and processes cross firm boundaries. Interdependencies are created between supply chain partners. The ability to effectively manage these interdependencies is referred to as coordination. In this study, coordination is examined at the operational level and strategic level. An increase in complexity is proposed to have a negative impact on the extent to which firms in the supply chain are able to effectively manage operational and strategic interdependencies.

The multiple aspects of product complexity identified in this study are proposed to have an impact on the three components of coordination, namely information sharing, decision synchronization and collective learning. Information sharing refers to the extent to which common understanding can be disseminated among supply chain partners. Under conditions of complexity, disseminating common understanding can be a challenge (Koufteros et al 2002; Koufteros et al 2005). As product complexity increases, supply chain entities will be required to exchange and process a higher volume and wide variety of product related information (Grover and Saeed, 2007). At the operational level, this includes exchange of product design specifications, purchase orders, order status, inventory levels, and demand forecasts. At the strategic level, this includes disseminating strategic plans, goals and objectives to all supply chain partners. Strategic objectives generally address product strategies, market strategies and supply chain strategies over the long run. Increase in number of components increases complexity of sourcing operations. For instance, consider a product comprising of 5 components and all components are being sources from external suppliers. Let us assume that the focal firm uses a dual sourcing policy. Information sharing has to be achieved with 10 supply chain entities. Compare this with a product comprising of 50 components. Assuming the same dual sourcing policy, information processing and sharing now has to be achieved with 100 supply chain entities. Information sharing becomes challenging when there is close interaction between individual components. When systems or components are closely coupled, a change in one part of the system will invariably necessitate changes in the other parts of the system too (Novak and Eppinger, 2001). In such a situation, difficulty involved in information processing will go up. Product non-decomposability will have a similar effect on information sharing as decomposability and component interactions are closely related. Products that rely on novel product technology or process technology make information processing a challenge because all aspects of the technology may not be well understood. For products relying on new technology, long term strategic objectives might be fuzzy thus making it more difficult to bring all supply chain partners on the same page.

Decision synchronization is the second component of coordination that is affected by increasing product complexity. In this study, decision synchronization refers to the extent to which participating actors become involved in joint decision making such as resolving conflicting objectives, mitigating uncertainty, redesigning workflow, and allocating resources. An increase in the number of product components essentially means more variables have to be considered in the decision making process. Keeping in mind all these decision variables, joint decision making can be tough to accomplish. Inability to handle the information processing requirements of joint decision making often results in firms making independent decisions that optimize firm objectives and not supply chain objectives. Independent decisions made at the firm level act against the objective of managing operational and strategic interdependencies between supply chain partners. Close interaction between product components increases the need to process information between supply chain partners. Inability to match information processing 'capability' to the information processing 'need' results in unresolved conflicts, goal uncertainty and overall loss of coordination. Technological novelty greatly contributes to task and goal uncertainty (Tatikonda and Rosenthal, 2000). Uncertainty brings with it new problems, unanswered questions and situations previously not encountered. Such situations again create information processing difficulties and thus affect decision synchronization.

The third component of coordination that is affected by product complexity is collective learning. Collective learning refers to the acquisition and diffusion of knowledge across the supply chain. Complexity of any nature makes the process of learning more tedious. The various aspects of product complexity make the acquisition and diffusion of knowledge increasingly difficult. As the information processing requirements of complex products are high, supply chain partners are required to exchange vast amounts of varied information to make sense of requirements. For instance, the learning process in the context of a new advanced technology is more intense, involved and time consuming. As a result knowledge acquisition and diffusion involves more effort and calls for an effective knowledge management system. Thus:

Hypothesis 3a: Product *complexity has a negative relationship with operational coordination.*

Hypothesis 3b: Product *complexity has a negative relationship with strategic coordination.*

3.1.4 Research hypotheses 4a and 4b (Impact of Supply Base Complexity on Coordination):

Supply base complexity is described in this study as a function of the number of suppliers, differentiation among suppliers and inter-relationships between suppliers in the supply base. Information processing requirements increase as multiplicity, differentiation and inter-relationships increase in the supply base. A large supply base essentially means information has to be transmitted to and from an array of entities within the supply chain. Supply chain requirements and subsequent changes in requirements have to be exchanged with all relevant supply chain entities. For instance, a supply base with a large number of suppliers will find it increasingly difficult to achieve common understanding and align their decisions. Coordination of operational decisions as well as strategic decisions is adversely affected when there is a multiplicity of suppliers (Paulraj, 2008). This is one of the reasons for supply base reduction policies. In a study by De Toni (1999), supply base reduction policies are shown to have a positive impact on information exchanges between supply chain partners regarding products and processes.

Information sharing and decision alignment can be hard to achieve when suppliers in the supply base are highly differentiated. Differentiation in terms of operational practices often means different standards and protocols are used for information storage, transmission and processing (Choi and Krause, 2006). The lack of standardized rules and processes is said to affect the extent to which coordination is achieved (Thompson, 1967). Integration of supply chain processes is a way to improve coordination. However, process integration is a challenge when suppliers are operating on a myriad of information processing standards (Ng et al., 2001). The importance of a common information standard for improved coordination is highlighted by the emphasis of Covisint and RosettaNet standards in the auto industry and electronics industry respectively. Learning efficiencies are lower when suppliers in the supply base have different operational capabilities. The focal firm will have to dedicate more time and resources to achieve collective learning with less capable suppliers. Based on these arguments:

Hypothesis 4a: *Supply base complexity has a negative relationship with operational coordination.*

Hypothesis 4b: *Supply base complexity has a negative relationship with strategic coordination.*

3.1.5 Research hypotheses 5a, 5b, 6a and 6b (Impact of Coordination on Supply Chain Performance):

Coordination between supply chain partners is a key determinant of supply chain performance (Xu and Beamon, 2006). Sanders (2008) proposes that operational coordination and strategic coordination determine performance outcomes in a buyer-supplier relationship. Both forms of coordination are proposed to have operational as well as strategic benefits. In this study, operational coordination and strategic coordination are proposed to have supply chain performance implications in terms of supply chain efficiency and supply chain responsiveness.

Information sharing and dissemination of common understanding is essential in achieving supply chain efficiency and responsiveness. The importance of information visibility, availability, transparency and sharing has been discussed extensively in supply chain literature (e.g.: Li et al 2005; Li and Lin 2006; Lee et al 2000; Lee et al 1997; Lin et al 2002; Cachon and Fisher, 2000). Information sharing can be for purposes of ensuring demand visibility, inventory visibility and overall understanding of key requirements. Operational information sharing such as point-of-sale information ensures efficiency and responsiveness at each stage of the supply chain. When supply chain entities do not have access to operational information, there is a mismatch between demand and supply (Lee et al 1997). This leads to reduced supply chain efficiencies because of either stock-outs or over-stocks. Non-availability of operational information reduces the ability of the supply chain to respond to changing customer and market changes (Li et al 2006). Sharing of strategic information such as product trends, designs and market outlook has efficiency and responsiveness implications as well. Li et al (2006) show that strategic information sharing reduces inventory cost and increases fill rate. Ramaya and Omar (2010) show that sharing strategic information improves supply chain responsiveness.

Decision synchronization by means of joint decision making increases efficiency of the supply chain by reducing inventories throughout the supply chain (Min et al 2005). Synchronization of strategic decisions such as facility location, carrier selection and flow management contribute to improving supply chain efficiency (Bagchi et al 2005). Joint decision making in terms of developing collaborative plans, forecasts and replenishment strategies improves both efficiency and responsiveness in the supply chain (Barratt, 2004).

Collective learning with supply chain partners creates supply chain efficiencies. Engaging in learning activities with supply chain partners creates efficiencies by saving significant amount of time and money (Wright, 2000; Humphreys et al., 2003; Song et al., 2009). In the context of product development, this shortens the time to market thereby making the supply chain more responsive. Gaining better understanding of customer requirements is another benefit of collective learning (Eriksson, 2010). Thus:

Hypothesis 5a: *Operational Coordination has a positive relationship with Supply chain efficiency.*

Hypothesis 5b: *Operational Coordination has a positive relationship with Supply chain responsiveness.*

Hypothesis 6a: *Strategic Coordination has a positive relationship with Supply chain efficiency.*

Hypothesis 6b: *Strategic Coordination has a positive relationship with Supply chain responsiveness.*

3.1.6 Research hypotheses 7 and 8 (Impact of Supply Chain Performance on Firm Performance):

The increasing reliance of firms on external suppliers implies that firm performance is greatly dependent on the performance of its supply chain. Close integration of supply chain partners and collaboration between supply chain partners has also contributed to the relationship between supply chain performance and firm performance. Previous studies have indicated a positive relationship between supply chain performance and firm performance (e.g. Peterson et al 2005; Li et al 2006; Hendricks and Singhal, 2005). The two aspects of supply chain performance identified in this study, namely supply chain efficiency and responsiveness contribute greatly to the extent to which firm objectives are achieved. Supply chain cost efficiency determines the extent to which a firm is able to keep its costs down. For instance, if suppliers are unable to operate efficiently the implications are seen at the buyers' end in the form of increased cost and higher inventories. Lack of responsiveness at the suppliers' end will reduce the ability of the focal firm to respond to changing customer and market demands. Firms dealing with non-responsive suppliers will have to hedge for uncertainty by employing buffer inventory and capacity. Suppliers' ability to respond to changes may eventually affect service levels at the buyer firm and result in lost sales and reduced customer base. Loss of market share is another negative implication for the firm. The extent to which supply chain performance is a key determinant of firm performance is highlighted by the supply chain management practices of Walmart and Dell. Walmart's financial success depends greatly on its ability to have an efficient supply chain and keep costs down throughout the supply chain. Dell can manage to have a customer lead time of 3 to 6 days by having responsive suppliers who are located close to Dell's manufacturing plants. The Just-In-Time delivery system used by Dell's suppliers enables Dell to keep its inventory cost to a minimum. Thus:

Hypothesis 7: *Supply chain efficiency has a positive relationship with firm performance.*

Hypothesis 8: *Supply chain responsiveness has a positive relationship with firm performance.*

3.1.7 Research hypotheses 9a, 9b, 10a and 10b (Impact of IOS on Coordination):

According to the information processing view, there are two ways to deal with the information processing implications of complexity and uncertainty. The first method is to reduce the need to process information. The second alternative is to increase the capability to process information. Internalizing activities and creation of slack resources are suggested as ways to reduce information processing need. In a supply chain, internalizing activities may not be a feasible alternative because of cost and managerial implications. Creation of slack resources works against the principles of lean and is not considered to be a very efficient alternative. Galbraith (1973) suggests two ways to increase the capability to process information – investment in vertical information systems and creation of lateral relations.

In this study, we propose the use of inter-organizational systems as a means to increase the information processing capability of the supply chain entities. The use of IOS creates information linkages between supply chain partners. These information linkages enable information flows between supply chain partners and ensure visibility throughout the supply chain (Subramani, 2004; Sanders 2008; Chong et al 2009). The use of information systems in the supply chain enables supply chain members to coordinate their decisions and align their actions and objectives more effectively. Joint decision making is more feasible with the use of inter-organizational systems (Petersen, 1999; Gunasekaran and Ngai, 2004). The use of information systems in inter-organizational contexts is also said to facilitate collective learning (Scott, 2000). In this study, the two proposed appropriations of IOS (transactional and relational) are said to have positive impacts on both operational coordination and strategic coordination. The most appropriate example for transactional IOS is the use of EDI in supply chains. EDI is used to automate information flows between supply chain members and improve transactional efficiencies (Sanders, 2008). The other important outcome of EDI is improved coordination between supply chain members (Vickery et al 2003). It is widely accepted that EDI improves operational coordination between supply chain entities (Sanders, 2008; Subramani, 2004). However, there are also strategic benefits from the use of transactional IOS such as EDI (Dearing, 1990; Mukhopadhyay and kekre, 2002; Philip and Pedersen, 1997). Sanders (2008) proposes strategic coordination benefits such as the strategic planning, planning for new products and the ability to collaborate with supply chain partners in future. However, transactional IOS is expected to have a stronger impact on operational coordination than on strategic coordination because of its inherent nature (Sanders, 2008; Subramani, 2004).

In this study, relational IOS use is proposed to enable the creational of relational ties between supply chain members. The use of collaborative systems is a manifestation of IOS use for relational purposes. Relational IOS moves beyond arm's length transactional relationships between partners. Collaborative systems such as Collaborative Planning Forecasting and Replenishment (CPFR) systems enable information coordination at both operational and strategic levels (Sari, 2008). Sherman (1998) recognizes CPFR as a strategic initiative. Cederlund et al (2008) illustrate the experience of Motorola with CPFR. Some of the benefits of CPFR outlined in the article include improved decision synchronization, the ability to collaborate with supply chain members and the opportunity to gain strategic insights. Decision support systems (DSS) also fall under relational IOS. Pinson et al (1997) describe the use of decision support systems as enablers of strategic planning, conflict resolution and coordination. Choi et al (2002) describe the use of an Intelligent Supplier Relationship Management System by Honeywell in order to coordinate activities of suppliers in its supply base. They identify Strategic learning with suppliers to be one of the advantages of the Intelligent Supplier Relationship Management System. Collaborative systems such as groupware and workflow systems are seen as enablers of supply chain coordination (Soroor and Tarokh, 2006; Wang and Archer, 2004). Thus:

Hypothesis 9a: *Transactional IOS has a positive relationship with Operational Coordination.*

Hypothesis 9b: *Transactional IOS has a positive relationship with Strategic Coordination.*

Hypothesis 10a: *Relational IOS has a positive relationship with Operational Coordination.*

Hypothesis 10b: *Relational IOS has a positive relationship with Strategic Coordination.*

3.1.8 Research hypotheses 11a and 11b (Impact of Boundary Spanning Capability on Coordination):

In an organization, boundary spanners are individuals who are responsible for developing contact and relationships with external entities. They are generally located at the periphery of the organization and act as points of contact for external agents (Lindgren et al 2008). In a supply chain, purchasing agents are generally recognized as boundary spanning individuals. The responsibilities of boundary spanners include developing communication channels and trust with external organizations (Kiessling et al., 2004; Zhang et al 2011). Boundary spanners occupy a place of importance as they are seen as the face of the organization (Adams, 1976). In such a situation, the capability of an organization to effectively span organizational boundaries becomes extremely critical. Boundary spanning capability is closely related to information processing capability (Dollinger, 1984). Boundary spanning capability increases the ability to process information. Aldrich and Herker (1977) recognize information processing to be the main function of boundary spanning roles. Tushman and Scanlan (1981) emphasize the information processing role of boundary spanners by proposing that boundary spanners communicate and translate information across organizational boundaries. Since the capability to process information has an impact on the ability to manage interdependencies (Galbraith, 1974), boundary spanning capability is expected to improve operational and strategic coordination. This thought is reflected in many streams of literature. For instance, Gittell and Weiss (2004) recognize the existence of cross-functional boundary spanners or liaisons as a coordinating mechanism. These boundary spanners are said to enable coordination by integrating work across boundaries. Product development literature recognizes project managers as boundary spanning coordinators (Allen, 1984; Clark and Wheelwright, 1992). Boundary spanning roles are said to be responsible for interfaces and information exchanges in inter-organizational relationships (Schermerhorn, 1977). Lindgren et al (2008) suggests that boundary spanning is essential for learning as it is seen as a "sense-making activity". Boundary spanning activities are said to enable task coordination and synchronize work efforts (Marrone, 2010). Marrone (2010) also proposes that organizational learning is an outcome of network boundary spanning actions. Another advantage of boundary spanning is its ability to foster joint problem solving which is critical for avoiding conflicts (Pitta and Franzak, 1997). Thus:

Hypothesis 11a: *Boundary spanning capability has a positive relationship with Operational Coordination.*

Hypothesis 11b: *Boundary spanning capability has a positive relationship with Strategic Coordination.*

3.1.9 Research hypotheses 12a and 12b (Impact of Collaborative Knowledge Management on Coordination):

In this study, Collaborative knowledge management refers to the routines in place to collectively create, store and access knowledge in the supply chain. (Li et al 2012). The routines and processes used for collaborative knowledge management greatly improve information flow within and between organizations (Hult et al 2004). Thus, this study looks at collaborative knowledge management as a way to increase information processing capability and thereby achieve improved coordination.

Knowledge management routines are used to resolve coordination issues internally across departments and project teams and externally with suppliers, customers and various other partners (Dustdar, 2005). According to Holland (1995), inter-organizational knowledge management systems contribute to improvements in organizational coordination. Handfield and Nichols (1999) propose the use of collaborative knowledge management practices to coordinate activities within the supply chain. Coordination is made possible partly because of the dissemination of useful information through existing knowledge management routines. Collaborative knowledge dissemination enables coordination by creating shared interpretations of knowledge (Hult et al 2004). Collaborative knowledge management systems enable supply chain participants to make joint operational and strategic decisions (Li, 2007). Availability of information made possible by knowledge management systems reduces equivocality and creates common understanding among supply chain partners (Hahn and Wang, 2009). Centralized storage of information creates easier access to information thereby improving learning efficiencies in the supply chain. Thus:

Hypothesis 12a: *Collaborative knowledge management has a positive relationship with Operational Coordination.*

Hypothesis 12b: *Collaborative knowledge management routines have a positive relationship with Strategic Coordination.*

3.1.10 Research hypotheses 13a and 13b (Impact of Supply Chain Relational Capital on Coordination):

Supply chain relational capital is defined as "the configuration and social structure of the group through which resources are accessed" (Cousins et al 2006). Relational capital is generally described in literature on the basis of trust, social interaction and mutual respect between partner firms (Kale et al 2000; Cousins et al 2006). Relational capital assumes importance in the context of alliances between two firms. Theory on relational capital suggests that the risk of opportunistic behavior can be controlled by developing relational capital (Kale et al 2000). In this study, relational capital is proposed to enhance information processing capability of the supply chain and thus enable better coordination. Trust and social interaction increase information processing capability of supply chain partners by developing communication channels (Butler, 1999; Gupta and Govindarajan, 2000; Lee and Whang, 2000). Relational capital has positive impacts on the three components of coordination identified in this study. Relational capital in the form of trust and socialization fosters information sharing, learning and decision synchronization. Trust is said to have has a positive impact on coordination (Blatt, 2009). Ballou et al (2000) recognize trust as an informal mechanism to create cooperation and coordination in a supply chain. Hoyt and Huq (2000) propose the strategy of coordination by trust and information sharing in buyer-supplier relationships. Trust reduces concerns of appropriation among transacting entities (Tsai, 2002). Once supply chain partners get over the barrier of perceived opportunism, information sharing can be achieved more effectively. The success of strategic alliances thus depends heavily on trust (Narasimhan and Nair, 2003; Kale et al 2000). Collective learning is also more effective when partners have a sense of trust, transparency and openness (Hamel, 1991; Doz and Hamel, 1998; Kale et al 2000). Joint decision making in the face of complexity requires the key ingredient of trust (Edelenbos and Klijn, 2007).

Socialization is another way to develop social capital. Gupta and Govindarajan (2000) describe socialization as an interaction mechanism to develop personal familiarity, improved communication, and problem solving. Wooldridge and Minsky (2002) propose socialization as a way to improve inter-functional coordination. Social ties and social interactions promote sharing of information and knowledge between interacting partners (Chiu et al 2006). Formal and informal socialization mechanisms are enablers of joint training and joint value creation (Zajac and Olsen, 1993; Cousins et al 2006). Thus:

Hypothesis 13a: *Supply chain relational capital has a positive relationship with Operational Coordination.*

Hypothesis 13b: *Supply chain relational capital has a positive relationship with Strategic Coordination.*

3.1.11 Research hypotheses 14a and 14b (Impact of Supplier Development on Coordination):

Supplier development is achieved by implementation of strategies such as supplier evaluation, supplier incentives and supplier involvement (Neely et al 1995; Modi and Mabert, 2007 Carr and Peterson, 2002; Vonderembse and Tracey, 1999). Supplier development activities are directed towards improving capabilities of suppliers in the supply base (Modi and Mabert, 2007). Information processing capability is one such capability that is enhanced as a result of supplier development activities. The enhanced ability of suppliers to process information ensures better coordination in the supply chain.

Supplier development programs create closer relationships between buyers and suppliers. These relationships move beyond transactional relationships to more cooperative relationships. Eventually suppliers realize that it is better to cooperate than indulge in opportunistic behavior. The motivational outcomes of supplier development result in improved coordination between buyer and supplier (Monczka and Morgan, 1993; Carr and Peterson, 1999). Whang (1993) shows that the provision of supplier incentives increases the suppliers' readiness to share operational and strategic information with the buyer. Petersen et al (2005) consider supplier involvement to aid in decision coordination of product designs, processes and supply chain design. Early supplier involvement during the development of new products provides an opportunity for joint decision making and collaborative setting of goals and targets. Thus:

Hypothesis 14a: *Supplier development has a positive relationship with Operational Coordination.*

Hypothesis 14b: *Supplier development has a positive relationship with Strategic Coordination.*

The next chapter discusses the development of measurement instruments and the steps involved.

Chapter 4

Instrument Development – Item Generation and Pilot Test

This chapter addresses development of measurement instruments for the various constructs identified in the research model. The methodology and steps involved are identified and explained.

The instruments to measure (1) supply chain efficiency, (2) supply chain responsiveness, (3) firm performance; were adopted from previous studies. These instruments have been widely accepted and used in the field of operations and supply chain management. Thus, they were not part of the pilot test.

The instruments to measure the following constructs were developed / modified and tested to ensure suitability to the context of this study:

(1) Product complexity (2) Supply base complexity (3) Operational Coordination (4) Strategic Coordination (5) Transactional IOS (6) Relational IOS (7) Boundary Spanning Capability (8) Collaborative Knowledge Management (9) Supply Chain Relational Capital (10) Supplier Development.

Instrument development involves three main tasks – (1) Item generation (2) Pilot testing (3) Large scale data analysis and instrument validation.

4.1 Item Generation:

Item generation is the first step in developing measurement instruments. It starts with a comprehensive review of related literature to identify the theoretical domain of the construct in question. An initial set of measurement items that address the various aspects of the theoretical concept are identified from literature. The main literature backing for the instruments developed in this study are identified in the table below.

Table 4.1: Constructs, Definitions and References

Construct	Definition	References
Product complexity	A function of (a) number of components (b) interaction between components (c) product decomposability (d) technological intricacy (e) technological novelty	Novak and Eppinger, 2001; Vachon and Klassen, 2002; Cooper et al., 1992; Fisher et al., 1999; Krishnan and Gupta, 2001; Ramdas and Sawhney, 2001; Bozarth et al., 2009; Khurana, 1999; Singh, 1997.
Supply base complexity	A function of (a) number of suppliers (b) differentiation among suppliers (c) interrelationships between suppliers	Choi and Krause, 2006; Bozarth et al., 2009; Handfield and Nichols, 1999; Ogden, 2006; Koufteros et al., 2007; Choi and Hartley, 1996; Choi and Hong, 2002; Choi et al., 2002; Wu and Choi, 2005.
Operational Coordination	Extent to which the focal firm manages interdependent processes for day-to-day activities with its supply chain partners.	Malone and Crowston, 1994; Thompson, 1967; Ballou et al., 2000; Simatupang et al., 2002; Simatupang et al., 2004; Cao, 2007; Sanders, 2008; Lee et al., 2000; Keeble and Wilkinson, 1999; Gambarotto and Solari, 2004; Cotic-Svetina et al., 2008.

Strategic Coordination	Extent to which the focal firm manages interdependent processes for long-term planning with its supply chain partners.	Malone and Crowston, 1994; Thompson, 1967; Ballou et al., 2000; Simatupang et al., 2002; Simatupang et al., 2004; Cao, 2007; Sanders, 2008; Lee et al., 2000; Keeble and Wilkinson, 1999; Gambarotto and Solari, 2004; Cotic-Svetina et al., 2008.
Transactional IOS	The extent to which the focal firm uses IOS for the exchange of structured information with its supply chain partners.	Subramani, 2004; Sanders, 2008; Cao, 2007; Riggins and Mukhopadhyay, 1994; Mukhopadhyay and Kekre 2002.
Relational IOS	The extent to which the focal firm uses IOS to enable long term relationships with its supply chain partners.	Subramani, 2004; Sanders, 2008; Cao, 2007; Gordon et al., 2008; Shen et al., 2008; Shafiei et al., 2012.
Boundary Spanning Capability	The extent to which the focal firm creates effective interfaces and connections with its supply chain partners.	Zhang et al., 2011; Levina and Vaast, 2005; Lindgren et al., 2008; Cohen and Levinthal, 1990; von Hippel, 1988.
Collaborative Knowledge Management	The extent to which the focal firm collectively creates, stores and accesses knowledge with its supply chain partners	Li et al., 2012; Smirnov and Chandra, 2000; Gunasekaran and Ngai, 2006; Dave and Koskela, 2009; Samaddar and Kadiyala, 2006;
Supply Chain Relational Capital	The extent to which the focal firm has mutual trust, respect and social interactions with its supply chain partners	Cousins et al., 2006; Nahapiet and Ghoshal, 1998; Krause et al., 2007; Kale et al., 2000.
Supplier Development	The extent to which the focal firm employs practices to improve capabilities of its supply chain partners.	Krause, 1997; Krause and Ellram, 1997; Humphreys et al., 2004; Modi and Mabert, 2007; Krause et al., 2000; Hanh et al., 1989; Carr and Pearson, 1999.

These items then have to be validated for content and reliability. The first validation required is content validity. This is the extent to which the domain of a concept is captured by the measure (Churchill, 1979). Content validity can be established by referring to literature and also consulting subject matter experts (academicians and practitioners). In this study, supply chain researchers and industry practitioners were consulted to establish validity of the initial list of items. Based on their feedback, items were either modified or changed to improve overall clarity. In total, 117 items and 15 constructs were created. The constructs and number of items in each construct are outlined below.

Product Complexity - 7 items

Supply Base Complexity - 11 items

Operational Coordination - 20 items

Strategic Coordination - 16 items

Transactional IOS - 6 items

Relational IOS - 6 items

Boundary Spanning Capability - 7 items

Collaborative Knowledge Management - 6 items

Supply Chain Relational Capital - 4 items

Supplier Development - 7 items

Supply Chain Efficiency – 4 items

Supply Chain Responsiveness - 5 items

Firm Performance - 9 items

Environmental Uncertainty - 4 items

Environmental Dynamism - 5 items

4.2 Scale Development:

4.2.1 Pilot Testing – Q Sort Methodology:

In this study, the measurement instruments were pilot tested using Q Sort methodology, which is widely employed in social sciences research (Moore & Benbasat, 1991). The basic objective of this method is to ensure agreement between (a) views of the researcher and that of an expert; and (b) views of a pair of experts; regarding measurement items.

For the first round of the Q sort, two judges were chosen. These two judges were expert practitioners in the supply chain area and were chosen based on the fact that they understood the research topic and had considerable experience about the matter. Interactions of the researcher with the judges are on a one-on-one basis and in this case they were scheduled on two separate days. The interaction with the judges is outlined below:

1. Researcher explains the research topic and in particular, the research model and the constructs in question.
2. Construct definitions are explained and then a set of note cards containing construct name and construct definitions are laid on the table in front of the judge.
3. Researcher has another set of note cards and each note card has one measurement item printed on it.
4. The judge is asked to place each item under the construct that they think is appropriate.

5. Along the way, the judge is allowed to ask questions or make comments about item wording and placements.

6. Steps 1 through 5 are repeated with the second judge as well.

After the first round of interaction with two judges, the item placements are evaluated on the basis of level of agreement. The two criteria used for this are (1) Moore and Benbasat's hit ratio (Moore and Benbasat, 1991), and (2) Cohen's Kappa coefficient agreement (Cohen, 1960). Hit ratio is a measure of the proportion of items that were sorted or placed by the judge according to the researchers' grouping of theoretical constructs. A high percentage indicates agreement between theoretical categories and actual categories. Cohen's Kappa coefficient is a measure of inter-rater agreement. It shows the level of agreement between raters after taking into account agreements merely by chance.

4.2.1.1 Q Sort – Round 1:

In this Q sort, 90 items and 14 constructs were included. A "Not Applicable" category was also included to ensure that judges are not forced to fit an item into a construct. Since some of the measurement instruments were adopted from previous studies, those constructs (and items) were excluded from the Q sort procedure. The two judges selected for this round were senior level managers (supply chain) employed in manufacturing organizations.

Table 4.2: Items Placement Ratio – First Round Sorting

		ACTUTAL CATEGORIES															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL	%
THEORETICAL CATEGORIES	1	14														14	100.0%
	2		22													22	100.0%
	3			14												14	100.0%
	4				12											12	100.0%
	5					14										14	100.0%
	6			1			13									14	92.9%
	7							8								8	100.0%
	8								10							10	100.0%
	9									11	1					12	91.7%
	10										12					12	100.0%
	11											14				14	100.0%
	12									1	1		8		2	12	66.7%
	13											1		7		8	87.5%
	14											1			13	14	92.9%

1 - Product complexity
2 - Supply base complexity
3 - Information sharing - Operational
4 - Decision Synchronization - Operational
5 - Collective Learning - Operational
6 - Information sharing - Strategic
7 - Decision Synchronization - Strategic
8 - Collective Learning - Strategic
9 - Transactional IOS
10 - Relational IOS
11 - Boundary Spanning Capability
12 - Collaborative Knowledge Management
13 - Supply Chain Relational Capital
14 - Supplier Development

Table 4.3: Inter-judge Raw Agreement Scores – First Round Sorting

		JUDGE 2													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
JUDGE 1	1	7													
	2		11												
	3			7											
	4				6										
	5					7									
	6						6								
	7							4							
	8								5						
	9									5					
	10										6				
	11											7			
	12												2		
	13													3	
	14														6

After the first round of sorting:

Table 4.4: Hit Ratio – Q-Sort Round 1

Total item placement = 180
Number of hits = 172
Overall hit ratio = 95.56%

Based on Inter-judge raw agreement scores,

Table 4.5: Agreement Ratio – Q-Sort Round 1

Total item placement = 90
Number of correct agreements = 82
Correct agreement ratio = 91.11 %

In order to estimate the level of agreement between judges while eliminating agreements merely by chance, Cohen's Kappa is used (Cohen, 1960). The table shown below is created to calculate Cohen's Kappa. The table shows the number of occasions on which the judges mutually agreed or disagreed.

Table 4.6: Cohen's Kappa Calculation – Q-Sort Round 1

		Judge 1		
		Accept	Reject	Total
Judge 2	Accept	82	1	83
	Reject	7	0	7
	Total	89	1	90

Using this table, Cohen's Kappa is calculated as

K = (90*82)-(89+83)/(90^2)-
(89+83)
K = 0.9092

A look at the numbers for the hit ratio, agreement ratio and Cohen's kappa suggest high level of agreement between judges and these numbers are well beyond the acceptable threshold. However, based on the interaction with the judges, there was still scope for improvement. In order to eliminate the confusion with some items, the wording of a few items was slightly modified. For example, collaborative knowledge management construct had a hit ratio of 66.7%, which called for improvement. After modification, the items were entered into a second round of sorting with a new pair of judges.

4.2.1.2 Q-Sort – Round 2:

As in the first round, 90 items (14 constructs) were entered into the second round of Q-Sort. The judges again were supply chain professionals from the manufacturing industry with considerable knowledge and experience.

Table 4.7: Items Placement Ratio – Second Round Sorting

		ACTUTAL CATEGORIES															
THEORETICAL CATEGORIES		1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL	%
	1	14														14	100.0%
	2		22													22	100.0%
	3			12			2									14	85.7%
	4				12											12	100.0%
	5					14										14	100.0%
	6						14									14	100.0%
	7							8								8	100.0%
	8								10							10	100.0%
	9									12						12	100.0%
	10										12					12	100.0%
	11											14				14	100.0%
	12												12			12	100.0%
	13													8		8	100.0%
	14														14	14	100.0%

Table 4.8: Inter-judge Raw Agreement Scores – Second Round Sorting

		JUDGE 2													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
JUDGE 1	1	7													
	2		11												
	3			6											
	4				6										
	5					7									
	6						7								
	7							4							
	8								5						
	9									6					
	10										6				
	11											7			
	12												6		
	13													4	
	14														7

After the second round of sorting:

Table 4.9: Hit Ratio – Q-Sort Round 2

Total item placement = 180
Number of hits = 178
Overall hit ratio = 98.89 %

Based on Inter-judge raw agreement scores,

Table 4.10: Agreement Ratio – Q-Sort Round 2

Total item placement = 90
Number of correct agreements = 89
Correct agreement ratio = 98.89 %

Cohen's Kappa was computed based on the table below:

Table 4.11: Cohen's Kappa Calculation – Q-Sort Round 2

		Judge 1		
		Accept	Reject	Total
Judge 2	Accept	88	1	89
	Reject	1	0	1
	Total	89	1	90

K = (90*88)-(89+89)/(90^2)-(89+89)

K = 0.9773

The modifications made after the first round of sorting provide the intended results. Hit ratio, agreement ratio and Cohen's Kappa show improvement. However, there was a sense that some items could be combined into a single item and some items could be eliminated, without compromising the content of the items. For example, in the product complexity scale, two items – "Our product is based on technology that is new to the firm" and "Our product is based on technology that is new to the industry" were changed to – "Our product is based on new technology". One item each was eliminated from SBC, ODS, OCL and SIS. Thus, the number of items went down from 90 to 85. The number of items in each construct is listed below.

1 - Product complexity - 6*
2 - Supply base complexity - 10*
3 - Information sharing – Operational - 7
4 - Decision Synchronization – Operational - 5*
5 - Collective Learning - Operational - 6*
6 - Information sharing - Strategic - 6*
7 - Decision Synchronization - Strategic - 4
8 - Collective Learning - Strategic - 5
9 - Transactional IOS - 6
10 - Relational IOS - 6
11 - Boundary Spanning Capability - 7

12 - Collaborative Knowledge Management - 6
13 - Supply Chain Relational Capital - 4
14 - Supplier Development - 7

Q-Sort is stopped after two rounds as the hit ratio, agreement ratio and Cohen's Kappa exhibit very good numbers. The next chapter talks about large scale data collection and further testing and validation of the measurement instruments.

Chapter 5

Data Collection – Large Scale Survey and Instrument Validation

5.1 Large Scale Data Collection:

This chapter follows up on the previous chapter by reporting on data collection and validating the measurement instrument. In order to do that, the first step involves the administration of the survey instrument to prospective respondents and large scale collection of data. Choosing the right respondents is extremely critical for the success of survey based research. In this research, the nature of the subject calls for respondents to be employed in manufacturing / supply chain roles in medium and large scale manufacturing enterprises. In particular, the following job titles were deemed to be suitable for this survey – purchasing manager, supply chain manager, purchasing director, VP of manufacturing, VP of Purchasing, VP of supply chain, VP of operations, CEO and President. Organizational members with these titles are considered to be well aware of processes that span organizational boundaries. Their position in upper management ensures that potential respondents have a good understanding of internal as well as external processes. Additionally, since the study relates to product manufacturing and supply chain processes, potential respondents were identified based on their employment in manufacturing firms.

A mailing list of prospective respondents was obtained from Lexis Nexis Academic Database. The list was initially created on the basis of NAICS codes. The table below identifies the NAICS codes that were included for consideration. NAICS codes 31 to 33 include firms that are involved in manufacturing operations. Since complexity of the product being manufactured is one of the main points of focus in this study, these NAICS codes were considered to be appropriate.

Table 5.1: NAICS Codes

31-33	**Manufacturing**
311	Food Manufacturing
312	Beverage and Tobacco Product Manufacturing
313	Textile Mills
314	Textile Product Mills
315	Apparel Manufacturing
316	Leather and Allied Product Manufacturing
321	Wood Product Manufacturing
322	Paper Manufacturing
323	Printing and Related Support Activities
324	Petroleum and Coal Products Manufacturing
325	Chemical Manufacturing
326	Plastics and Rubber Products Manufacturing
327	Nonmetallic Mineral Product Manufacturing

331	Primary Metal Manufacturing
332	Fabricated Metal Product Manufacturing
333	Machinery Manufacturing
334	Computer and Electronic Product Manufacturing
335	Electrical Equipment, Appliance, and Component Manufacturing
336	Transportation Equipment Manufacturing
337	Furniture and Related Product Manufacturing
339	Miscellaneous Manufacturing

The initial mailing list was then filtered on the basis of firm size (number of employees), firm revenue and job titles. Since the study addresses various aspects of complexity, coordination and information technology use, medium and large scale manufacturing enterprises with at least 100 employees and revenue of at least $10 million were considered suitable. Smaller firms are generally limited by the scale of their operations and availability of resources (mainly information technology) and thus may not be ideal for this study. For instance, small firms are less likely to use Inter-organizational systems (IOS) in their interactions with supply chain partners. The filtered mailing list thus had 5000 names and e-mail addresses. An e-mail invitation to participate in the survey was sent out to these 5000 e-mail addresses. 3023 of these sent e-mails bounced back either because the address in the database was wrong or because the individual was no longer part of the organization. The invitation included an introduction of the researcher and the research topic. Prospective respondents were asked to respond about their willingness to participate in the survey. After the participants indicated their willingness to be part of the survey, a web link with the survey and relevant instructions was sent to them. After the first wave of invites, 322 people sent their consent to participate. Out of that 280 completed the survey. After 2 weeks, a second request and invite was sent to the people who had not responded to the initial request. After this request, 76 responded with their consent and the survey link was sent to them. 56 out of 76 completed the survey. In total, 336 responses were received. 65 of those surveys were incomplete and thus had to be excluded. The final count of complete and usable surveys was 270. The response rate based on the number of survey links sent out is 270 / (322 + 76) = 67.84%, which represents a very high response rate. Considering the number of invites sent out, the response rate is 270 / (5000-3023) = 13.66%, which is still a healthy response rate.

In order to ensure that there is no significant difference between respondents and non-respondents, a test for non-response bias was performed. As part of this exercise, a chi-square test was conducted between two groups – 1. First wave of respondents – these are the people who responded to the first request/invite; and 2. Second wave of respondents - these are the people who responded after the second request/invite was sent. A non-response bias analysis was conducted to check for significant differences between the two groups based on firm size (number of employees) and annual sales. The tables below show that there are no significant differences the two groups based on chi-square. Thus, non-response bias is not a concern in this study.

Table 5.2: Test for Non-Response Bias – Firm Size

Variable - No. Of Employees	Round 1 (214)		Round 2 (52)		Chi Square Test
	Observed	Expected	Observed	Expected	
1 to 50	3 (1.4%)	2.4 (1.1%)	0 (0%)	0.6 (1.1%)	Chi-Square = 1.880 df = 5 P-value = 0.866
51 to 100	7 (3.3%)	6.4 (3%)	1 (1.9%)	1.6 (3%)	
101 to 250	25 (11.7%)	25.7 (12%)	7 (13.5%)	6.3 (12.1%)	
251 to 500	32 (14.9%)	33.8 (15.8%)	10 (19.2%)	8.2 (15.8%)	
501 to 1000	25 (11.7%)	25.7 (12%)	7 (13.5%)	6.3 (12.1%)	
> 1000	122 (57%)	119.9 (56%)	27 (51.9%)	29.1 (55.9%)	

Table 5.3: Test for Non-Response Bias – Annual Sales

Variable - Annual Sales in Millions	Round 1 (213)		Round 2 (52)		Chi Square Test
	Observed	Expected	Observed	Expected	
< 5	1 (0.5%)	0.8 (0.4%)	0 (0%)	0.2 (0.4%)	Chi-Square = 1.111 df = 5 P-value = 0.953
5 to < 10	2 (0.9%)	2.4 (1.1%)	1 (1.9%)	0.6 (1.1%)	
10 to < 25	4 (1.8%)	4 (1.9%)	1 (1.9%)	1 (1.9%)	
25 to < 50	17 (7.9%)	16.1 (7.5%)	3 (5.8%)	3.9 (7.5%)	
50 to < 100	27 (12.7%)	28.1 (13.2%)	8 (15.4%)	6.9 (13.3%)	
> 100	162 (76.1%)	161.6 (75.9%)	39 (75%)	39.4 (75.8%)	

5.2 Sample Demographics:

This section outlines the demographics of the sample based on multiple criteria.

5.2.1 Respondents by job title:

The survey was targeted mainly at people in managerial roles in the purchasing, supply chain, manufacturing and operations departments; managers in these functions are deemed to have an overarching understanding of the operations of the company. Accordingly, the chart shows that a majority of respondents were in the roles of director (43.8%) and vice-president (34.9%). Managers accounted for 15.4%, while the rest comprised of CEO/President (2.4%) and Others (3.4%). See figure A-1 in Appendix A.

5.2.2 Respondents by job function:

The nature of the study called for people with good understanding of internal processes as well as boundary spanning processes. Purchasing is one such boundary spanning activity. 32.2% of the respondents identified themselves under purchasing roles. As expected, manufacturing (23.6%) accounted for a large chunk of the sample. Corporate executives accounted for 20.5% of the respondents. The rest of the sample were identified as distribution (4.8%), sales (3.1%) others (15.8%). See figure A-2 in Appendix A.

5.2.3 Respondents by number of years at the organization:

In terms of number of years served in their current organization, 41.4% of the respondents served between 3 to 10 years. The next highest was 23.3% for people who served more than 20 years in the organization. 15.4% of the respondents served between 10 to 15 years; 10.6% served less than 3 years; and 9.2% served between 15 to 20 years. See figure A-3 in Appendix A.

5.2.4 Firm size by number of employees:

A majority of the companies (54.3%) had more than 1000 employees. The next highest was 16.2% for firms with 251 to 500 employees. This was followed by 12.4% for firms with 501 to 1000 employees. The rest of the sample was accounted as follows – 101 to

250 employees (12%); 51 to 100 employees (3.4%); and 1 to 50 employees (1.7%). As expected, a majority of the respondent firms can be classified as large or medium scale companies. See figure A-4 in Appendix A.

5.2.5 Firms by annual sales (in millions of $):

In terms of annual sales, 75.2% of the firms had more than $100 million in annual sales. 12.8% of the sample had between $50 to $100 million in annual sales. 7.6% of the firms had between $25 to $50 million in annual sales. The rest of the respondent firms (4.5%) had annual sales of less than $25 million. See figure A-5 in Appendix A.

5.2.6 Firms by age:

A majority of the firms (52.4%) were in operation for more than 50 years. 20.9% of the firms were in business between 30 to 50 years; 15.1% of the firms were in business between 20 to 30 years; 7.9% of the firms were in business between 10 to 20 years. The rest of the firms (3.7%) were in operation for less than 10 years. See figure A-6 in Appendix A.

5.2.7 Firms by position in the supply chain:

The nature of this study calls for participation from firms mainly involved in manufacturing and to a smaller extent, distribution. The question here allowed the respondents to select multiple options based on their varied roles in the supply chain. For example, a manufacturing firm may also be involved in wholesale and distribution activities. Accordingly, 82.9% of the firms identified themselves as manufacturers.

23.6% of the respondents identified themselves as being involved in distribution. 5.8% of the firms were involved in retail. See figure A-7 in Appendix A.

5.3 Large Scale Instrument Validation:

The results of any empirical study can be considered meaningful if the measurement instruments are valid and reliable. According to Bagozzi (1980) and Bagozzi and Phillips (1982), validity and reliablity are key factors here. The validity of a measurement instrument determines whether it is actually measuring what it is intended to measure (Hair et al 2006). Reliability of a measurement instrument indicates consistency. In the case of latent constructs, reliability indicates the extent to which indicators are interrelated and shows that all indicators are measuring the same thing (Nunnally, 1978; Cronbach, 1990).

Validity of a measurement instrument can be assessed in terms of content validity, convergent validity and discriminant validity (Bagozzi, 1980; Bagozzi and Phillips, 1982). Content validity is generally assessed by a comprehensive review of literature (Nunnaly, 1978) to ensure cogency of the subject matter. Q-sort is another way to assess content validity. These two checks for content validity are discussed in the previous chapter.

One of the first steps in instrument validation is item purification. Corrected Item Total Correlation (CITC) scores are used to purify scale items. According to Nunnally and Bernstein (1994), 0.3 is an acceptable threshold for Corrected Item Total Correlation (CITC). Items with CITC below 0.3 are generally removed from the analysis. However, in some cases these items may be retained if there is strong theoretical support for the inclusion of these items. Reliability of the instrument is also checked at this stage by examining Cronbach's Alpha values. Cronbach's alpha ranges from 0 to 1. A score of 0.7 is said to be acceptable (Nunnaly, 1978), however lower thresholds are sometimes deemed to be acceptable under certain situations. Deletion of items with low CITC scores can improve the overall reliability of the scale.

Convergent validity is the extent to which indicators of a construct share variance in common (Hair et al 2006; Campbell, 1960). This is an indication that two measures of the same concept are correlated and also that the scale is measuring the intended concept (Hair et al 2006). Discriminant validity indicates that one construct is distinct from another construct and also that it captures or measures a phenomenon that other measures do not (Hair et al 2006; Campbell, 1960). Factor analysis is used to evaluate these two aspects of validity.

Exploratory factor Analysis (EFA) is used as an initial assessment of convergent validity of the measurement scales (Raubenheimer, 2004). The basic idea here is to group highly intercorrelated variables into distinct factors. High factor loadings on the intended scale indicate convergence. Generally factor loadings of 0.5 and higher are considered acceptable. However, as sample size increases, factor loadings less than 0.5 are also considered acceptable. For instance, Hair et al (2006) indicate that factor loadings of 0.35 are significant for sample sizes of 250 and up. Cross loading of items onto more than one factor is not desirable. This is an indication that the item may have to be dropped from the analysis.

Confirmatory Factor Analysis (CFA) provides a confirmatory test of the measurement theory and enables the researcher to confirm or reject the proposed theory (Hair et al., 2006). CFA output provides model fit indices to evaluate the validity of the measurement model. Goodness of Fit (GFI), Adjusted Goodness of Fit (AGFI) and Root Mean square Redisual (RMR) values are used to evaluate model fit. The acceptable threshold for the indices are – GFI > 0.85; AGFI > 0.8 and RMR < 0.1 (Hair et. al., 2006; Hadjistavropoulos et. al., 1999; MacCallum et. al., 1996).

CFA is used to further assess convergent and discriminant validity. Discriminant validity can be assessed in CFA by evaluating the correlation coefficients of constructs Hair et al (2006). This technique involves pair-wise comparison of the correlation coefficients to the square root of the average variance extracted (AVE). Square root of AVE estimate that is greater than the correlation coefficient indicates discriminant validity (Fornell and Larcker, 1981; Koufteros, 1999; Koufteros et al., 2001).

Another method to assess discriminant validity using CFA is the Chi-square difference test (Bagozzi and Yi, 1988). This method involves examining the difference in chi-square values between a correlated and uncorrelated model with the two constructs. A significant difference in chi-square values indicates adequate discriminant validity (Hair et al., 2006).

EFA, CFA and tests for convergent and discriminant validity are discussed in the next section.

5.4 Large Scale Instrument Validation Results:

The following 15 constructs were part of the large scale instrument validation – Product complexity, Supply base complexity, Operational Coordination, Strategic Coordination, Transactional IOS, Relational IOS, Boundary spanning capability, Collaborative knowledge management, Supply chain relational capital, Supplier development, Supply chain efficiency, Supply chain responsiveness, Firm performance, Environmental dynamism and Environmental uncertainty. The following section describes item purification and validation of the above mentioned constructs.

5.4.1 Product complexity:

In the administered survey instrument, Product complexity scale consisted of 5 items. As part of the item purification, these 5 items were subjected to reliability analysis using SPSS. Corrected Item Total Correlation (CITC) scores and Cronbach's alpha are analyzed to determine the reliability of the scale. The objective here is to determine the suitability of individual items to be part of the measure. The general approach is to delete items which have low CITC values and determine whether deleting these items would improve the overall reliability (Cronbach's alpha) of the scale.

Table 5.4: Product Complexity – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
PC_1	Our product is composed of a large number of components	.430	.64
PC_2	Our product is composed of components that are closely interrelated such that a change in one component results in a change in another component	.387	
PC_3	Our product cannot be easily decomposed into separate modules	.151	
PC_4	Our product is based on technology that is complex	.580	
PC_5	Our product is based on new technology	.445	

The CITC score for item PC_3 was well below the threshold of 0.3 and thus this item was dropped from the analysis. Dropping this item improved the Cronbach's alpha value to 0.7. The CITC scores of all 4 items at this point are well above the threshold and deleting any of these items does not improve alpha value any further.

Table 5.5: Product Complexity – Reliability Analysis

Item Code	CITC	Alpha
PC_1	.445	**.7**
PC_2	.400	
PC_4	.600	
PC_5	.487	

In the next step, factor analysis was conducted to establish convergent and discriminant validity. The four remaining items from the product complexity scale were entered into exploratory factor analysis. As part of this analysis, varimax method of rotation was chosen. This is one of the most popular methods of rotation as it simplifies the interpretation of the solution (Abdi, 2003). All four remaining items of the product complexity scale emerged into a single factor. The factor loadings were well above 0.5, which is generally the acceptable limit. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was acceptable. KMO is a test to determine whether the partial correlations among variables are small. KMO scores range between 0 and 1. Higher scores are desirable. 0.5 is considered to be an acceptable threshold for KMO (Kline, 1994; Hair, et al., 1998, George & Mallery 2001; Tabachnick & Fidell 2007).

Table 5.6: Product Complexity - Construct level exploratory factor analysis

	Component 1
PC_4	.833
PC_5	.758
PC_1	.673
PC_2	.625
Eigen value = 2.11 % of variance = 52.8 KMO = 0.56 Cronbach's Alpha = 0.7	

The 4 items from EFA were entered into a Confirmatory Factor Analysis (CFA) using SEM statistical package Analysis of Moment Structures (AMOS). The output of AMOS provides modification indices which suggested the need to correlate the error terms for items PC_1 and PC_2. Once this was done, the output indicated acceptable model fit with GFI of 0.984, AGFI of 0.835 and RMR of 0.05. Discriminant validity was determined using pair-wise correlation analysis. Table B-1 in appendix B shows the presence of acceptable discriminant validity.

5.4.2 Supply Base Complexity:

The administered survey had 8 items as part of Supply base complexity scale. Reliability analysis for these items shows that CITC score for some items is below the threshold. For instance, items SBC_1, SBC_2, SBC_4, SBC_7 and SBC_8 have CITC below 0.3. Items are deleted one by one starting with the one with the lowest CITC score. As items are deleted, changes to CITC scores are noted.

Table 5.7: Product Complexity – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
SBC_1	We have a large number of suppliers in our supply base	.287	.54
SBC_2	We have multiple suppliers for most components	.109	
SBC_3	Suppliers in our supply base differ in their technical capabilities	.371	
SBC_4	Suppliers in our supply base differ in their operational practices	.254	
SBC_5	Suppliers in our supply base differ in their firm culture	.336	
SBC_6	Suppliers in our supply base are geographically dispersed	.348	
SBC_7	Suppliers in our supply base supply to one another	.209	
SBC_8	Suppliers in our supply base compete with each other	.242	

Item SBC_2 is the first item to be deleted. As a result, CITC scores of items change slightly. More importantly, CITC of SBC_4 crosses the threshold of 0.3. SBC_8 is the next one to be deleted, followed by SBC_7 and then SBC_1. As this is done, CITC of SBC_6 drops below the threshold and thus has to be deleted. Finally, three items with CITC scores well above the threshold are left as shown in the table below. Cronbach's alpha for these items is 0.71, which is acceptable.

Table 5.8: Supply Base Complexity – Reliability Analysis

Item Code	CITC	Alpha
SBC_3	.502	**.71**
SBC_4	.571	
SBC_5	.502	

Factor analysis of these three items results in one single factor with good factor loadings. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is acceptable at 0.66. The table below shows results of the factor analysis.

Table 5.9: Supply Base Complexity - Construct level exploratory factor analysis

	Component 1
SBC_4	.828
SBC_5	.777
SBC_3	.775
Eigen value = 1.89 % of variance = 63.02 KMO = 0.66 Cronbach's Alpha = 0.71	

The 3 items from EFA were entered into Confirmatory Factor Analysis (CFA). However, with just 3 items the model in AMOS becomes saturated and thus using goodness of fit to test the model is not possible. One way to work around this is by validating a 3 item construct with another construct that has already been validated. In this case, a correlated model with product complexity and supply base complexity can be tested for model fit. Thus, a correlated a model of the 3 items SBC construct and 4 items PC construct were tested using CFA. The resulting output of AMOS indicated acceptable model fit with GFI of 0.977, AGFI of 0.945 and RMR of 0.05. The regression weights for the SBC three items were above the threshold of 0.6. Pair-wise correlation analysis in Table B-1 of appendix B shows the presence of acceptable discriminant validity.

5.4.3 Operational Coordination:

Operational Coordination is proposed to be a multi-dimensional construct consisting of three dimensions - Operational Information Sharing (OIS), Operational Decision Synchronization (ODS) and Operational Collective Learning (OCL). OIS was represented by 7 items, ODS by 5 items and OCL by 6 items. Reliability analysis was done on each of the three dimensions and the purified items were then together entered into factor analysis to establish convergent and discriminant validity. Reliability analysis results are discussed below.

5.4.3.1 Operational Information Sharing

The 7 OIS items were checked for reliability. Two of the items had CITC scores below 0.4. Even though the threshold is 0.3, these two items (OIS_1 and OIS_2) were dropped in order to improve the overall reliability of the scale. Upon deletion of these two items, Cronbach's alpha increased from 0.75 to 0.77.

Retaining items 1 and 2 would have been desirable as they address important aspects of information sharing, namely sharing of product related information and customer requirements. However, for the sake of reliability of the overall construct they were ultimately removed from the analysis. OIS scale items are shown below in Table 5.10 and reliability numbers are shown below in Table 5.11.

Table 5.10: Operational Information Sharing – Large scale survey items, CITC and Cronbach's alpha

Item Code	**Survey Item**	**CITC**	**Alpha**
	We share information with supply chain partners regarding ….		
OIS_1	… product specifications	.332	.75
OIS_2	… end customer requirements	.348	
OIS_3	… short term demand forecasts	.549	
OIS_4	… production schedules	.568	
OIS_5	… inventory replenishment requirements	.494	
OIS_6	… inventory status	.487	
OIS_7	… delivery schedules	.503	

Table 5.11: Operational Information Sharing – Reliability Analysis

Item Code	CITC	Alpha
OIS_3	.563	**.77**
OIS_4	.560	
OIS_5	.563	
OIS_6	.578	
OIS_7	.447	

OIS items 3, 4, 5, 6 and 7 were entered into factor analysis. All 5 items converged into a single factor as expected. Factor loadings were acceptable with four of the five items having factor loadings above 0.7. Table 5.12 below shows the factor loadings for the OIS scale items.

Table 5.12: Operational Information Sharing - Construct level exploratory factor analysis

	Component 1
OIS_6	.753
OIS_5	.750
OIS_3	.747
OIS_4	.735
OIS_7	.626

5.4.3.2 Operational Decision Synchronization

The administered scale had 5 items as part of Operational Decision Synchronization (ODS). Reliability analysis of these 5 items resulted in CITC scores well above the threshold and a good Cronbach's alpha score of 0.84. The analysis indicates that there is no need to exclude any of the items. CITC scores are shown in Table 5.13 below.

Table 5.13: Operational Decision Synchronization - Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	We make joint decisions with supply chain partners for day-to-day management of …		
ODS_1	… inventory	.598	.84
ODS_2	… material flow	.618	
ODS_3	… production schedules	.735	
ODS_4	… production capacity	.672	
ODS_5	… delivery schedules	.581	

ODS items 1 to 5 were entered into factor analysis and all items converged into a single factor with strong factor loadings. Two of the items have loadings above 0.8 and the rest of the items have factor loadings above 0.7, as shown in the table 5.14 below.

Table 5.14: Operational Decision Synchronization - Dimension level exploratory factor analysis

	Component 1
ODS_1	.851
ODS_2	.803
ODS_3	.760
ODS_4	.744
ODS_5	.731

5.4.3.3 Operational Collective Learning

This dimension of Operational coordination was represented by 6 items in the survey. CITC scores of these items are all well above the threshold and Cronbach's alpha value of 0.87 ensures adequate reliability of the scale.

Table 5.15: Operational Collective Learning – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	We jointly develop understanding and competencies with supply chain partners for day-to-day management of …		
OCL_1	… ordering processes	.626	.87
OCL_2	… inventory	.696	
OCL_3	… material flow	.703	
OCL_4	… production activities	.712	
OCL_5	… production capacity	.654	
OCL_6	… delivery schedules	.679	

The 6 OCL items were then entered into factor analysis, which resulted in a single factor with strong factor loadings. Table 5.16 below shows the factor loadings for all 6 items.

Table 5.16: Operational Collective Learning - Dimension level exploratory factor analysis

	Component 1
OCL_1	.808
OCL_2	.807
OCL_3	.801
OCL_4	.786
OCL_5	.762
OCL_6	.744

The next step in the instrument validation process is factor analysis at the construct level. As proposed earlier, Operational coordination is represented by three dimensions. Factor analysis at the construct level is conducted in order to ensure both convergent and discriminant validity. This ensures that the three lower order dimensions converge to a single higher order construct and at the same time ensures that they are distinct from each other. 16 items in total are entered into factor analysis and factor loadings are analyzed. Cross loading of items is not desirable. The initial rotated component matrix shows that some of the items are loading on more than one factor. For instance, items OIS_4, ODS_1 and OCL_6 load onto two factors. These items are deleted one by one, while noting any changes to the factor loadings. Deletion of these items from the analysis results in cross loadings of a few other items – OIS_7, ODS_5, OCL_4 and OCL_5. The items with the strongest cross loadings are deleted first. As items are deleted, on many occasions factor loadings change and some of the cross loadings change and items load onto a single factor. In this case, ODS_5 changed from cross loading to loading onto a single factor. Thus ODS_5 could be retained. The final rotated component matrix is shown in Table 5.17 below. It shows three factors with three items each in them. The three factors account for about 70% of the total variance, with the construct reliability figure being a healthy 0.84. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is good at 0.82.

Table 5.17: Operational Collective Learning - Construct level exploratory factor analysis

	Component		
	1	2	3
ODS_4	.866		
ODS_3	.865		
ODS_5	.648		
OCL_1		.859	
OCL_2		.798	
OCL_3		.729	
OIS_5			.858
OIS_3			.763
OIS_6			.693

Eigen value	3.99	1.31	1.02
% of variance	44.36	14.57	11.3
KMO		.824	
Cronbach's Alpha		.841	

In the next step, the second order Operational Coordination construct was subjected to Confirmatory factor analysis. The model fit indices (GFI = 0.954; AGFI = 0.915; RMR = 0.05) were acceptable as indicated by the CFA output. In order to determine discriminant validity, the three first order factors (OIS, ODS, OCL) were analyzed using correlation analysis. Table B-1 of appendix B shows the presence of acceptable discriminant validity.

In addition to this, the Chi-square differences test was also conducted for the three dimensions of OC. This involves a pair-wise comparison of constructs in AMOS while testing for significant differences in chi-square between correlated and single models. Table 5.18 below shows significant differences in chi-square at $p<0.000$ thus indicating acceptable discriminant validity.

Table 5.18: Chi-square difference test – Operational Coordination

	Chi-square (df)		
Construct Pair	**Single**	**Correlated**	**Difference**
OIS - ODS	245.042 (28)	178.971 (27)	66.071 (1)
ODS - OCL	410.134 (32)	225.378 (31)	184.756 (1)
OCL - OIS	159.586 (32)	96.000 (31)	63.586

5.4.4 Strategic Coordination:

Strategic Coordination is described to be a multi-dimensional construct consisting of three dimensions - Strategic Information Sharing (SIS), Strategic Decision Synchronization (SDS) and Strategic Collective Learning (SCL). SIS was represented by

6 items, SDS by 4 items and SCL by 5 items. Reliability analysis was done on each of the three dimensions and the purified items were then together entered into factor analysis to establish convergent and discriminant validity. Reliability analysis results are discussed below.

5.4.4.1 Strategic Information Sharing:

The 6 SIS items were first analyzed for reliability using SPSS. CITC scores of all 6 items were above the threshold and the resulting Cronbach's alpha was 0.8. Deleting the item with the lowest CITC score (SIS_6) was considered. However, deleting this item was not going to improve the reliability of the instrument any further. Moreover, SIS_6 was addressing an important aspect of information sharing. Thus all items were retained.

Table 5.19: Strategic Information Sharing – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	We share information with supply chain partners regarding ….		
SIS_1	… strategic plans for products	.559	.8
SIS_2	… market trends	.604	
SIS_3	… long-term customer preferences	.609	
SIS_4	… changes to supply chain processes	.557	
SIS_5	… changes in technology	.576	
SIS_6	… long-term demand forecasts	.450	

All 6 items were subjected to factor analysis and as expected, they loaded on to a single factor. Five out of the six items had factor loadings above 0.7. Item SIS_6 had a factor loading of 0.601, which is still acceptable. Table 5.20 below shows the factor loadings of all SIS items.

Table 5.20: Strategic Information Sharing - Dimension level exploratory factor analysis

	Component 1
SIS_3	.756
SIS_2	.753
SIS_5	.722
SIS_4	.712
SIS_1	.711
SIS_6	.601

5.4.4.2 Strategic Decision Synchronization:

Strategic Decision Synchronization scale included 4 items. Reliability analysis numbers from the table below shows that CITC scores for all items are acceptable. Cronbach's alpha of 0.82 indicates good reliability of the scale.

Table 5.21: Strategic Decision Synchronization - Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	We make joint decisions with supply chain partners for …		
SDS_1	… strategic inventory planning (eg: inventory locations, warehouse locations, distribution centers)	.644	.82
SDS_2	… strategic planning of production activities (eg: long-term production and capacity planning)	.701	
SDS_3	… strategic planning of logistics and distribution	.725	
SDS_4	… strategic planning of new product design and development activities	.524	

The four SDS items were subjected to factor analysis, which revealed convergence into a single factor. The factor loadings of three of the four items are above 0.8, which is a good indication of a strong factor.

Table 5.22: Strategic Decision Synchronization - Dimension level exploratory factor analysis

	Component 1
SDS_3	.869
SDS_2	.851
SDS_1	.811
SDS_4	.704

5.4.4.3 Strategic Collective Learning:

Five items were part of the strategic collective learning scale in the administered survey. Reliability analysis shows that CITC for all five items is well above the threshold. Cronbach's alpha is also good at 0.82. Individual items and their CITC scores are outlined in the table below.

Table 5.23: Strategic Collective Learning – Large scale survey items, CITC and Cronbach's alpha

Item Code	**Survey Item**	**CITC**	**Alpha**
	We jointly develop understanding and competencies with supply chain partners for…		
SCL_1	… strategic planning of new products	.526	.82
SCL_2	… strategic planning of production activities	.696	
SCL_3	… strategic planning of inventory	.603	
SCL_4	… identifying strategic trends in customer requirements	.615	
SCL_5	… strategic planning of supply chain process improvements	.642	

Factor analysis of these five items showed that they converge into a single factor. Items 2, 3, 4 and 5 have factor loadings above 0.7. The loading for item 1 is slightly less at 0.685. All items are retained and form a single factor.

Table 5.24: Strategic Collective Learning - Dimension level exploratory factor analysis

	Component 1
SCL_2	.826
SCL_5	.790
SCL_3	.762
SCL_4	.761
SCL_1	.685

After the individual dimensions are validated, the next step involves validation at the construct level. 15 items from the three dimensions are subjected to factor analysis to check for convergent and discriminant validity. Initial rotated component matrix indicates a few cross loadings. Items SIS_1, SCL_2 and SCL_5 show significant cross loadings. Deletion of SIS_1 results in a cross loading for item SIS_3. After deleting the cross loading items, it is noticed that two items have loadings below the acceptable threshold. Thus these two items are also deleted from the analysis. The final factor loadings are shown in the table below. There are three clean factors with a good reliability score of 0.851 and KMO of 0.844. About 70% of the total variance is explained by these three factors.

Table 5.25: Strategic Coordination - Construct level factor analysis

	Component		
	1	2	3
SDS_3	.830		
SDS_1	.827		
SDS_2	.797		
SCL_1		.882	
SDS_4		.717	
SCL_4		.698	
SIS_4			.761
SIS_2			.747
SIS_5			.734

Eigen value	4.14	1.16	1.02
% of variance	45.98	12.88	11.28
KMO		.844	
Cronbach's Alpha		.851	

In the next step, the second order Strategic Coordination construct was subjected to Confirmatory factor analysis. The model fit indices (GFI = 0.963; AGFI = 0.930; RMR = 0.04) were acceptable as indicated by the CFA output. The three first order factors (SIS, SDS, SCL) were analyzed for discriminant validity using correlation analysis. Table B-1 of appendix B shows the presence of acceptable discriminant validity.

Chi-square differences test was also conducted for the three dimensions of SC. Pair-wise comparison of chi-square values shows significant difference in chi-square at $p<0.000$ thus confirming discriminant validity.

Table 5.26: Chi-square difference test – Strategic Coordination

	Chi-square (df)		
Construct Pair	**Single**	**Correlated**	**Difference**
SIS - SDS	71.046	4.252	66.794
SDS - SCL	105.414	16.286	89.128
SCL - SIS	108.24	30.165	78.075

5.4.5 Transactional IOS:

Transactional IOS is proposed to be a single dimensional construct with 6 items in the administered survey. All 6 items were subjected to reliability analysis using SPSS. The table below shows that CITC score for all items is well above 0.7 and instrument reliability factor Cronbach's alpha is very good at 0.925. All items can thus be retained.

Table 5.27: Transactional IOS – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	Our firm and supply chain partners use Inter-Organizational Systems (IOS) for …		
TIOS_1	… automated exchange of information	.834	.925
TIOS_2	… automated order processing	.794	
TIOS_3	… automated exchange of inventory information	.758	
TIOS_4	… automated exchange of production schedules	.742	
TIOS_5	… automated exchange of delivery schedules	.799	
TIOS_6	… standardized information exchanges	.781	

Factor analysis at the construct level reveals that all 6 items load onto a single factor with good factor loadings. All loadings are above 0.8. Almost 73% of the variance is explained by this one factor. KMO is also good at 0.89. Thus convergent and discriminant validity is not an issue.

Table 5.28: Transactional IOS - Construct level exploratory factor analysis

	Component 1
TIOS_1	.890
TIOS_5	.865
TIOS_2	.861
TIOS_6	.851
TIOS_3	.834
TIOS_4	.821
Eigen value = 4.37 % of variance = 72.9 KMO = 0.89 Cronbach's Alpha = 0.925	

The 6 TIOS items from were then subjected to Confirmatory Factor Analysis (CFA). The modification indices suggested improvement in model fit by correlating error terms for

items 3-4 and 4-5. Analysis of these three items suggested that they are indeed measuring different aspects of TIOS usage. Thus it was decided to correlate the error terms. Once this was done, the output indicated acceptable model fit with GFI of 0.974, AGFI of 0.922 and RMR of 0.029. Discriminant validity was acceptable as determined by pair-wise correlation analysis shown in Table B-1 of appendix B.

5.4.6 Relational IOS (RIOS):

Relational IOS is proposed to be a single dimensional construct with 6 items in the administered survey. All 6 items were subjected to reliability analysis using SPSS. The table below shows that CITC score for four out of six items is above 0.8 and the other two items are well above 0.7. Reliability factor Cronbach's alpha is very good at 0.94.

Table 5.29: Relational IOS – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	Our firm and supply chain partners develop close ties and long-term relationships by using Inter-Organizational Systems (IOS) for …		
RIOS_1	… interactive communication	.825	.94
RIOS_2	… conferencing	.797	
RIOS_3	… exchange of ideas	.867	
RIOS_4	… problem resolution	.835	
RIOS_5	… activity planning	.829	
RIOS_6	… strategy formulation	.766	

Factor analysis of the six items results in a single factor with all factor loadings well above 0.8. Over 76% of the total variance is explained by this one factor. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is very good at 0.9.

Table 5.30: Relational IOS - Construct level exploratory factor analysis

	Component 1
RIOS_3	.911
RIOS_4	.888
RIOS_5	.885
RIOS_1	.880
RIOS_2	.859
RIOS_6	.838
Eigen value = 4.62 % of variance = 76.95 KMO = 0.9 Cronbach's Alpha = 0.94	

The 6 RIOS items from were then subjected to Confirmatory Factor Analysis (CFA) in AMOS. The modification indices suggested that model fit could be improved by correlating error terms for items 2-6 and 5-6. Analysis of these three items suggested different aspects of RIOS use being addressed in these three items. However, RIOS_6 which relates to strategy formulation may be a leading factor for the other two items. Thus it was decided to retain all three items and correlate the error terms. Model fit was acceptable with GFI of 0.969, AGFI of 0.906 and RMR of 0.02. There was adequate proof of discriminant validity as shown by the pair-wise correlations in Table B-1 of appendix B.

5.4.7 Boundary Spanning Capability:

Boundary spanning capability was represented by 7 items in the survey. Table 5.31 below shows that CITC for all items is above 0.6, which is acceptable. Cronbach's alpha for the scale is good at 0.87.

Table 5.31: Boundary spanning capability – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	In our firm, individuals (eg: purchasing managers, supply chain managers) who interact with supply chain partners…		
BSC_1	… effectively represent our requirements	.605	.87
BSC_2	… effectively represent our strategy	.605	
BSC_3	… have adequate knowledge of our firm's products	.671	
BSC_4	… have adequate knowledge of our firm's capabilities	.770	
BSC_5	… have adequate knowledge of our firm's internal processes	.615	
BSC_6	... strive to reach equitable solutions with supply chain partners when differences arise	.610	
BSC_7	… serve as source of useful external information	.635	

All 7 items were then entered into factor analysis. All items loaded onto a single factor with all factor loadings above 0.7. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is good at 0.85. About 56% of the total variance is explained by this factor. Table 5.32 below shows the individual factor loadings.

Table 5.32: Boundary spanning capability - Construct level exploratory factor analysis

	Component 1
BSC_4	.852
BSC_3	.776
BSC_7	.740
BSC_5	.728
BSC_6	.717
BSC_2	.716
BSC_1	.708
Eigen value = 3.94 % of variance = 56.21 KMO = 0.85 Cronbach's Alpha = 0.87	

Confirmatory factor analysis of the 7 BSC items indicates adequate loadings with good model fit indices. GFI was 0.976, AGFI was 0.938 and RMR was 0.017. A comparison of square root of AVE and factor correlation figures in table B-1 from Appendix B shows the presence of acceptable discriminant validity.

5.4.8 Collaborative Knowledge Management:

Collaborative Knowledge Management was represented by 6 items in the survey. Reliability analysis of these items resulted in CITC scores above the threshold. Two of the six items have CITC below 0.6. However, deletion of these items did not affect overall reliability positively. Thus, these items were retained. Moreover, these two items represent knowledge acquisition, which is an important part of collaborative knowledge management. Overall reliability of the scale is good with a Cronbach's alpha of 0.88.

Table 5.33: Collaborative knowledge management - Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	Our firm and supply chain partners collaborate to …		
CKM_1	… acquire new knowledge	.562	.88
CKM_2	… update existing knowledge	.595	
CKM_3	… compile and organize knowledge resources	.756	
CKM_4	… maintain shared knowledge repositories/databases	.682	
CKM_5	… ensure easy access to desired knowledge	.789	
CKM_6	… ensure fast access to desired knowledge	.788	

Factor analysis of these six items results in two factors. However, item CKM_3 cross loads and thus becomes necessary to delete this item. After deleting CKM_3, two clean factors emerge with good factor loadings as shown in table 5.34 below.

Table 5.34: Collaborative Knowledge Management - Construct level exploratory factor analysis

	Component	
	1	2
CKM_1		.909
CKM_2		.893
CKM_4	.841	
CKM_5	.922	
CKM_6	.913	
Eigen value	3.17	1.1
% of variance	63.3	21.8
KMO	.72	
Cronbach's Alpha	.85	

Items 1 and 2 form a factor, which relates to acquisition of knowledge. Items 4, 5, and 6 form another factor which relates to the access of knowledge. Item 3 (CKM_3) was initially included to address collaborative storage of knowledge. However, cross loading of this item indicates that it could be part of both acquisition and access of knowledge. It is most likely that the process of knowledge storage is a given when we have both acquisition and access. Thus, the two dimensions of collaborative knowledge management identified are Collaborative knowledge acquisition (CKM_AQ) and Collaborative knowledge access (CKM_AC). These two factors account for about 85% of the total variance. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is acceptable at 0.72. Overall reliability of the scale is more than acceptable with a Cronbach's alpha of 0.85.

In the next step, the second order Collaborative Knowledge Management construct was subjected to Confirmatory factor analysis. The model fit indices were good with GFI of 0.988, AGFI of 0.954 and RMR of 0.016. In order to determine discriminant validity, the two first order factors (CKM_AQ and CKM_AC) were analyzed using correlation analysis. The square root of AVE for both constructs was greater than factor correlations. Table B-1 of appendix B shows the presence of acceptable discriminant validity.

5.4.9 Supply Chain Relational Capital:

Supply Chain Relational Capital was represented by 4 items in the survey. Reliability analysis of these items resulted in CITC scores above the threshold. Overall reliability of the scale is more than acceptable with a Cronbach's alpha of 0.84.

Two of the six items have CITC below 0.6. However, deletion of these items did not affect overall reliability positively. Thus, these items were retained. Moreover, these two items represent knowledge acquisition, which is an important part of collaborative knowledge management. Overall reliability of the scale is good with a Cronbach's alpha of 0.88. There was no indication of reliability going up by deleting any of the items. Thus all four items were retained for the analysis.

Table 5.35: Supply Chain Relational Capital – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	The relationship between our firm and supply chain partners is characterized by …		
SCRC_1	… mutual trust	.706	.84
SCRC_2	… mutual respect	.698	
SCRC_3	… close, personal interaction	.617	
SCRC_4	… a sense of professional camaraderie	.694	

Factor analysis of the four items resulted in a single factor with healthy factor loadings. 68% of the total variance was explained by this single factor. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was acceptable at 0.76.

Table 5.36: Supply Chain Relational Capital - Construct level exploratory factor analysis

	Component 1
SCRC_1	.854
SCRC_2	.847
SCRC_4	.831
SCRC_3	.773
Eigen value = 2.74 % of variance = 68.38 KMO = 0.76 Cronbach's Alpha = 0.84	

Confirmatory factor analysis of the 4 SCRC items indicates adequate item loadings. The modification indices suggest the need to correlate error terms for items 3 and 4. Closer analysis of these two items indicates item 4 to be a leading factor for item 3. However, since item 3 addressed interaction and item 4 addresses camaraderie, it was decided retain both items and correlate their respective error terms. The resulting model fit was good with GFI of 0.994, AGFI of 0.939 and RMR of 0.007. Table B-1 from Appendix B shows square root of AVE to be 0.763 and greater than construct correlations. Thus it shows the presence of acceptable discriminant validity.

5.4.10 Supplier Development:

Supplier development was represented by 7 items in the survey. Reliability analysis results in table 5.37 below shows that all CITC scores are above the threshold. Even though two of the CITC numbers are below 0.5, deleting these two items (SD_5 and

SD_6) does not improve the overall reliability of the scale. It was thus decided to retain all the items at this stage.

Table 5.37: Supplier development – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	Our firm…		
SD_1	… conducts formal evaluation of supplier performance on a regular basis	.660	.84
SD_2	… provides feedback to suppliers after evaluation	.698	
SD_3	… has a certification program to rate supplier quality	.553	
SD_4	… provides incentives for improved supplier performance	.631	
SD_5	... promises consideration for increased business to suppliers in the future for improvements in their performance	.485	
SD_6	… involves supplier representatives in internal teams (e.g. product development)	.499	
SD_7	… includes suppliers in continuous improvement programs	.623	

All 7 supplier development items were entered into factor analysis. Two factors emerged. However, SD_4 cross loaded onto both factors. SD_4 was thus deleted to get two clean factors. Items 1, 2 and 3 emerged as the first factor and items 5, 6 and 7 emerged as the second factor. Items 1, 2 and 3 address the issue of evaluation of supplier performance. Thus the first factor can be called Supplier Evaluation (SD_SE). Items 5, 6 and 7 address increased involvement of suppliers in activities and continuous improvement programs. The second factor can thus be referred to as Supplier Involvement (SD_SI). These two factors thus constitute Supplier Development. The two factors account for about 71% of the total variance. KMO and Cronbach's alpha are acceptable at .735 and 0.81 respectively.

Table 5.38: Supplier Development - Construct level exploratory factor analysis

	Component	
	1	2
SD_1	.919	
SD_2	.922	
SD_3	.710	
SD_5		.658
SD_6		.849
SD_7		.809
Eigen value	3.14	1.14
% of variance	52.26	18.97
KMO	.735	
Cronbach's Alpha	.81	

The second order Supplier Development construct was subjected to Confirmatory factor analysis. Results of CFA indicate adequate factor loadings and item loadings. The model fit indices were good with GFI of 0.982, AGFI of 0.954 and RMR of 0.05. The two first order factors (SD_SE and SD_SI) were analyzed for discriminant validity using correlation analysis. The square root of AVE for both constructs was greater than individual factor correlations. Table B-1 of appendix B shows the presence of acceptable discriminant validity.

5.4.11 Supply Chain Efficiency:

Supply chain efficiency was represented by 4 items in the survey. Reliability analysis shows CITC scores to be above the threshold and acceptable. The analysis also indicates that deleting item SCE_2 would increase the overall reliability slightly to 0.73. However, since SCE_2 was the only item addressing the aspect of inventory, it was decided to retain this item.

Table 5.39: Supply Chain Efficiency – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	Our firm's supply chain is successful in …		
SCE_1	… minimizing overall cost	.540	.72
SCE_2	… minimizing inventory levels	.428	
SCE_3	… providing reliable delivery	.644	
SCE_4	… meeting quality specifications	.485	

The four SCE items were subjected to factor analysis. All items converged into a single factor. As expected, item SCE_2 had the weakest factor loading. However, the factor loading of 0.647 was acceptable and thus the item was retained. The single factor accounted for 56% of the explained variance. KMO of 0.67 was on the lower side, but still was considered acceptable.

Table 5.40: Supply Chain Efficiency - Construct level exploratory factor analysis

	Component 1
SCE_3	.847
SCE_1	.747
SCE_4	.743
SCE_2	.647
Eigen value = 2.25 % of variance = 56.18 KMO = 0.67	

Confirmatory factor analysis of the 4 SCE items indicated adequate item loadings. The modification indices indicated the improvement in model fit by correlating error terms for items 1 and 2. A close look at these two items indicates that they similar to the extent that both refer to minimizing something. However, item 1 refers to minimizing cost whereas item 2 refers to minimizing inventory. Thus both items were retained and errors were correlated. Model fit indices indicate acceptable fit with GFI = 0.986, AGFI = 0.865 and RMR = 0.018. Chi-square difference test was used to test discriminant validity of the outcome variables in this study. Supply chain efficiency was paired with supply chain responsiveness to test for discriminant validity. Table 5.43 in section 5.4.12 shows the presence of acceptable discriminant validity.

5.4.12 Supply Chain Responsiveness:

Supply chain responsiveness was represented by 5 items in the survey. Reliability analysis shows CITC scores to be above the threshold and acceptable. The analysis also indicates that deleting any of the items would result in a decrease in reliability. Thus all items were retained at this stage.

Table 5.41: Supply Chain Responsiveness – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	Our firm's supply chain is successful in …		
SCR_1	… responding quickly to changes in customer demand	.561	.81
SCR_2	… responding quickly to changes in competitor strategies	.650	
SCR_3	… responding quickly to changes in technology	.623	
SCR_4	… reducing lead time	.569	
SCR_5	… introducing new products to the market	.550	

The five SCR items were entered into factor analysis and all items converged into a single factor. All factor loadings were beyond 0.7 and thus considered adequate. 56% of the total variance was explained by this single factor. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was acceptable at 0.81.

Table 5.42: Supply Chain Responsiveness - Construct level exploratory factor analysis

	Component 1
SCR_2	.802
SCR_3	.780
SCR_4	.730
SCR_1	.725
SCR_5	.717
Eigen value = 2.82 % of variance = 56.45 KMO = 0.81	

Confirmatory factor analysis of the 5 SCR items indicated adequate item loadings. Model fit is acceptable with GFI = 0.971, AGFI = 0.912 and RMR = 0.035. In order to establish discriminant validity, the two supply chain performance constructs (SCE and SCR) were subjected to Chi-square difference test. A significant difference in chi-square value at the $p<0.000$ level indicates adequate discriminant validity.

Table 5.43: Chi-square difference test – Supply Chain Efficiency and Supply Chain Responsiveness

	Chi-square (df)		
Construct Pair	**Single**	**Correlated**	**Difference**
SCE - SCR	184.392 (27)	81.684 (26)	102.708 (1)

5.4.13 Firm Performance:

Firm performance is represented by 9 items in the administered survey. Results of the reliability analysis are shown in table 5.44 below. CITC scores for these 9 items range from 0.35 to 0.71. Some of these items (FP_1, FP_2) have CITC scores that are close to the acceptable threshold of 0.3. Analysis showed that deleting these items would not make any difference to scale reliability. Since these were the only items addressing price and quality, it was decided to retain them. Overall reliability at this stage was 0.84.

Table 5.44: Firm Performance – Large scale survey items, CITC and Cronbach's alpha

Item Code	Survey Item	CITC	Alpha
	Our firm is successful in …		
FP_1	… offering competitive prices on our products	.359	.84
FP_2	… offering high quality products to our customers	.394	
FP_3	… achieving on-time delivery to customers	.423	
FP_4	… responding to changing customer requirements	.417	
FP_5	… reducing time-to-market for new products	.579	
FP_6	… increasing market share	.622	
FP_7	… increasing revenue	.714	
FP_8	… increasing Return on Investment (ROI)	.736	
FP_9	… increasing Return on Assets (ROA)	.692	

Two factors emerged from the factor analysis of all 9 items. However, item FP_5 was loading onto both factors. FP_5 had to be deleted in spite of the fact that it was the only item addressing time-to-market performance of the firm. Two clean factors emerged after deleting this item. Items 1, 6, 7, 8 and 9 came together as the first factor. Items 2, 3 and 4 came together as the second factor. A look at the first factor indicates that market performance aspect of the firm. The second factor items address operational performance aspect of the firm. Thus, operational performance (FP_OP) and market performance (FP_MP) make up the two dimensions of Firm Performance.

Almost 62% of the total variance was explained by these two factors. KMO and Cronbach's alpha were acceptable at 0.78 and 0.82 respectively.

Table 5.45: Firm Performance - Construct level exploratory factor analysis

	Component	
	1	2
FP_8	.880	
FP_9	.857	
FP_7	.843	
FP_6	.777	
FP_1	.492	
FP_3		.813
FP_4		.784
FP_2		.622
Eigen value	3.66	1.29
% of variance	45.7	16.1
KMO	.78	
Alpha	.82	

The second order Firm Performance construct was subjected to Confirmatory factor analysis. Results of CFA indicate adequate factor loadings and item loadings. The model fit indices were good with GFI of 0.965, AGFI of 0.93 and RMR of 0.033. The two first order factors (FP_MP and FP_OP) were analyzed for discriminant validity using chi-square difference test. As shown in table 5.46 below, the difference in chi-square was significant at $p<0.000$ thus indicating adequate discriminate validity.

Table 5.46: Chi-square difference test – Firm Performance

	Chi-square (df)		
Construct Pair	**Single**	**Correlated**	**Difference**
FP_MP and FP_OP	75.936 (19)	39.499 (18)	36.437 (1)

To summarize, all measurement scales used in this study were subjected to validation. The scale items were initially purified, checked for reliability and finally tested for convergent and discriminant validity. Almost all of the scales have proved to be good in terms of validity and reliability; where as some of them have proved to be acceptable. The next chapter will discuss hypothesis testing and its results.

Chapter 6

Hypothesis Testing and Results

In this chapter, the proposed research model will be tested using Structural Equation Modeling (SEM) methodology. SEM is a technique used to explain relationships between multiple variables using a series of multiple regression equations. SEM is part of several specialized software packages such as AMOS, LISREL etc. In this study, AMOS will be used for structural equation modeling.

SEM has two parts to it – measurement model and structural model (Anderson and Gerbing, 1988). Measurement model part of SEM is where measured variables are connected to latent variables in order to validate the measurement instrument (Byrne, 2001). Validation of measurement instruments has already been addressed in Chapter 5. Structural model part of SEM is where relationships between latent variables are examined (Joreskog and Sorbom, 1977). This is based on the proposed research model shown in figure 6-1 below. As part of assessing the structural model, overall model fit was examined and at the same time individual relationships (i.e. parameter estimates) between variables as specified by the research hypotheses ware examined. Model fit was assessed by the following model fit indices – Goodness of Fit (GFI), Adjusted Goodness of Fit (AGFI), Root Mean Square Residual (RMR), Normed Fit Index (NFI) and Comparative Fit Index (CFI).

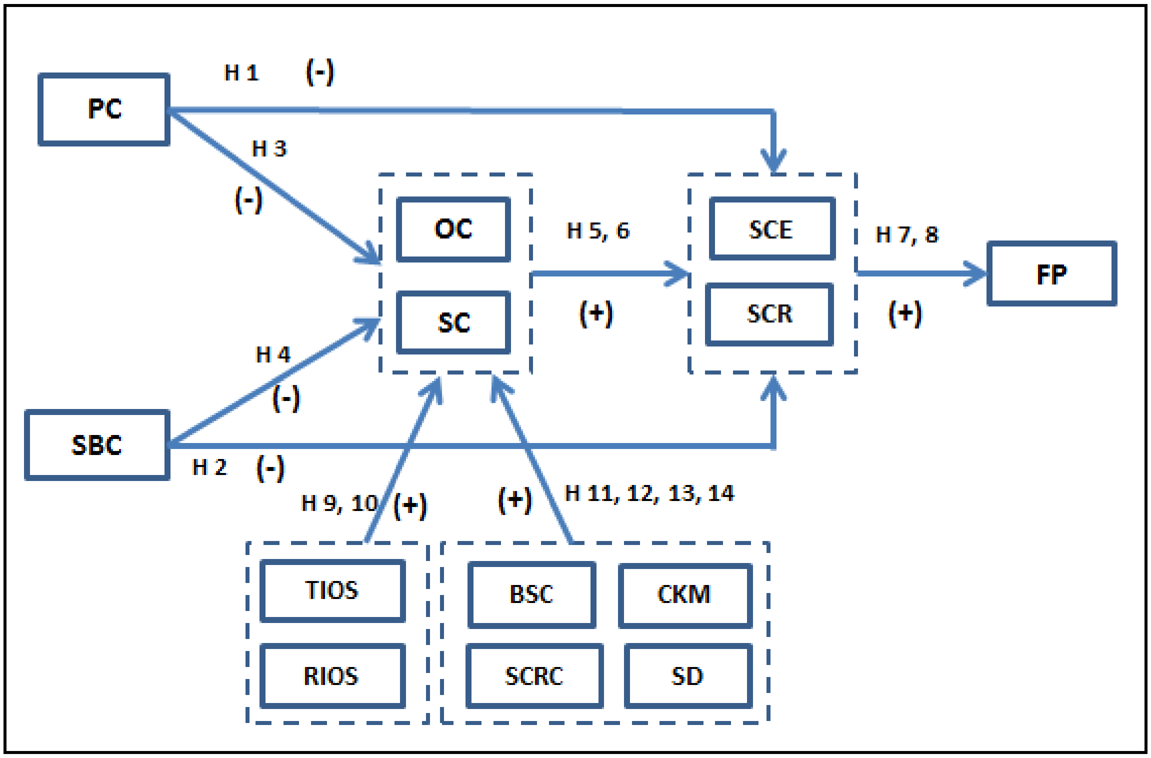

Figure 6-1: Research model

PC = Product Complexity; SBC = Supply Base Complexity; OC = Operational Coordination; SC = Strategic Coordination; SCE = Supply Chain Efficiency; SCR = Supply Chain Responsiveness; FP = Firm Performance; TIOS = Transactional IOS; RIOS = Relational IOS; BSC = Boundary Spanning Capability; CKM = Collaborative Knowledge Management; SCRC = Supply Chain Relational Capital; SD = Supplier Development

6.1 Results of the structural model:

The structural model shown in figure 6-1 was tested using AMOS. 14 hypotheses were proposed as part of this structural model. Individual hypotheses were determined to be supported (or not supported) based on the standardized regression coefficient value and the critical ratio, which is commonly referred to as the t-value. Out of the 14 hypotheses, 8 were supported; 2 were partially supported and 4 were not supported. Table 6.1 below identifies the proposed relationships, their path coefficients, respective t-values and significance levels.

Table 6.1: Results of hypotheses

Hypothesis	Proposed Relationship	Regression Coefficient	t-value	Supported or Not
H1a	PC➔SCE	-.023	-.384	No
H1b	PC➔ SCR	.079	1.319	No
H2a	SBC➔ SCE	-.145	-2.497**	Yes
H2b	SBC➔ SCR	-.128	-2.189**	Yes
H3a	PC➔OC	.079	1.590	No
H3b	PC➔SC	.086	1.641	No
H4a	SBC➔OC	.059	1.192	No
H4b	SBC➔SC	.001	.025	No
H5a	OC➔SCE	.182	2.421**	Yes
H5b	OC➔SCR	.206	2.734***	Yes
H6a	SC➔SCE	.225	3.036***	Yes
H6b	SC➔SCR	.174	2.331**	Yes
H7	SCE➔FP	.253	4.108***	Yes
H8	SCR➔FP	.395	6.419***	Yes
H9a	TIOS➔OC	.299	4.738***	Yes
H9b	TIOS➔SC	.124	1.866*	Yes
H10a	RIOS➔OC	.021	.348	No
H10b	RIOS➔SC	.055	.854	No
H11a	BSC➔OC	.200	3.486***	Yes
H11b	BSC➔SC	.123	2.035**	Yes
H12a	CKM➔OC	.167	3.173***	Yes
H12b	CKM➔SC	.295	5.319***	Yes
H13a	SCRC➔OC	.083	1.446	No
H13b	SCRC➔SC	.176	2.917***	Yes
H14a	SD➔OC	.177	3.010***	Yes
H14b	SD➔SC	.099	1.603	No
GFI = 0.94; AGFI = 0.751; RMR = 0.039; NFI = 0.892; CFI = 0.904 *** = p<0.01; **= p<0.05; *= p<0.1				

6.2 Discussion of structural model and hypothesis testing results:

The structural model tested as part of this study proposes three broad relationships. First, it examines the direct effect of complexity (product complexity and supply base complexity) on performance (supply chain efficiency, supply chain responsiveness and firm performance). Second, it examines the indirect effect of complexity on performance as mediated by coordination (operational and strategic). Third, it examines the effect of mitigating mechanisms in improving coordination in the face of complexity.

For a researcher it is always desirable that proposed relationships are supported. However, this is not always the case. The situation is the same in this study as well. Even though some of the relationships are not supported, it is essential to examine the possible reasons for lack of support and try to provide theoretical explanation for it. The next section discusses all proposed hypotheses and their results. Specifically in cases where hypotheses are not supported, the possible reasons for lack of support are examined.

6.2.1 Discussion of hypothesis results:

Hypothesis 1a: *Product complexity has a negative relationship with supply chain efficiency. (Not Supported)*

Hypothesis 1b: *Product complexity has a negative relationship with supply chain responsiveness. (Not Supported)*

Product complexity is something that has been on the rise over the years. Products around us have become complex in terms of features and functionalities. As a result, managing manufacturing activity has become extremely challenging. In most cases, inability to manage these complexities results in lower performance throughout the supply chain. However, this relationship was not supported by the data. Even though the relationship between product complexity and supply chain efficiency had a negative path coefficient, it was not large and significant enough to support the hypothesis. This result was surprising since previous studies have addressed the negative impact of product complexity on various aspects of manufacturing plant performance such as cost, inventory levels, delivery reliability, unit fill rate, order fill rate, lead time etc. (Lee and Tang, 1997; Alfaro and Corbett, 2003; Closs et al 2010; Gottfredson and Aspinall, 2005). The same was expected at the supply chain level since it affects activities both up and down the supply chain. However, lack of support might not necessarily mean lack of any kind of relationship between the two. There is a possibility that the relationship between product complexity and supply chain performance is an indirect one. Product complexity might be affecting something else which in turn might result in decreased supply chain performance. This thought is further developed and examined in the revised model.

Hypothesis 2a: *Supply base complexity has a negative relationship with supply chain efficiency. (Supported)*

Hypothesis 2b: *Supply base complexity has a negative relationship with supply chain responsiveness. (Supported)*

These two hypotheses propose that the more complex the supply base, the less efficient and responsive is the supply chain. The data supported these two relationships with beta values of -.145 and -.128; and t-values of 2.497 and 2.189 for H2a and H2b respectively. Both these relationships were supported at 95% significance level. This indicates that as supply bases become more and more complex, it becomes harder to manage activities within the supply chain. Inability to manage activities will negatively affect efficiency and responsiveness throughout the supply chain. This is precisely the reason why companies in the recent past have been focused on supply base rationalization and optimization. As supply bases grow in size and as they become more differentiated, orchestrating activities to meet the goals of the organization becomes an uphill task (Choi and Krause, 2006). In the recent past, we have also seen manufacturers work closely with their suppliers and provide them with the necessary skills, both technical and non-technical. This is an attempt by suppliers to reduce the extent of differentiation in terms of skills. US based manufacturing companies have also focused their attention on developing suppliers close to the home market to counteract the effects of a geographically dispersed supply base (Lee, 2004). Thus lower complexity in the supply base is desirable for the sake of manageability.

Hypothesis 3a: *Product complexity has a negative relationship with operational coordination. (Not Supported)*

Hypothesis 3b: *Product complexity has a negative relationship with strategic coordination. (Not Supported)*

Hypothesis 4a: *Supply base complexity has a negative relationship with operational coordination. (Not Supported)*

Hypothesis 4b: *Supply base complexity has a negative relationship with strategic coordination. (Not Supported)*

These two hypotheses examine the indirect relationship between complexity and performance. It is proposed that Operational Coordination and Strategic Coordination fully mediate the relationship between product complexity/supply base complexity and supply chain performance. This relationship was intended to explain how coordination of activities in the face of complexity becomes challenging and the resulting lack of coordination drives down performance throughout the supply chain. For instance, information sharing is one of the key dimensions of both operational and strategic coordination. As products and supply bases become increasingly complex, information sharing requirements increase. Supply chain members are required to share an increased volume of highly varied and often unclear information with a large number of supply chain partners. In most cases, supply chains are not equipped to handle this state of information sharing as effectively as they would like to. A similar situation arises when we take into account decision synchronization and collective learning, which are the other two dimensions of coordination. Thus a negative relationship was proposed. However, both hypotheses failed to get any support in this regard. Very few studies, if any, actually address the issue of complexity and coordination. This is an extremely important issue as coordination mechanisms are key to the success of any supply chain. This is more so in instances where complexity within the system cannot be reduced to a great extent. For example, product complexity is bound to increase as more features are added to products and as products become more technologically advanced. This kind of progression as far as products are concerned is something that cannot be avoided. In such a situation, the next best thing for supply chains would be to address their coordination mechanisms which would take care of the situation in spite of complexities in the system. The same would apply to the context of supply bases increasing in terms of complexity.

The lack of support for hypotheses 3 and 4 might indicate the increased emphasis of and dependence on supply chain contracts and incentives to achieve coordination in the supply chain. Supply chain contracts and incentives are said to be strong determinants of coordination in the supply chain (Giannoccaro and Pontrandolfo, 2004). Among the different models of supply chain contracts discussed in literature, incentive mechanisms (Lee and Whang, 1999) and revenue sharing contracts (Cachon and Lariviere, 2000) are prominent ones. Monetary incentives and contractual obligations might be motivating factors for coordination in spite of the complexities at the product and supply base level.

The non-significance of the fully mediating relationship might also indicate the possibility of a moderating relationship for operational and strategic coordination. Both these forms of coordination might moderate the relationship between complexity and supply chain performance – i.e. the presence of effective coordination mechanisms might reduce the negative effect of complexity on supply chain performance. This will be further discussed later as part of the future scope of this study.

Hypothesis 5a: *Operational Coordination has a positive relationship with Supply chain efficiency. (Supported)*

Hypothesis 5b: *Operational Coordination has a positive relationship with Supply chain responsiveness. (Supported)*

Operational coordination as described earlier in this study focuses on managing interdependent processes for day-to-day activities in the supply chain. The extent to which supply chains manage this operational interdependence greatly determines the outcome of the supply chain in terms of cost, quality, reliability, lead time, flexibility, time-to-market etc. In any supply chain, coordination calls for extensive sharing of information and combined decision making. Reluctance to do this or failure to do this will result in higher cost, inventory stock-outs, excess inventory, longer lead times and slower response to changes. The data strongly supports this idea. H5a is found to be significant at the 95% level with a t-value of 2.421 and a path coefficient of .182. H5b is found to be significant at the 99% level with a t-value of 2.734 and a path coefficient of .206. This reiterates the importance of working closely with suppliers and encourages supply chains to move away from arms-length relationships. This also highlights the importance of coordination mechanisms for companies that are focused on being lean and responsive to customer needs.

Hypothesis 6a: *Strategic Coordination has a positive relationship with Supply chain efficiency. (Supported)*

Hypothesis 6b: *Strategic Coordination has a positive relationship with Supply chain responsiveness. (Supported)*

Strategic coordination in this study refers to managing interdependencies in terms of long term strategic activities. The data supports the idea that strategic coordination is necessary for achieving high levels of efficiency and responsiveness in the supply chain. H6a is found to be significant at the 99% level with a t-value of 3.036 and a path coefficient of .225. H6b is found to be significant at the 95% level with a t-value of 2.331 and a path coefficient of .174. This result indicates the importance of sharing strategic information. This goes against the general perception that information that is strategic in nature cannot be disclosed to outsiders. Companies definitely have to be careful with sharing of strategic information. However, there are advantages to sharing certain kinds of strategic information with supply chain partners. For instance, sharing strategic trends and long term customer requirements with supply chain partners is common in certain industries. This result also indicates the importance of collaborative planning and decision making. For instance, Collaborative Planning Forecasting and Replenishment (CPFR) is a form of strategic coordination that is widely used by companies such as Walmart, P&G, Campbell Soups, Nabisco etc. More so in the technology sector, joint decision making and sharing of strategic information helps supply chain partners in staying up to date with customer trends and technology trends. This increases responsiveness and reduces wastage throughout the supply chain. Both these hypotheses (5 and 6) highlight the importance of effective coordination mechanisms, which are very often not given the importance they deserve when supply networks are designed.

Hypothesis 7: *Supply chain efficiency has a positive relationship with firm performance. (Supported)*

Hypothesis 8: *Supply chain responsiveness has a positive relationship with firm performance. (Supported)*

Firms today are no longer considered isolated entities. More often than not, their survival, growth and success depend greatly on the performance of their supply chain. A firm cannot be expected to flourish in spite of having a weak supply chain. Hypotheses 7 and 8 thus propose that a firms' performance is dependent on the extent to which its supply chain is efficient and responsive. The data provides strong support to these two hypotheses. H7 is found to be significant at the 99% level with a path coefficient of .253 and t-value of 4.108. H8 is found to be significant at the 99% level with a path coefficient of .395 and t-value of 6.419. This result further validates the practices of some of the leadings firms like Walmart, HP, Zara, Apple etc. These firms work closely with their supply chain partners to ensure that their entire supply chain is as efficient and responsive as possible. They know that the success of their firm depends on the success of their supply chain.

Hypothesis 9a: *Transactional IOS has a positive relationship with Operational Coordination. (Supported)*

Hypothesis 9b: *Transactional IOS has a positive relationship with Strategic Coordination. (Supported)*

These two hypotheses address the first mitigating mechanism in improving coordination in the face of complexity. As per information processing theory, one way to improve coordination is by increasing information processing capability between supply chain partners. The use of transactional IOS tools is one way to improve information processing capability.

The relationship between Transactional IOS and the two coordination constructs was found to be positive and significant. As expected, transactional IOS had a stronger relationship with operational coordination than with strategic coordination. H9a is found to be significant at the 99% level with a t-value of 4.738 and a path coefficient of .299. H9b is found to be significant at the 90% level with a t-value of 1.866 and a path coefficient of .124. EDI is a classic example of TIOS. EDI enables automation and standardization of information flows. This greatly improves the speed, accuracy and ease of information exchange between supply chain members. The significance of H9b shows that the use of transactional IOS tools can also have strategic benefits. Transactional IOS is seen as an enabler of collaboration and joint decision making in the context of strategic activities as well.

Hypothesis 10a: *Relational IOS has a positive relationship with Operational Coordination. (Not Supported)*

Hypothesis 10b: *Relational IOS has a positive relationship with Strategic Coordination. (Not Supported)*

Relational IOS tools are said to be enablers of close ties between supply chain partners and they go well beyond arm's length relationships that are typical in many supply chains. These tools are expected to help supply chain partners in their quest to collaborate with each other and work closely with each other. They are also said to be useful in instances where information is ambiguous and unstandardized. Relational IOS tools help supply chain partners discuss ideas, brainstorm, identify trends and solve problems. The expected result is in the form of improved coordination at both operational and strategic levels. However, the data failed to provide support to these two relationships. There might be multiple reasons for this. One possible reason might be the extent to which firms have adopted Relational IOS tools in their processes. The adoption of transactional tools like EDI is more common than the adoption of relational tools. Survey data shows that a large percentage of survey respondents (85%) identified that they use EDI for transactions with supply chain partners. On the other hand, relational tools were being used by a comparatively smaller percentage of respondents. Relational tools such as collaborative design tools, decision support systems, blogs, wikis were being used by 14.35%, 14.35%, 7.83% and 3.48% of the respondents respectively. Another issue might be the length of usage. Some of these relational tools are relative new to industry and many supply chains might have adopted them in the very recent past. As a result, it might be a while before any measurable performance improvements are seen. A second reason for the lack of support for these two relationships might be the presence of a mediating variable. There might be something else that is mediating the relationship between relational IOS and coordination. This will be discussed in the next chapter as part of the future scope of this study.

Hypothesis 11a: *Boundary spanning capability has a positive relationship with Operational Coordination. (Supported)*

Hypothesis 11b: *Boundary spanning capability has a positive relationship with Strategic Coordination. (Supported)*

The data provided strong support to these two hypotheses. H11a was proved to be significant at the 99% level with a t-value of 3.486 and path coefficient of .2. H11b was significant at the 95% level with a t-value of 2.035 and path coefficient of .123. Support for these two relationships highlights the importance of boundary spanning activities in any supply chain. Organizational individuals with boundary spanning responsibilities play a very important role. These individuals act as a go-to between organizations. They are responsible for the transfer and translation of requirements from external to internal entities and vice-versa. Boundary spanners such as purchasing managers also play the role of mediators when issues arise. Thus boundary spanners have a crucial role and a much broader role to play in supply chains. The success of any supply chain depends on the extent to which they are able to manage strategic and operational interdependencies. Effective boundary spanning capability certainly influences how well these interdependencies are managed.

Hypothesis 12a: *Collaborative knowledge management has a positive relationship with Operational Coordination. (Supported)*

Hypothesis 12b: *Collaborative knowledge management routines have a positive relationship with Strategic Coordination. (Supported)*

These two hypotheses were strongly supported by the data. Both hypotheses were found to be significant at the 99% level. H12a had a t-value of 3.173 and a path coefficient of .167. H12b had a t-value of 5.319 and a path coefficient of .295. Strong support to these two relationships emphasizes the importance of joint involvement of supply chain partners in managing knowledge resources. Key activities here are the joint acquisition of knowledge and shared access to knowledge resources. Knowledge management literature has previously addressed the issue of shared routines and interpretations in enabling coordination (Hult et al 2004). Joint creation of knowledge helps supply chain partners in gaining common understanding of processes within the system. This is precisely why major corporations share knowledge resources and databases with their suppliers. The importance of collaborative knowledge management is amplified in the context of increased complexity. Companies dealing with complex products and complex supply bases often resort to the use of knowledge management systems to manage information and know-how within the system. Without such a collaborative system things can easily get out of hand and unmanageable. The ability to have access to and retrieve the required knowledge resources also helps supply chains partners in their quest toward developing new knowledge. Companies find this especially helpful in the area of new product development. Thus collaborative knowledge management is a key enabler of coordination.

Hypothesis 13a: *Supply chain relational capital has a positive relationship with Operational Coordination. (Not Supported)*

Hypothesis 13b: *Supply chain relational capital has a positive relationship with Strategic Coordination. (Supported)*

Relational capital addresses issues of trust, mutual respect and interaction between supply chain partners. The existence of adequate social capital is said to improve communication between supply chain partners and provides access to required resources. The data however only provided partial support to the relationship between relational capital and coordination. The positive effect of supply chain relational capital on strategic coordination was strongly supported at the 99% significance level with a t-value of 2.917 and path coefficient of .176. The data failed to support the relationship between supply chain relational capital and operational coordination. The reason for this might be the existence of an indirect relationship between relational capital and operational coordination, with the mediating variable being strategic coordination. Social interaction, which is a major component of relational capital, might be more common in the higher echelons of a firm's management thus leading to improved coordination at the strategic level. This improvement at the strategic level then most likely translates into improvements at the operational level. Thus, there is lack of support for the direct relationship between relational capital and operational coordination. This is a possible explanation that needs to be further examined. Existent literature provides very limited insight into this issue as studies do not clearly delineate between strategic and operational aspects of coordination.

Hypothesis 14a: *Supplier development has a positive relationship with Operational Coordination. (Supported)*

Hypothesis 14b: *Supplier development has a positive relationship with Strategic Coordination. (Supported)*

Supplier development activities such as supplier evaluation, supplier certification and supplier involvement are extremely common in most large organizations. It is taken on with the aim of improving the performance and output of a firm's suppliers. This study proposes positive impacts of supplier development on coordination at both operational and strategic levels. The relationship between supplier development and operational coordination is strongly supported at the 99% significance level with a t-value of 3.010 and a path coefficient of .177. The data however fails to support the relationship between supplier development and strategic coordination. This was surprising since previous studies (eg: Petersen et al., 2005) have addressed strategic benefits to supplier development activities such as supplier involvement. The support for the positive impact of supplier development on operational coordination indicates that there are definitely continued benefits in monitoring, evaluating and working closely with suppliers. Manufacturers should continue this practice in an effort to improve capabilities in their supply base.

6.3 Revised Structural Model:

The model fit indices of the original structural model were acceptable, except for the AGFI which was below the acceptable threshold at 0.751. At the same time, some of the proposed main relationships were not supported by the data. In an effort to address the unsupported relationships and further improve the model fit indices, changes to the structural model were made. The changes were deemed necessary in an effort to understand the relationships between product complexity - coordination and product complexity – performance. Addressing these relationships is expected to provide more clarity to the issue of complexity and its effects in the supply chain.

The revised structural model is shown in figure 6-2 below. The following changes were made to the revised structural model. First, the path between product complexity and supply chain performance constructs was eliminated. This was replaced by a new path between product complexity and supply base complexity which indicates a positive relationship between the two. Second, a new path proposing a positive relationship between strategic coordination and operational coordination was added. Third, the paths between strategic coordination and the two supply chain performance constructs were eliminated. Fourth, a new path proposing a positive relationship between supply chain efficiency and supply chain responsiveness was added. Fifth, since the role of Relational IOS as a mitigating mechanism was not supported, it was decided to eliminate this construct from the analysis. Sixth, the effect of Transactional IOS on coordination was restricted to operational coordination rather than both forms of coordination. The rest of the relationships remained the same. The objective here was twofold – improve the model fit and also to uncover some other interesting relationships between the constructs.

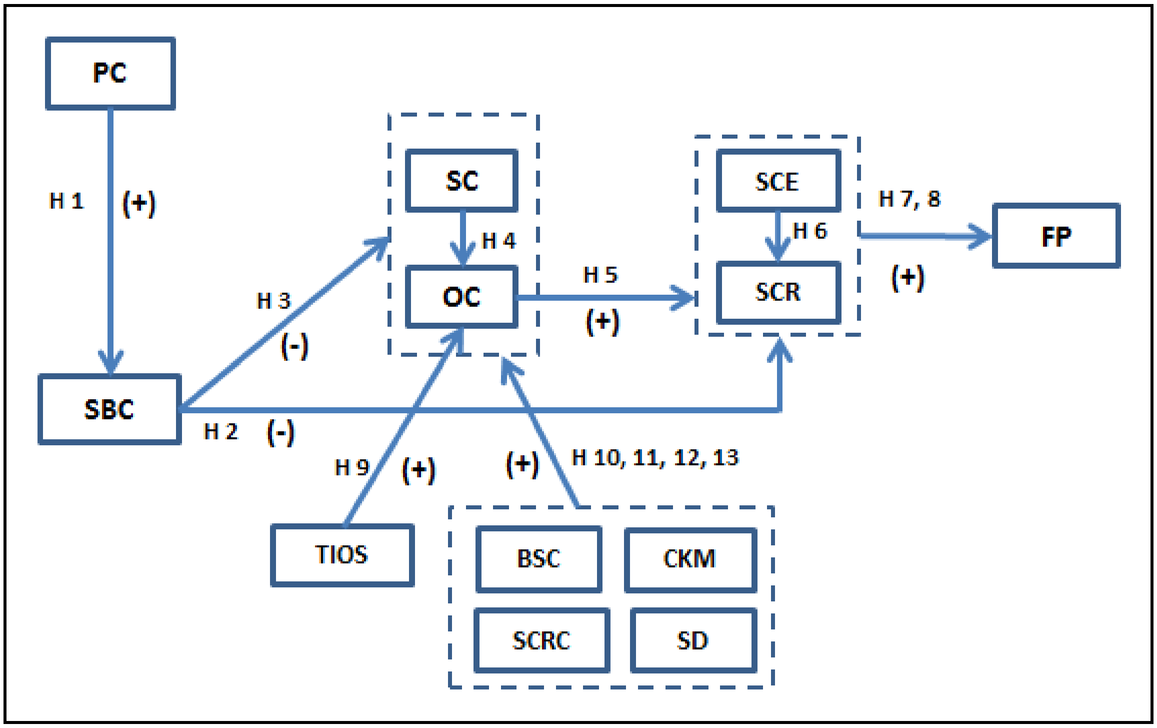

Figure 6-2: Revised structural model

PC = Product Complexity; SBC = Supply Base Complexity; OC = Operational Coordination; SC = Strategic Coordination; SCE = Supply Chain Efficiency; SCR = Supply Chain Responsiveness; FP = Firm Performance; TIOS = Transactional IOS; RIOS = Relational IOS; BSC = Boundary Spanning Capability; CKM = Collaborative Knowledge Management; SCRC = Supply Chain Relational Capital; SD = Supplier Development

6.3.1 Results of the revised structural model:

The revised structural model was tested using AMOS. The model fit indices of the revised model are shown to be better than the original model. Even though GFI remains the same, there is considerable improvement in AGFI which improved from 0.751 to

0.84. NFI remains the same at 0.892. RMR and CFI also show slight improvements. The results of the individual relationships are shown in the table below. 9 out of the proposed 13 relationships are supported. 3 hypotheses are partially supported and 1 fails to find any support. Interestingly, some of the relationships that were supported in the original model failed to receive any support this time around. For instance, the relationship between Supply base complexity and supply chain responsiveness was found to be negative and significant in the original model. The same turned out to be insignificant in the revised model. The relationship between boundary spanning capability and strategic coordination was positive and significant in the orginal model but failed to receive support in the revised model. Relationship between collaborative knowledge management and operational coordination which was earlier positive and significant was deemed insignificant in the revised model. As in the original structural model, there was no support for the mediating role of operational and strategic coordination. This may be an indication that coordination mechanisms moderate the relationship between complexity and supply chain performance.

Table 6.2: Results of hypotheses – Revised structural model

Hypothesis	Proposed Relationship	Regression Coefficient	t-value	Supported or Not
H1	PC➔SBC	.248	4.193***	Yes
H2a	SBC➔SCE	-.187	-2.92***	Yes
H2b	SBC➔SCR	-.031	-.628	No
H3a	SBC➔OC	.073	1.74*	No
H3b	SBC➔SC	-.004	-.089	No
H4	SC➔OC	.328	7.646***	Yes
H5a	OC➔SCE	.756	8.554***	Yes
H5b	OC➔SCR	.163	3.169***	Yes
H6	SCE➔SCR	.533	10.356***	Yes
H7	SCE➔FP	.251	4.090***	Yes
H8	SCR➔FP	.394	6.417***	Yes

H9	TIOS→OC	.202	5.096***	Yes
H10a	BSC→OC	.226	5.398***	Yes
H10b	BSC→SC	.090	1.514	No
H11a	CKM→OC	.039	.999	No
H11b	CKM→SC	.331	6.157***	Yes
H12a	SCRC→OC	.072	1.709*	Yes
H12b	SCRC→SC	.192	3.161***	Yes
H13a	SD→OC	.185	4.387***	Yes
H13b	SD→SC	.192	3.514***	Yes
GFI = 0.94; AGFI = 0.84; RMR = 0.031; NFI = 0.892; CFI = 0.915 *** = p< 0.01; **= p< 0.05; *= p< 0.1				

6.3.2 Discussion of new paths in the revised structural model:

H1 (Revised model) *– Product complexity has a positive relationship with Supply base complexity. (Supported)*

The nature of the product being manufactured by a firm, to a large extent, dictates the structure of the firm's supply chain. For instance, if the product being manufactured is fairly simple in terms of design and requires standard components that are easily available in the open market, the firm is more likely to engage in arm's length relationships focused on getting the best price. On the other hand, manufacturing a complex product like a car calls for a different kind of supply chain structure. A car is a complex product made of thousands of components and many of these components are complex in terms of their underlying technology. Large number of individual components would mean an increase in the number of suppliers in the supply base. Complex underlying technology would necessitate the need for increased involvement with supply base and also increased dynamics within the supply base. Many a times, novelty of the associated technology adds another layer of complexity to the supply base and the resulting interactions. With an increase in the number of suppliers in the supply base, the level of differentiation in terms of practices and skills is also likely to increase. All these factors put together results in a supply base with a higher level of complexity.

This relationship was strongly supported at the 99% significance level with a t-value of 4.193 and a path coefficient of .248.

H4 (Revised model) *– Strategic coordination has a positive relationship with Operational coordination. (Supported)*

The notion that strategy influences operation is widely accepted in management literature. Porter (1990) discusses the influence of strategy for operational effectiveness and performance. Kaplan and Norton (1996) present a management system linking strategy to operations where the strategic plan is the basis for the operational plan, which in turn leads to the execution stage. In the same vein, coordination at the strategic level is expected to have positive impacts on coordination at the operational level. The intent and willingness to share strategic information and make joint decisions at the strategic level is expected to give the necessary push for increased cooperation and collaboration at the operational level. Strategic coordination is more often than not the domain of top management and upper middle level management. Once organizations and supply chain partners agree to coordinate for strategic activities, this is expected to eventually translate into improved coordination at operational level. This relationship was strongly supported at the 99% significance level with a t-value of 7.646 and a path coefficient of .328.

H6 (Revised model) *– Supply chain efficiency has a positive relationship with Supply chain responsiveness. (Supported)*

Supply chain efficiency and Supply chain responsiveness are two commonly used performance metrics in supply chain literature. Organizations and supply chains are constantly trying to improve these two aspects of supply chain performance. Numerous antecedents have been identified for these two measures of supply chain performance. However, the relationship between the two has not been addressed. Theories of competitive capabilities and trade-off suggest that it is a question of one or the other and firms cannot have both. However, companies have realized that survival and success in today's time depends on the extent to which firms can achieve both efficiency and responsiveness. It is not necessary that they have to be the best at both. However, it is not sensible for firms to ignore one of them. The best supply chains in operation today are equally well known for their efficiency as well as responsiveness. For instance, consider the supply chains of computer manufacturers like HP and Dell. They are hailed for their customer responsiveness. At the same time, they do operate in a very efficiency manner. Hopp and Spearman (2004) describe the example of a company called Moog Inc. which is a manufacturer of precision servo valves. They describe the use of lean practices in this company to improve overall efficiency. As part of the lean initiative, inventory buffers were gradually reduced over time and at the same time optimal inventory levels for some of the items were determined. Along with an increase in efficiency, the company also noticed that customer responsiveness and service levels also improved. Thus, the proposed relationship suggests that supply chain efficiency can have a positive impact on supply chain responsiveness. This relationship was strongly supported at the 99% significance level with a t-value of 10.356 and a path coefficient of .533.

6.4 Testing for Common Method Bias:

Common method bias or common method variance is a concern in survey research. This refers to “variance that is attributable to the measurement method rather than to the construct of interest” (Bagozzi and Yi, 1991; p. 426). Among the many potential sources of common method bias, common rater effect is prominent. This effect refers to the artifactual covariance between the predictor and the criterion variable produced as a result of both these variables being rated by the same individual (Podsakoff et al., 2003). The ideal way to do away with common rater effect is to have two different respondents for the predictor and criterion variables. However, this may not be practical/possible given the diminishing survey response rates in the recent past. Some of the suggested survey design remedies to deal with this include (a) assuring and ensuring anonymity of the respondent and thus reducing the likelihood that their responses are edited to be more socially desirable; and (b) Temporal separation of predictor and criterion variables by situating the two in different sections of the survey (Podsakoff et al. 2003). In this study, these two design precautions were incorporated into the administered survey instrument.

A commonly used post-hoc statistical technique to test for common method variance is Harman’s single factor test (Andersson and Bateman, 1997; Aulakh and Gencturk, 2000). This technique involves entering all variables into an exploratory factor analysis to determine whether one single factor accounts for a large percentage of variance. The assumption is that if there is considerable common method variance, either one single factor will emerge or one single factor will account for a majority of covariance among measures (Podsakoff et al. 2003). In this study, survey items were entered into exploratory factor analysis and the number of factors extracted was fixed to 1. The resulting percentage of variance extracted by a single factor was 21.47%. This number is small enough to suggest that common method variance is not a concern.

6.5 Chapter Summary:

This chapter describes the assessment of the structural model and testing of individual relationships that were part of the structural model. The structural model was assessed using model fit indices provided by AMOS. Individual relationships were assessed based on the path coefficient and their significance. The research model presented in this study proposed 14 main relationships. Evaluation of this structural model indicated support for 8 of the hypotheses, partial support for 2 and no support for 4 hypotheses. In an effort to improve the overall model fit, a revised structural model was presented. The model fit of the revised model was slightly better than the initial model. Three additional relationships were proposed as part of this new model. In total, 13 main relationships were part of the new model. 9 out of the proposed 13 hypotheses were supported. 3 hypotheses were partially supported and 1 was unsupported.

Based on the results of this empirical study, the next chapter will discuss academic contributions, practical implications, limitations, and future research directions.

Chapter 7

Contributions, Limitations and Future Research

This chapter discusses (1) academic contributions of the study, (2) contributions to practice, (3) limitations and (4) scope for future research.

7.1 Academic Contributions:

Complexity is an integral part of any manufacturing system or supply chain. This level of complexity has however increased gradually over the years and the trend seems to continue. Companies have been struggling to manage the effect of complexity in their supply chains. The effort to reduce complexity in the system in terms of product and supply base complexity is not always an option as customers and competition fuel the need for better products with more features and functionalities. Technological advancement has also resulted in products that were beyond the realm of imagination just a few years ago. The only option for manufacturers in such a situation is to explore ways to manage the effects of complexity. Inability to manage this will eventually hurt the bottom-line of companies. This study addresses this important issue and explores the effect of complexity on performance and proposes mechanisms to manage the effects of complexity in the supply chain.

Current studies on supply chain complexity look at either product complexity or supply base complexity (eg: Closs et al., 2010; Jacobs and Swink, 2011; Bozarth et al., 2009; Choi and Krause, 2006). This study is one of the early ones to explore the effect of both product complexity and supply base complexity. It is also one of the first ones to examine the relationship between complexity and coordination at both operational and strategic levels. Empirical data collected from 270 supply chain professionals in the US manufacturing industry are used to examine the proposed relationships. The results of this study enhance our understanding of various facets of complexity, coordination, performance and their interactions. Some of the main contributions to theory are identified below.

First, this study draws concepts from three theories – Complexity theory, Coordination theory and Information Processing theory and links them in an effort to provide a better understanding of intricate relationships in a supply chain context. In doing so the study provides a theoretical framework to understand and explain how product complexity and the resulting supply base complexity increases information processing needs within the supply chain and how the inability to process information or the lack of information processing capability creates coordination challenges in the supply chain, thus affecting performance.

Second, this study identifies the role of Operational coordination, Strategic Coordination in the context of system complexity. It builds on previous studies (Lee, 2000; Simatupang et al 2004; Kanda & Deshmukh, 2008) and identifies multiple dimensions of operational and strategic coordination. It differs from previous studies (Sanders, 2008; Simatupang et al 2004) by identifying coordination dimensions other than information sharing. Decision synchronization and Collective Learning are identified in addition to Information Sharing. This is a contribution to the development of coordination as a multi-dimensional construct.

Third, various mechanisms that mitigate the effects of product complexity and supply base complexity on performance are identified and tested. These mechanisms are crucial in managing the ill effects of complexity in the system. The use of Transactional IOS tools and Relational IOS are identified as information technology (IT) based mechanisms to increase information processing capability and thus manage the effects of complexity. Other mechanisms that are not predominantly IT based are also identified in this study. For instance, improving supply chain relational capital and focusing on supplier development activities are found to be effective in managing the effects of complexity in the supply chain. Examination of the indirect effect of these mechanisms on performance and the idea that they can be considered as coordination enhancers provides additional justification for their continued role in supply chains. The use of information processing theory to explain the mitigating effect further validates the applicability of the theory in the supply chain context.

Fourth, this study develops and validates measurement instruments for ten constructs - Product complexity, Supply base complexity, Operational Coordination, Strategic Coordination, Transactional IOS, Relational IOS, Boundary Spanning Capability, Collaborative Knowledge Management, Supply Chain Relational Capital and Supplier Development. These instruments can be used by researchers in future studies.

Fifth, the results of the structural model highlight a few interesting and surprising relationships. The study initially proposed a negative effect of product complexity on supply chain performance, which was not supported by the data. This indicates that the relationship between product complexity and supply chain performance is probably mediated by another variable. The examination and subsequent support for supply base complexity as a mediating variable between product complexity and supply chain performance indicates that product complexity has a profound effect on the structure of the supply chain. The lack of support for coordination as a mediator between complexity and supply chain performance suggests that supply chain contracts and incentive mechanisms may be strong determinants of coordination in the supply chain. The results indicate the importance of operational and strategic coordination between supply chain partners in improving supply chain performance. The results also validate the importance of both IT and non-IT means in improving coordination between supply chain partners.

Interestingly, the lack of support for some of the proposed relationships goes against conventional notion. The results suggest that product complexity does not directly impact supply chain performance, which is counterintuitive to what is suggested in theory. The lack of support for the negative relationship between complexity and coordination again goes against accepted theory. These counterintuitive results call for further examination of theory concerning (a) the relationship between product complexity and supply chain performance; and (b) mediating role of coordination in the relationship between complexity and supply chain performance. Rather than dismissing these results as anomalies, it is worthwhile examining them as new directions to existing theory. Exploring further the context in which these new directions occur is important for further developing them. These unexpected results further contribute to the uniqueness of this study.

7.2 Contributions to practice:

First, this study contributes to practice by addressing and identifying the impacts of various aspects of product and supply base complexity on performance as a whole. Supply chain managers will find this extremely useful in their quest to manage the ever changing dynamics and interactions in the supply chain. By identifying the various components of complexity, this study helps managers gain a better understanding of factors that contribute to increase in complexity in the supply chain. More importantly, this study makes an effort to show managers the need to shift focus from "reducing complexity" to "managing complexity".

Second, this study highlights the importance of information sharing, decision synchronization and collective learning in the supply chain. It emphasizes the importance of sharing strategic information and joint decision making with regards to strategic activities. It shows that there are tangible benefits to coordination at both operational and strategic levels. Improved efficiencies in terms of overall cost, quality and delivery reliability are some of the benefits of operational coordination in the supply chain. Increased coordination at the strategic level translates into faster response to changes in customer demand and market conditions.

Third, this study identifies both IT and non-IT mechanisms that organizations can employ in an effort to improve coordination with supply chain partners. It shows the benefits of having shared information systems i.e inter-organizational systems (IOS). It outlines the appropriations of IOS for transactional tasks as well as relational tasks. Transactional systems can be used for automation and standardization of day-to-day supply chain processes such ordering, invoicing, production scheduling and inventory management. Relational systems are appropriate when the task on hand requires collaboration and handling of unstructured information. These systems can be used for brainstorming, collective problem solving, forecasting and identifying trends. Additionally, this study highlights the benefits of IOS for organizations that are skeptical about the use and deployment of IOS in their supply chain. It identifies the importance of boundary spanning roles and benefits of social capital in buyer-supplier relationships.

The contributions identified above can be beneficial to organizations looking to improve supply chain performance. It can help identify areas of improvement and prioritize deployment of resources based on intended outcomes. For instance, organizations facing coordination challenges at the operational level might be better off investing in inter-organizational systems (IOS) that can standardize, automate and improve information flows between supply chain partners. However, this solution is fairly capital intensive requiring buy-in from internal as well as external partners. Another area of focus might be creating more effective interfaces between supply chain partners. This is where the role of boundary spanners comes into the picture. Individuals with boundary spanning roles can pave the way for better coordination by enabling communication and information exchanges. This calls for boundary spanners who are well aware of organizational and inter-organizational processes. Training and experience can be handy here. Organizations looking to improve planning activities with a long term focus might be better off starting at the upper echelons of management in an effort to building trust and improving relations with supply chain partners. Closer interaction with supply chain partners can be an effective way to build trust and mutual respect. Sharing strategic information with supply chain partners in terms of forecasts, customer/technology trends can provide benefits in the form of improved efficiency and responsiveness throughout the supply chain. Investing in Collaborative Knowledge Management systems can also be considered in the long run.

7.3 Limitations:

As with most studies, this study has its limitations. Single respondent bias is one such limitation in this study. This arises from the fact that a single respondent is asked to answer questions about both the practices and performance of the organization. However, because of declining response rates to surveys it is extremely challenging to get multiple respondents from the organization to answer different parts of a survey.

The lack of secondary data for the performance constructs can be seen by some as a limitation. The presence of secondary data is useful when dealing with constructs such as firm performance. It gives a researcher an additional option to validate the results of the study.

The sample size of 270 may be considered a limitation taking into account the number of constructs and size of the research model. A larger sample size would have been ideal when testing such a complex structural model.

The final limitation might be with respect to some of the measurement instruments. For instance, the two main complexity constructs have reliability scores in the range of 0.7 and one of the control variables (Environmental Uncertainty) has a reliability score of 0.62. Since the complexity constructs form the crux of the study, it would have been ideal to have higher reliability scores for these two constructs.

7.4 Scope for future research:

This study has proposed a research framework and operationalized the framework by identifying constructs that fit into the framework. Future research could look into developing the framework further or on the other hand could identify additional constructs that can be developed into a much more exhaustive research model. It is also worthwhile looking further into the two complexity constructs to identify other dimensions of complexity, if any. The same can be said about the two coordination constructs.

Another interesting option would be to develop a research model where operational coordination and strategic coordination are tested as moderators for the relationship between complexity and performance. The proposed mitigating variables can also be tested as moderators for the relationship between complexity and supply chain performance. Future research could consider collecting secondary data along with primary data from public companies in an effort to further validate some of the relationships proposed in this study. Development of measurement instruments based on secondary data for product complexity and supply base complexity can be extremely interesting. Development of a complexity index for products and supply chains is something that could be considered.

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Appendix A

Sample Demographics

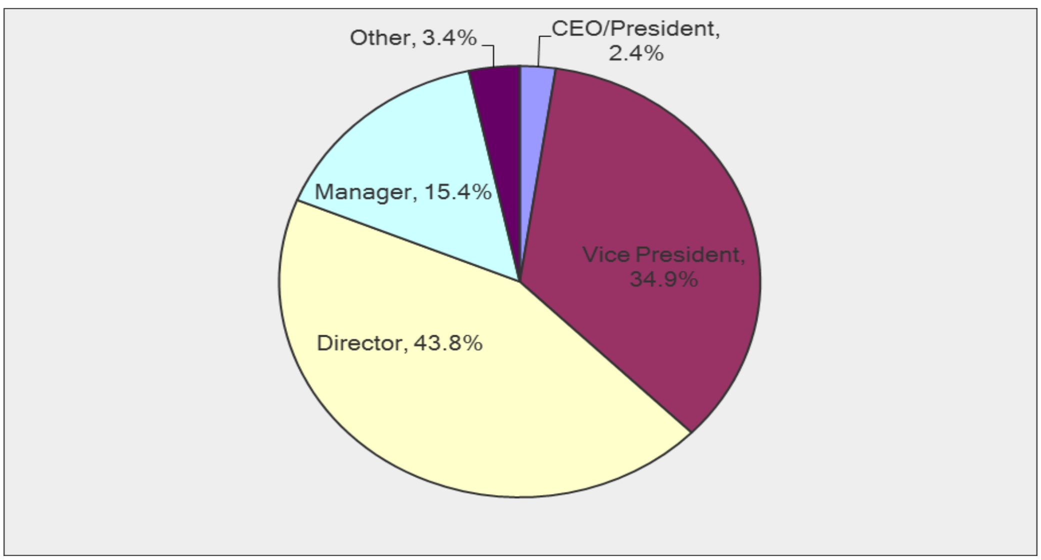

Figure A-1: Respondents by job title

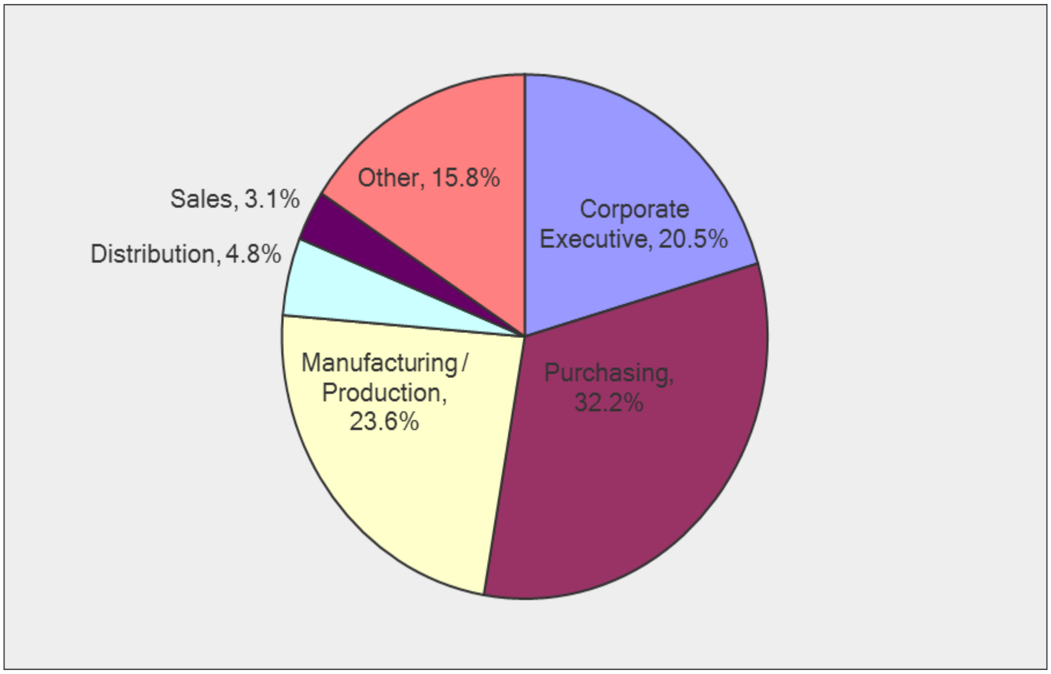

Figure A-2: Respondents by job function

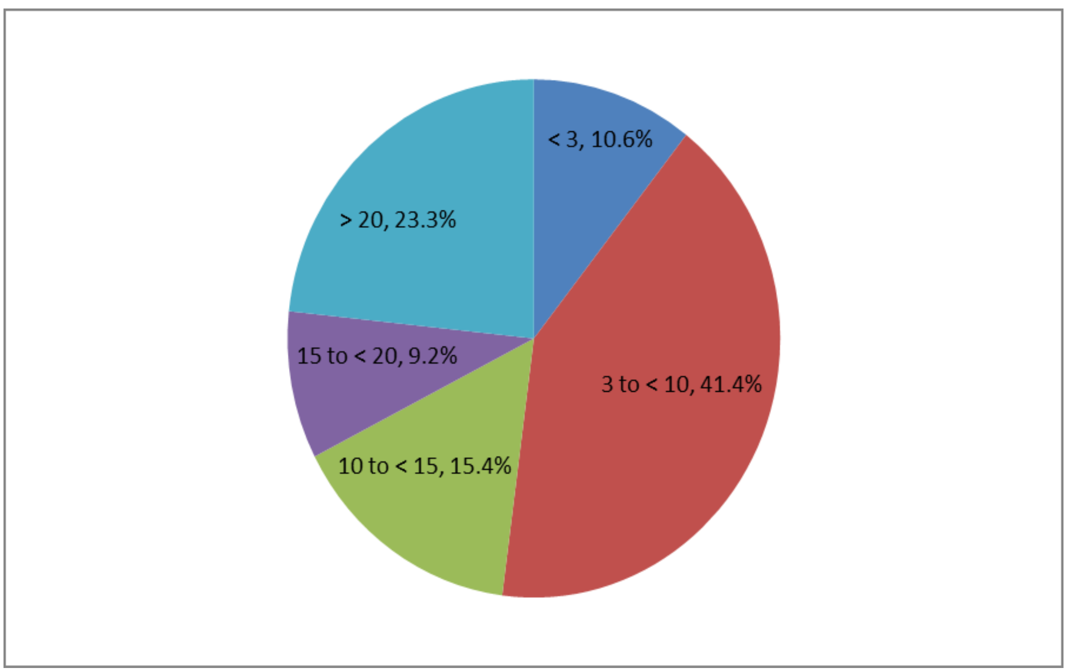

Figure A-3: Respondents by number of years in the organization

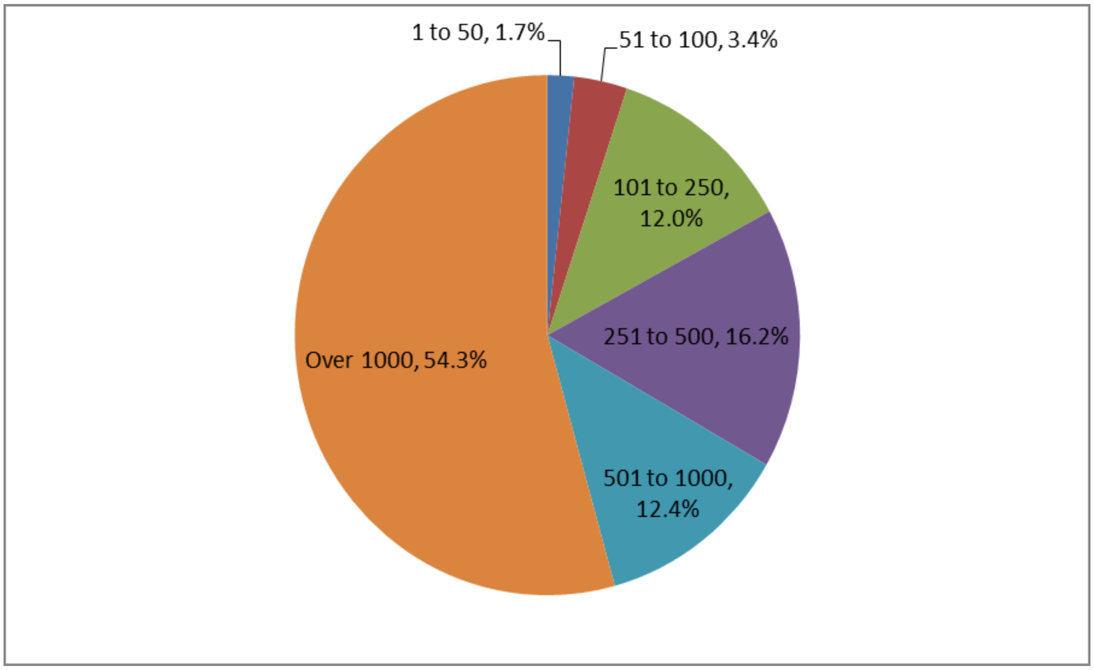

Figure A-4: Firm size (number of employees)

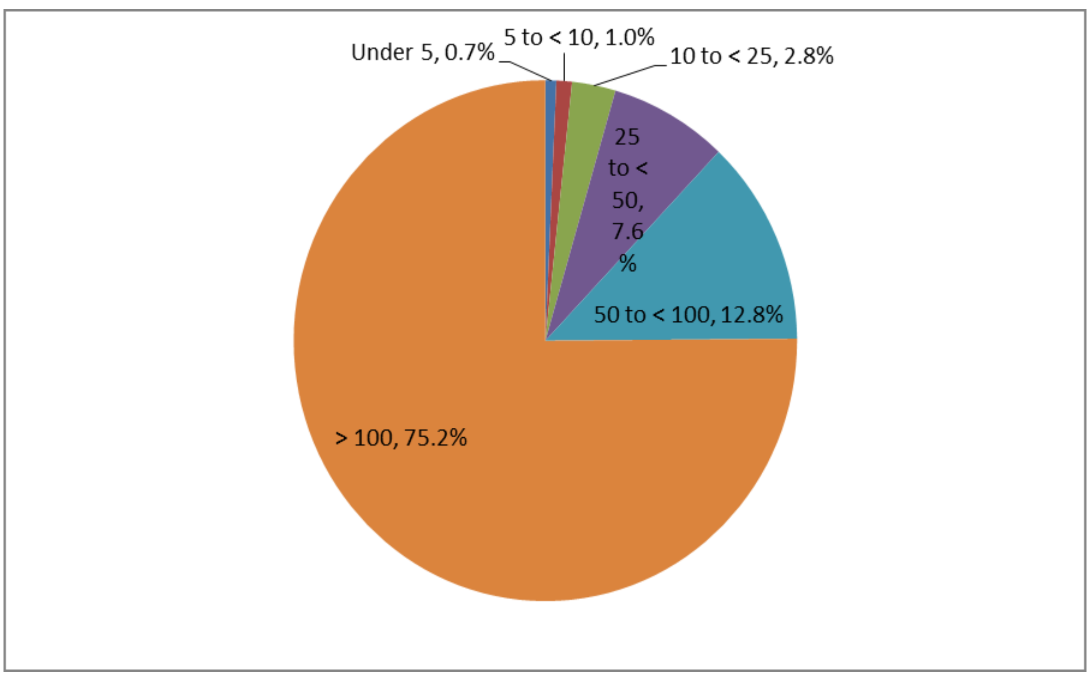

Figure A-5: Annual sales of respondent firms in millions of $

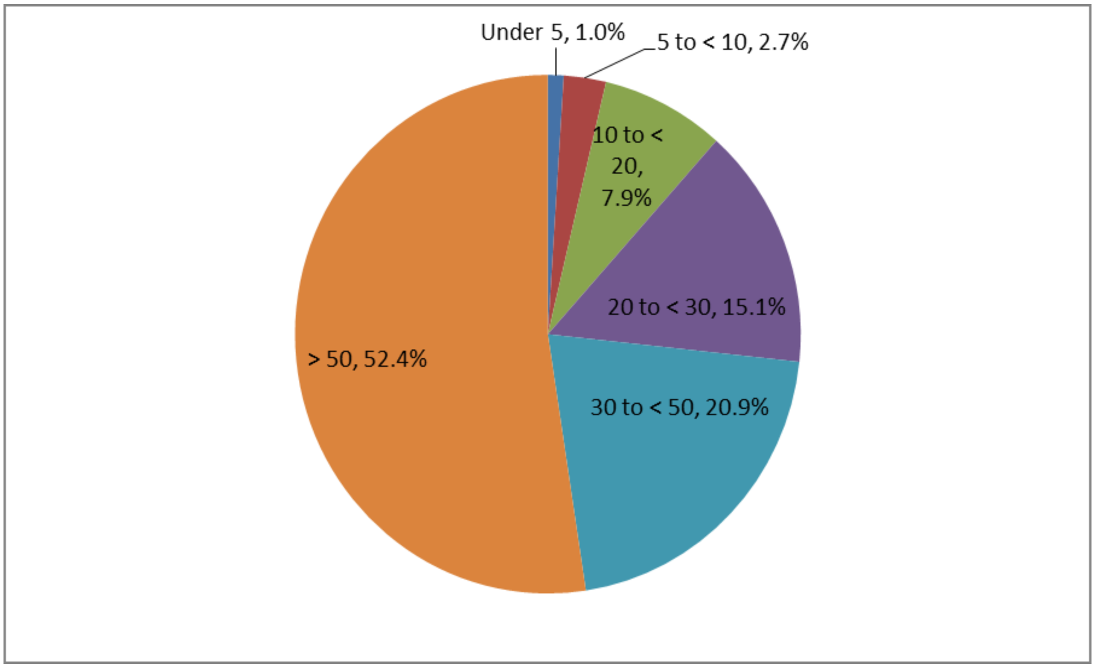

Figure A-6: Age of the respondent firms

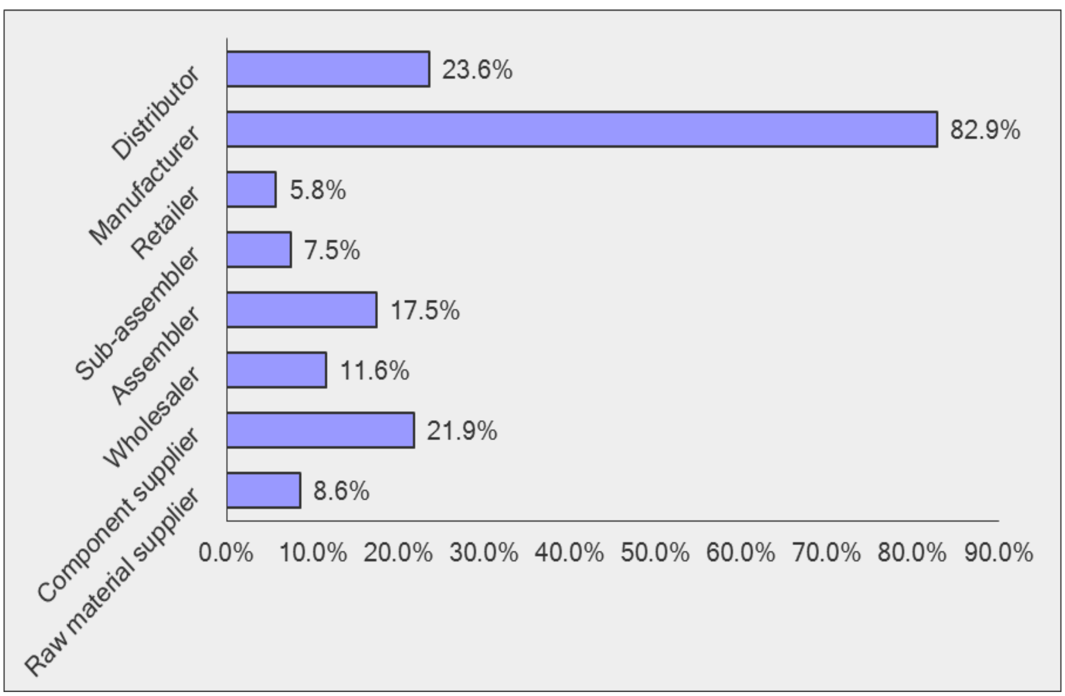

Figure A-7: Firms' position in the supply chain

Appendix B

Discriminant Validity

Table B.1: Correlations and Discriminant Validity

	PC	SBC	TIOS	RIOS	BSC	OIS	ODS	OCL	SIS	SDS	SCL	CKM_ AQ	CKM_ AC	SCRC	SD_SE	SD_SI
PC	**0.617**															
SBC	0.277	**0.671**														
TIOS	0.248	-0.051	**0.815**													
RIOS	0.128	-0.118	0.616	**0.851**												
BSC	0.117	-0.151	0.046	0.158	**0.682**											
OIS	0.254	0.162	0.452	0.318	0.244	**0.686**										
ODS	0.314	0.088	0.413	0.279	0.332	0.443	**0.767**									
OCL	0.144	0.002	0.415	0.389	0.400	0.583	0.625	**0.772**								
SIS	0.297	0.006	0.346	0.332	0.465	0.503	0.433	0.551	**0.659**							
SDS	0.148	-0.059	0.315	0.304	0.269	0.530	0.495	0.634	0.598	**0.796**						
SCL	0.161	0.057	0.275	0.335	0.347	0.480	0.498	0.575	0.674	0.650	**0.743**					
CKM_AQ	0.059	0.085	0.180	0.317	0.451	0.163	0.246	0.483	0.506	0.388	0.508	**0.848**				
CKM_AC	0.018	-0.063	0.225	0.344	0.178	0.175	0.206	0.390	0.425	0.311	0.303	0.507	**0.886**			
SCRC	0.074	-0.053	0.226	0.304	0.613	0.244	0.237	0.452	0.464	0.255	0.482	0.510	0.247	**0.763**		
SD_SE	0.348	0.063	0.351	0.204	0.351	0.349	0.297	0.297	0.350	0.201	0.216	0.143	0.088	0.311	**0.842**	
SD_SI	0.292	0.188	0.496	0.379	0.360	0.543	0.507	0.534	0.508	0.387	0.515	0.456	0.319	0.413	0.513	**0.698**