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Supply Chain Flexibility: the Antecedents, Driving Forces, and Impacts on Performance

By

Ying Liao

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An Abstract of

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Supply chain flexibility has emerged as an important strategy for achieving competitive advantages. This study represents one empirical effort to develop a conceptual framework of supply chain flexibility and explore the complex relationships among the antecedents, driving forces, supply chain flexibility, and its impacts on performance.

Valid and reliable measures of supply flexibility, logistics flexibility, spanning flexibility, and outsourcing were developed. The instrument development process involved an extensive review of literature, structured interviews with practitioners and evaluations with experts in the field, a pilot study, and a large-scale survey. The large-scale survey yielded 201 responses from supply chain/purchasing/operations/logistics executives. Structural equation modeling (AMOS) methodology was used to test the

causal relationships between constructs.

The research results support the hypotheses that higher levels of supply chain practices will lead to improved supply chain flexibility, and improved supply chain flexibility further will bring about improved performance. It also supports the direct relationship between environmental uncertainty and supply chain flexibility.

The results of this study have several important implications for practitioners. Postponement, information flow facilitation, and supplier management are supply chain practices that an organization may consider to adopt to improve different aspects of supply chain flexibility. A set of valid and reliable measurements developed in this study enable the companies to evaluate supply chain flexibility, and further benchmark across different companies. Moreover, the findings also imply that fast changes in supply side, customer demand, technology, and competition drive companies to implement supply chain strategy to achieve competitive advantages.

Directions and recommendations for future research include refinement of construct definition and measurement items for revalidation; examination of the relationship between supply chain flexibility and overall supply chain performance in a variety of industry settings to confirm a generalized flexibility – performance linkage; and examination of the proposed relationships by bringing some contextual variables into the model, such as organizational size and supply chain structure.

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1. INTRODUCTION

Supply chain is regarded as a continuous process to produce and deliver a final product or service, from the first supplier to the final customer (Supply Chain Council, 2004; Mentzer et al., 2001; Tan, 2001). The supply chain encompasses all the information, physical and financial flows across the value delivery chain of the manufacturer, its suppliers, and its downstream channel members. As pointed out by numerous researchers, traditional competition of company versus company is changing toward a business model where supply chains compete against supply chains (Christopher, 1992; Spekman et al., 1994; Vickery et al., 1999). Supply chain management, therefore, is implemented to enhance competitive performance by closely integrating the internal functions within a firm and effectively linking them with external operations of suppliers and other channel members. The strategic importance of supply chain management has been widely underscored.

Rapid evolving technologies, increasingly competitive intensity, turbulent markets and increased supply chain complexity have contributed to making the current business environment more turbulent, complex and uncertain. The uncertainty may be about future demand from customers, about a supplier's ability to meet a delivery promise, or about the quality of materials or components from suppliers (Davis, 1993). A typical response to uncertainty is to build flexibility into the supply chain (Day, 1994; Prater et al., 2001; Zhang et al., 2002). Numerous authors have identified the need to manage, reduce or eliminate the impact of uncertainty across the supply chain through flexibility (Chistopher, 1992; Towill et al., 2002). Supply chain flexibility enables companies to introduce new products quickly (Lummus et al.,2003; Zhang et al., 2003; Mahapatra and Melnyk, 2002), support rapid product customization (Zhang et al., 2003; Mahapatra and Melnyk, 2002), shorten manufacturing lead times (Garavelli, 2003; Zhang et al., 2003; Wadhwa and Rao, 2003), reduce cost for customized products (Zhang et al., 2003; Mahapatra and Melnyk, 2002), improve supplier performance (Garavelli, 2003; Zhang et al., 2003), reduce inventory levels (Lummus et al., 2003; Zhang et al., 2003; Aggarwal, 1997), and deliver products in a timely manner (Lummus et al., 2003; Zhang et al., 2003; Mahapatra and Melnyk, 2003). Fashion, mobile phone, and bicycle industry are examples of industries that have attempted to implement supply chain flexibility strategy with varying degree of success (Christopher et al., 2004, Catalan and Kotzab, 2003; Fisher, 1997). Wal-Mart, Hewlett Packard (HP), General Electric Inc., and Benetton exemplify the benefits of supply chain flexibility (Christopher et al., 2004; Prater et al., 2001). Many firms are now beginning to recognize that supply chain flexibility is crucial to build sustainable competitive edge in an increasingly turbulent marketplace.

Understanding flexibility as an important strategy from a supply chain perspective is critical in the supply chain management for several reasons. First of all, according to Lau (1996), flexibility has become more important today in achieving competitive advantage as the environment is changing faster than ever before. In many innovative product categories, such as computer and electronic devices, uncertainty of customer requirements and demand is a fact of life and creating a responsive supply chain is one method of avoiding the impacts of uncertainty (Fisher, 1997). Secondly, achieving flexibility can be expensive if companies insist focusing on internal operations only (Slack, 1987; Fisher, 1997). For instance, companies are delivering customized products for specific customers by allowing them to provide specific desired product specifications. In order to create such customer values, traditionally, companies may choose to spend money on excess inventories, additional capability to change (i.e., machinery, skilled workers), additional time necessary to change, and the cost of disruption. However, in the context of supply chain, flexibility does not always require complex and expensive machinery. Flexibility has been argued to be available without major investment in technology (Aggarwal, 1997). One method of improving a firm's responsiveness is through the strategic approaches of supplier management, which emphasizes supplier's contributions to the value creation within the supply chain. A company may, rather than producing a large range of products itself, use a network of suppliers to deliver such product mix flexibility (Mason et al., 2002; Upton, 1994). In other words, suppliers in the network needed to be more flexible and willing to take greater risks in co-developing customized products. Thirdly, cross-functional and inter-organizational efforts are critical for the improvement in variety and speed of responses as a reaction to uncertainty (Yusuf et al., 1999; Gunasekaran, 1999). From a system perspective, most flexibility is achieved with certain collaborative arrangements with suppliers or other partners in the supply chain on the basis of a variety of hardware, methods, and systems. A successful company must therefore acquire the capability to achieve and explore the competitive advantages in synergy across the supply chain (i.e., responsive logistics, information sharing across supply chain partners) (Gunasekaran, 1999; Narasimhan et al., 2004). For example, Benetton captures information at the retailer point-of-sale and transmits this information back to production facilities (Christopher, 1998). Benetton's manufacturing process can reduce response time by several weeks in that way. Finally, recent trends, such as supply chain integration and outsourcing, make the achievement of high-level performances in terms of cost, quality and time to market ever more dependent on the quality and effectiveness of the supply network. Companies are forced to wonder just how vulnerable their supply chains are to unforeseen disruptions. For example, what if a supplier faces a labor strike? The unforeseen events like this, can have devastating effects on business operations, and result in millions of lost dollars. The company may need to reassign the tasks between supply sources and logistics networks on a timely basis. In other words, companies must have the ability to restructure the supply chain quickly and economically (Lummus et al., 2003). In particular, "after September 11, 2001, the security of supply chain has become a major concern to public and private sectors" (Lee and Whang, 2005). Unsecured supply chain is risky with unauthorized delays and real/potential incidents that could create a negative disruption or additional cost to maintain smooth material and information flows. With appropriate management approaches, new technology, and re-engineered operational processes, companies can create an adaptive and responsive supply chain which allows them to effectively achieve high supply chain security (Lynch and Mornis, 2003). Without good understanding of supply chain flexibility in the front-end, it is less clear about what it takes to make a supply chain flexible and its impact on performance outcomes.

Supply chain flexibility was first discussed as a performance measurement in supply chain, which is to measure a supply chain's ability to accommodate volume, diversity and schedule fluctuations from supply chain entities (Beamon, 1999; Chan, 2003). Recent research stared to view supply chain flexibility from a strategic perspective (Duclos et al., 2003; Zhang et al., 2002; Lee, 2004). Supply chain flexibility is now recognized as a crucial weapon to increase competitiveness in such a complex and turbulent marketplace, especially for innovative products (Day, 1994; Prater et al., 2001; Duclos et al., 2003; Fisher, 1997). Koste and Malhotra (1999b), while presenting a perspective on research opportunities in manufacturing flexibility, emphasized that the flexibility in the supply chain as a competitive edge should be explored. A flexible supply chain is one with the ability to respond to changes in customer demand as well as upstream changes. Developing competence in supply chain flexibility is expected to have long-term impact on the supply chain competitiveness and business performance.

In spite of these efforts, the availability of the literature with clear definition of supply chain flexibility is still limited to date. Supply chain flexibility is a complex, multidimensional, and hard-to-capture concept. The confusion and ambiguity about supply chain flexibility seriously inhibit its effective implementation and management. In some literature on supply chain flexibility, it is inherent to the concept of supply chain agility. According to Christopher (2000), the agile supply chain is market sensitive, virtual, network-based, and process aligned. This is supported by Naylor et al. (1999) and Prater et al. (2001), who suggested that agility means using market knowledge to deliver customer value in a volatile marketplace. Other studies emphasized the network-based characteristic and stated that agility requires the ability to thrive on change and uncertainty based on the flexible structure, in which the rapid reconfiguration of resources is possible (Dreyer and Gronhaug, 2004). Along with a different line, Narasimhan and Das (2000) argued that firms who want to achieve high agility should focus on developing high levels of operational flexibilities. Therefore, flexibility is regarded as a key characteristic of agile supply chain (Christopher, 2000). In the exploratory research of Prater et al. (2001), Lummus, et al. (2003), and Vickery et al. (1999), Supply chain flexibility is defined as the ability of an organization's supply chain to effectively and economically respond to internal and external uncertainties. This definition depicts the purpose of supply chain flexibility, while the nature of it is still not clearly defined. Referred to the concept of agile supply chain, supply chain flexibility is both market-oriented and network-focused. From the perspective of satisfying customer demands, the focus is to maximize the speed of response to changes in customer expectations. Supply chain flexibility is then viewed as external capabilities to adapt to provide products and services in a rapidly changing market. External capabilities are founded on the internal competencies of a supply chain. That is, supply chain network competences become the foundation for external, customer-facing capabilities (Zhang et al., 2002). From the network-focused point of view, Prater et al. (2001) breaks the concept of supply chain flexibility into the promptness with and the degree to which a firm can adjust its supply chain speed, destinations, and volumes. Lummus et al. (2003) defines that flexibility of entire supply chain is a result of interrelationships among supply chain partners. It reflects the network abilities that enable firms to cope with changes from suppliers, market, and technology etc. Firms who can better structure, coordinate, and manage the relationships with their partners in a network commit to better, closer, and more flexible relationships with their final customers (Christopher, 2000). It can be argued that the route to sustainable flexibility lies in being able to leverage the respective strengths and competencies of network partners to achieve greater responsiveness to market. The definition of supply chain flexibility should explicitly describe the nature of coordination between supply chain partners as well as market orientation. Therefore, supply chain flexibility is defined here as the firm's ability of configuring and managing the supply chain through collaboration supply chain partners in responding to a rapidly change environment in an effective and efficient manner. This above definition reveals several meanings: (1) each supply chain entity is a key determinant of the ability of the overall supply chain to make rapid changes with respect to market changes (Lummus et al., 2003; Mason et al., 2002); (2) supply chain flexibility includes the inter-organizational coordination. It engages technology, process, information and human factors towards coordination for developing a pattern of relationship that has capability to reconfigure supply chain and address uncertainties (Mahapatra and Melnyk, 2002); (3) flexibility in dealing with rapid changes must not result in performance deterioration such as a loss of productivity and quality (Ahmed et al., 1996; Volberda, 1998); and (4) the purpose of implementing supply chain flexibility is to mitigate the impact of uncertainty on business performance (Dreyer and Gronhaug, 2004).

There is no doubt that supply chain flexibility is a multi-dimensional construct. The literature on flexibility has a dominant functional orientation. Flexibility is discussed in related to supply chain functions such as sourcing, manufacturing, delivery, product development, and delivery (Vickery et al., 1999; Pujawan, 2004; Swafford et al., 2000). In this perspective, functions they refer to have been developed into a holistic process to be managed across organizational boundaries. Chan (2003) simply categorized flexibility into input, processes, output, and its improvement within the supply chain. Although there is only a limited number of authors have begun to discuss flexibility from the supply chain perspective, recent research goes beyond process alignment because the flexibility of the entire supply chain is a result of both the functional entities responsiveness and supply network characteristics (Lummus et al., 2003). From this point of view, supply chain flexibility should be captured in related to not only supply chain functions but also supply chain configuration (i.e., inter-organizational connectivity, and buyer/supplier relationships) (Zhang et al., 2002; Young et al., 2003). For instance, as product life cycles become shorter and shorter, managing product changes is now a routine challenge faced by many high-tech companies. Engineering changes involved in product changes may require new suppliers, new bills of materials, and new requirements for existing parts. Companies must be able to restructure the supply chain including supplier, contract manufacturers and service supports in a timely manner (Lee and Whang, 2005). The companies that achieve flexibility through a constant review and realignment of closely linked supply chain networks can be found in different industries across the world (Bruce et al., 2004; Fisher, 1997; Catalan and Kotzab, 2003). The enhanced synchronization across the chain has been shown to help speed up product development and introduction (Kulp et al., 2005; Lee and Whang, 2005).

Regardless of the increased attention to and numerous expectations from supply chain flexibility, many problems still exist in the implementation of supply chain flexibility by organizations. Three critical issues are missing in previous studies relating to supply chain flexibility. First, though there have been some studies extending the concept of flexibility to the context of supply chain (Fisher, 1997; Christopher, 2000), most of these studies are functionally focused and fail to show the cross-functional, cross-business nature of supply chain flexibility (Lummus et al., 2003). For example, the potential of certain types of functional flexibility (i.e., manufacturing flexibility, logistics flexibility) to enhance the lead time performance of supply chain attracted the attention of some researchers and as a result number of studies could be found in the literature (Wadhwa and Rao, 2003; Garavelli, 2003). However, the concept of supply chain flexibility remains vague. The empirical studies that validate sound conceptual models of supply chain flexibility and the establishment of a reliable and valid instrument to measure the concept of supply chain flexibility are still lacking.

Second, although benefits of flexibility (i.e., manufacturing flexibility, product development flexibility) in enhancing organizational performance are documented in literature (Singh and Sushil, 2004; Zhang et al., 2003; Kara and Kayis, 2004), the mechanism by which flexibility interacts with environment in improving performance is not fully developed in the context of supply chain. With high degree of flexibility, companies can handle uncertainties and variations in both internal and external environment. Therefore, the functioning can be continued effectively regardless of changes (Ramasesh and Jayakumar, 1991). For companies in situations considering investments in flexibility, it is necessary to assess carefully exactly what aspect of supply chain flexibility could benefit the company's market performance and customer satisfaction in certain context of environment. The need for further research aimed at an applied orientation is advocated (Kara and Kayis, 2004; Vickery et al., 1999). In other words, there is still a need to link supply chain flexibility to the benefits they carry and to determine which flexibility dimensions are the most critical responses to environmental uncertainty across industries.

Third, little research has been directed towards understanding how the supply chain flexibility can be achieved (Lummus et al., 2003). Few empirical studies have addressed the basic, but very important question, in supply chain flexibility: what are the antecedents of supply chain flexibility. With an absence of good understanding of the factors influencing supply chain flexibility, to achieve high degree of supply chain flexibility is still a difficult task. The study focusing on finding out the methods, tools, and managerial practices as key contributors for developing, improving and implementing supply chain flexibility needs more attention from both practitioners and academicians.

Finally, no studies have simultaneously considered the causal relationships among these constructs: driving factors for supply chain flexibility, supply chain practices, supply chain flexibility, and supply chain performance.

The empirical investigation explaining both the antecedents and components of supply chain flexibility has been scarce in the literature. Because research in the area of supply chain flexibility is still in an early stage, this study seeks to provide three main contributions. First, this study attempts to investigate the dimensions of supply chain flexibility through an extensive literature review and provide a comprehensive understanding on supply chain flexibility. Second, a reliable and valid measurement of supply chain flexibility will be developed. Third, this study proposes a theoretical framework to study antecedents and consequences of supply chain flexibility. Chapter 2 is the literature review on the theoretical foundation and various constructs of supply chain flexibility. The overall framework that depicts the relationships between the constructs and the development of hypotheses are presented in Chapter 3. The research methodology for generating items for measurement instruments appears in Chapter 4. This methodology includes pre-testing with practitioners and academicians, and a pilot study using the Q sort method. Large-scale survey, reliability, and validity results are reported in Chapter 5. In Chapter 6, the results of hypotheses testing are shown, using structural equation modeling methodology. Chapter 7 documents the dimension level analyses. And finally, Chapter 8 concludes with the summary of research findings and major contributions, implications for managers, limitations of the research, and recommendations for future research.

2. LITERATURE REVIEW

Flexibility is normally considered as an adaptive response to the uncertainties from internal process, supply side, and customer side (Gupta and Goyal, 1989; Sethi and Sethi, 1990; Gerwin, 1993; Davis, 1993; Towill et al., 2002). A flexible system must be capable of changing effectively in order to deal with changing environment. Referring to the previous research on flexibility, different perspectives of flexibility can be outlined. The functional aspect is concerned with specific operation performance of an organization (i.e., flexibility in manufacturing, marketing, and logistics, etc.) (Sanchez, 1995; Sanchez and Perez, 2003). For instance, flexible manufacturing system reflects the ability to respond to changes in customers' needs, as well as to unanticipated changes stemming from competitive pressure. Flexibility in product development enables the company to launch a product as a response to external or internal changes to the development process. The strategic aspects is long-term oriented and investigate how well an organization addresses and adapts its strategic decisions to unexpected changes in competitive environment (Evans, 1991; Gerwin, 1993; Lau, 1994; 1996). The hierarchical aspects capture the flexibility at shop, plant, functional or organizational levels (Slack, 1987; Gupta, 1993; Koste and Malhotra, 1999; Volberda, 1997). Along with this line, the competence-capability aspects address issues that can assist organizations in identifying which flexibility capabilities are critical to their customers and which flexibility competencies support those capabilities (Zhang et al., 2003; Suarez et al., 1996). That is, flexibility capabilities possessed by the company are used to accommodate sources of variability to which the company must respond and which are seen as flexible by the market, whereas the flexibility competence is the set of capabilities a company nurtures to respond to its environment. Different aspects make efforts to give better understanding on flexibility by exploring generalizable measures that span multiple industries (Slack, 1983; Sethi and Sethi, 1990; Gerwin, 1993; Upton, 1994; Koste and Malhotra, 1999; D'Souza and Williams, 2000; Pujawan, 2004).

Higher levels of flexibility invariably offer more advantages under turbulent market conditions. In concerning with specific operational performance features of manufacturing, flexibility was suggested to improve machine utilization, work-in-process inventory, cycle time, product quality, and delivery performance (Upton, 1994; Narasimhan et al., 2004). To acquire a sustainable competitive advantage, strategic flexibility emphasizing on developing skills such as knowledge, capability, and flexibility organizational structure should be developed (Lau, 1994; 1996; Dreyer and Gronhaug, 2004). Despite the substantial research effort in functional and organizational flexibility, the concept of flexibility in the context of supply chain has been extremely elusive. Therefore, the study attempts to explain this by inferring from previous research on the nature of flexibility.

2.1 From Manufacturing Flexibility to Supply Chain Flexibility

A review of the previous literatures on flexibility reveals much of the focus has been on manufacturing flexibility. The research in 80s and mid 90s mainly focused on the flexibility of the manufacturing systems, which led to the development of flexible manufacturing systems and a considerable body of knowledge on the manufacturing flexibility. Flexibility is widely recognized as a multi-dimensional concept within the manufacturing function (Gupta and Goyal, 1989; Sethi and Sethi, 1990; Upton, 1995; Pagell and Krause, 1999; Parker and Wirth, 1999; Koste et al., 2004). The dimensions of manufacturing flexibility have been explored in a huge amount of previous research. Thirteen dimensions of manufacturing flexibility commonly depicted in previous research are: machine, labor, material handling, routing, operation, mix, volume, expansion, modification, new product, delivery, process, and production. These dimensions are widely discussed as the adaptive response to environmental uncertainty in manufacturing strategy (Gupta and Goyal, 1989; Gerwin, 1993). Further, the manufacturing flexibility literature has recognized that manufacturing flexibility is not only a potential element of a manufacturing strategy, but it may also be a component of marketing and R&D strategies as well (Hyun and Ahn, 1992; Sethi and Sethi, 1990). Manufacturing flexibility is also recognized as one element of business strategy, with certain dimensions impacting growth and financial performance of the firm (Gupta and Somer, 1996; Chang et al., 2000).

Evidences from various empirical studies show that although practices associated with manufacturing flexibility are essential for continuous improvement in business performance, it seldom create any sustainable competitive advantage if market structure, demand, and technologies continue to evolve unexpectedly. Strategic flexibility is broadly discussed as a source of competitive edges in dynamic environment. Business units, IT projects, and R&D functions have all found value in creating an effective response to uncertainty (Young-Ybarra and Wiersema, 1999; Evans, 1991). The emphasis of strategic flexibility is on developing skills such as knowledge, capabilities, and a flexible organizational structure that are strategic in nature (Lau, 1996). In other words, strategic flexibility reflects a firm's own ability of responding to uncertainty with the support of its superior knowledge and capabilities. The capabilities contribute to strategic flexibility consist of people, processes, products, and integrated systems. But strategic flexibility is still discussed as an internal capability of an organization (Duclos et al., 2003).

Some authors argued that all resources in a system contribute the flexibility. Advanced manufacturing technology cannot be totally effective without flexible labor and vice versa. Neither can be effective without a set of procedures, systems, and controls which are capable to cope with the flexibility of the physical processes. Based on this perspective, in 1990's, companies recognized the necessity of attaining flexibility by means of looking beyond the borders of their own firm to their suppliers, and customers to improve overall customer values. Firms have recognized that to be responsive to end customer demand, all partners in the chain must be flexible in responding to changes. This notion is reinforced in the supply chain measurement literature, as "flexibility to a changing environment" is viewed as an important strategic performance metric (Beamon, 1999; Gunasekaran et al., 2001). A limited number of authors have begun to discuss flexibility from a supply chain perspective. Vickery et al. (1999) studied the relationship between supply chain flexibility and firm's financial performance and market performance. They argued that, excellent performers on supply chain flexibility are rewarded at the bottom line (i.e., overall firm performance). However, their study only focused on internal functional area responsibilities for supply chain flexibility performance. The investigations on the connections to suppliers and/or channel members are still missing.

2.2 Supply Chain Flexibility

Supply chain flexibility is defined as the firm's ability of configuring and managing the supply chain through collaboration with supply chain partners in responding to a rapidly change environment in an effective and efficient manner. Have a flexible supply chain provides significant competitive advantages including the ability to outperform rivals on both customer value creation (i.e., delivery, variety of products, and service) and company financial performance (i.e., ROI, ROS) (Zhang et al., 2002; Vickery et al., 1999). Fisher (1997) discussed that creating a responsive supply chain is crucial for innovative products with unpredictable demand. In the fashion markets, the more flexible and higher velocity supply chain proves more competitive than the lower-cost (Christopher et al., 2004).

Supply chain flexibility should be examined from both a customer-oriented and an integrative perspective, which extends beyond the organization's boundaries to other participants in the supply chain (Lau, 1994; Ahmed et al., 1996). This is brought forward as early as 1994 by Lau. He argued that flexibility is associated not only with manufacturing capabilities, but is also important for the linkages between manufacturing units and their suppliers and customers across the supply chain. This is also referred from previous literatures on strategic flexibility, which proposed that strategic flexibility is composed of resource flexibility and coordination flexibility (Sanchez, 1995; Lau, 1996). Therefore, Vickery et al. (1999), Wadhwa and Rao (2003), Garavelli (2003), and

Lummus et al. (2003) suggested that the development of supply chain flexibility should involve the consideration of flexibility components in each supply chain participants and their interrelationships.

This need has driven researchers such as Pujawan (2004}, and Garavelli (2003) to define and measure it for individual dimensions (i.e., new product flexibility and logistics flexibility). Vickery et al. (1999) and Pujawan (2004) extended their definition by aggregating components of flexibilities that directly impact a firm's customer and the shared responsibility of two or more functions along the supply chain. Moving toward a model of supply chain flexibility, a review of current literature was used to identify important characteristics of each component identified in existing conceptual model. In an empirical study, Vickery et al. (1999) proposed the following dimensions of supply chain flexibility based on operational flexibility literature: product flexibility which refers to the ability of customizing product to meet customer requirements; volume flexibility which refers to the ability of effectively adjusting production in response to customer demand changes; launch flexibility, which refers to the ability of bringing new products to the market as quickly as possible; access flexibility, which refers to the ability of providing widespread and intensive distribution coverage; and responsive flexibility, which refers to the ability of responding to the target market needs.

It is still not clear how to combine internal flexibility, both operational and strategic, with the external integration necessary to make the entire supply chain flexibility. While many analytical models have been proposed to handle operational issues in supply chain management, models for dealing with the entire supply chain as a whole system are scarce. Duclos et al. (2003) moved away from the traditional perspective of flexibility and proposed a more integrative conceptual framework. They also depicted six components of supply chain flexibility by considering activities required in a supply chain to meet customer demands. Namely, they are operations system, market, logistics, supply, organization, and information systems. The addressed view of supply chain flexibility incorporates both within-firm (i.e., operations, organization, and information systems) and between-firm flexibility (i.e., logistics, market, and supply). Aligned with this conceptual model, Lummus et al. (2003) developed a model of supply chain flexibility with five components: operations systems, logistics processes, supply network, organizational design and information systems.

The supply chain operations reference (SCOR) model is a strategic tool that allows firms to perform very thorough fact based analyses of all aspects of their current supply chain developed by the Supply Chain Council. It can be used as a common model for implementing supply chain management strategies. Source, make, deliver and return are identified as basic supply chain processes in SCOR model (Supply Chain Council, 2004). Therefore, flexibility in sourcing, manufacturing, and delivery are considered as the dimensions of supply chain flexibility (Prater et al., 2001). By considering additional aspects, Swafford et al. (2000) and Pujawan (2004) discussed four main dimensions of supply chain flexibility including flexibility of the product delivery system, production system, product development, and supply system since supply chain functions are considered to be consist of sourcing, product design, manufacturing/production, and delivery. This study follows the supply chain operations reference (SCOR) model and proposes four sub-constructs of supply chain flexibility on the basis of previous research on manufacturing flexibility, strategic flexibility, and limited writings on supply chain flexibility. Market-oriented flexibility includes manufacturing, product development, and delivery flexibility, which capture the main customer values delivered by supply chain; supply flexibility which addresses flexibility from the upstream supply chain; and logistics flexibility and spanning flexibility which address the network characteristics of flexibility. Before developing reliable and valid measures for supply chain flexibility, it is rational to first define and discuss all dimensions of supply chain flexibility: (1) market-oriented flexibility (including manufacturing flexibility, product development flexibility, and delivery flexibility), (2) supply flexibility, (3) logistics flexibility, and (4) spanning flexibility (Figure 2.1). The following section will present a detailed review of existing literature concerning each of the components proposed above.

The domain of flexibility is comprised of different flexibility types or dimensions, which each dimension having its own constituent elements. This assertion is well-supported by existing conceptual literature in the field of manufacturing flexibility, whereby three elements of range, mobility, and uniformity have been used to define any flexibility dimension (Slack, 1983; Upton, 1994; Koste and Malhotra, 1999). Range is typically regarded as the extent to which a system may adapt, either in number of possible options (number) or in the degree of difference between different options (heterogeneity). The mobility element addresses the ease with which the system moves from one state to another. It is assessed via transition penalties such as time and cost. The uniformity element represents any deterioration of the system associated with invoking a flexible response, measured as quality in most of the cases. However, the flexibility research in the context of supply chain asks for the need for an additional element since supply chain flexibility adds the requirements of attribute reflecting the cross-business nature of supply chain management (Pujawan, 2004). This is especially true for supply chain flexibility dimensions related to network structure (i.e., supply flexibility, logistics flexibility, and spanning flexibility).

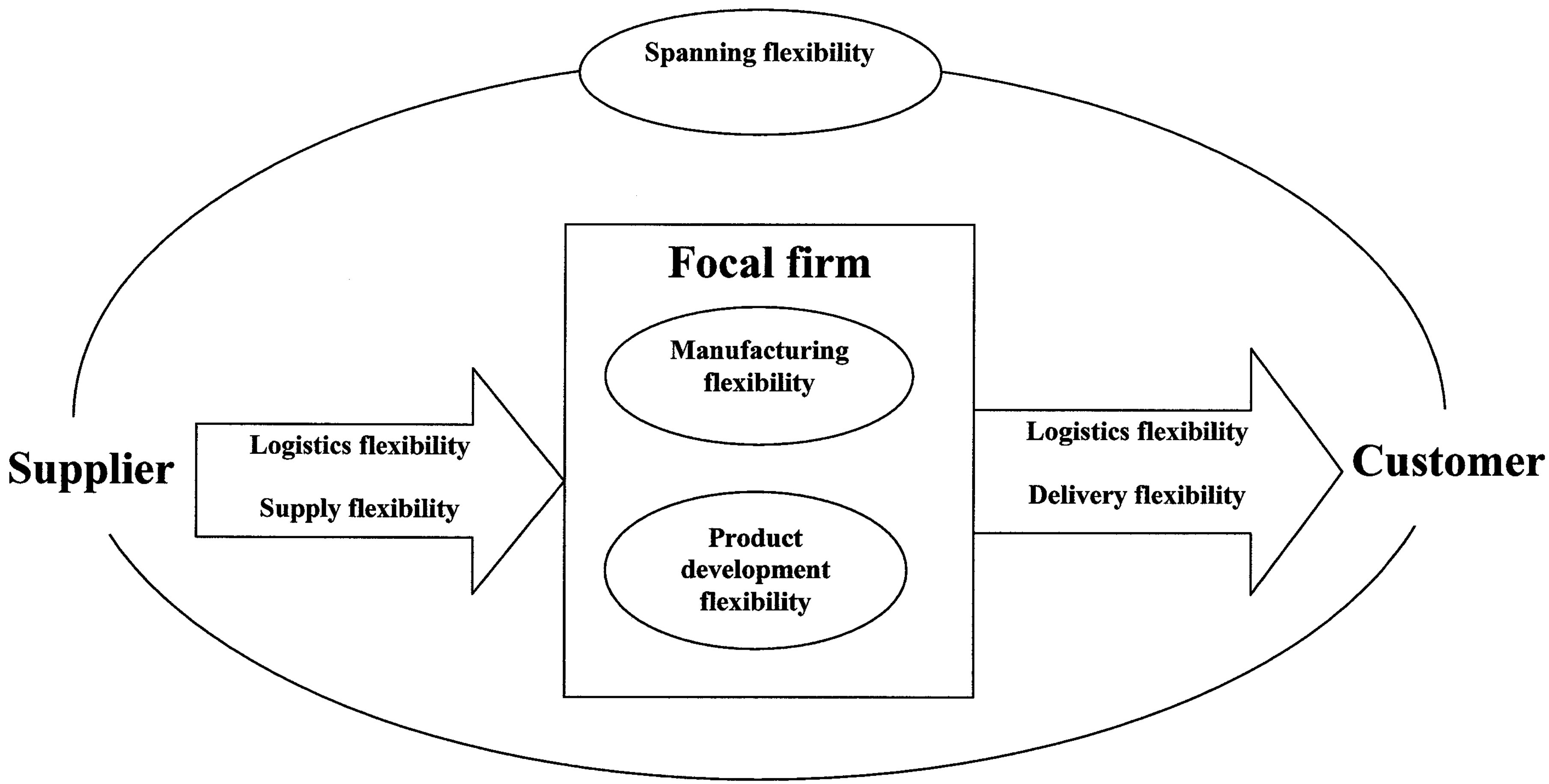


Figure 2.1 Supply Chain Flexibility Sub-constructs

2.2.1 Market-oriented Flexibility

Market-oriented flexibility refers to the ability of the firm to respond to environmental uncertainty by adjusting operational process across the supply chain including production, product development, and delivery (Gerwin, 1993; Brandyberry et al., 1999). Some other researchers have defined this ability as market flexibility (Sethi and Sethi, 1990; Gupta and Somers, 1992; Vokurka and O'Leary-Kelly, 2000), which originally emphasizes the importance of market orientation in manufacturing (Sethi and Sethi, 1990). Market-oriented flexibility enables the firm to respond to new business opportunities without seriously affecting the business processes. It is crucial in assessing the responsiveness of an organization's processes to shifts in market needs (Brandyberry et al., 1999). Gerwin (1993) defined one set of flexibility dimensions in his classification as "market-oriented" because they are related to uncertainties in market acceptance of different products, length of product life cycle, specific product characteristics, and aggregate product demand. The set of flexibility consists of mix, changeover, modification, and volume flexibilities. Market-oriented flexibility subsumes the distribution flexibility according to Ranta and Alabian (1988). Brandyberry et al. (1999) examined two properties of market-oriented flexibility, namely modification and volume flexibility when they investigated the relationship between advanced manufacturing technology implementation and market-oriented flexibility. In a similar sense, Suarez et al. (1996) classified flexibility in routing, system and component as lower-order flexibility types lead to first-order flexibility types including mix, volume, new product and delivery time, which are directly affect the competitive advantages and customer value creation of the whole supply chain. Given previous discussion, manufacturing, new product development, and delivery flexibility are viewed as market-oriented flexibility in responding to environmental uncertainty in this study (Ranta and Alabian, 1988; Vokurka and O'Leary-Kelly, 2000; Sethi and Sethi, 1990; Gupta and Somers, 1992). Table 2.1 shows these sub-constructs, along with their definitions and supporting literature.

Constructs	Definitions	Literature
Manufacturing flexibility	The ability to quickly and effectively adjust production processes with respect to market changes.	Gupta and Goyal, 1989; Sethi and Sethi, 1990; Suarez et al., 1995; Kara and Kayis, 2004; Gerwin, 1993; Koste and Malhotra (1999); Pagell and Krause, 1999; Gupta and Sommer, 1992; Parker and Wirth, 1999; Upton, 1994; Slack, 1983; Gupta and Goyal, 1989
Product Development Flexibility	The ability of to rapidly and effectively introduce and launch new products and modify existing products with respect to market changes.	Koste and Malhotra, 1999; Klassen and Angell, 1998; Ellie and Penner-Hahn, 1994; Hyun and Ahn, 1992; Dixon, 1992; Gerwin, 1993; Upton, 1994; Iansiti, 1995; Viswadanadham and Raghavan, 1997; Singh and Sushil, 2004; Thomke, 1997; Tatikonda and Rosenthal, 2000
Delivery Flexibility	The ability of a company to effectively deliver products to customers in respond to changes in planned delivery dates, volume and destination.	Slack, 1987; Beamon, 1999; Pagell and Krause, 2004; Pujawan, 2004; Sethi and Sethi, 1990; Christopher, 2000; Huppertz, 1999

Table 2.1 Sub-constructs for Market-oriented Flexibility

2.2.1.1 Manufacturing Flexibility

Manufacturing flexibility is defined as the ability to quickly and effectively adjust production processes with respect to market changes. (Gupta and Goyal, 1989; Sethi and Sethi, 1990; Suarez et al., 1996; Kara and Kayis, 2004; Pagell and Krause, 1999; Gupta, 1993; Parker and Wirth, 1999; Slack, 1983). The topics of manufacturing flexibility have been investigated in various contexts. There is significant variation in perspectives when manufacturing flexibility is investigated in more specific dimensions and elements. At the lower levels of manufacturing flexibility, plant, shop floor, and individual resource have an internal focus including machine, material handling. Not until reaching the strategic level, the manufacturing flexibility is viewed as a linkage among corporations in many functional areas and has an external focus on achieving customer satisfaction (Koste and Malhotra, 1999). This hierarchy perspective corresponds to capability and competence as described by Day (1994). In this respect, companies achieve visible competitive flexibility to the customers by building capabilities on a set of infrastructures and processes. Flexibility capabilities are manifested in such typical business performance as new product development, service delivery and order fulfillment. In other words, flexibility capabilities are viewed as output flexibilities that are readily perceived by customers (Nilsson and Nordahl, 1995b). Along with these lines, Grubbstrom and Olhager (1997) identified mix and volume flexibility as output flexibilities, which are direct responses to market demand.

Very little has been done in studying the manufacturing flexibility in the context of supply chain. When bring flexibility to the supply chain context where manufacturing flexibility is considered only one functional dimension, its sub-dimensions need to be reconstructed (Pujawan et al., 2004). Focusing on the flexibility that have been widely discussed in manufacturing flexibility area, manufacturing is generally responsible for volume flexibility and mix flexibility in contribution to the supply chain flexibility (Suarez et al., 1996; Zhang et al., 2002; Zhang et al., 2003). The reason for considering these two aspects were threefold: first, these flexibilities are visible to the customers, and are therefore representative of flexibility capabilities; second, each of these flexibilities contributes to the capabilities that enable companies to deal successfully with unpredictable and volatile marketplace; and finally, each of these flexibilities has been addressed in the literature.

Flexibility in production volume allows organizations to respond to the variation in customer demand levels. For instance, a volume flexible company is able to maintain a high level of delivery reliability by preventing out-of-stock conditions for products that are suddenly in high demand with relatively lower inventory than the competitors. Flexibility in product variety represents the ability to produce a broad range of products or variants with presumed low changeover costs. There is a strong movement in industry towards increased product variety and shorter lead time (Swaminathan, 2001).

Sethi and Sethi (1990), Koste et al. (2004), D'Souza and Williams (2000), and Zhang et al. (2003) have helped to identify the underlying aspects of manufacturing flexibility. The range concerns the width of feasible volume and degree of variety in products at which the firm can still make profit (Slack, 1983; Gerwin, 1993; Upton, 1994). The heterogeneity of flexibility captures the span of product lines that the volume and product feature changes can be accepted (Slack, 1983; Upton, 1994). Cost and time required changing the production level and transit to a different product mix indicates the mobility attribute while manufacturing system performance (i.e., efficiency, profitability, and productivity) give a measure of uniformity (Koste et al., 2004; Zhang et al., 2003; Koste and Malhotra, 1999).

2.2.1.2 Product Development Flexibility

The ability to rapidly develop products with fewer resources and shorter development cycle time has an increasing impact on a firm's success by creating relative advantages in market share, profit, and long-term competitive advantage (Wheelwright and Clark, 1992). With rapid development of technology, and fast changing of customers' needs and preferences, it has become increasingly important for firms operating in highly dynamic market environment to have high degree of flexibility in the product development to ensure their market success (Iansiti, 1995; Thomke, 1997). Product development flexibility refers to the ability of a company to rapidly and effectively introduce and launch new products and modify existing products with respect to market changes (Dixon, 1992; Gerwin, 1993; Upton, 1994; Iansiti, 1995; Viswanadham and Raghavan, 1997; Singh and Sushil, 2004). The ability to accommodate evolving design requirements, and design with flexibility can be very beneficial in leading to better design solutions with respect to customer needs and technologies (Thomke, 1997; Tatikonda and Rosenthal, 2000), pursuing a more efficient development strategy that can tolerate a higher risk of design changes (Thomke, 1997; Sanchez, 1996; Jin, 2001), and avoiding the need for product changes entirely (Iansiti and MacCormack, 1997).

Originally, flexibility in the context of product development has been examined by researchers in the context of manufacturing (Suarez, 1996; Klassen and Angell, 1998; Koste and Malhotra, 1999), where the focal company solely takes responsibility of developing new products. On the other hand, approaches in managing product development risks through well-coordinated efforts of various members in the supply chain have also been emphasized in previous studies. Narasimhan et al. (2004) showed empirical evidence that the supplier's involvement in product design and innovation has significant positive influence on product development flexibility. Some other studies suggested that a close relationship with suppliers also plays a role in increasing product development flexibility (Christopher, 2000; Suarez et al., 1995). Product development flexibility should have take account of the inter-organizational linkages and cross supply chain wide efforts (Zhang et al., 2002; Pujawan, 2004).

Product development flexibility enables the companies to respond quickly to changing customer needs with new innovative products or modifications to existing products. New product development and modifications to existing products are distinctive. That is, a product is new if its characteristics differed from other products the company made previously (Dixon, 1992), whereas modification involves just minor changes in current products rather than the development of an entirely new product that result from corrective processes or changing customer requirements (Ramasesh and Jayakumar, 1991; Pagell and Krause, 2004). The organizational skills, required technologies, and processes are significantly different from developing innovative product to modifying existing products (Jin, 2001). Therefore, new product development flexibility should be addressed via two aspects: new product flexibility and modification flexibility (Koste and Malhotra, 1999; Klassen and Angell, 1998; Ellie and Penner-Hahn, 1994; Hyun and Ahn, 1992).

Several alternative measures for product development flexibility have been proposed in the literature. Obvious measures capture the following four attributes of product flexibility: (1) range-number attribute reflected by the average number of new and modified products introduced into production (Sethi and Sethi, 1990; Gupta and Somers, 1992; Koste et al., 2004); (2) range-heterogeneity differentiated by the variety of product newness and modifications (Ramasesh and Jayakumar, 1991; Koste et al., 2004);

(3) mobility attribute addresses the penalties in terms of time and costs incurred in new product and modified product development (Gupta and Somers, 1992; Singh and Sushil, 2004; Koste et al., 2004); and (4) uniformity attribute captures the degree of impact on manufacturing system performance outcomes when a new or modified product is introduced in the production system (i.e., efficiency, profitability, and productivity) (Koste et al., 2004).

2.2.1.3 Delivery Flexibility

Delivery flexibility was defined as the ability to move planned delivery dates in some previous research (Slack, 1987; Beamon, 1999). However, this is not sufficient since supply chain must have the ability to accommodate rush orders and special orders in case of delivery requirements change. By taking into account a number of considerations, delivery flexibility is defined as the ability of a company to effectively deliver products to customers in respond to changes in planned delivery dates, volume and destination (Pagell and Krause, 2004; Pujawan, 2004). Delivering products to customers at the right time, at the right place, and at the right price has become a new challenge. Simply stated, to manage flexible delivery is worth more than low costs and short lead times. Delivery flexibility also has to be a resource supporting new market strategies. In today's business, companies are pushing inventory back to their suppliers in an effort to reduce their inventory level and improve their return on assets. Therefore, customers are asking for smaller and more frequent delivery.

Delivery flexibility has been discussed as an important dimension of market-oriented flexibility. Sethi and Sethi (1990) depicts that market flexibility subsumes delivery flexibility, which includes means of creating flexibility in place, time, size, and assortment of deliveries to achieve customer satisfaction. Christopher (2000) recognizes flexible delivery as a key element in gaining advantages in the market. In highly competitive companies in a turbulent business environment, a cost and lead-time-oriented delivery concept is not enough. Creating flexible delivery in responding to smaller, more frequent orders challenges the company's supply chain design (Huppertz, 1999).

Based on the above discussion, delivery flexibility is reflected in terms of the ability that a company can accommodate special or nonroutine requests in delivery time (i.e., expedited shipments delivery), destination, volume and other demands in case that specific customer requirements changes (Pujawan, 2004; Fawcett et al., 1997). It is also depicted by the ability to accommodate small and frequent delivery order (Pujawan, 2004).

2.2.2 Supply flexibility

Supply flexibility is defined as the ability of a firm to efficiently and effectively reconfigure the supply base and maintain a responsive supply base with respect to environmental changes (Nilsson and Nordahl, 1995a; Duclos et al., 2003; Singh and Sushil, 2004; Narasimhan et al., 2004). The recognition of the strategic importance of purchasing in many organizations has increased in recent years (Spekman et al., 1994; Narasimhan and Das, 1999). The reasons include price competitiveness, responsiveness, cost concern, and the speed of new product introduction (Monczka et al., 1998). The ability to meet the changing needs of customers requires flexibility in sourcing product from raw materials to outsourced finished product. The dynamics observed in a supply network emerge from the local interactions of supply chain participants in the ever-changing structure of the network (Brueckner et al., 2005). Smart firms, such as Cisco and Gap, tailor different supply chains to the nature of markets for products. And these supply chains can serve as backups in case of emergency (Lee, 2004).

The supply function is said to be flexibility if the supply network is designed with respect to market changes and has supply chain partners with ability to match different product and market conditions (i.e., short-term bids, long-term contracts, and strategic relationship) (Lummus et al., 2003; Pujawan, 2004). In their paper to propose a conceptual model of supply chain flexibility, Lummus et al. (2003) discusses supply chain flexibility as a result of the flexibility of each entity in the supply chain and their interrelationships. That is, coupled with the ability of restructure the supply base, companies must bring suppliers who can be more flexible and willingness to take greater risks in responding to changes into the supply network. Given the above discussion, supply network flexibility and supplier flexibility are viewed as supply flexibility in responding to environmental uncertainty in this study. The list of these sub-constructs, along with their definitions and supporting literature, are provided in Table 2.2.

Constructs	Definitions	Literature
Supply Network Flexibility	The ability of a firm to efficiently and effectively reconfigure the supply with respect to environmental changes.	Duclos et al., 2003; Singh and Sushil, 2004; Narasimhan et al., 2004; Pujawan, 2004; Lummus et al., 2003; Gosain et al., 2005; Otto and Kotzab, 2003
Supplier Flexibility	The suppliers' willingness and ability of responding to the changes requested by buyers.	Gunasekaran, 1999; Sanchez, 1995; Fisher, 1997; Mason et al., 2002; Pujawan, 2004; Young et al., 2003; Volberda, 1996

Table 2.2 Sub-constructs for Supply Flexibility

2.2.2.1 Supply network flexibility

.There is a growing recognition that individual businesses no longer compete as stand-alone entities, but rather as supply chains. In the network competition, companies who can better structure, coordinate, and manage the supply network commit to more flexible relationships with their partners (Christopher, 2000). To secure good fit between product and supply chain structure is an essential issue in managing a supply chain (Otto and Kotzab, 2003). Since customer tastes change quickly, companies need to respond quickly and supply the new products/services. Meeting these needs in the supply chain requires the ability to switch supply sources effectively and rapidly. Therefore, supply chain should be designed with change in mind. Literature has discussed that supplier associations and networks are effective arrangements for providing a responsive structure for achieving quick response in a supply chain (Power et al., 2001). In other words, enough architectural flexibility should be built up into the supply chain structure in adapting to the changes (Upton, 1994).

This study builds on the pioneering works of Lummus et al. (2003), Pujawan (2004), and Duclos et al. (2003) in regard to the importance of taking a flexible perspective in designing supply network. Gosain et al. (2005) operationalized supply flexibility as a single item measuring the ease of replacing the partner in the focal firm's supply chain relationship. Referring to manufacturing, product development flexibility and limited empirical studies on supply chain flexibility, a more comprehensive perspective is taken in this study. Supply flexibility is operationalized by three attributes: (1) the number of alternate supply sources and the extent to which the supply capacity can be varied (Pujawan, 2004) capture the supply range attribute of supply network flexibility; (2) the time and cost incurred for switching supply sources are potential transition penalties which represent mobility attribute of supply flexibility. They also reflect the ease with which the supply network move from one state to another (Otto and Kotzab, 2003); and (3) the extent of how the incoming material's quality and delivery performance affected by switching supply sources (Pujawan, 2004) addresses the consistency of performance with changes. More flexible supply network will exhibit less fluctuation in performance outcomes.

2.2.2.2 Supplier Flexibility

Supplier flexibility refers to the suppliers' willingness and ability of responding to the changes requested by buyers. From strategic sourcing perspective, flexibility in the sourcing side of the supply chain plays a direct role in the performance in the downstream supply chain. Often, it is the ability and willingness to accommodate that limits the ability of a manufacturer to respond effectively and rapidly to customer demands (Gunasekaran, 1999). As the company sees the need to change partners to launch a new product, new partners with the required capabilities must be found in a prompt manner. From the resource-based view, flexibility in supply chain partners motivates the speed, ease, and cost of responding to new knowledge, new technologies, market changes, or other developments that arise during the course of work (Sanchez, 1995). In particular, in certain industries characterized by innovative products or short product life cycle (i.e., electronics, computer), firms are most successful if they can work with suppliers who have the ability of satisfying changes in buyers requests (Pujawan, 2004). Therefore, having a network of key suppliers able to synchronize their production and deliveries with the requirements of the company are preferred for short lifecycle or innovative products (Fisher, 1997; Mason et al., 2002).

In evaluating supplier flexibility, supply partners must be able to react to variances even more quickly. From the resource-based point of view, flexibility in supply partners motivates the speed, ease, and cost of responding to new technologies, market changes, or other developments in business (Sanchez, 1995; Young et al., 2003). In addition, supplier flexibility is also captured by the willingness of suppliers to adapt, change or adjust to changes without resorting to a series of new contracts and renegotiations (Volberda, 1996).

2.2.3 Logistics Flexibility

Logistics flexibility refers to the ability of a firm to efficiently and effectively manage physical materials flow and physical distribution network with respect to environmental changes. (Duclos et al., 2003; Zhang et al., 2002). Companies have traditionally taking a uniform approach to logistics network design in organizing their inventory activities to meet a single service standard. There exists a need for flexibility in logistics in the short term to offer operational opportunities, and in the long term to apply to new marketing channel positions. As a result, the logistic system must be more flexible than the traditional planning-based network (Catalan and Kotzab, 2003; Christopher, 2000; Van Hoek, 2000; Anderson et al., 1997).

In designing logistics systems, certain large companies which have the capability to develop more sophisticated information and computer systems do not; instead, they chose to rely on more flexible logistic networks which allow for adaptation. Such adaptation could be a source of differentiation for a manufacturer (Cunningham, 1996). Jensen (1997) developed and analyzed the concept of inter-organizational logistics flexibility. The executive flexibility and planning flexibility are introduced as logistical flexibility dimensions, depending on whether the flexibility refers to the execution or the planning of logistics activities. As Barad and Sapir (2003) noted in their discussion on flexibility in logistic systems, logistics flexibility combines principles of routing flexibility and decision-making flexibility. Routing flexibility is associated with physical resources, while decision-making flexibility is based on logistic network, including the flexible design of distribution system. In sum, we consider logistics flexibility conducive to the implementation of supply chain flexibility as physical distribution and logistics channel flexibility. The list of these sub-constructs, along with their definitions and supporting literature, are provided in Table 2.3.

Constructs	Definitions	Literature
Physical Distribution Flexibility	The ability of a company's logistic system to accommodate variations in distribution process or customer demand changes while maintaining a satisfactory level of performance.	Day, 1994; Langley and Holcomb, 1992; Barad and Sapir, 2003; Pujawan, 2004; Sethi and Sethi, 1990; Koste and Malhotra, 1999
Logistics Channel Flexibility	The ability of adjusting logistics structure to incorporate a speedy response to future needs of the existing markets or new markets.	Bradley, 1997; ; Rao et al., 1994; Perry, 1991; Fawcett and Clinton, 1997; Zhang et al., 2002; Barad and Sapir, 2003

Table 2.3 Sub-constructs for Logistics Flexibility

2.2.3.1 Physical Distribution Flexibility

Physical distribution plays a crucial role in seamless supply chain operations. In order to meet ever-increasing expectations, the basic work of physical distribution has shifted from operationally meeting low cost of high service criteria to providing a responsive physical connection across the supply chain operations (i.e., supply, production, and delivery) (Stank and Glodsby, 2000). Physical distribution flexibility is defined as the ability of a company's logistic system to accommodate variations in distribution process or customer demand changes while maintaining a satisfactory level of performance (Day, 1994; Langley and Holcomb, 1992; Barad and Sapir, 2003).

The physical distribution flexibility can be referred to the routing flexibility at the shop floor lever, which is defined as the ability of processing products by using alternate routes through the manufacturing system economically and effectively (Sethi and Sethi, 1990; Koste and Malhotra, 1999). Alternate routes may use different machines, different operations, or different sequences of operations. Extended to the context of supply chain, physical distribution flexibility is introduced as the possibility of shifting the production of a component or final product to different sites of a given stage of the supply chain. Physical distribution flexibility is critical to supply chain flexibility because it allows firms to find alternate warehousing and transportation in case of the scheduled delivery changes or distribution system overloads. These alternate routes increase the options available to management, thereby enhancing the flexibility of whole supply chain (Daugherty and Pittman, 1995). For example, what if the truck is in an accident during shipping? The unforeseen events like this, can have devastating effects on logistic performance, and result in millions of lost dollars. The company may overcome it through transfer stocks from a nearby location and make arrangements with alternative transportation carrier so the products can be supplied to the right location on a timely basis. These possible options can not be explored without sufficient information concerns of the unexpected situation occurrences as well as the capability of the nearby location and alternative transportation mode. Therefore physical distribution flexibility is reflected in the ability to schedule different routes in each day of delivery, the ability of the company to obtain trucks form different resources, and ability of transportation carrier to distribute a variety of goods with a wide range of loads (Pujawan, 2004; Barad and Sapir, 2003; Day, 1994; Langley and Holcomb, 1992).

As a measure of the range aspect of physical distribution flexibility, Pujawan (2004) suggested the straightforward measurements of the number of transportation modes available, and the product mix can be accepted in a delivery load. We have tried to operationalize the mobility and uniformity attributes of physical distribution as following: the cost and time incurred for adjusting distribution mode captures the mobility while the logistics performance gives a measure of uniformity.

2.2.3.2 Logistics Channel Flexibility

Logistics structure flexibility refers to the ability of adjusting logistics structure to incorporate a speedy response to future needs of the existing markets or new markets. Traditionally, each logistics channel is responsible for all of its channel tasks. A logistic system should have the ability to deliver distinct product to distinct customers in serving their distinct requirements with respect to changing channels (Bradley, 1997). For instance, Lee (2004) described the adaptation of Toyota's distribution system to Prius, the hybrid car it launched in the United States in 2000. Convinced that the uncertainties are too great to allocate the Prius to dealers based on past trends, Toyota customized products to demand and managed inventory flawlessly through keeping inventory in central stockyards. The dealers take responsibilities of taking orders, communicating customer orders via Internet. The car is then shipped from stockyard to dealers and delivered to buyers. That is, there is a fundamental difference in what different markets of logistics structure will demand. Under this consideration, 3M has identified five logistics channels to serve 80 separate businesses, with teams established to develop customized logistics structure for each channel (Rao et al., 1994). The need for increased flexibility and responsiveness in the logistics structure means that companies must periodically examine logistics channel settings and adjust according to market evolvement, economics changes, and marketing channel decisions (Perry, 1991; Fawcett and Clinton, 1997; Zhang et al., 2002).

Some research works take a perspective that supply chain is an integrated logistics network (Ellram, 1991; Tan et al., 1998). From their point of view, supply chain represents a network of firms linking flows from raw material supply to final delivery. Therefore, it is reasonable to refer measurements of logistics structure flexibility to supply network flexibility. In this study, logistics channel flexibility is operationalized by: (1) the number of logistics channels for different product/services which addresses the range attribute of logistics flexibility; (2) the time and cost incurred for restructuring logistics channels are potential transition penalties which represent mobility attribute of logistics flexibility. They also reflect the ease with which the logistics network moves from one state to another; (3) the extent of how the logistics performance affected by restructuring logistics channels addresses the uniformity attribute.

2.2.4 Spanning flexibility

Without accurate, current information about supply and demand conditions, even a supply chain that is physically capable of high flexibility cannot respond efficiently to real-time changes. Spanning flexibility refers to the ability of a firm to efficiently and effectively distribute various information manage information sharing connectivity along the supply chain with respect to environmental changes (Lummus et al., 2003; Aranda, 2003; Zhang et al., 2002). On one hand, spanning flexibility involves aligning information dissemination along the supply chain quickly and accurately so supply chain participants share knowledge about plans, requirements, and status on a timely basis (Duclos et al., 2003; Zhang et al., 2004). On the other hand, today's business faces an immediate challenge of leveraging information sharing connectivity in a manner that is flexible, cost effective, manageable, and reliable (Sanders and Premus, 2002; Heinrich and Betts, 2003). In this increasingly information-intensive work environment, linking stakeholders of organizations (e.g., customers, suppliers, and other business partners) through vital information networks is the noticeable practice of the excellent supply chain management (Mentzer et al., 2000; Towill, 1997). Therefore, this study proposed that both information dissemination flexibility and information sharing connectivity between supply network partners are essential for reaching spanning. These sub-constructs, along with their definitions and supporting literature, are documented in Table 2.4.

Constructs	Definitions	Literature
Information Dissemination Flexibility	The ability of a firm to efficiently and effectively distribute and share various information along the supply chain with respect to environmental changes	Bowersox et al., 1999; Aranda, 2003; Zhang et al., 2002; Perez and Sanchez, 2001
Information Connectivity Flexibility	The ability of companies to adjust and adapt information sharing connectivity with suppliers in response to new conditions, needs of other supply chain partners and market evolvement.	Duclos et al., 2003; Lummus et al., 2003; Day, 1994; Lwson et al., 1999; Christopher et al., 2004

Table 2.4 Sub-constructs for Spanning Flexibility

2.2.4.1 Information Dissemination Flexibility

Physical dissemination flexibility refers to the ability of a firm to efficiently and effectively distribute and share various information along the supply chain with respect to environmental changes. According to Bowersox et al. (1999), in coordinating complex process, flexibility in information dissemination is one of the most important prerequisite of a high level of connectivity between the firm and its supply chain partners. Information dissemination flexibility enables information visibility within the supply chain, and information passing along the supply chain. With effectively sharing and quickly disseminating information, bundles of services such as the adding of product features and specific product configuration can be offered and aligned to individual customer requirement. By surveying suppliers of one auto manufacturer, Perez and Sanchez (2001) reported that firms who want to achieve just-in-time delivery were collecting and disseminating information from the supplier side such as production planning, quality control method, and cost structure of each production stage.

Information dissemination flexibility involves disseminating information along the supply chain quickly and accurately so participants share knowledge about plans, requirements, and status. The number of ways and variety of data can be shared seamlessly across the supply chain (Aranda, 2003; Zhang et al., 2002) represent the range of alternate information distribution channels. The easiness to obtain information from different internal and external sources captures the mobility attribute. Finally, the quality of the information indicates the uniformity of information dissemination flexibility.

2.2.4.2 Information Connectivity Flexibility

Information connectivity flexibility refers to the ability of companies to adjust and adapt information sharing connectivity with suppliers in response to new conditions, needs of other supply chain partners and market evolvement. It is about to carefully plan and manage the whole information connectivity system flexibility rather than focus only on technology implementation. The information connectivity flexibility provides the ability to make demand-information driven decisions at the last possible moment in time ensuring that diversity of offering is maximized and lead-times, expenditure, cost and inventory minimized (Lowson et al., 1999). It also determines the speed with which firms acquire information from a mass of accessible data and transform it into valuable business assets. Changes within the supply chain may be inhibited if the information sharing channel cannot respond to these changing needs (Lummus et al., 2003; Duclos et al., 2003). In the fashion industry, retailers and their suppliers are more closely connected through flexible information sharing processes or channels. As a result, the connection through the supply chain is flexible enough to cope with sudden changes in demand with daily point-of-sale analysis, and feedback of customers' likes and dislikes (Christopher et al., 2004). In other words, information connectivity flexibility integrates activities by reaching across organizational boundaries to satisfy changing customer needs (Day, 1994).

The above discussion point to the following aspects capturing the concept of information connectivity flexibility: (1) time and cost required to set up new structured information connectivity; (2) the information sharing quality with regard of different information sharing channels; and (3) agreement on and ability of adjusting the information sharing process and content to deal with changes in the business environment by suppliers.

2.3 Environmental Uncertainty as Driving Forces for Supply Chain Flexibility

In the context of supply chain, environmental uncertainty is defined as the attributes of internal and external changes that influence supply chain strategy, structure and performance (Towill et al., 2002; Mason-Jones and Towill, 1998). Environmental uncertainty is a complex concept, which has received different definition such as complexity, variability, and vulnerability in previous literature (Kara and Kayis, 2004; Prater et al., 2001).

The environmental uncertainty has been studied extensively. However, various authors have conceptualized and measured the environmental uncertainty differently. Environmental uncertainty may be uncertainty about future demand or uncertainty about a supplier's ability to meet a delivery promise, or about the quality of materials or components. (Christopher, 1992; Bowersox and Closs, 1996, Wilding, 1998). Wernerfelt and Karani (1987) evaluated environmental uncertainty using four dimensions: demand, supply, competitive, and external. Ettlie and Reza (1992) defined environmental uncertainty as having four dimensions: customers, suppliers, competitors and technology. Davis (1993) and Mason-Jones and Towill (1998) have segmented supply chain uncertainties into four areas: manufacturing, supplier performance, customer deliveries and customer demand. As an extension, Towill et al. (2002) consider environmental uncertainties coming from process uncertainty, supplier uncertainty, customer uncertainty, and control uncertainty.

This study chooses to follow Ettlie and Reza (1992) by using four sub-constructs to measure environmental uncertainty: customer uncertainty, supplier uncertainty, competitor uncertainty, and technology uncertainty. These sub-constructs have two main attributes that make it appropriate for our discussion. First, this set of measurements enables a systematic approach of evaluating the uncertainty experienced by a supply chain. The supplier and customer uncertainty are concerned with changes within the supply chain while competitor and technology uncertainty are related to external pressures to the supply chain. It should be noted that these measures incorporate a much broader conceptualization of the environmental uncertainty than those used in some operations management research. For example, many operations management studies have focused on demand and or product mix uncertainty (Pagell and Krause, 1999; Prater et al., 2001). The second reason for using this specific set of measures is to provide linkages to previous research in the context of supply chain. Focusing on supply chain instead of individual organization, Li (2000) and Zhang et al. (2002) also adopted this classification in their study of supply chain management and value chain flexibility respectively. Table 2.5 shows environmental uncertainty constructs, its sub-constructs, and construct definitions.

Constructs	Definitions	Literature
Environmental Uncertainty	The attributes of internal and external changes that influence supply chain strategy, structure and performance.	Zhang et al., 2002; Chang et al., 2002; Davis, 1993; Hahn et al., 1990; Kara and Kayis, 2004; Ettlie and Reza, 1992; Pagell and Krause, 1999; Prater et al., 2001; Towill et al., 2002; Mason-Jones and Towill, 1998
Customer uncertainty	The extent of changes and unpredictability associated with customer demands.	Zhang et al., 2002; Chang et al., 2002; Davis, 1993; Christopher, 1992; Bowersox and Closs, 1996a; Wilding, 1998; Chen et al., 1992; De Toni and Tonchia,1998; Kara and Kayis, 2004; Towill et al., 2002

	Supplier uncertainty	The extent of changes associated with supplier's performance.	Zhang et al., 2002; Chang et al., 2002; Davis, 1993; Towill et al., 2002; Dixon, 1992; Krajewski and Ritzman, 1999; Swenseth and Buffa, 1991
	Competitor uncertainty	The extent of changes associated with business competition.	Hahn et al., 1990; Chang et al., 2002; Zhang et al., 2002; Kerin et al., 1992; Chen et al., 1992
	Technology uncertainty	The extent of technological changes within the industry.	Iansiti, 1995; Thomke and Reinertsen, 1998; Gerwin, 1993; Chen et al., 1992; Randall et al., 2003; Kekre and Srinvasm, 1990; Chang et al., 2002

Table 2.5 Environmental Uncertainty Construct, its Sub-constructs, and Construct Definitions

2.3.1 Customer Uncertainty

Customer uncertainty is defined as the extent of changes and unpredictability associated with customer demands. Competitive pressures such as falling product life cycles and intense global competition have altered the nature of customer value requirements (Yusuf et al., 1999). Beyond quality and prices, customers today ask for variety, customized products and services, competitive prices, and flexible delivery in terms of volume, mix, timing and place. For instance, as customers reduce inventories, their demand rates become volatile (Aggarwal, 1997). In high-technology industry, customer demands are highly uncertain in terms of product options and volume (Chang et al., 2002). If a product is highly fashionable then by its intrinsic nature its demand will be unpredictable. However, customer uncertainty is impossible to remove entirely from the supply chain. Hence, the identifying and understanding of customer uncertainty experienced by the supply chain is needed for improving customer value satisfaction. Numerous authors have identified the need to manage, minimize and remove uncertainties from customer orders in order to improve the effectiveness of their business processes (Christopher, 1992; Bowersox and Closs, 1996; Wilding, 1998).

Since it is a well-known fact that satisfying customer needs is the central purpose of any business (Doyle, 1994), customer focus is a key driving force of flexibility. In fact, the pressure to revitalize manufacturing over the last decade has been rooted in customers' demand for a greater variety of reliable products with short lead times (Draaijer, 1992). As customer demands are dynamic in nature (Shepetuk, 1991), firms need redefine product strategies, reconfigure chain of resources to improve overall customer values (Sanchez, 1995). Sethi and Sethi (1990) suggested the importance of developing the capability of adjusting the level of production for responding to highly uncertain market demands. From the marketing perspective, Chen et al. (1992) and De Toni and Tonchia (1998) identified market-related sources of flexibility needs, including increased product diversity, short product life, increased customization, and shorter delivery time. Overall, customer uncertainty involves the fluctuations and variations in volume and composition of demand; and the extent of predictability of customer preference and customer profile.

2.3.2 Supplier Uncertainty

Supplier uncertainty is defined as the extent of changes associated with supplier's performance. Supplier uncertainty results from poorly performing suppliers not meeting focal firms' requirements, thereby it handicaps the whole value-added processes. It can be evaluated by looking at the degree of predictability of supplier's delivery performance and product quality (Towill et al., 2002; Chen and Paulraj, 2004). Poor quality of incoming parts adds significantly to buyer's cost in terms of inspection, rework and returns, purchasing, and over-production. In the past, firms commonly contracted with a large number of suppliers for cost reduction purpose. A significant shift has occurred from the traditional adversarial buyer-seller relationships to the use of a limited number of qualified suppliers (Chen and Paulraj, 2004). By reducing their supplier bases, firms will be able to take advantage of partnerships with their suppliers. However, heavy reliance on a limited number of suppliers can be disastrous if the partner does not meet expectations (Maloni and Benton, 1997). From another perspective, uncertainty from suppliers propagates through the supply chain and leads to inefficient processing and non-value adding activities such as creating safety buffers, capacity or inventory to prevent a bad chain performance. This, in turn, increase uncertainty with respect to production schedules, orders to suppliers, and the likelihood of providing high levels of customer service (Swenseth and Buffa, 1991; Davis, 1993).

Supplier quality, flexibility, delivery, and cost performance are intermediate outcomes of the implementation of an appropriate supply chain strategy (Ahire et al., 1996). Krajewski and Ritzman (1999) argued that manufacturing firms should improve the ability to change and adjust the production in order to deal with quality problems and delivery inconsistency from suppliers. Dixon (1992) depicted that supply uncertainty drives firms to offer different product options to meet customer demand. In addition, Chang et al. (2002) observed from the high-technology industry that the uncertainty of procuring necessary components from suppliers could force firms to increase volume flexibility. Therefore, supplier uncertainty includes indicators that represent quality, timeliness and the inspection requirements of the suppliers.

2.3.3 Competition Uncertainty

Competition uncertainty is defined as the extent of changes associated with business competition. The market openness associated with globalization has increased the speed, frequency, and magnitude of access to all national markets including a new and more diverse set of competitors (Wolf, 2000). Also, the ever-increasing trend in outsourcing simulates the influx of new competitors (Quinn and Hilmer, 1994) Generally speaking, the number of competitors and the range of market competition uncertainty are both characterized by frequent and substantial change.

With regard to perceived competition uncertainties, supply chain flexibility is required for a firm to cope with external forces in a rational and manageable way (Zhang et al., 2002). As the market uncertainty increases due to the addition of new competitors or the new actions of exiting firms, firm's strategies are evolving in responding to such competitive pressures. For example, as competitors introduce new models, customers start switching supply sources, and firms are forced to make design changes quickly. When competitors start offering multiple quality and price levels, the firms need more flexible product mixes (Chen et al., 1992). According to Chang et al. (2002), the capability of offering various products and agile product development allows firms to lessen instability from competition. Adapted from work by Werner et al. (1996), competition uncertainty is captured by changes in competitors' strategy and prices, in the markets served by competitors and the entry of new competitors into the market.

2.3.4 Technology Uncertainty

Technology uncertainty refers to the extent of technological changes within the industry.

The business environment created by information technology is characterized by virtually unprecedented levels of technical uncertainty (Iansiti, 1995). The agile product development literature proposes that increased pace of technological innovation and its related technological obsolescence have increased the instability of product requirements (Thomke and Reinertsen, 1998; Iansiti, 1995). On the other hand, technology innovation provides numerous opportunities for firms such that it triggers development and introduction of new products (Gerwin, 1993; Chen et al., 1992). In addition, the rapid development of information technology is increasing the customer expectations and the competition base through accessing to global supply chain.

In today's markets, technological forces are changing at an ever-increasing rate. For firms competing in the industry in the face of such uncertainty, the choice of supply chain is affected by the uncertainty surrounding these competing technologies. Specially, in the high-technology industry characterized by short product life cycle, severe competition and constant technology innovation, firms are forced to research and develop new products in a flexible way (Iansiti, 1995; Chang et al., 2002). Firms with flexible supply chain will be more capable of adapting to changes and will handle this uncertainty at a lower cost. Kekre and Srinivasan (1990) asserted that the development of product mix flexibility is an effective way to take new market opportunities presented by technology innovation. Technology uncertainty is operationalized based on Chen and Paulraj' work (2004) and measured by extent of technological changes evident within the industry.

2.4 Supply Chain Management Practices for Supply Chain Flexibility

Supply chain management is a process for designing, developing, optimizing and managing the internal and external components of the supply chain. The essence of supply chain management is as a strategic weapon to develop sustainable competitive advantages. The supply chain management practices have been engaged by many firms to enhance competitiveness in the marketplace. Examples can be found in the United Colors of Benetton (Simchi-Levi et al., 2000), Wal-Mart (Lummus and Vokurka, 1999), and Campell Soup Company (Fisher, 1997). Supply chain management practices have been observed to contribute to fast respond to short-term changes in demand or supply (Lee, 2004; Simatupand et al., 2002), shorten lead times (Power et al., 2001; Simatupand et al., 2002), lower transportation costs (Stank et al., 2001), and improved customer service (Power et al., 2001; Stank et al., 2001). Companies embracing the concept of supply chain management are enjoying above business performance improvement (i.e., Hewlett Packard, Exrox, and Toyota). Therefore, supply chain management practices represent the new opportunities for differentiation from competitors and performance improvement (Zielke and Pohl, 1996).

The requirement for firms to become more flexible to the needs of customers, the changing conditions of competition and increasing levels of environmental turbulence is driving interest in exploring the critical success supply chain management practices for supply chain flexibility. An empirical study by Narasimhan and Das (1999) reported that supply chain management practices could be quite useful in the development of delivery, modification, and volume flexibilities. Most of the companies will immediately assume that supply chain flexibility will require more technology and investment. Nothing could be further from the truth. Most companies already have the infrastructure in place to create a flexible supply chain. What they need is a fresh attitude and a new culture to prepared to keep changing networks; and instead of looking out for their interests alone, take responsibility for the entire chain. This can be challenging because there are no technologies that can do those; only management can make them happen.

The SCOR-model has been developed by Supply-Chain Council (SCC) to describe the business activities associated with all phases of satisfying a customer's demand. The model itself contains several sections and is organized around the five primary management processes of Plan, Source, Make, Deliver, and Return (shown in **Figure 2.2)**. SCOR-model provides a unique framework that links business process, metrics, best practices and technology features into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chain management and related supply chain improvement activities. Another supply chain management research area revealed is the necessity of information technology to foster information sharing (Humphreys et al., 2001). Lockamy III and McCormack (2004) suggested that the effective usage of IT can have a dramatic impact on each of the four decision areas provided in SCOR Model (Plan, Source, Make, Deliver, and Return). An analysis of practices related to business activities plan, source, make, and deliver resulted in the introduction of postponement, supplier management, information flow facilities, and outsourcing as antecedents of supply chain flexibility. Return activities is not included because the reverse supply chain is not concerned in this discussion. Table 2.6 lists these four dimensions along with their definitions and supporting literature.

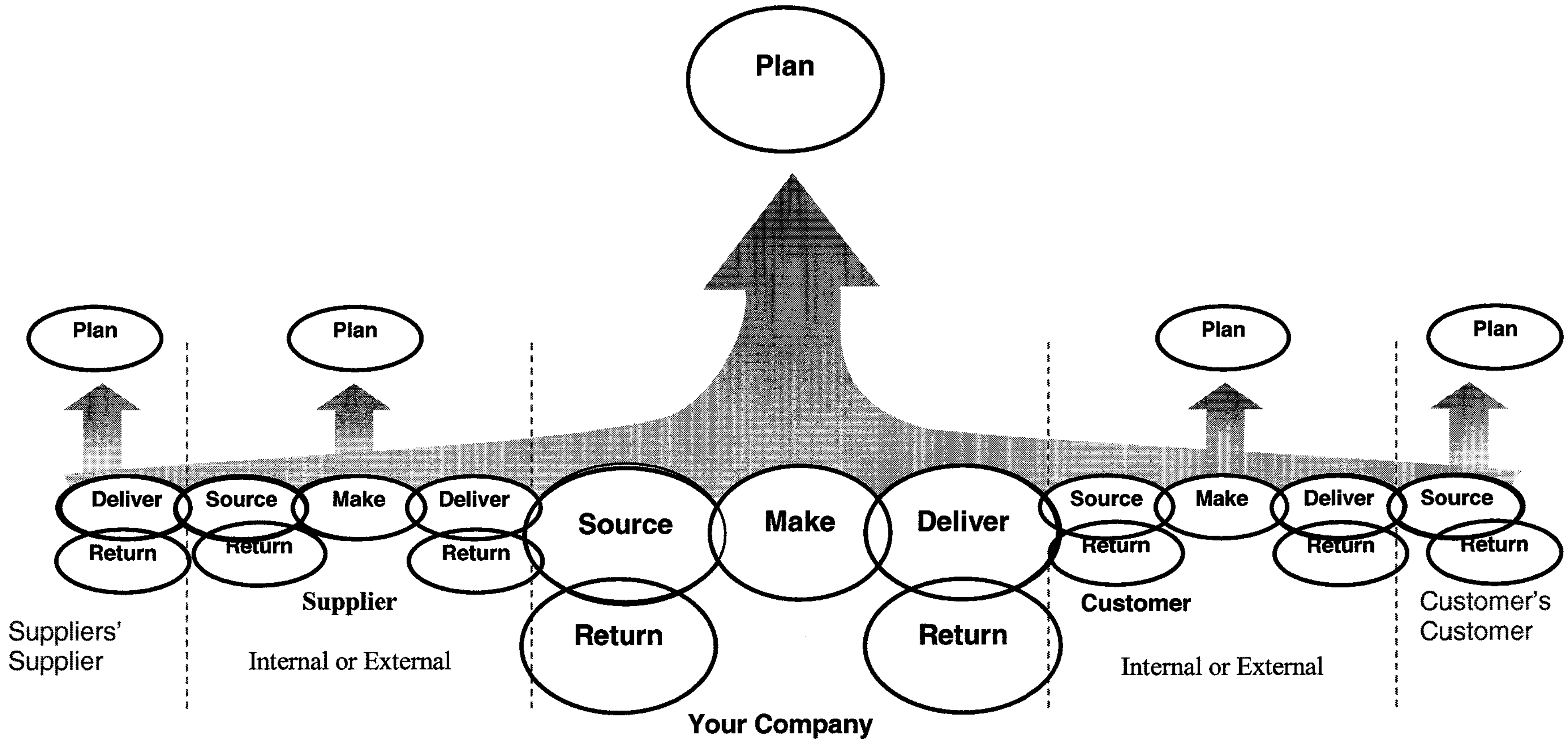


Figure 2.2 Four Major Management Process in Supply Chain

(Adapted from Supply Chain Operations Reference Model version 6.1, Supply-Chain Council (2004))

Constructs	Definitions	Literature
Postponement	The practices of delaying activities in the supply chain as late as possible until actual customer orders are received.	Van Hoek, 1998; Yang and Burns, 2003; Beamon, 1998; Naylor et al., 1999; Van Hoek et al., 1999a; Van Hoek et al., 1999b; Feitzinger and Lee, 1997; Bowersox and Closs, 1996; Catalan and Kotzab, 2003; Pagh and Cooper, 1998; Richardson, 2000; Waller et al., 2000
Information flow facility	The acts to improve breadth, quality, and frequency of information sharing and information quality for functional and strategic purposes.	Moberg et al., 2004; Langley, 1986; Closs et al., 1997; Billington and Johnson, 2005; Heinrich 2003
Supplier management	The management efforts to develop better and more responsive supply base.	Spekman et al., 1994; Narasimhan and Das, 1999; Pooler and Pooler, 1997; Novack and Simco, 1991; Chen and Paularaj, 2004; Narasimhan et al., 2004; Narasimham and Das, 2000; Singh and Sushil, 2004; Christopher, 2000
Outsourcing	The practice of transferring internal business activities and functions to third parties for business.	Gilley and Rasheed, 2000; Quinn and Hilmer, 1995; Quinn and Hilmer, 1994; Jennings, 1997; Alexander and Young 1996; Fill and Visser, 2000

Table 2.6 Supply Chain Management Practices Sub-constructs and Definitions

2.4.1 Postponement

Postponement refers to the practices of delaying activities in the supply chain as late as possible until actual customer orders are received (Van Hoek, 1998a; Yang and Burns, 2003; Naylor et al., 1999). Postponement has been increasingly implemented as an important supply chain strategy as forecast and planning becomes very complex in today's business (Feitzinger and Lee, 1997; Van Hoek, 1998a). Postponement fosters a new way of thinking about the supply chain (Yang and Burns, 2003) and requires a reconfiguration of the supply chain (Van Hoek, 1999). Considering the potential of postponement in saving inventory holding and carrying costs, the longer and wider the supply chain, the greater the potential benefits of postponement (Richardson, 2000). In the leagile supply chain, for example, postponement is used to move the decoupling point closer to the end-user and increase the efficiency and the effectiveness of the supply chain (Naylor et al., 1999). In order to respond to rapidly changing customer demands, the ability of the supply chain postponing product differentiation and pack product in-transit is critical in achieving mass customization. In other words, postponement allows firms to be flexible in developing different version of the product as needed (Waller et al., 2000).

Postponement was mainly discussed as an operational method to move towards a mass customization strategy (Van Hoek et al., 1999; Feitzinger and Lee, 1997). Bowersox and Closs (1996) discussed three types of postponement: (1) time postponement, which involving the delaying of activities until orders are received in time; (2) place postponement, which involving the delaying of moving goods downstream in the chain until orders are received; and (3) form postponement, which involving the delaying of activities that determine the form and function of products until orders are received. In time postponement the key differential is the timing of inventory deployment to the next location in the distribution center (Bowersox et al., 1999). The search for place postponement has led many companies in European to create European distribution centers from which they service a wider market (Christopher, 1998). When implemented in combination, time and place postponement is considered logistics flexibility. Zinn and Bowersox (1988) identified four different practices of form postponement: labeling, packaging, assembly and manufacturing. Form postponement is also labeled manufacturing postponement in some studies (Bowersox and Closs, 1996).

The postponement evolution can be seen in the trend towards marketing, logistics, manufacturing, purchasing, and distribution process in the context of supply chain (Van Hoek et al., 1999; Yang et al., 2004). Postponement can be extended further upstream in the supply chain to suppliers of components and raw materials, or downstream in the delaying of transportation costs, warehousing, and storage costs (Waller et al., 2000). Upstream and downstream postponements were proposed while they are too broad to be followed. In detailed, engineering, purchasing, component manufacturing, product manufacturing, final manufacturing, packaging and shipment postponement are identified as applications along the supply chain (Van Hoek et al., 1999).

2.4.2 Information Flow Facility

Information flow facility refers to the acts to improve breadth, quality, and frequency of information sharing and information quality for functional and strategic purposes (Moberg et al., 2004). These information flows include both demand information flowing up the supply chain from customers to sales, marketing, manufacturing, product design and procurement, and supply information that flows down the supply chain, from procurement, manufacturing, sales, and distribution to distributor, retailers and customers. Without accurate, current information about supply and demand conditions, even a supply chain that is physically capable of high flexibility (i.e., machine flexibility, setup flexibility, and flexible manufacturing system) lack of responsiveness to actual market conditions as they evolve. Many previous studies have inferred that information is a resource enhancing operational effectiveness, efficiency and flexibility (Langley, 1986; Closs et al., 1997). The sources of flexibility in the supply chain were of little relevance when the information necessary to effectively exploit them was unavailable (Billington and Johnson, 2005). In particular, Heinrich and Betts (2003) depicted steps for transforming a supply chain into an adaptive business network. The adaptive business network requires instantaneous visibility into important information enabled by advances in technology and supply chain management. Therefore, more recent supply chain practices, such as information technology utilization and information sharing, have further improved the informational efficiency of the supply chain (Moberg et al., 2004). The list of these sub-constructs, along with their definitions and supporting literature, are provided in Table 2.7.

Constructs	Definitions	Literature
IT utilization	The extent of information technology applications in supporting efficient business processes and effective decision making.	Kim and Narasimhan, 2002; Bovel and Martha, 2000; Closs et al., 1997; Kim and Narasimhan, 2002; Auramo et al., 2005; Narasimhan and Kim, 2001; Kim and Narasimhan, 2002; Narasimhan and Kim, 2002
Information sharing	The practices of capturing and disseminating timely and accurate information for efficient business processes and effective decision making.	Mentzer et al., 2000; Mason-Jones and Towill, 1997; Towill, 1997;Gosain et al., 2005; Mason-Jones and Towill, 1999; Christopher, 2000; Zhao et al., 2002

Table 2.7 Sub-constructs of Information Flow Facility and Their Definitions

2.4.2.1 Information Technology Utilization

Information technology utilization refers to the extent of information technology applications in supporting efficient business processes and effective decision making. From the information processing perspective, internal and external uncertainty are defined as the difference between the amount of information required and processed. Organizations must attempt to close the information gap by developing information processing mechanism. As environmental and technological complexities increase, the increasing requirements for information exchange and processing between business units and partners are associated with the utilization of information technology. Supply chain is an example of an IT-enabled inter-organizational configuration where the coordination of business processes between organizations is the key to good performance. Information technology can enhance coordination in supply chains by reducing uncertainty and enhancing decision-making and communications. With the realization of global competition and advances in information technology, the utilization of IT can have direct influences on value creation by integrating firm's supply chain activities (Kim and Narasimhan, 2002). Bovel and Martha (2000), in quoting a 1999 survey by Mercer Management Consulting, indicates that information technologies was a major indicator of supply chain management best practices, particularly if employed to connect customers, suppliers and value adding activities. Generally speaking, information technology contributes to high quality products, enhanced productivity, efficient machine utilization, and increased logistics efficiency and flexibility (Closs et al., 1997; Kim and Narasimhan, 2002). In particular, Auramo et al. (2005) sums up the benefits of IT in supply chain management and proposes that IT enables enhancement of service level, improvement in operational efficiency, improvement in information quality, and agile supply chain operating models. IT seems to be particular important in fast clock speed industries

(Guimaraes et al., 2002) or when flexibility and agility are needed (Sanders and Premus, 2002; Heinrich and Betts, 2003).

By reviewing relevant literature, the utilization of IT has two major characteristics in today's business. First, the role of IT must be raised from information processing to refine firm capabilities. Second, IT should not only automate the physical operations in supply chain management but optimize connections among supply chain (Narasimhan and Kim, 2001; Kim and Narasimhan, 2002; Narasimhan and Kim, 2002). These views imply that IT plays different roles in supply chain management. The most typical role of IT in SCM is to streamline activities and improve operational efficiencies (i.e., through increased standardization, tighter process controls, reduced manual intervention, and reduced friction in transaction). In addition, IT is more importantly viewed to have a role in supporting the collaboration and coordination of supply chain. For example, Lee et al. (1997) present IT as one of the key cures for bullwhip effect in supply chains. Finally, IT can be used for new capabilities creation, decision support, and long-term business processes improvement. In this instance, the analytical power of computers is used for analysis of point-of-sale data to understand patterns in customer preferences, patterns in the sale of complementary products. Elaborating on the commonly viewed functional and strategic roles of IT in supply chain management, a number of methods can be used to classify information technologies utilization. This study proposes to measure IT utilization by AMT, functional IT, and strategic IT (Barki et al., 1993; Narasimhan and Kim, 2001; Kim and Narasimhan, 2002)

2.4.2.2 Information sharing

Information sharing refers to the practices of capturing and disseminating timely and accurate information for efficient business processes and effective decision making. Although many researchers have emphasized the importance of information sharing in supply chain management, it is a hug challenge for management. Information sharing aims to capture and disseminate timely and relevant information to enable decision makers to plan and control supply chain operations. Successful information sharing requires not only capable information technology but effective information networks as well (Gosain et al., 2005).

Flexibility can only be achieved within a supply chain by concentrating as much attention on information flow as is traditionally devoted to material flow (Mason-Jones and Towill, 1999; Christopher, 2000). In today's volatile environment, with high speed changes and opportunities appearing and disappearing quickly, adapting to new customer needs and exploiting new market requires high information awareness and, at the same time, high flexibility. For instance, Wal-Mart broke down the barriers to information sharing and opens its consumer information to Procter & Gamble, one of its main suppliers. It is then Procter & Gamble's responsibility to keep shelves full and thus maximize Wal-Mart sales. This information sharing benefits both companies individually and hence their supply chain is far more flexible. Higher environmental variation will make information sharing more beneficial in improving the performance of the supply chain (Zhao et al., 2002). Still others, such as Benetton's unique responsive capability comes form improved information visibility including rapid online feedback, to determine which colors are selling and the appropriate color mixture for remaining sweaters (Kulp et al., 2005).

Shared information varies from tactical to strategic in nature, including demand forecasts, order information, and inventory levels etc. (Mentzer et al., 2000). Originally, information sharing focuses on achieving specific business purposes (e.g., meeting delivery dates, monitoring inventory status, and responding to customer inquiries). Beyond functional perspective, successful supply chains must view their information as a strategic asset and a source of competitive advantages (Mason-Jones and Towill, 1997). With appropriately sharing information between suppliers and other supply chain entities, all members within the supply chain can "seamlessly" work together to serve the end consumer (Towill, 1996). This study measures the practice of information sharing by considering two key dimensions identified by Gosain et al. (2005): the breadth and the quality of information sharing. The breadth of information sharing indicates to what extent the information is share in a broad range of areas including information about actions, changes, and feedbacks. The quality of information sharing is associated with relevance, timeliness, completeness, and value added.

2.4.3 Supplier management

The recognition of the strategic importance of purchasing in many organizations has increased in recent years (Spekman et al., 1994; Narasimhan and Das, 1999). It is due to the pressures from price competitiveness, responsiveness, cost concern, and the speed of new product introduction. Further, the increasing emphasis on supply chain management has sharpened top management's focus on the value-added potential of supply management (Nelson et al., 2002). Supplier management is differ from supply chain management in that supply chain management emphasizes all aspects of delivering products to customers, whereas supplier management is defined as the management efforts to develop better, and more responsive supply base (Pooler and Pooler, 1997). The concept of supplier management moves beyond the typical transaction focus of purchasing and is a more comprehensive description encompassing the important evolution to a strategic focus of procurement. Supplier management is becoming increasingly integrated with the strategic plans for the company to maximize responsiveness. According to Dobler and Burt (1996), the increasing emphasis on supplier management requires that supply managers take a more strategic view of what they do. Supplier management plays a key liaison role between external suppliers and internal organizational operations in creating and delivering value to customers (Novack and Simco, 1991).

The prevalence of supplier management appears to have benefited drastically from the increasing globalization of markets and the trendy practice of achieving flexibility. The ability to meet the changing needs of customers requires the management of business and relationships with supply partners (i.e., supplier relationship management). Supplier selection, development, and relationship management play a crucial role in supply management have been recognized (Chen and Paularaj, 2004; Narasimhan et al., 2004; Narasimham and Das, 2000; Singh and Sushil, 2004; Christopher, 2000). The list of these sub-constructs, along with their definitions and supporting literature, are provided in Table 2.8.

2.4.3.1 Supplier selection

Supplier selection refers to the practices to define the criteria used to evaluate and select suppliers in order to configure and establish a responsive supply base (Choi and Hartley, 1996; Vonderembse and Tracey, 1999). It is the most fundamental responsibilities of supply management. The importance of supplier selection roots in the reason that it impacts following up activities across the supply chain such as production, inventory management, and logistics. Direct suppliers have assumed the responsibility for design, production and logistics. Consequently, selecting suppliers for specific goods and services is a critical decision for most firms, since supplier performance can have a direct financial and operational impact on the business (Bailey et al., 1994; Ittner et al., 1999). Specifically, suppliers who are unwilling to share information on cost, quality and production can be screened out, because willingness to share information is viewed as a signal of the trustworthiness of the supplier.

Constructs	Definitions	Literature
Supplier selection	The practices to define the criteria used to evaluate and select suppliers in order to configure and establish a responsive supply base.	Choi and Hartley, 1996; Vonderembse and Tracey, 1999; Bailey et al., 1994; Ittner et al., 1999; Weber et al., 1991; Verma and Pullman, 1998; Lummus et al., 2003
Supplier development	The practices to improve supplier's performance and capabilities in effectively and efficiently responding to environmental changes.	Krause and Ellram, 1997; Krause et al., 1998; De Toni and Nassimbeni, 2000; Hahn et al., 1990; Watts and Hahn, 1993; Reed and Walsh, 2002
Strategic supplier partnership	The practices to establish long-term relationships with suppliers for a lasting competitiveness of the entire supply chain.	Sheridan, 1998; Mentzer et al., 2000; Monczka et al., 1998; Wagner and Johnson, 2004; Bensaou, 1999; Cannon and Perrault, 1999

Table 2.8 Sub-constructs of Supplier Management and Their Definitions

Early works on supplier selection identified a number of supplier attributes which managers tradeoff when choosing a supplier (Weber et al., 1991; Verma and Pullman, 1998; Choi and Hartley, 1996). However, new business process and competition have changed the traditional supplier selection criteria such as price, quality, and delivery reliability. Many manufacturing firms have given increasing attention to strategic supplier selection in the effort of establishing and sustaining their competitive advantages (Lummus et al., 2003). Particularly, Verma and Pullman (1998) identified flexibility as one of the most important supplier selection criteria. In an empirical study of purchasing managers in manufacturing firms, Narasimham and Das (2000) suggests that for manufacturers who are seeking new product, volume and modification flexibilities, new supply partners with the required flexibility in product modification and delivery must be found. Choi and Hartley (1996) reported that the capability of suppliers to make product volume changes is a significant factor in supplier selection in the automotive industry. Therefore, the ability of company to react quickly to customer demand is dependent on the reaction capability of suppliers to make changes accordingly.

2.4.3.2 Supplier development

Supplier development is defined as the practices to improve supplier's performance and capabilities in efficiently and effectively responding to environmental changes (Krause and Ellram, 1997; Krause et al., 1998). Firms are putting efforts on supplier development for the purposes of (1) ensuring that supply sources that provide satisfied overall value of goods and services that meet their requirements; firms have reported the need for supplier improvement in quality, delivery, cost reduction, new technology adoption and product design (De Toni and Nassimbeni, 2000); (2) creating and maintaining a network of competent suppliers for long term competitive advantages (Hahn et al., 1990; Watts and Hahn, 1993). Watts and Hahn (1993) proposed that supplier development efforts should focus on developing supplier future capabilities in technology and product development rather than on current quality and cost. In that way, companies put significant efforts into developing competent supply network.

Supplier development can be either reactive or strategic. Reactive efforts are made to increase the performance of laggard suppliers; while strategic efforts aim to increase the capabilities of the supply base to enhance the buying firm's long-term competitive advantages (Krause et al., 1998). The purchasing literature has stressed the importance of supplier development in supporting a firm's strategy by ensuring that suppliers' performance and capabilities meet the needs of the buying firm (Krause and Ellram, 1997). Specifically, enhancing the technological capability of the supply network through supplier development increasingly contributes to innovation, which is vital to the competitive success (Reed and Walsh, 2002).

Various supplier development practices have been depicted, including buying from alternative suppliers to provide competition for current suppliers (Hahn et al., 1990), evaluation of supplier performance (Hahn et al., 1990; Watts and Hahn, 1993), training and education of a supplier's personnel (Monczka et al., 1993), exchange of information between buyer and supplier (Humphreys et al., 2004), communications (Prahinski and Benton, 2004; Humphreys et al., 2004), and awards (Monczka et al., 1993). By linking supplier development to just-in-time purchasing, De Toni and Nassimbeni (2000) categorized supplier development into supplier monitoring, supplier assistance and training, supplier incentives, and supplier organizational integration. Based on the discussion, supplier development practices are classified into:

- transaction-specific supplier development, which represents direct involvement of the buying company in developing suppliers performance and capabilities (Humphreys et al., 2004)
- supplier evaluation, which provides valuable information about general areas of weakness where performance improvements are needed (Prahinski and Benton, 2004; Humphreys et al., 2004); and
- supplier incentive, which recognizes supplier's achievements/performance in the form of awards (Monczka et al., 1993; De Toni and Nassimbeni, 2000)

2.4.3.3 Strategic supplier partnerships

Strategic supplier partnerships refer to the practices to establish long-term relationships with suppliers for a lasting competitiveness of the entire supply chain (Shin et al., 2000; Carr and Pearson, 1999). As companies outsource an increasing amount of the value of their products, suppliers are undoubtedly becoming increasingly important for the success of today's companies, which rely heavily on external sources for materials, products, services, technology, and innovation. Strategic supplier partnership opens opportunities for both buyers and suppliers to leverage their advantages to deliver value throughout the supply chain. For example, Honda of America and Chrysler, often cited for their leading practices in developing partnership relationships with suppliers, have achieved great benefits from it (Sheridan, 1998). Therefore, it is recognized that a partnership with the appropriate firm can help add value to existing products. For example, partnerships that improve time to market or distribution times, and the skills base of both partners help tot increase the perceived value of a particular firm.

A large and rich body of literature on supplier relationships management has been developed focusing on strategic partnership (Li et al., 2006; Mentzer et al., 2000; Monczka et al., 1998; Choi and Hartley, 1996; Kotabe et al., 2003). Strategic supplier partnership provides a framework for strategic collaboration, ensuring open communication channels, quicker resolution of problematic issues and higher responsiveness (Mentzer et al., 2000). By developing strategic partnership with suppliers, it is possible to work more effectively with a few important suppliers who have passion to help each other succeed, place a high priority on the relationship, and include shared risks, opportunities, strategies, and technology road maps. A strategic partnership emphasizes direct, long-term association, encouraging mutual planning and problem solving efforts (Gunasekaran et al., 2001; Li et al., 2006). That is, through supplier partnership, supply chain partners are willing to share risks and reward and maintain the relationship over a longer period of time. The supplier will become part of a well-managed chain and will have a lasting effect on the competitiveness of the entire supply chain.

2.4.4 Outsourcing

In prior research, the definitions of outsourcing focused on the purchase of goods or services that were previously produced internally. But some researchers argued that defining outsourcing simply in terms of procurement activities does not capture the true strategic nature of the issue (Gilley and Rasheed, 2000; Quinn and Hilmer, 1995). Quinn and Hilmer (1995) proposed that outsourcing combines the concentration on the firm's own resources on a set of "core competencies" and the utilization of external suppliers' investments, innovations, and specialized professional capabilities. Their discussion implies that outsourcing is the consequence of the adoption of a resource-based strategy. We define outsourcing as the practice of transferring internal business activities and functions to third parties. Outsourcing is an increasingly important initiative being pursued by many companies to leverage their companies' skills and resources and seek competitive edges from third parties. For example, in the US, Intel considers that its core competencies are centered on design skills and extensive test-feedback systems, and recognizes that logistics services do not form the basis of competitive advantages. Hence, their logistics requirements are outsourced to external parties (Quinn and Hilmer, 1994).

The potential for outsourcing has moved on from those activities that are normally regarded as of peripheral concern to the companies to include critical functions such as design and manufacturing with almost the entire value chain open to the use of outside supply (Jennings, 1997). Gilley and Rasheed (2000) viewed outsourcing in terms of peripheral outsourcing when firms acquire peripheral activities from external suppliers, and core outsourcing when firms acquire activities that are considered highly important to long-term success. In the same line, Alexander and Young (1996) made a distinction between "non-strategic" and "strategic" outsourcing. In describing outsourcing as strategic, they highlight whether the company have a strategic policy concerning outsourcing and have a consideration of outsource "core" activities are two key criteria. Outsourcing is also considered as a continuum from short-term market exchange to long-term relational exchange by Fill and Visser (2000). In sum, outsourced functions can be either core or peripheral, and they are complementary for firms to build up their competitive edges. Table 2.9 lists sub-constructs of outsourcing, along with their definitions and supporting literature.

Constructs	Definitions	Literature
Core outsourcing	The process of transferring internal business activities and functions to third parties for the potential for creating strategic business value.	Quinn and Hilmer, 1995; Jennings, 2002; Billington and Johnson, 2005; Zhao and Calantone, 2003
Peripheral outsourcing	The process of transferring peripheral internal business activities and functions to third parties for cost saving, superior quality achievement and other operational efficiency improvement.	Embleton and Wright, 1998; Quinn et al., 1990; Jennings, 2002; Quinn, 1992; Gonzalez et al., 2005

Table 2.9 Sub-constructs of Outsourcing and Their Definitions

2.4.4.1 Core Outsourcing

Core outsourcing refers to the process of transferring internal business activities and functions to third parties for the potential for creating strategic business value. Strategically, outsourcing can provide the buyer with greater flexibility (Quinn and Hilmer, 1995; Jennings, 2002), especially in the purchase of rapidly developing new technologies, fashion goods, or myriad components of complex systems (Quinn and Hilmer, 1995). For example, athletic footwear is technology- and fashion-intensive, and requiring high flexibility at both the production and marketing levels. Nike, Inc., the largest supplier of athletic shoes in the world, outsource 100 percent of its shoe production and keeps only key technical components of "Nike Air" system in house (Quinn and Hilmer, 1994). The greater flexibility enabled by outsourced manufacturing allows technology firms to be highly responsive to market conditions and evolving opportunities (Billington and Johnson, 2005).

When firms began selling their factories and farming out manufacturing in the'80s and '90s to boost efficiency and focus their energies, most insisted all the important research and development would remain in-house. But firms are turning toward a new model of innovation. Today, the likes of Dell, Motorola, and Philips are buying complete designs of some digital devices from Asian developers, tweaking them to their own specifications, and slapping on their own brand names. These can include U.S. chipmakers, Taiwanese engineers, Indian software developers, and Chinese factories. When the whole chain works in sync, there can be a dramatic leap in the speed and efficiency of product development. Giving complicated product development tasks to others is a way to incorporate their expertise into one's own product development project (Zhao and Calantone, 2003). Some of the firms are now moving from specification-driven toward prototyping-driven product development. With the outsourcing of rapid prototyping, prototypes can be effectively used to communicate customer demand, technology requirements, and production capabilities. Therefore, the specifications of new product can be determined as late as possible in response to customer demand changes.

2.4.4.2 Peripheral Outsourcing

Operational outsourcing refers to the process of transferring peripheral internal business activities and functions to third parties for cost saving, superior quality achievement and other operational efficiency improvement. The peripheral tasks are characterized as (1) routine, (2) well delineated, (3) can be measured and managed at arms length, (4) readily provided by suppliers, and (5) have little potential competitive advantages in the value chain (Embleton and Wright, 1998). Companies choose to take a broad approach to outsourcing may decide to outsource many peripheral activities. By handing over the management and operation of certain routine and repetitive tasks to an outside source, firms can see enhanced operational performance in three ways: (1) outsourcing can provide access to "best in world" quality for particular activities or components (Quinn et al., 1990; Embleton and Wright, 1998); (2) outsourcing enables the development of more focused capabilities for increasing responsiveness to market changes (Quinn et al., 1990; Jennings, 2002); (3) outsourcing peripheral activities to the lower-cost suppliers may lead to incremental improvements in a firm's overall cost position (Jennings, 2002; Quinn, 1992). Small companies can benefit from economies of scale through outsourcing; while large companies benefit by outsourcing to lower cost locations, to the supply market that multiple suppliers competing with each other for supplying a few buyers, and keeping long-term supplier relationship. The results of a survey made in large Spanish show that long-term outsourcing contracts of IT convert variable costs into fixed costs, and make technology spending more predictable (Gonzalez et al., 2005).

2.5 Supply Chain Performance

The importance of performance measures have been long recognized (Beamon, 1999; Gunasekaran et al., 2001; Chan et al., 2003; Chan and Qi., 2003). Performance measurement is critical elements in translating a firm's mission and strategy into reality. It is supposed to contribute much to business management and performance improvement by playing the important roles of monitoring performance, enhancing motivation, improving communications, and diagnosing problems (Melnyk et al., 2004). The battleground in today's business is supply chain versus supply chain, with emphasis on continuous improvement across the supply chain. It is critical therefore to focus management attention on the performance measurement of supply chain to enable short-term tactical management activities, to support decision-making, to inform the strategy making process, and finally, to enable longer term resource planning to be effective (Hausman, 2005; Gunasekaran et al., 2004).

Supply chain performance refers to the extent to which a supply chain in meeting end-customer requirement and operational efficiency to deliver that performance. (Hausman, 2005). The definition implies that supply chain performance measures effectiveness and efficiency in relation to how well the goals are met. In the supply chain context, effectiveness has an outward-looking perspective and is concerned with the extent to which the end-customer demands are satisfied (i.e., delivery performance and responsiveness). It can therefore be described as an outcome of the system. Efficiency, on the other hand, is an inward-looking factor that reflects how well the resources are utilized in the achievement of output (i.e., cost and inventory performance) (Lai et al., 2002; Webster, 2002). Integrating these two aspects capture the performance expectations of member firms on both input and output sides of supply chain activities. Therefore, both aspects of supply chain performance must be recognized, or firms fail to ensure multi-functional and multi-firm attention in performance management. For instance, General Motors's was impeccable in their inventory management in the early eighties. However, the customer service has bad reputation among end-consumers because of the poor inventory control systems of GM dealers and the lack of information flow integration between GM and its dealers. That is, while GM's factory performance was great, the overall supply chain was not competitive (Hausman, 2005). The supply chain performance measures must therefore be cross-firm and cross-function in nature. Along with this line, Tompkins and Ang (1999) and Van Hoek (1998b) agree that the supply chain performance measurement must be designed to ensure that all the sub-systems and organizations in a supply chain act in the same manner to support market share, value, and profit.

Some authors such as Handfield and Nichols (1999) proposes criteria for "effective supply chain performance measurement" and suggests that an effective supply chain performance measurement should: (1) measuring overall supply chain performance rather than only the performance of the individual chain member; and (2) have one central, overriding focus: continual improvement of end-customer service. Therefore, we summarize above research findings and propose four dimensions of supply chain performance in this study: supply link, reliability, time-based, and cost performance. These four aspects capture the efficiency and effectiveness of a supply chain and reflect the inter-organizational characteristics of supply chain performance measurement. The efficiency of a supply chain is assessed by costt and supply link performance. The cost dimension deals operations-related performance measures, while supply link performance relates to supply process. On the other hand, reliability and time-based performance measurements reflect the effectiveness of a supply chain and connect to make and delivery processes. Table 2.10 lists these four dimensions along with their definitions and supporting literature.

2.5.1 Supply link performance

Supply link performance refers to the extent to which a supply chain in improving the supplier performance and the linkages with supply partners to support demand satisfaction. The links in a supply chain that directly impacts supply side performance are supplier performance and supplier relationship. They are primary determinant of customer satisfaction. Supplier performance and quality of relationship as two measures of supply side performance have attracted the attention of practitioners and researchers (Gunasekaran et al., 2004; Gunasekaran et al., 2001; Stevens, 1990; Beamon, 1998).

The supplier performance is considered a very critical dimension of supply chain performance because supplier involvement helps downstream chains to improve overall quality, reduce cost, and achieving competitive advantages (Stevens, 1990; Beamon, 1998; Gunasekaran et al., 2001). In the current study, the supplier's performance is an operational measure of key competitive success factors, namely product quality (Prahinski and Benton, 2004; Shin et al., 2000; Vonderembse and Tracy, 1999), delivery performance (Shin et al., 2000; Prahinski and Benton, 2004; Beamon, 1998; Vonderembse and Tracy, 1999), and responsiveness to change requests (Prahinski and Benton, 2004).

Previous studies have contended that buyer-supplier relationship is vital in supply chain operations and as such for efficient and effective sourcing (Macbeth and Ferguson, 1994; Ellram, 1991). Therefore, performance evaluation of supplier is simply not enough for assessing supply links – relationships must be evaluated. The aspects that need to be considered in the evaluation of relationships are the ones that promote and strengthen them (Gunasekaran et al., 2004). The measurements of relationship quality may be the extent of trust, commitment, and satisfaction (Dorsch et al., 1998; Maloni and Benton, 2000; Fynes et al., 2005; Roberts et al., 2003). Trust is the firms' belief that their supply partner will perform actions that will result in positive outcome for the supply chain (Maloni and Benton, 2000; Fynes et al., 2005). Several researchers have started to propose measurement of overall supply chain performance including assessing the extent to which supply chain relationships are based on mutual trust (Fawcett and Clinton, 1997; Bello and Gilliland, 1997). Commitment refers to the willingness of trading partners to exert effort on behalf of the relationship and suggests a future orientation in which firms attempt to build a relationship that can be sustained in the face of unanticipated problems (Gundlach et al, 1995). Satisfaction is a summary measure that provides an evaluation of the quality of all past interactions and relationships with supply chain partners (Roberts et al., 2003; Dorsch et al., 1998).

Constructs	Definitions	Literature
Supply chain performance	The extent to which a supply chain in meeting end-customer requirement, and operational efficiency in the supply chain to deliver that performance.	Beamon, 1999; Gunasekaran et al., 2001; Chan et al., 2003; Chan and Qi, 2003; Lai et al., 2002; Bechtel and Jayaram, 1997; Chan and Qi, 2003; Melnyk et al., 2004;Gunasekaran et al., 2004
Supply link performance	The extent to which a supply chain in improving the supplier performance and supplier relationship quality to support demand satisfaction.	Gunasekaran et al., 2004; Gunasekaran et al., 2001; Stevens, 1990; Beamon, 1998; Prahinski and Benton, 2004; Shin et al., 2000; Maloni and Benton, 2000; Fynes et al., 2005
Reliability	The extent to which a supply chain in performing the promised activities and services dependably and accurately	Lai et al., 2002; Rushton and Oxley, 1989; Chan and Qi, 2003; Crosby and Lemay, 1998

	Time-based performance	The extent to which a supply chain in improving the speed and responsiveness, with which products or customer services are designed, manufactured, delivered, and supported	Blackburn, 1991; Cater et al., 1995; Jayaram et al., 1999; Droge et al., 2004; Carter et al., 1995; Handfield and Pannesi, 1992; Vickery et al., 1995; Safizadeh et al., 1996; Jayaram et al., 2000; Handfield, 1995
	Cost	The effectiveness in managing costs associated with operating the supply chain.	Lai et al., 2002; Chan, 2003; Stewart 1995; Gunasekaran et al., 2004; Beamon, 1999

Table 2.10 Supply Chain Performance Construct, its Sub-construct, and Their Definitions

2.5.2 Reliability

Reliability is traditionally regarded as a measure of supply chain delivery performance which means the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer (Supply Chain Council, 2004; Lai et al., 2002; Rushton and Oxley, 1989). Chan and Qi (2003) extends the concept of reliability to dependability of specific event or activity, especially from the customers' point of view. In this study, the board of reliability performance measurements is suggested as: delivery reliability, order fulfill reliability, and quality reliability (Lai et al., 2002; Crosby and Lemay, 1998).

2.5.3 Time-based performance

Time-based competitive advantage has recently received substantial attention in supply chain management because time-based competition has been the focus of considerable interest among practitioners and academics alike (Blackburn, 1991; Cater et al., 1995;

Jayaram et al., 1999). Time-based performance refers to the extent to which a company is able to improve the speed and responsiveness, with which products or customer services are designed, manufactured, delivered, and supported (Droge et al., 2004; Carter et al., 1995). For many companies, time as a source of competitive advantages has been increasingly recognized. Some companies concentrated on increasing product development and launch speeds, while others have focused on improving manufacturing, delivery, and customer response times. Many companies pursuing time-based strategies (i.e., flexibility) have experienced landmark improvements in various dimensions of time-related performance (Jayaram et al., 1999). These dimensions span the entire value delivery system starting with suppliers and ending with customers.

The key dimensions of time-based competitive advantages include delivery speed (Handfield and Pannesi, 1992; Vickery et al., 1995), new product development and introduction time (Vickery et al., 1995; Droge et al., 2004; Safizadeh et al., 1996), , manufacturing lead-time (Jayaram et al., 2000), and customer responsiveness (Handfield, 1995; Jayaram et al., 1999). Jayaram et al. (1999) extended the scope of previous studies by examining a more comprehensive set of time-based performance measures including procurement lead time.

The purpose of implementing supply chain flexibility is to effectively respond to environmental changes on a timely basis. Therefore time-based competitive advantages should receive more recognition in the research of supply chain flexibility. In this study, the time-based performance is captured by time to market which is pertained to new product development (i.e., product development time, product introduction time), time to product which is pertained to the procurement, production, and delivery stages of the supply chain (i.e., procurement lead time, manufacturing lead time, and delivery speed and reliability), and customer responsiveness which refers to the ability of responding in a timely manner to the needs of customers.

2.5.4 Cost

Cost is always one of the indispensable aspects in assessing the performance of business activities and processes. The profit of a firm is directly affected by the cost of its operations. Thus, costs associated with supply chain operations is the most significant direct kind of measurement. Supply chain costs are the costs associated with operating the supply chain (Supply Chain Council, 2004; Beamon, 1999; Kim and Narasimhan, 2002). In evaluating supply chain performance in transport logistics, Lai et al. (2002) advocates that total logistics management costs and return processing costs are measurement indicators of operations efficiency in the transport logistics context. Moving towards a full picture of supply chain costs measurements, Chan (2003) suggested supply chain costs consisting of distribution, manufacturing, inventory carrying, and intangible costs such as quality costs and coordination cost. Additionally, on the basis of survey results from various industries, Stewart (1995) identified information processing cost as the largest contributor to logistics costs. Information process cost is associated with order management such as order entry and order follow/updating (Gunasekaran et al., 2004; Stewart, 1995). As a result, distribution, manufacturing, inventory carrying and information carrying costs are recognized as measures for supply chain costs.

3. THEORETICAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

When understand the phenomenon of supply chain flexibility, it is helpful to have a framework within which to work and from which testable hypotheses can be drawn. A theoretical framework enables prediction made about the likely outcome of supply chain flexibility initiative. It enables observed business behavior to be evaluated and therefore provides better explanations of the motivations for the achievement of supply chain flexibility and its consequences.

3.1 Theoretical Framework

To better understand the antecedents, driving forces and the impacts of supply chain flexibility on performance, a framework is established which describes the causal relationships between drivers and facilitating factors of supply chain flexibility, supply chain flexibility, and performance. The rationale underlying this research framework is straightforward. First, supply chain flexibility is driven by environmental uncertainties. Second, supply chain flexibility is facilitated by factors such as information flow facility, supply management, postponement, and outsourcing. Third, a higher level of supply chain flexibility will improve time-based competitive advantages, and firm performance in terms of operational performance, and market and financial performance. Figure 3.1 depicts the proposed relationships among ten constructs discussed in Chapter 2. The numbers next to each arrow correspond to the hypotheses to be developed later in this chapter. Figure 3.1 shows that supply chain management practices will directly influence supply chain flexibility and supply chain flexibility will further affect supply chain performance. Moreover, it is hypothesized that supply chain flexibility is driven by environmental uncertainty. The following section will provide theoretical support for each hypothesis.

3.2 Research Hypothesis 1 (Environmental Uncertainty and Supply Chain Flexibility)

Many researchers have considered environmental uncertainty an important driver for seeking flexibility (Zhang et al., 2002; Pagell and Krause, 2004; Chang et al., 2002). In a highly uncertain environment with changing markets and rapidly developed technology, companies must improve the ability to respond quickly to changes in the market, to deliver new customer values, and to adapt their businesses rapidly to meet and exceed their customers' requirements. Many operations management studies suggest that manufacturing companies should develop flexibility for the sake of dealing with short product life cycles and environmental uncertainty more effectively (Prater et al., 2001; Pagell and Krause, 2004). In an environment characterized by fast changing customer demand, the need for mass customization and flexibility is growing (Tan et al., 1998). Therefore, supply chain flexibility is required for a firm to cope with external forces.

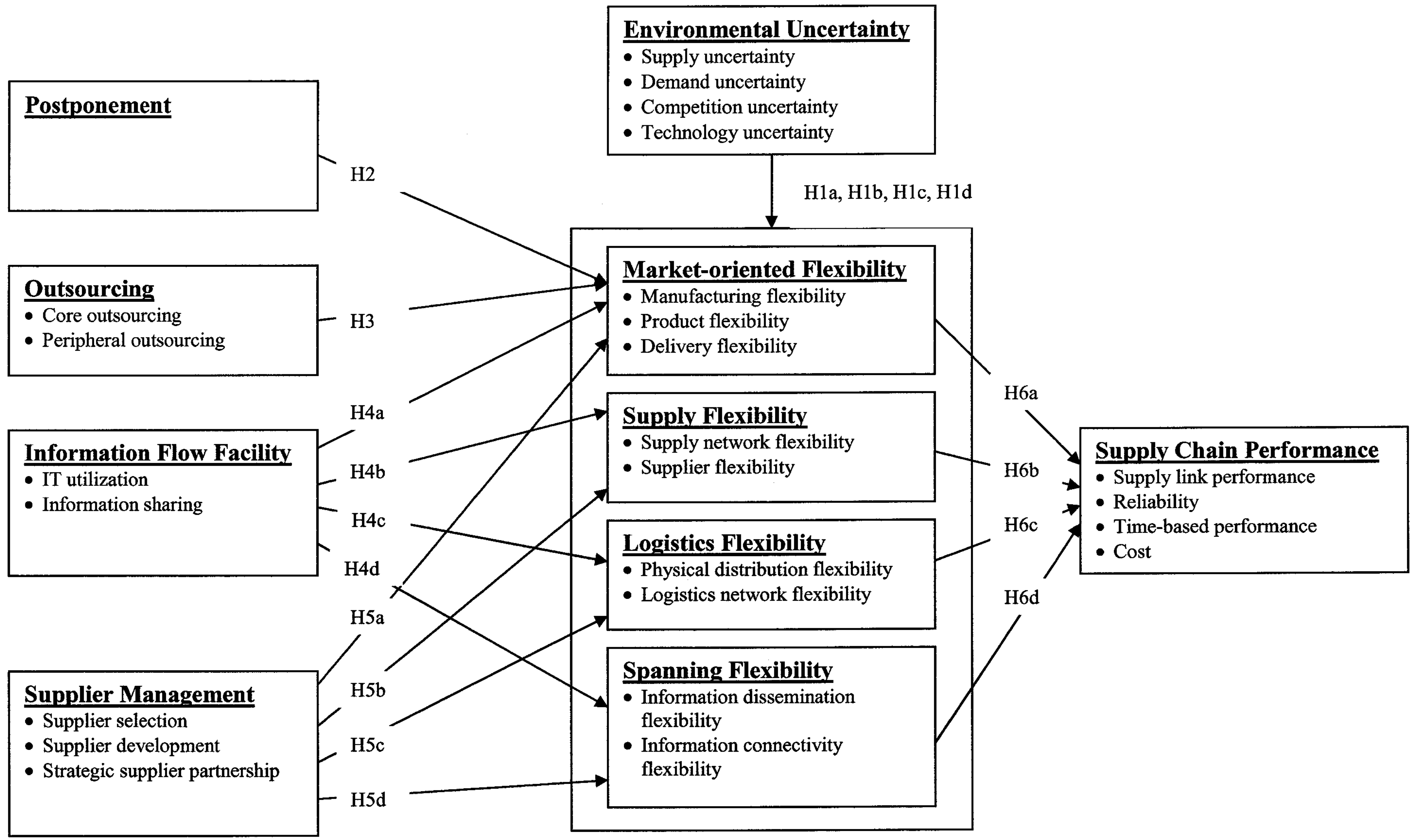


Figure 3.1 A Supply Chain Flexibility Research Framework (detailed)

The evidence explaining this phenomenon can be found in both conceptual and empirical research. Chang et al. (2002) states that aligning manufacturing flexibility with environmental uncertainty is necessary as firms develop their business strategy. They also suggested that as firms face challenges of various uncertainties from the market, suppliers, competitors and technology, they must invest and develop specific types of manufacturing flexibility to respond. Extending to the context of supply chain, different environmental uncertainties may require different efforts in achieving supply chain flexibility. Chang et al. (2002) empirically shows that uncertainty in demand, supply side, competition, and technology will drive firms to seek new product development flexibility and manufacturing flexibility, which is in terms of volume and mix flexibility. Zhang et al. (2002) proposes that firms operating in a high uncertain environment are more likely to seek high supply chain flexibility including product development, manufacturing, logistics, and spanning. To keep pace with the fast changing market environment including technology, competition and customers' preferences, firms use flexible approaches to manage product development (Singh and Sushil, 2004). The above arguments lead to:

Hypothesis 1a: The level of environmental uncertainty is positively related to the. level of market-oriented flexibility

Hypothesis 1b: The level of environmental uncertainty is positively related to the level of supply flexibility.

Hypothesis 1c: The level of environmental uncertainty is positively related the level of logistics flexibility.

Hypothesis 1d: The level of environmental uncertainty is positively related to the level of spanning flexibility.

3.3 Research Hypothesis 2 (Postponement and Market-oriented Flexibility)

The adoption of postponement strategy balances global efficiency and customer responsiveness (Van Hoek et al., 1999). In particular, postponed manufacturing can allow firms to strike balance between cost and rapid customization to deal with the increasingly demanding and turbulent environment (Van Hoek et al., 1999). Hewlett-Packard provides a well-known example of postponed manufacturing in the electronics industry. When assembling printers Hewlett-Packard first builds a standard printer and postpones the addition of power leads and manuals depending upon customer-specifications (i.e., power wattage, language for manuals). The main benefit related to postponement stems from the fact that one can delay the decision point for differentiation. This enables much product flexibility at very little extra cost (Feitzinger and Lee, 1997). Lee and Whang (2000) differentiate the value of postponement as "uncertainty resolution" and "forecast improvement". Postponement of manufacturing in the distribution channel was found to allow rapid delivery of customized products. It is the trend that warehouses are designed to help suppliers respond appropriately to customer demand by providing such services as client-specific packaging, labeling, and material handling (Lummus et al., 2003). A growing number of firms are developing capability to modify or customize products at the distribution center. This postponement helps to achieve significant reductions in lead time when special customer requirements come in (Daugherty and Pittman, 1995). Anand and Mendelson (1998) study the increased flexibility of delayed production in a multiproduct supply chain on a binary demand distribution. In the context of product development, reaction capabilities, which are the capabilities to introduce changes late in the process at low cost and time is shown to be critical for development flexibility (Verganti, 1999). Dell postpones virtually every operation in their supply chains and applies this approach to every order. In other words, Dell can cope with complexity with expanding product variety (Van Hoek, 2001). Therefore, hypothesis 2 suggests:

Hypothesis 2: Postponement is positively related to market-oriented flexibility.

3.4 Research Hypothesis 3 (Outsourcing and Market-oriented Flexibility)

The performance implications of outsourcing decision have been widely debated. However, with little empirical research conducted to determine weather and to what extent outsourcing influences firm performance, Gilley and Rasheed (2000) found no direct impact of peripheral and core outsourcing intensity on the financial, innovation, or stakeholder performance of the firm overall. Their finding should be not interpreted as outsourcing has no effect on firm performance. It is highly likely that outsourcing has an effect on the individual functional areas in which it occurs. Therefore, the extent to which potential intermediate outcomes from outsourcing are translated into firm level effects should be examined. Outsourced manufacturing and online sales channels allows technology firms to be highly responsive to market conditions and evolving opportunities (Billington and Johnson, 2005). Strategically, outsourcing can provide the buyer with greater flexibility in the purchase of rapidly developing new technologies, fashion goods, or the myriad components of complex systems (Quinn and Hilmer, 1995).

Focusing on outsourcing of manufacturing in the telecom equipment industry, Berggren and Bengtsson (2004) revealed that sourcing form third party suppliers increases flexibility and reaction speed to market changes. External suppliers can be used as buffers to absorb production fluctuations and provide internal production stability. Outsourcing presents firms with the opportunity to avoid the constraints of their own productive capacity in meeting changes in the volume of sales (Jennings, 2002; Young and Knight, 1998). For example, Ericsson and Nokia reduce the risk of being caught with over-capacity in a negative business cycle with falling demand. While Nike has a strategy of production partners which produce lower volumes, co-develop products, and co-invest in new technologies. They are expected to handle most surges in volumes themselves (Quinn and Hilmer, 1994). The implementation of outsourcing may also facilitate the ability of the firms to change the product range in response to market conditions. This may be achieved through resource leverage. For instance, Cisco caters to the demand for standard, high-volume networking products by commissioning contract manufacturers in low-cost countries such as China. For its wide variety of mid-value items, Cisco uses vendors in low-cost countries to build core products but customizes those products itself in major markets such as United States and Europe. For highly customized, low-volume products, Cisco uses vendors close to main markets (Lee, 2004).

In the context of product development, outsourcing helps a firm to increase the flexibility to reconfigure and deploy product creation resource chains through accessing market resources (Sanchez, 1996). The number and diversity of product development resources a firm can access increase with its ability to use modular product design and quick-connect electronic interfaces to coordinate product development resources. For example, Nike acquires technologies through joint development ventures with companies holding relevant technology resources to design athletic and special-purpose shoes (Korzeniewicz, 1994). To rapidly deploy a broad base of product development resources through outsourcing enables a quick response to diverse and rapidly changing market preferences. The above discussions suggest the following sub-hypothesis:

Hypothesis 3: Outsourcing is positively related to market-oriented flexibility.

3.5 Research Hypothesis 4 (Information Facility and Supply Chain Flexibility)

3.5.1 Research Hypothesis 4a (Information Facility and Market-oriented Flexibility)

The role of technology in facilitating flexibility has received significant support in theory. As more and more firms recognize information technology as a competitive weapon, it seems to be particularly important in fast clock speed industries (Guimaraes et al., 2002) or when flexibility and agility is needed (Sanders and Premus, 2002; Heinrich and Betts, 2003). EDI (electronic data exchange) facilitated flexible manufacturing, automated warehousing, rapid logistics are good examples. One specific area where information technology may provide flexibility is through the creation of information system architectures that provide the foundation for rapid response to changing market conditions (Allen and Boynto, 1991). Firms choosing to compete on the basis of flexibility, particularly product, mix, and delivery flexibility, consider information technology an important enabler (Sanders and Premus, 2002). Elcoteq, a contract manufacturer of electronics component has been able to build a supply chain that can quickly react to demand changes at the market by implementing information technologies such as EDI and customer relationship management software (Auramo et al., 2005). The results of an empirical study of 57 top-tier suppliers to the North American automotive industry showed that the three dimensions of information system infrastructures including design-manufacturing integration, manufacturing technology and information technology directly influence the delivery speed, responsiveness to customer, agile product development manufacturing (Jayaram et al., 2000). Singh and Sushil (2004) also brought out two-tier flexibility-strategy model for success in product development and asserted that flexibility in use of computer/IT technologies has significant relationship with product development flexibility.

Information plays a key role in allowing firms to be more responsive to customer needs. Higher customer demand variation will make information sharing more beneficial in reduction in ordering lead-time (Zhao et al., 2002). Daugherty et al. (1995) examined the relationships between information and customer response. Their hypotheses state that higher levels of shared information and communications with supply chain partners lead to greater responsiveness. The point of sales information between Wal-Mart Stores and Proter & Gamble, one of its main suppliers, is a good example of enhancing supply chain flexibility by enriching information sharing. Wal-Mart basically broke down the barriers to information sharing and opened its consumer information to Procter & Gamble for deciding how frequently and how much stock to deliver to meet the consumer service level (Mason-Jones and Towill, 1997). Armistead and Mapes (1993) found that information sharing among supply chain entities lead to ability to change volume quickly for both supplier and buyer. Based on the above literature support, this study argues that information sharing is most likely to bring market-oriented flexibility to the focal firm. Hence, Bruce et al. (2004) stated that information sharing between supply network partners is essential for reaching operational flexibility by allowing decision makers to easily manipulate the content and format of retrieved information. In view of the substantial support for IT utilization and information sharing as important antecedents of market-oriented flexibility, we bring forward the following sub-hypothesis:

Hypothesis 4a: The information flow facility is positively related to market-oriented flexibility.

3.5.2 Research Hypothesis 4b (Information Facility and Supply Flexibility)

Venkatraman (1994) argues that information technology has become a fundamental enabler in creating and maintaining flexible business networks. It enables building flexibility in network by facilitating rapid information exchange between firms. Thus, the attainment of external flexibility to some degree depends on the IT utilization that links members across the supply chain. Firms that wish to compete effectively in today's competitive environment need to develop cross-organizational information processing capabilities which are flexible. Many researchers agree that IT reduces the cost of coordination (Malone et al., 1987). It is because the IT reduces communication costs and fosters standardization of infrastructure and data formats. This progress releases constraints on how management can disseminate information and coordinate activities in the supply chain. Therefore, IT has the potential to facilitate – or enable – the development of coordination mechanism and supply chain structure on an effective and efficient basis. In other words, information technology will facilitate quick partnership formation by making available the right information and hence developing a virtual network.

Sharing information allows both companies and their suppliers to sense the need for change in their current process configuration and develop mechanisms for dealing with changes. Companies and their suppliers that engage in broader and higher-quality information exchanges are likely to be better aware of new opportunities and more ready for potential opportunities, whereas those without this information may not be able to sense and adapt to key industry events (Madhavan et al., 1998). Further, greater sharing of information would also allow collective knowledge and consensus on action to emerge faster with new partners (i.e., component), yielding supply flexibility (Gosain et al., 2005). Based on the above discussion, we bring forward the following sub-hypothesis:

Hypothesis 4b: The information flow facility is positively related to supply flexibility.

3.5.3 Hypothesis 4c (Information Facility and Logistics Flexibility)

In addition, the use of information technology as a means to enhance logistics competence (i.e., flexibility) has been widely espoused. Firms must fully exploit the capabilities of information processing and communications technologies allowing logisticians access to a greater range of operational and logistics data worldwide. Routine asset visibility, shared with major vendors and carriers, will be commonplace. Hence a more flexible and responsive logistics structure is realizable (Perry, 1991). Cunningham (1996) sought to identify practices leading to more flexible logistics systems which allow for learning and adaptation and found that developing more powerful information systems for coordinating their logistics functions make them more competitive. Abrahamsson et al. (2003) described logistics platforms driven by a positive information technology/information system development as a resource base for serving new and emerging market channels in long-term cost- and service-efficient ways and constantly being able to taking new positions in the market. For instance, if a new third-party logistics provider becomes available, it has been found open EDI systems improve the efficiency of coordination between buyers and new suppliers, which results in high ability to change partners quickly corresponds to changes (Malone et al., 1987).

Additionally, the distribution chain in any firm relates to the use of information to manage more effectively the functions of transportation, storage, warehousing, and freight forwarding. Firms with real-time information availability have been able to make distribution operations more flexible. An ability to share information allows firms to sense the need for change in their current process configuration and develop mechanisms for dealing with changes. Firms that engage in broader and higher-quality information exchanges with current partners are likely to be better aware of new opportunities and more ready for potential partners, whereas those without this information may not be able to sense and adapt to key industry events (Madhavan et al., 1998). Based on the above discussion, we bring forward the following sub-hypothesis:

Hypothesis 4c: The information flow facility is positively related to logistics flexibility.

3.5.4 Hypothesis 4d (Information Facility and Spanning Flexibility)

More than ever before, today's information technology is permeating the supply chain at every point. The information dissemination infrastructure can be designed so as to provide flexibility by allowing the firms to adapt the information flow to new competitive environment. The direct relationship between information technology utilization and the capability to distribute and share information through the service delivery system, to use alternative processing routes to deliver a service, and the ease with capacity expansion is verified within the service setting of engineering consulting firms by Aranda (2003). Evgeniou's work (2002) suggested that not only information technology but also information sharing practices affects the firm's efficient and effectiveness in distributing and sharing information along the supply chain to respond quickly to various customer needs. Based on the above discussion, we bring forward the following sub-hypothesis:

Hypothesis 4d: The information flow facility is positively related to spanning flexibility.

3.6 Research Hypothesis 5 (Supplier Management and Supply Chain Flexibility)

3.6.1 Hypothesis 5a (Supplier Management and Market-oriented Flexibility)

The importance of supplier development for new product time and cost minimization has already been proved in the automotive industry. For example, if purchasing identifies a supplier with unique process technology suited to manufacturing Sanchez and Perez (2003) showed the results of a survey of Spanish automotive suppliers on the implementation of supplier development in flexibility in new product development. Supplier development and supplier relationship management contributes to achieving flexibility through improving supplier performance and coordination among supply chain partners. It has been argue that to effectively manage the relationship is one key to improve suppliers' short-term operational benefits and long-term strategic advantages (Stuart, 1993).

Strategic partnerships among independent firms, such as raw-material suppliers, manufacturers, distributors, third-party logistics providers and retailers, is the key to attaining the flexibility necessary to enable them to progressively improve logistics processes in response to rapidly changing market conditions (Simatupang et al., 2002). Poor coordination among the chain members can cause dysfunctional operational performance. Some of the negative consequences of poor coordination include higher inventory costs, longer delivery times, higher transportation costs, higher levels of loss and damage, and lowered customer service (Lee et al., 1997). Several examples of companies (i.e., Mercedes in Germany) established a long-term contract with a logistics firm which allowed for the development of an individualized service (Cunningham, 1996). Close relationship with suppliers is associated with greater mix, volume, and new product flexibility (Suarez et al., 1996). Based on the discussion, we bring forward the following hypothesis:

Hypothesis 5a: The supplier management is positively related to market-oriented flexibility.

3.6.2 Hypothesis 5b (Supplier Management and Supply Flexibility)

The selection, development, and integration of suppliers with flexibility was found a key determinant of flexibility in the context of manufacturing and new product development (Narasimham and Das, 2000; Singh and Sushil, 2004). Selecting suppliers with capabilities in responding to changes has direct impact on local firms' flexibility (Bailey et al., 1994; Ittner et al., 1999). Some researchers provide certain empirical support for such theories in the context of flexibility. Nilsson and Nordahl (1995b) regarded supplier flexibility in terms of product, mix, volume, and delivery as input flexibility leading to buyers manufacturing flexibility. Singh and Sushil (2004) found that higher flexibility in selection of suppliers or partners leads to higher level of product development in terms of quality, time and cost under dynamic market environment. Hence, firms use a variety of activities in supplier selection and development to improve suppliers' performance and/or capabilities for achieving flexibility. Nishiguchi (1994), after an in-depth analysis, attributed Japanese car manufacturers' flexibilities primarily to a supply base distinguished by strong manufacturing flexibility capabilities. Based on the discussion, we bring forward the following hypothesis:

Hypothesis 5b: The supplier management is positively related to supply flexibility.

3.6.3 Hypothesis 5c (Supplier Management and Logistics Flexibility)

According to the network theory, the firm's relations to other companies often constitute its most valuable resource (Fine, 1998). The importance of strategic supplier partnership in striving toward a flexible supply chain has received considerable support in the literature (Van Hoek et al., 2001; Christopher, 2000; Christopher et al., 2004). Christopher (2000) states that alliance of partners linked into networks are a primary ingredient of agility in a variety of functions including logistics. To increase flexibility towards the changing requirements of customer, companies select external companies with broader and more flexible cooperative arrangement to perform logistics functions (Skjoett-Larsen, 2000). This kind of third-party logistics providers offer savings and transportation channel alternative by leveraging the combined volume of their customer base to realize economies of scale the focal firms may not be able to reach on their own under demand changing circumstance. The third parties can offer quicker entry into a new distribution environment with minimal impact to the existing fulfillment network (Huppertz, 1999). The third party logistics providers also involve in value-adding services such as final assembly, packaging, quality control, and information services. Therefore, the ability to serve distinct customer shipping requirements, the ability to vary warehouse space and services are important criteria help to achieve flexibility in all logistics functions (Skjoett-Larsen, 2000; Lummus et al., 2003). Based on the discussion, we bring forward the following hypothesis:

Hypothesis 5c: The supplier management is positively related to logistics flexibility.

3.6.4 Hypothesis 5d (Supplier Management and Spanning Flexibility)

Supplier management efforts have helped change the apprehensive attitude towards supply chain information sharing and coordination since the improvement of information flows has been regarded as an untapped source of value creation. Strategic supplier partnership is a relationship between buyers and suppliers that entails multifunctional interactions from engineering and marketing to production planning, inventory, and quality management. To possess such exceptional supplier linking capabilities, companies must devote substantial resources to develop competencies that allow it to communicate openly with its partners with flexible information connectivity and information dissemination paths (Gosain et al., 2004). On the other hand, through supplier development activities, all parties can establish a positive tone and reinforces relationships, fosters communication, and develop trust. Consequently, the parties would like to invest in information infrastructure and dedicate resources to tine initiative to ensure responsive information transfers (Kulp et al., 2005). Therefore, the ability of supply chain parties to created a cooperative infrastructure for capturing, disseminating, and monitoring information assets under uncertain circumstances can be improved. Based on the discussion, we bring forward the following hypothesis:

Hypothesis 5d: The supplier management is positively related to spanning flexibility.

3.7 Hypothesis 6 (Supply Chain Flexibility and Supply Chain Performance)

Supply chain flexibility can enable a range of improvements including shortened product lifecycles, more frequent changes in product features, mix, and production volumes. These improvements come not only from one function or one participant but from a responsive structure for achieving better performance along a supply chain as well (Duclos et al., 2003; Lummus et al., 2003).

3.7.1 Hypothesis 6a (Market-oriented Flexibility and Supply Chain Performance)

Market-oriented Flexibility enhances delivery reliability because a flexible delivery system can cope with unplanned and unexpected events resulting from both process and supplies (Zhang et al., 2002). Flexible product design capabilities can increase manufacturability by simplifying product structure, reducing the number of parts and increasing standardization. This, in turn, makes product quality easier to control. On the other hand, different groups can effectively coordinate on product design, production, distribution, and service thus assuring the delivery of quality products and service (Day, 1994). Delivery flexibility speeds the right product to the customer with multiple transportation modes (Davis, 1993).

Time-based performance improvement comes from fast development of new products or fast customizing of products and flexible operation and distribution across the supply chain. Wadhwa and Rao (2003) presented the results of a simulation study and indicated that the order fulfillment lead time decreases with increasing levels of manufacturing flexibility. Specifically, the companies can attain significant improvements in lead time performance since the volume and mix variations can be absorbed by the supply chain with flexibility. With delivery flexibility, firms should also be able to deliver to a certain request date, the specific product the customer requires to the specific location even when the needs change over time. With flexible product development, firms can quickly respond to a rapidly changing environment with product modification and new product commercialization. Flexible designs in product development lead to simplified product structures (Sanchez, 1996). This, in turn, makes the product development faster and easier. Similarly, because modular product design creates flexible platforms for leveraging product variations and upgrades capable of meeting a range of product attributes, performance, levels, and costs, the introduction of improved products is faster (Singh and Sushil, 2004). Overall, Nair (2005) provided evidence of a positive relationship between the operational policies and performance. He observed that supply chain flexibility mediates the effect of manufacturing postponement and centralized distribution on the delivery competence and customer responsiveness.

Cost minimization is achieved by better utilizing resources such as production and distribution capacities while minimizing inventory, transportation and production costs. Cost performance improves as flexibility embedded in the supply chain may lead to simplified product structures, operations process, and distribution channel. Instead of having products go from one site to another in a fixed patter, it is possible to have products produced and shipped directly to a customer, by-passing the many stopovers that are non-value added. Market-oriented flexibility also utilizes production and distribution resources more efficiently because non-value added time is reduced. With shorter set-up times, it is possible to work with a smaller lot size, which reduces the costs of inventory (Chen et al. 1992; Day, 1994). These discussions suggest a positive relationship between market-oriented flexibility and supply chain performance:

Hypothesis 6a: Market-oriented flexibility is positively related to supply chain performance.

3.7.2 Hypothesis 6b (Supply Flexibility and Supply Chain Performance)

With recognizing supply network as a complex adaptive system, firms with supply network that is more diversified are more likely to absorb market fluctuations (Choi et al., 2001). Supply network flexibility enable companies tap into a responsive supply base to ensure reliable supply of the products. Since inter-organizational networks are strategic resources that managers design and develop over time in order to meet their objectives, the ability to change the supply networks over time and in response to competition changes provides the network participants take advantage of opportunities to improve their individual positions and performance (Madhavan et al., 1998). With supplier flexibility, there is a mechanism to easily communicate ideas, design files and collaborate on problem solving; when a new design requires new materials, it is easy to obtain suppliers confirmation on their ability to supply the new materials. Supply link improves as network-focused flexibility increases because the integration of flexibility along the value chain enables better cross-functional collaboration and inter-organizational coordination. All these contribute to building up trust and commitment to buyer-supplier relationships. These discussions suggest a positive relationship between supply flexibility and supply chain performance:

Hypothesis 6b: Supply flexibility is positively related to supply chain performance.

3.7.3 Hypothesis 6c (Logistics Flexibility and Supply Chain Performance)

Flexible distribution network can accommodate unexpected disruptions in materials and the delivery of finished goods (Gupta, 1993; Upton, 1995). As markets continue to change, logistics flexibility enables sourcing product from raw materials to finished product on a timely basis. If the entire logistics process is more flexible than a competitor's, the supply chain should have fewer assets tied up in inventory. With flexible logistics capability, high-quality materials are delivered on time for shortening manufacturing lead time (Davis, 1993). Inventory in transit should also be reduced as supply chain partners choose modes of transportation that shorten lead times (Lummus et al., 2003). As evidence, firms can restructure the logistics network of their materials flows to gain efficiency. Time-based performance improvement can come from operation and distribution across the supply chain. Cost performance improves as flexibility embedded in the logistics may lead to simplified operations process, and distribution channel. Instead of having products go from one site to another in a fixed patter, it is possible to have products produced and shipped directly to a customer, by-passing the many stopovers that are non-value added. These discussions suggest a positive relationship between logistics flexibility and supply chain performance:

Hypothesis 6c: Logistics flexibility is positively related to supply chain performance.

3.7.4 Hypothesis 6d (Spanning Flexibility and Supply Chain Performance)

The information spanning flexibility between buyers and suppliers commits to providing better and more accurate and timely information to suppliers. For instance, latest forecast of requirements allow suppliers to plan their available capacity more effectively (Handfield, 1995; Ring and Van de Ven, 1994). The more quickly this type of information is shared, the more quickly the suppliers can react. With spanning flexibility, better information flows have allowed the reduction of component and product inventories throughout the supplier chain (Billington and Johnson, 2005). Additionally, facilitated by the spanning flexibility, synchronized replenishment plans can be created, which leading to closer matching of production and distribution to current demand (Billington and Johnson, 2005; Lee and Whang, 2005b). Additionally, better information sharing and information quality associated with spanning flexibility contributes positively to partnership quality (Walton, 1996; Lee and Kim, 1999). A responsive information sharing connectivity will support the information interchange between the customer and the entire supply chain, so that firms can use the information to support diverse strategies for design, manufacturing, and distribution, resulting in the enhancement of customer responsiveness (Lau and Lee, 2000). Cisco has been one of the most successful companies engaged in using agile information system infrastructure for improving delivery lead time and customer responsiveness. With elaborate web-based information system linking Cisco and its supply chain partners, all the necessary information flow are taken care to make information visible across the supply chain. As a result, fifty-five per cent of Cisco's sales are shipped directly from the subcontract manufacturers to the customer, without having to stop at Cisco's distribution centers (Lee and Whang, 2005b). Therefore, the following hypothesis is proposed:

Hypothesis 6d: Spanning flexibility is positively related to supply chain performance.

In sum, this chapter provides a theoretical framework for understanding the driving forces, antecedents and consequences of supply chain flexibility and develops fourteen hypotheses based on literature review. After a vast literature review, proper methodologies are required to collect data for confirmatory analysis of the research model. The following chapter will discuss research methodology for generating items for measurement instruments before initiating the large-scale data gathering.

4. INSTRUMENT DEVELOPMENT PHASE I - ITEM GENERATION AND PILOT TEST

In this chapter, the instruments are developed and tested. The instruments to measure include (1) Market-oriented flexibility (MF), (2) Supply Flexibility (SF), (3) Logistics Flexibility (LF), (4) Spanning Flexibility (PF), (5) Environmental Uncertainty (EU), (6) Information Facilities (IF), (7) Supplier Management (SM), (8) Postponement (PTMT), (9) Outsourcing (OU), (10) Supply Chain Performance (SCP). Instruments to measure Market-oriented flexibility, environmental uncertainty, information facilities, supplier management, postponement and supply chain performance were adopted from previous studies with minor modifications (Chen and Paulraj, 2004; Werner et al., 1996; Kyobe, 2004; Chen and Paulraj, 2004; Tracy et al., 1999; Narasimhan and Kim, 2001). Since these instruments have been tested in previous studies and were found to be valid and reliable, they will not be tested again in the pilot study.

The instruments to measure supply flexibility, logistics flexibility, spanning flexibility and outsourcing will be developed and pilot tested in this chapter. The development of the instruments of these four constructs was carried out in three stages. In the first pre-pilot stage, potential items were generated through an extensive literature review and from construct definitions. Then the initial pool of items was pre-tested with one practitioner and five academicians. The respondents were asked to provide feedback about the clarity of the questions, instructions, and the length of the questionnaire. Based on the feedback, items were added, modified or discarded to strengthen the constructs and content validity. The second stage was scale development and testing through a pilot study using Q-sort method. Items placed in a common pool were subjected to three sorting rounds by the judges to establish which items should be in the various categories. The objective was to pre-assess the convergent and discriminant validity of the scales by examining how the items were sorted into various construct categories. Analysis of inter-judge agreement about the items placement identified both bad items as well as weakness in the original definitions of the constructs. The instruments were then further refined based on pilot study results. The third stage is later described in Chapter 4, including all the validity and reliability tests using the data from a large-scale sample. Research hypotheses were then tested based on the large-scale data analysis.

4.1 Item generation

Proper generation of measurement items of a construct determines the validity and reliability of an empirical research. The very basic requirement for a good measure is content validity, which means the measurement items contained in an instrument should cover the major content of a construct (Churchill, 1979). Content validity is usually achieved through a comprehensive literature review and interviews with practitioners and academicians. A list of initial items for each construct was generated based on a comprehensive review of relevant literature. The general literature bases for items in each construct are briefly discussed below.

The items for SCF (manufacturing flexibility, delivery flexibility, product development flexibility, supply flexibility, logistics flexibility, and spanning flexibility) were generated based on previous flexibility literature in the field of manufacturing, marketing, logistics, information system, and supply chain (D'Souza and Williams, 2000;

Koste et al., 2004; Sethi and Sethi, 1990; Pujawan, 2004; Lummus et al., 2003; Aranda, 2003; Duclos et al., 2003; Zhang et al., 2002). The items for supply management (supplier selection, supplier development, and supplier relationship management) were generated through supply chain management literature and purchasing literature (Choi and Hartley, 1996; Humphreys et al., 2004; Krause and Ellram, 1997; Wagner and Johnson, 2004). The items for postponement (manufacturing postponement, logistics postponement, and product development postponement) were mainly generated through previous work on postponement by Zinn and Bowersox (1988), Van Hoek (1998a), Pagh and Cooper (1998), and Yang et al. (2004). The items for outsourcing were developed mainly from research by Gilley and Rasheed (2000). The items for supply chain Performance (supply link, reliability, time-based, and cost performance) were generated primarily from some recent works on supply chain management and performance measurement by Beamon (1999), Gunasekaran et al. (2004), Gunasekaran et al. (2001), Lai et al. (2002), Droge et al., (2004); Carter et al. (1995), and Jayaram et al. (1999).

4.2 Pre-test

After potential items were generated through a literature review and from construct definitions, a rigorous procedure must be followed to ensure brevity, understandability and content validity of the measurement items. The items were first pre-tested by experts in the business and academic fields to review the items for clarity and content. The pre-test was directed to three professors of the College of Business Administration at the University of Toledo and Ball State University, one practitioner in materials management and purchasing, and three Ph.D. students in Manufacturing Management at the University of Toledo. The respondents were asked to provide feedback about the clarity of the questions and the consistency with construct definitions. By incorporating their feedback, items were modified, discarded, or added to strengthen the constructs and content validity.

4.3 Scale Development: the Q-Sort Method

Q-sort methodology was invented in 1953 by British physicist-psychologist William Stephenson and it combines the strengths of both qualitative and quantitative research traditions (Dennis and Goldberg, 1996) and in other respects provides a bridge between the two (Sell and Brown, 1984). The study used Q-methodology that merges qualitative and quantitative methodologies allowing a view of the data from a subjective perspective. Q-methodology is a way of finding out about what people make of a particular issue or topic – their opinions, judgments, understandings and so on. Operationally, Q-methodology asks respondents to systematically force-sort a set of statements based on how strongly they agree or disagree with each statement (Jacobson and Aaltio-Marjosola, 2001). This study employed purchasing and supply chain professionals with experience in supply chain management as judges. The judges were purchasing/materials managers from Owens Corning, Peterson Spring, and American Honda. Several studies have shown that the use of judges who are highly representative of the population to which the study hopes to generalize, adds significant strength to the preliminary results of the study (Anderson and Gerbing, 1991; Maurer et al., 1991). Findings from research by Maurer et al. (1991) recommend that the use of between five and eighteen expert judges to achieve traditionally acceptable levels of generalizability. The objective of using Q-sort methodology was to pre-assess the convergent and discriminant validity of the scales by examining how the items were sorted into various factors or dimensions.

Items created and passed through pre-test were placed in a common pool. They were subjected to three Q-sort rounds by two independent judges per round. Each judge was provided with operational descriptions of the four categories (supply network flexibility, logistics flexibility, spanning flexibility, and outsourcing). The judges were then asked to allocate each measurement item into the category that they feel the item belongs to/fits best into. If they believe that the statement does not fit into any of the categories, or is not clear, or fits into more than one category, then they may categorize it as "Not Applicable". The sorting was without replacement and forced-choice (i.e., no measurement items may be allocated into two categories or remain unallocated). At the end of each sorting round, the judges involved in that round were interviewed by phone or face-to-face meeting to describe why they had allocated certain practice constructs to certain categories. We also inquired as to whether we were missing any important practices for each category. This provided additional qualitative insights into their choices and aided in refining the wording of each construct definition. The items were then examined and inappropriately worded or ambiguous items could be either modified or eliminated. after each round.

To assess the reliability of the sorting conducted by the judges, three different measures were used: inter-judge agreement level, Cohen's Kappa (Cohen, 1960), and Moore and Benbasat's "hit ratio" (Moore and Benbasat, 1991). The degree of agreement between judges forms the basis of assessing construct validity and improving the reliability of the constructs. The degree of agreement is calculated by counting the number of items that both judges agree to place into certain category, though the category in which the item was sorted together by both judges may not be the originally intended category. The percentage of total items agreed is computed to obtain the rate of inter-judge raw agreement scores. The second criterion is the Cohen's Kappa (k), which is an index of inter-rater reliability when coding qualitative/categorical variables. Kappa's calculation uses a term called the proportion of chance (or expected) agreement. This is interpreted as the proportion of times raters would agree by chance alone. Cohen's Kappa index is a method of eliminating chance agreements, thus evaluating the true agreement score between two judges. The Cohen's Kappa coefficient is equal to 0 when there is no more agreement than chance; it is equal to 1 when there is perfect agreement. There is no general agreement exists with respect to required scores. However, recent studies have considered scores greater than 0.65 to be acceptable (e.g. Jarvenpaa 1989; Solis-Galvan, 1998). Landis and Koch (1977) have provided a more detailed guideline to interpret kappa by associating different values of this index to the degree of agreement beyond chance. The following guideline is suggested:

Value of Kappa	Degree of Agreement Beyond Chance
.76 - 1.00	Excellent
.40 - .75	Fair to Good (Moderate)
.39 or less	Poor

Thirdly, the Moore and Benbasat's "hit ratio" was used to assess both the reliability and validity of the measurement items. It requires analysis of how many itmes were placed by the panel of judges correctly in the "target" category. The result reflects the ratio of "correct" assignments to total assignments, summed over all measurement items belonging to a particular category. A higher percentage of items placed in the target construct indicates a higher degree of interjudge agreement across the panel. Although an assessment of what may be considered an adequate "hit ratio" score has not yet been developed, it can be used to identify potential problem areas. Table 4.1 contains the number of items for the constructs entering Q-sort methodology. The Q-sort results are detailed next.

Construct ID	Description	# Items
1	Supply flexibility	6
2	Logistics flexibility	10
3	Spanning flexibility	9
4	Outsourcing	8

Table 4.1 Number of Items per Construct for Q-Sort Methodology

4.4 Results of First Sorting Round

In the first round, the inter-judge raw agreement scores averaged 88% (Table 4.2), the initial overall placement ratio of items within the target constructs was 94% (Table 4.3), and the Cohen's Kappa score averaged 0.84.

The calculations for Cohen's Kappa coefficient are shown below.

$$k = \frac{N_i X_{ii} - \sum_i (X_{i+} X_{+i})}{N_i^2 - \sum_i (X_{i+} X_{+i})} = \frac{(33)(29) - 273}{33^2 - 273} = .84$$

The calculation of the k is based on Table 4.2. N_i is the number of total items (103); X_{ii} is the total number of items on the diagonal (that is, the number of items agreed on by two judges); X_{i+} is the total number of the items on the i^th^ row of the table; and X_{+i} is the total number of items on the i^th^ column of the table. Following the guidelines of Landis and Koch (1977) for interpreting the Kappa coefficient, the value of 0.84 indicates an excellent level of agreement (beyond chance) for the judges in the first round. This value is slightly lower than the value for raw agreement which is 0.88. The level of item placement ratios averaged 0.94. For instance, the lowest item placement ratio value was 0.83 for the supply network flexibility, indicating a low degree of construct validity. On the other hand, spanning flexibility obtained a 100% item placement ratio, indicating a high degree of construct validity.

		Judge 1				
		1	2	3	4	NA
Judge 2	1	4	2	1		
	2		9			
	3			9		
	4				7	1
	NA					
	Total Items: 33		# of agreement: 29		Agreement ratio:88%	

Table 4.2 Inter-Judge Raw Agreement Scores (First Round)

		Actual						
		1	2	3	4	NA	Total	Hit %
Theory	1	10	1	1			12	83%
	2	1	19				20	90%
	3			18			18	100%
	4				15	1	16	94%
	Total Item: 66		Hits: 62				Hit %: 94%	

Table 4.3 Moore and Benbasat Hit Ratio (First Round)

Some of the items were revised and reworded before initiating the second round of the Q-sort. The results from the second round support the changes done to the rewording of the measurement items. All three measures are improved. The inter-judge agreement increased to 97% (Table 4.4). The value for Kappa coefficient of .96 is higher than the value obtained in the first round (.84) (Table 4.5), indicating an excellent level of agreement for the judges in the second round. The level of item placement ratios averaged increased to 98%. For instance, the lowest item placement ratio value was 92% for supply network flexibility. Three out of four constructs (logistics flexibility, spanning flexibility, and outsourcing) obtained a 100% item placement ratio, indicating a high degree of construct validity.

		Judge 1				
Judge 2		1	2	3	4	NA
	1	5				
	2		10	1		
	3			9		
	4				8	
	NA					
	Total Items: 33		# of agreement: 32		Agreement ratio:97%	

Table 4.4 Inter-Judge Raw Agreement Scores (Second Round)

		Actual						
Theory		1	2	3	4	NA	Total	Hit %
	1	11	1				12	92%
	2		20				20	100%
	3			18			18	100%
	4				16		16	100%
	Total Item: 66		Hits: 65				Hit %: 98%	

Table 4.5 Moore and Benbasat Hit Ratio (Second Round)

Since the second round has achieved an excellent overall placement ratio of items within the target constructs (98%), all the items were kept for the third sorting round. The third sorting round was used to re-validate the constructs. Again, two judges were involved in the third sorting round. In the third round, the inter-judge raw agreement scores averaged 97% (Table 4.6), the initial overall placement ratio of items within the target constructs was 93% (Table 4.7), and the Cohen's Kappa score averaged 0.98.

		Judge 1				
		1	2	3	4	NA
Judge 2	1	6				
	2		10			
	3			9		
	4		1		7	
	NA					
	Total Items: 33		# of agreement: 32		Agreement ratio:97%	

Table 4.6 Inter-Judge Raw Agreement Scores (Third Round)

		Actual						
		1	2	3	4	NA	Total	Hit %
Theory	1	12					12	100%
	2		20				20	100%
	3			18			18	100%
	4		1		15		16	94%
	Total Item: 66		Hits: 65				Hit %: 98%	

Table 4.7 Moore and Benbasat Hit Ratio (Third Round)

5. INSTRUMENT DEVELOPMENT PHASE II - LARGE-SCALE ADMINISTRATION AND INSTRUMENT VALIDATION

A large-scale on line survey was the instrument for data gathering. One important factor in an empirical study is the quality of respondents. In the case of the current study, the respondents are expected to have the best knowledge about the operation and management of the supply chain in his/her organization. Based on literature and recommendations from practitioners, it was decided to choose supply chain/purchasing/manufacturing/logistics Vice Presidents/Directors/Managers as the respondents for the current study. The following is a detail of the process followed for selecting the sample, collecting data and confirming the measurement models for the constructs.

5.1 Data Collection Methodology

The data were collected using the Web-based method. The respondents in the sample represent six industries, defined at the two-digit SIC level: 23 "Apparel and other textile products", 30 "Rubber and Plastics", 34 "Fabricated Metal Products", 35 "Industrial and Commercial Machinery", 36 "Electronic and Other Electric Equipment", 37 "Transportation Equipment". Since this research focuses on the supply chain management practices and flexibility, it was decided to direct the survey to VP, Directors, or Managers of Supply Chain, Purchasing, Logistics, or Operations, as well as leaders in Strategic Development and Planning, or other leaders in the firm who have visibility on supply chains, logistics, and purchasing strategies and operations. Therefore, the respondents were limited to purchasing/ manufacturing/materials executives and included CEOs, presidents, vice presidents, managers, and directors for current study. An email list was obtained from two sources: RSA Teleservices and Lead411. RSA Teleservices is a leading direct marketing consulting company and provider and compiler of business to business mailing lists, executive contact databases, and outsourced executive lists. RSA Teleservices has the largest Fortune 500 and Fortune 1000 executive contact database. From the Fortune 1000 Global Supply Chain Executives database, 5,292 names were generated. Lead411 is a web based application suite that provides detailed and comprehensive company intelligence. With the corresponding SIC codes and titles, 1,081 names were from Lead411. Combining two email lists resulted in a list of 6,273 names. This email list was then further refined through the following steps: 1) if some names were shown more than one time, only one of these names were kept and the reduplicate ones were removed; were removed in consideration of home privacy of respondents; 2) since the large scale survey was going to be implemented using online data gathering, those names with no email address were removed. In most studies, if there are multiple names from the same organization, the person with the most relevant job title will picked and the others are removed. Therefore, the refinement resulted in a list of 5,707 names. Differing from other studies, all the names from the same organization passed the first screening in this study since they were not determined as the "real" respondents at this point. Only people showing willingness to participate in this study will be regarded as "real" respondents. The way of determining respondent pool is described in detailed as follows.

To ensure a reasonable response rate, the survey was sent in three waves. First, an email was sent to the 5,707 names inviting them to participate in the study with a brief description of the research, stating that the information collected would be used for research purposes only and it would be treated with the utmost confidentiality. The URL to start the survey was not shown in this invitation message. In the email, people were directed to reply with a blank email thus implying their consents of filling a survey if they did agree to participate to the study.

During the first week after the first email, a total of 88 respondents expressed their willingness to participate. The researcher then used emails which indicating or implying the willingness of participation to send a follow up email. In the email, the respondents were directed to respond to the survey by three ways: (1) by completing by clicking on the link that would take them to the on-line questionnaire (http://uac.utoledo.edu/uacsurveys/SupplyChainFlexibility.asp); (2) by sending it by fax by clicking on the link that would take them to the PDF format of the questionnaire in the following site: http://uac.utoledo.edu/uacsurveys/SupplyChainFlexibility.pdf; or (3) by requesting a hard copy from the researcher. Also, we received a few emails asking for the survey to be faxed or emailed to them as attachment since they were not allowed to download any file from unauthorized websites. After examining the first three sets of digits of remote address (IP), a few online responses were eliminated due to the doubt that they were coming form the same unit of analysis. The first wave produced 59 complete and usable responses. All but a few of the questionnaires were received via Internet.

One week after the first email sent, a second refinement of the email list was completed for the following reasons: (1) the emails were rejected; (2) we received an email saying that they no longer work for the company and/or they felt they were not qualified to provide the current answers; (3) we received an email saying that they declined the invitation without any reasons or with different reasons, (4) we received an email saying that they wanted their names to be removed from the list This resulted in the removal of another 560 names. Therefore, the email list contained 5,147 names.

Then a second wave invitation emails were sent expressing gratitude to those who have already responded and asking to respond to those who have not yet responded. A total of 112 respondents either agreed to participate or would like to receive the questionnaire for participation consideration. Similar with the first wave, only these 112 respondents actually read or at least view the questions. Also, a purification of the online responses was performed using the remote address (IP), a total of 76 completed and usable on-line and faxed questionnaires were received after the second wave data collection.

Finally, a third wave invitation emails were sent to obtain a satisfied response rate and enough data for further analysis. A third refinement of the email list was completed and resulted in the removal of another 84 names. Therefore, A third wave invitation emails were sent to 5,063 names. Additional 88 respondents expressed their willingness to participate. The URL leading to the on-line survey was sent to these 88 respondents, and a total of 66 complete and usable responses were generated in the third wave, adding faxes and email submissions. Online responses were purified after investigating the IP addresses to see if the responses came from the same company and location. As a result, a total of 288 respondents either agreed to participate or received the questionnaire for consideration and the total usable responses were 201.

Numerous outcome rates are commonly cited in survey reports and in the research literature. Response rates are of the indicators most likely to be reported. Often it is assumed that the lower the response rate, the more question there is about the validity of the sample, as nonresponse can introduce bias. Often response rates in survey research are calculated simply by dividing the number of completed interviews by the number of individuals who were selected to participate in the research. However, response rate must be defined and calculated in different ways to justice the complexity of research design, sampling process, and the practical difficulties of contacting and assessing potential survey participants (AAPOR, 2000; Peter et al., 2001). As Groves and Lyberg (1988) noted, "there are so many ways of calculating response rates that comparisons across surveys are fraught with misinterpretations".

Regarding survey conducted on line, researchers have to wrestle with a variety of problems that influence response rates. E-mail messages may not be read by the targeted person and unknown delivery status are good examples. If the e-mail is not read by the targeted person (for reasons of change of employment, death, illness, etc.), it is less likely for researchers to get word back. In addition, e-mail may be successfully delivered to the address, but never seen by the addressee because of spam filters, inboxes that are too full, or a host of other technical reasons (AAPOR, 2006). In order to solve the problems, an invitation message was sent to samples to confirm the eligible respondents. AAPOR (2000) offers a new tool that can be used as a guide to one important aspect of a survey's quality. As defined by AAPOR (2006), the response rate is the number of complete interviews with reporting units divided by the number of eligible reporting units in the sample. It can be described as:

$$Response\_Rate = \frac{I + P}{(I + P) + (R + NC + O)}$$

In an internet survey, I represents completed response which every one of the questions is answered; and P stands for partials, or completes with missing data. The total of I and P yields 201 usable responses in the current study. Refusals (R) can occur in online surveys when the recipient replies to the email invitation stating that he or she does not want to participate in the survey. Refusals can also be viewed in an implicit way where a respondent visits the Internet survey but fails to complete any of the survey items. A total of 184 refusals were received in the study. And 18 responses were incomplete and unusable (Refusal calculated as 184+18). Non-contact (NC) of relevance to online surveys refer to those cases where some evidence is obtained that the selected respondent is eligible but unable to complete the questionnaire; for this study, the second case is reserved for 87 instances (calculated as 288-201) where a receipt was sent that the potential respondent has received and/or opened the email message and agree to participate in the research, but no further response is received. The residual category of others (O) is reserved for all other cases where the recipient of the survey invitation is unable to complete the survey for a variety of possible reasons such as physical or mental incapacity, language barrier, and so on. These cases are likely to be rare and no case applies to this category in this study. Given the online survey administration process, situations in which nothing is known about whether the invitation to participate in the Internet survey ever reached the person to whom it was addressed are not counted in the respondents pool in this study. Therefore, the response rate reported in this study is:

$$\text{Response\_Rate} = \frac{I+P}{(I+P)+(R+NC+O)} = \frac{201}{201+(202+87)} = 41\%$$

Besides response rate, AAPOR (2000) also defines cooperation rates as the proportion of all cases completed of all eligible units ever contacted. Along with this line, a few recent studies in Operations Management, with similar data collection process, have reported the cooperation rate as response rate by dividing the number of completed interviews by the number of individuals who agreed to participate in the research similar data collection process (Swink et al. 2005; Schroeder et al., 2002). Therefore, in current study, only 288 counted in the final sample size sine the other respondents never received the survey. The total usable sample 201 was compiled for a satisfactory response rate of 69.8% (calculated as 201/288). Follow-up calls indicated that most non-respondents believed: (1) they had insufficient time to complete the survey; (2) they didn't have enough knowledge to answer the questions; and (3) their companies didn't have supply chain issues.

5.2 Sample Characteristics of the Respondents and Organizations

This section will discuss sample characteristics in terms of the respondents (job title, job function, knowledge about supply chain issues, and years stayed at the organization), and the organizations (industry, employment size, annual sales, and tiers across supply chain).

5.2.1 Sample Characteristics of the Respondents

The results are shown in Table 5.1

Job Title: about one third of the respondents (34%) are CEO/President, while 23% state they are Director and 24% are titled as Manager. The rest of respondents (18%)

belong to the "others" category.

Job Function: more than one third of the respondents (35%) choose purchasing as their area of expertise, while 35% of respondents are responsible for manufacturing/operations, 25% are responsible for supply chain management, and about half of them are responsible for logistics and transportation. Overall, the respondents of this survey are persons responsible for purchasing, supply chain management, logistics, and manufacturing/operations, and they are qualified to answer the questions on supply chains, logistics, and purchasing strategies and operations.

Knowledge about Supply Chain Issues: The respondents are expected to have the best knowledge about the operation and management of the supply chain in his/her organization. Although most respondents are at high executive/management level in a variety functions, their qualification of answering supply chain related questions might be questioned since the questions are related to cross-functional issue in supply chain management. Three questions asking the respondents' understanding of and collaboration with other business functions were designed to confirm their eligibility.

Question 1: Please indicate the extent of your understanding of other business functions/processes within your company.

61% of the respondents indicate the extent of their understanding of other business functions/processes within their companies is great; 27% of them respond the extent as "considerable"; and only 1% of the respondents indicate that the extent is small. Overall, the average of the extent of the respondents' understanding of other business functions/process is 4.5 out of 5 (1 = Not at all, and 5 = To a great extent).

Question 2: Please indicate the extent of collaboration with other business *functions within your company in your day-to-day work.*

Over half of the respondents (55%) indicate the extent of collaboration with other business functions in their day-to-day work is great; and more than one third of them (35%) have considerable extent of collaboration with other business function in their daily work. Respondents who have little collaboration with other business functions in their daily job only account for 1%. Overall, the average is 4.44 out of 5 (1 = Not at all, and 5 = To a great extent).

Question 3: Please indicate the extent to which you jointly resolve operations problems with other business functions within your company.

About half of the respondents (49%) indicate that they jointly resolve operations problems with other business functions to a great extent; and 35% of them respond the extent as considerable. Again, a few respondents (3%) indicate small extent of jointly problem solving. Overall, the average is 4.29 out of 5 (1 = Not at all, and 5 = To a great extent).

The responses to these three questions show that the respondents have enough knowledge and are eligible to answer questions related to cross-functional supply chain issues.

Years Stayed at the Organization: about half of respondents (44%) indicate they have been with the organization over 10 years, while 17% indicate having been at the organization between 6-10 years, and 25% of respondents state their years stayed at the organization as between 2-5. The respondents with years stayed at the organization less than 2 years account for only 13% of the sample.

Figure 5.1, 5.2., 5.3, 5.4, 5.5and 5.6 display respondents by job titles, job functions, three questions on respondents' knowledge about supply chain issues, and years worked at the organization respectively.

1.	**Job Titles** (201)	
	CEO/President	33.83% (68)
	Director	23.38% (47)
	Manager	24.38% (49)
	Others	18.41% (37)
2.	**Job Functions** (201)	
	Corporate Executive	47.76% (96)
	Purchasing	35.32% (71)
	Transportation	18.41% (37)
	Manufacturing/operations	34.83% (70)
	Distribution	10.95% (22)
	Supply chain management	24.88% (50)
	Logistics	29.85% (60)
	Sales	31.34% (63)
	Other	14.93% (30)
3.	**Years worked at the organization** (200)	
	Less than 2 years	13.43% (27)
	2-5 years	24.88% (50)
	6-10 years	16.92% (34)
	More than 10 years	44.28% (89)

Table 5.1 Characteristics of Respondents

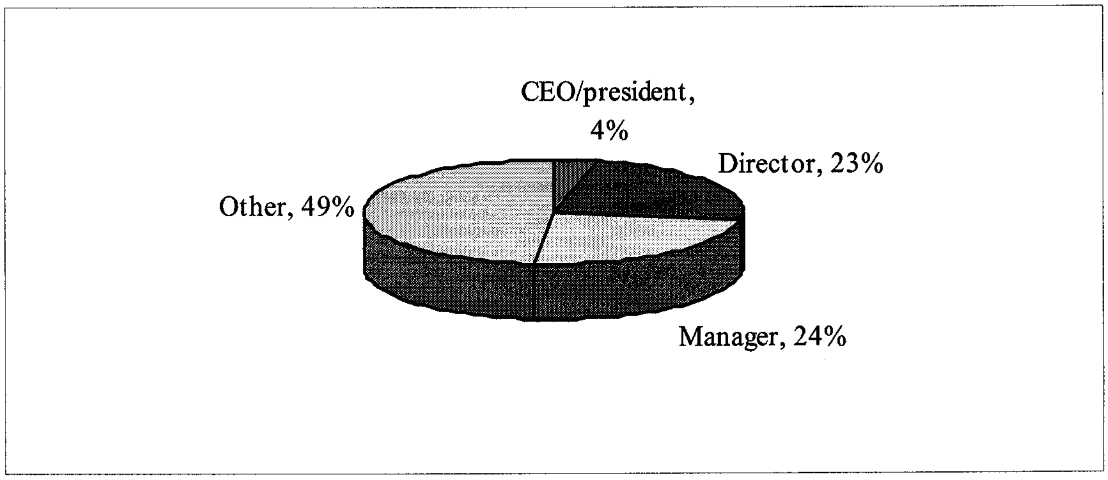


Figure 5.1 Respondents by Job Title

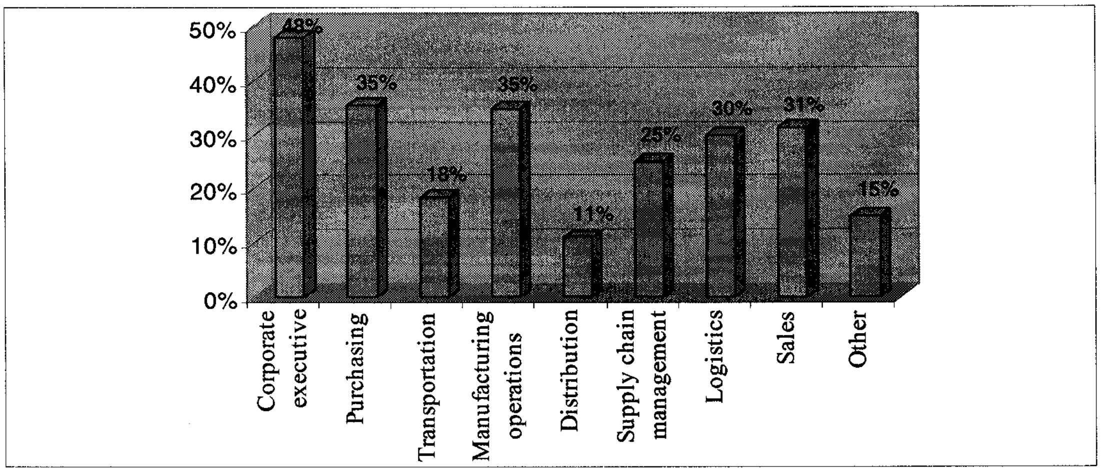


Figure 5.2 Respondents by Job Function

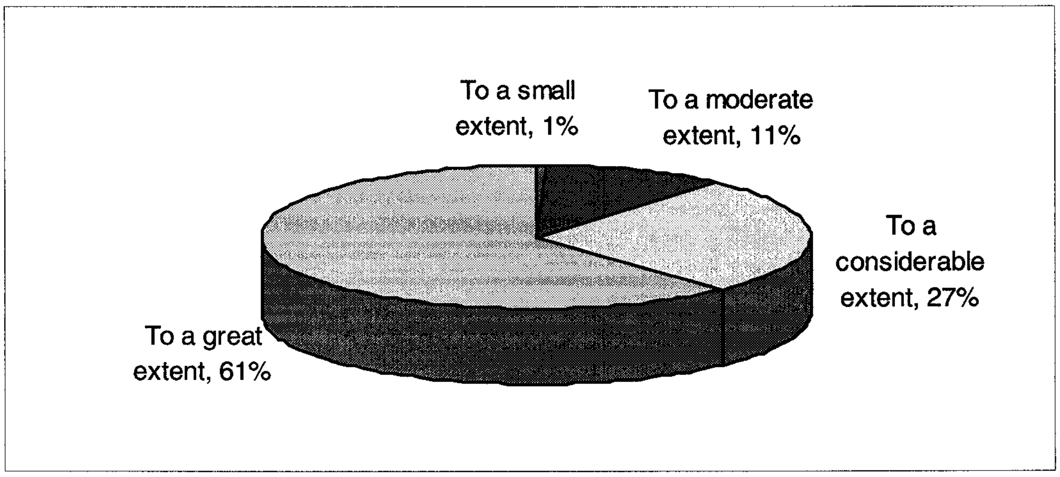


Figure 5.3 Respondents by the extent of understanding of other business functions/processes within their company

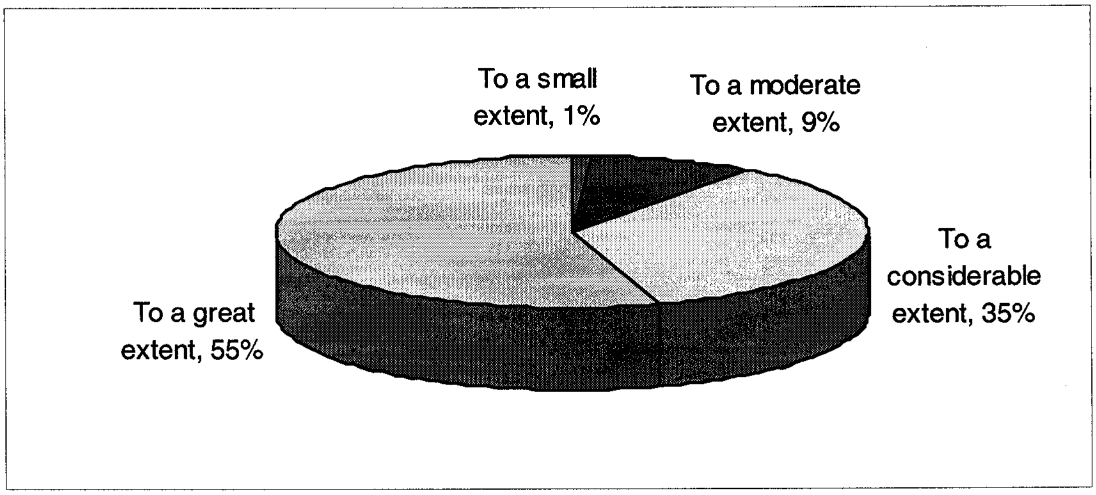


Figure 5.4 Respondents by the extent of collaboration with other business functions in day-to-day work

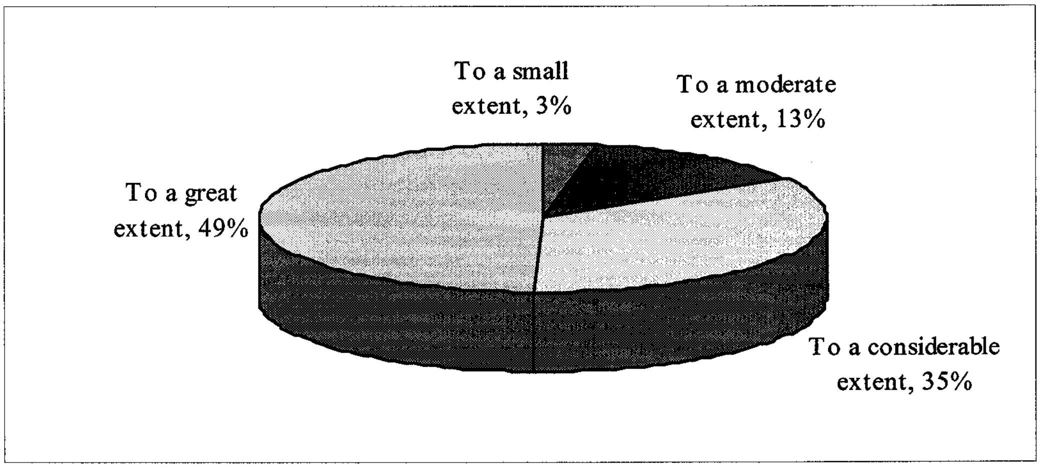


Figure 5.5 Respondents by the extent of jointly problem solving with other business functions

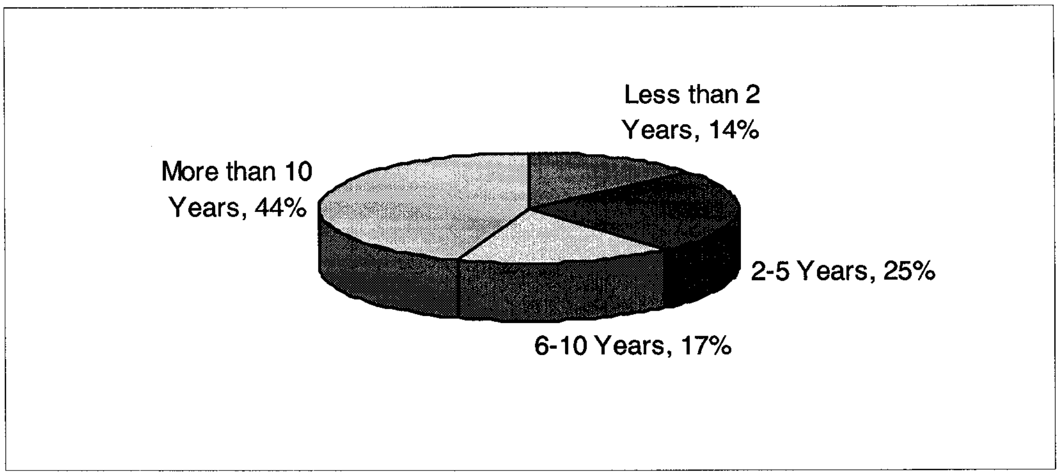


Figure 5.6 Respondents by Years Worked at the Organization

5.2.2 Sample Characteristics of the Organizations

The results are shown in Table 5.2

Industry (based upon SIC code): about half of respondents (49.75%) indicate their organization is in the Electronic and Other Electric Equipment industry; 22.89% of respondents are in the Industrial and Commercial Machinery; about same number of them is in the Fabricated Metal Products industry (5.47%) and Transportation Equipment industry (6.97%). In addition, 1.99% and 2.99% of respondents are in the Apparel and other textile products industry and Rubber and Plastics industry, respectively. Finally, the rest of respondents ((9.95%) indicate their organization is in other industries.

Employment size: 36.87% of organizations have between 1 and 100 employees. Organizations with between 101-500 employees account for 30.35% of the sample, and another about one third of organizations (30.85%) have over 1000 employees. The rest (11.44%) have between 501-1000 employees.

Annual sales: Almost half of the organizations (45.77%) have sales volumes exceeding 100 million and about 31.84% of the organizations have sales volumes below 25 million. 9.45% and 10.45% of the respondents have sales volumes between 25-50 million and between 50-100 million respectively.

<u>Horizontal Position of an Organization in the Supply Chain</u>: A company can be positioned at or near the initial source of supply (raw material and component supplier), be at or near the ultimate customer (distributor/wholesaler/retailer), or somewhere between these end points of the supply chain (assembler and manufacturer). Among all surveyed organizations, manufacturers account for 82.59%, assemblers and sub-assemblers accounts for 26.37% and 15.42% respectively. In addition, 4.89% and 27.86% of respondents consider themselves raw materials suppliers and component suppliers correspondingly. Furthermore, distributors, wholesalers, and retailers account for 24.88%, 12.94%, and 9.45% respectively (Note: one company may occupy multiple positions and may represent multiple data items, the calculation of the percentage is based on the total sample size of 201).

<u>Tiers across supply chain</u>: The supply chain may be long, with numerous tiers, or short, with few tiers. The results show that 39.3% of supply chains have less than or equal to 3 tiers, while 14.92% have six or more than 6 tiers across the supply chains. The rest (41.29%) have 4 or 5 tiers within their supply chains.

1.	**Industry – SIC** (201)	
	Apparel and other textile products (23)	1.99% (4)
	Rubber and Plastics (30)	2.99% (6)
	Fabricated Metal Products (34)	5.47% (11)
	Industrial and Commercial Machinery (35)	22.89% (46)
	Electronic and Other Electric Equipment (36)	49.75% (100)
	Transportation Equipment (37)	6.97% (14)
	Other	9.95% (20)

2.	**Number of employees** (200)	
	1-50	14.43% (29)
	51-100	12.44% (25)
	101-250	18.41% (37)
	251-500	11.94% (24)
	501-1000	11.44% (23)
	over 1000	30.85% (62)
3.	**Average annual sales** (196)	
	Less than $5 mil	8.46% (29)
	$5 to $9 mil	9.95% (25)
	$10 to $24 mil	13.43% (37)
	$25 to $49 mil	9.45% (24)
	$50 to $99 mil	10.45% (23)
	More than $100 mil	45.77% (62)
4.	**Position of your company** (201)	
	Raw material supplier	4.98% (10)
	Component supplier	27.86% (56)
	Sub-assembler	15.42% (31)
	Assembler	26.37% (53)
	Manufacturer	82.59% (166)
	Distributor	24.88% (50)
	Wholesaler	12.94% (26)
	Retailer	9.45% (19)
5.	**Number of tiers** (192)	
	Less than or equal to 3	39.3% (79)
	4-5	41.29% (83)
	6-7	11.44% (23)
	8-10	1.99% (4)
	More than 10	1.49% (3)

Table 5.2 Characteristics of Organization

Figure 5.7 to Figure 5.11 display the surveyed organization according to industry, employment size, annual sales, horizontal positions in the supply chain, and tiers of supply chain, respectively.

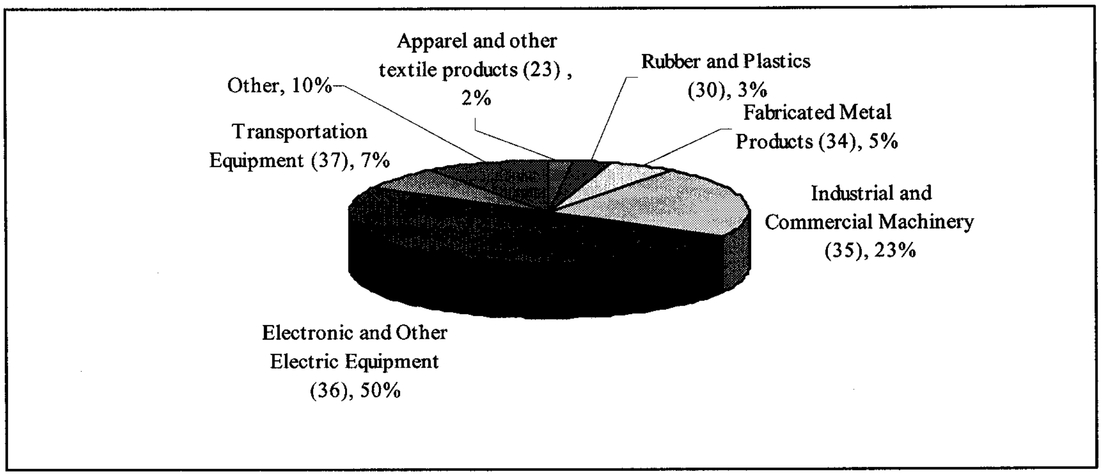


Figure 5.7 Organizations by Industry (SIC code)

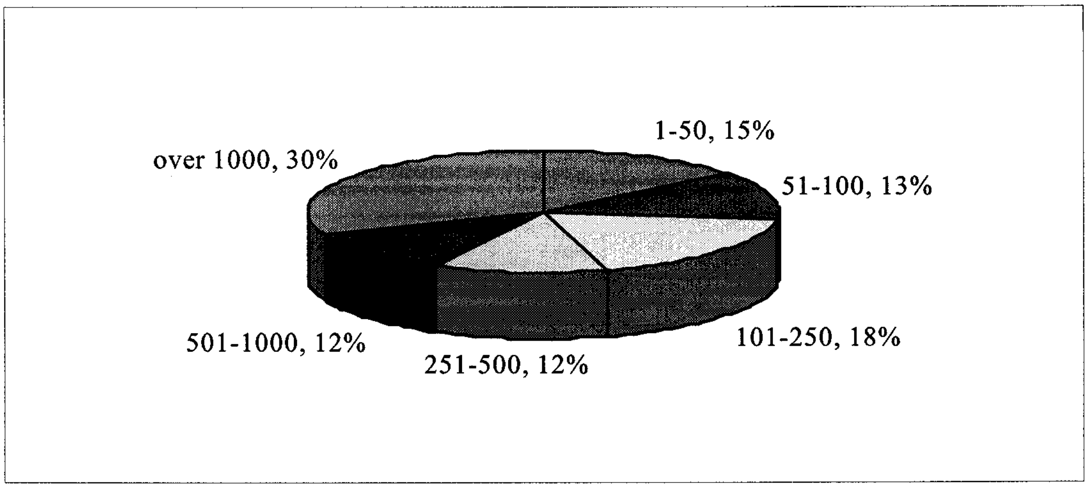


Figure 5.8 Organizations by Number of Employees

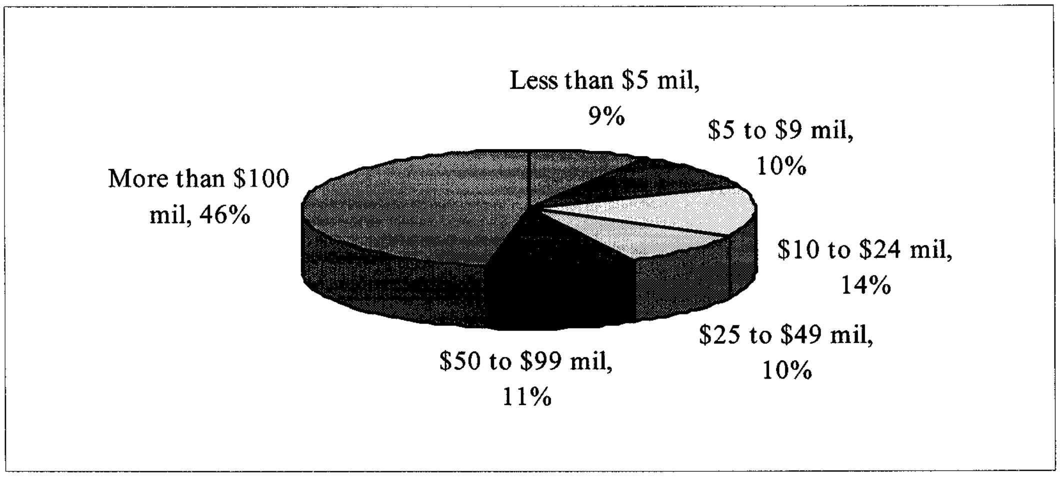


Figure 5.9 Organizations by Annual Sales

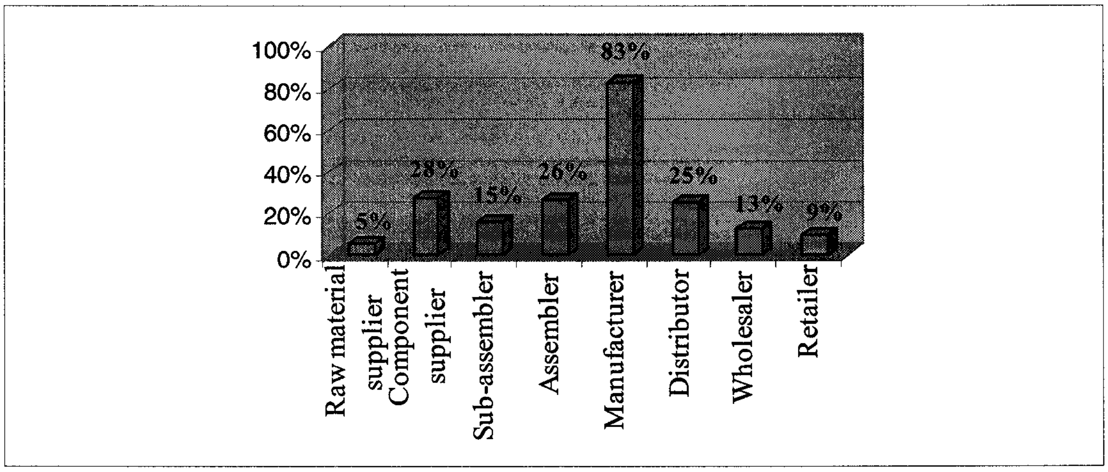


Figure 5.10 Organizations by Horizontal Positions in the Supply Chain

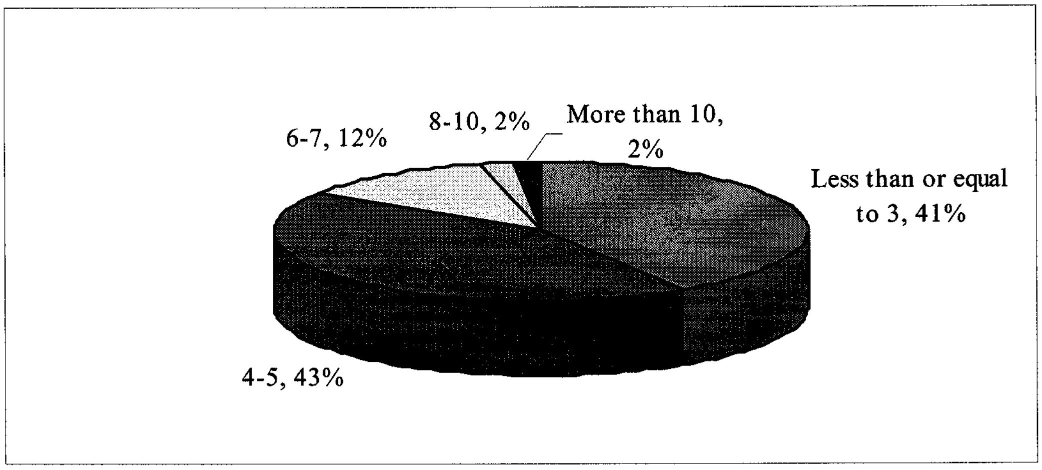


Figure 5.11 Organizations by Tiers of Supply Chain

5.3 Non-response Bias Analysis

Non-response bias analysis is an important issue in conducting a large-scale survey since a bias may affect the validation of responses. In the current study, although a 69.8 percent response rate is quite high, findings from the survey would not accurately characterize industries if there were large differences between respondents and non-respondents.

In this research, two non-response bias analyses were done using chi-square test. The first comparison was made between the sample of 5147 and the respondents of 201. The critical chi-squared for 6 degrees of freedom ($\alpha = 0.05$) is 12.59 and the computed chi-squared (7.52) is less than this value. Therefore, the results show that there is no significant difference between the sample of 5147 and the respondents of 201 when considering the percentages in SIC codes at 0.05 level of significance (Table 5.3).

SIC Codes	Expected Freq. (%) (f_e)	Observed Freq. (%) (f_o)	$(f_e - f_o)^2 / f_e$
Apparel and other textile products (23)	5 (2.49%)	4 (1.99%)	0.2
Rubber and Plastics (30)	5 (2.49%)	6 (2.99%)	0.2
Fabricated Metal Products (34)	17 (8.46%)	11 (5.47%)	2.11
Industrial and Commercial Machinery (35)	42 (20.90%)	46 (22.89%)	0.38
Electronic and Other Electric Equipment (36)	91 (45.27%)	100 (49.75%)	0.89
Transportation Equipment (37)	23 (11.44%)	14 (6.97%)	3.52
Others	18 (8.96%)	20 (9.95%)	0.22
Total	201 (100%)	201 (100%)	0.0
Chi-square Test	$\chi^2 = 7.52, df = 6$		

Table 5.3 Comparison of SIC Codes Distribution for Non-respondent Bias

In addition, most researchers view non-response bias as a continuum, ranging from fast responders to slow responders. Therefore, another non-respondent bias analysis was done by comparing respondents who responded after the initial wave, those who responded to the second wave, and those who responded after the third wave. Since there were 59 responses in the first wave, 76 responses in the second wave, and 66 responses in the third wave, adjustments were make to the frequencies, based on the original percentage. For instance, the SIC code 35 showed a frequency of 12 (20.3%) out of the total of 59 responses in the first wave. To make the adjustment, the researcher used the percentage and obtained the expected frequency in the second wave based on the total of the second wave (76*0.203). The adjustment is necessary since the chi-squared test requires both frequencies to show equal sums. Results of this comparison are shown in Table 5.4. Likewise, there is no difference between those three groups. Both tests exhibit that the respondents represent an unbiased sample.

5.4 Large-scale Instrument Assessment Methodology

The collected data was then submitted to rigorous reliability and validity assessment using the 201 responses. In order to validate the measurement instrument, the collected data needs to be analyzed with the following objectives in mind: purification, factor structure (initial validity), unidimensionality, reliability, and the validation of second-order construct. The methods that were used for each analysis are corrected-item total correlation (for purification), EFA (exploratory factor analysis for factor structure and initial validity), structural equation modeling (for unidimensionality of first-order factor model), and structural equation modeling and T coefficient (for the validation of second-order construct), and Cronbach's alpha (for reliability).

First wave vs. Second wave				
SIC Code	**1st wave**	**2nd wave**	**2nd wave**	**Chi-square Test**
	Freq. (%)	**Expected Freq. (%)**	**Observed Freq. (%)**	
Apparel and other textile products (23)	1 (1.69%)	1 (1.69%)	1 (1.31%)	$\chi^2 = 9.42$ $df = 6$ $p > 0.1$
Rubber and Plastics (30)	2 (3.4%)	3 (3.4%)	2 (2.63%)	
Fabricated Metal Products (34)	2 (3.4%)	3 (3.4%)	4 (5.3%)	
Industrial and Commercial Machinery (35)	12 (20.3%)	15 (20.3%)	21 (27.6%)	
Electronic and Other Electric Equipment (36)	35 (59.3%)	45 (59.3%)	34 (44.7%)	
Transportation Equipment (37)	2 (3.4%)	3 (3.4%)	6 (8.5%)	
Others	5 (8.5%)	6 (8.5%)	8 (10.5%)	
Total	59 (100%)	76 (100%)	76 (100%)	
Second wave vs. Third wave				
SIC Code	**2nd wave**	**3rd wave**	**3rd wave**	**Chi-square Test**
	Freq. (%)	**Expected Freq. (%)**	**Observed Freq. (%)**	
Apparel and other textile products (23)	1 (1.31%)	1 (1.31%)	2 (2.53%)	$\chi^2 = 3.96$ $df = 6$ $p > 0.1$
Rubber and Plastics (30)	2 (2.63%)	2 (2.53%)	2 (2.53%)	
Fabricated Metal Products (34)	4 (5.3%)	3 (5.3%)	5 (8.5%)	
Industrial and Commercial Machinery (35)	21 (27.6%)	18 (27.6%)	13(19.7%)	
Electronic and Other Electric Equipment (36)	34 (44.7%)	30 (44.7%)	31 (46.7%)	
Transportation Equipment (37)	6 (8.5%)	5 (8.5%)	6 (9.09%)	
Others	8 (10.5%)	7 (10.5%)	7 (10.5%)	
Total	76 (100%)	66 (100%)	66 (100%)	

Table 5.4 Comparison of SIC Codes Distribution among First, Second, and Third Wave for Non-respondent Bias

The instrument items were first purified by examining the Corrected Item-to-Total Correlation (CITC) scores of each item with respect to a specific dimension of a construct. The need to purify the items (i.e., getting rid of "garbage items") before administering factor analysis is emphasized by Churchill (1979). The CITC score is a very good indicator of how well each item contributes to the internal consistency of a particular construct dimension as measured by the Cronbach's Alpha coefficient (Cronbach, 1951). As a general rule, items with a CITC score of lower than 0.50 should be removed. However, a slightly lower CITC score may be acceptable if that particular item is considered to be important to the construct dimension. On the other hand, certain items with CITC score above 0.50 may also be removed if their deletion can improve the overall reliability of the specific dimension. This can be determined by examining the "Alpha if deleted" score. Also, we must be aware that low CITC scores may sometimes indicate multiple underlying factors in the current dimension.

After purifying the items, an exploratory factor analysis (EFA) of the items in each construct was conducted. The statistical package SPSS 8.0 for Windows was used to conduct both items purification and exploratory factor analysis (EFA) of the items in each construct. Exploratory factor analysis (EFA) is generally used to discover the factor structure of a measure and to explore potential latent sources of variance and covariance in observed measurements. Principal Component analysis was used as factor extraction method, and VARIMAX was selected as the factor rotation method. Also, MEANSUB command was used in most cases to replace the missing values with the mean score for that item. A scale with good internal consistency should have all items load on one factor. If multiple factors emerged, the possibility of splitting the items into multiple dimensions were carefully examined, and theoretical justifications were sought. As a general rule of thumb, when the sample size is 50 or large, factor loadings greater than 0.30 are considered to be vsignificant; loadings of 0.40 are considered more important; and loadings of greater than 0.50 are very significant (Hair, et al., 1992). To ensure the high quality of instrument development process in the current study, 0.50 was used as the cutoff score for factor loadings, i.e., items with loadings lower than 0.50 will generally be removed. To streamline the final results, factor loadings below 0.4 were not reported. Items were further purified if serious cross-loadings (i.e., an item loaded very close to 0.50 on both factors) were observed.

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was calculated for all dimension-level and construct-level factor analysis. This measure ensures that the effective sample size is adequate for the current factor analysis. Generally, a KMO score in the 0.90's is considered outstanding, the 0.80's as very good, the 0.70's as average, 0.60's as tolerable, 0.50's as miserable, and below 0.50 as unacceptable.

Then, in order to further validate the measurement instrument, the confirmatory factor analysis (CFA) was performed. More recently, the structural equation modeling (SEM) has gained an increasing popularity due to its robustness and flexibility in establishing CFA (Truong, 2004). This research used SEM to test instrument validity in both the first-order and second-order factor model. First-order factor models are those in which correlations among the observed variables can be described by a smaller number of latent variables, each of which may be considered to be one level; these factors are termed primary or first-order factors. Another important aspect of instrument assessment is the validation of second-order construct. The purpose is to demonstrate the structural relationships between the dimensions (first-order factors) and to specify a second-order factor model, which posits that the first-order factors estimated are actually sub-dimensions of a broader and more encompassing construct.

One of the most widely used SEM software is AMOS. Using AMOS, measurement and confirmatory factor analysis can be conducted; the overall of model fit and individual parameter estimate tests can be tested simultaneously. Model-data fit was evaluated based on multiple goodness-of-fit indexes. Goodness-of-fit measures the correspondence of the actual or observed input (covariance or correlation) matrix with that predicted form the proposed model. Goodness-of-fit measures are of three types: (1) absolute fit measures assess only the overall model fit (both measurement and structural models collectively); (2) Incremental fit measures compare the proposed model to another model specified by the researcher, most often referred to as the null model; and (3) Parsimonious fit measures relate the goodness-of-fit of the model to the number of estimated coefficients required to achieve this model fit. The purpose being to determine the amount of fit achieved by each estimated coefficient.

Chi-square Fit Index is perhaps the most common fit test. AMOS refers to this simply as *chi-square*, and others call it chi-square goodness of fit. The chi-square fit index tests the hypothesis that an unconstrained model fits the covariance/correlation matrix as well as the given model. The chi-square value should not be significant if there is a good model fit. A problem with this test is that the larger the sample size, the more likely the rejection of the model and the more likely a Type II error. The chi-square fit index is also very sensitive to violations of the assumption of multivariate normality. Therefore, it has been suggested that it must be interpreted with caution in most applications (Joreskog and Sorbom, 1989). For that reason, chi-square/degree of freedom (χ^2 / df) is used with values less than 3 indicate good fit (Carmines and McIver, 1981).

Besides *Chi-square Fit Index,* AMOS reports a large number of alternative measures of model fit. Some of the other measures of overall model fit are goodness of fit index (GFI), adjusted goodness of fit index (AGFI), comparative fit index (CFI), normed-fit index (NFI), root mean square residual (RMR), and root mean square error of approximation (RMSEA). Goodness of fit index (GFI) varies from 0 to 1, but theoretically can yield meaningless negative values. Adjusted goodness of fit index (AGFI) AGFI is a variant of GFI which uses mean squares instead of total sums of squares in the numerator and denominator of 1-GFI. It varies from 0 to 1 too; but theoretically can yield meaningless negative values. Comparative fit index (CFI) compares the absolute fit of specified model to the absolute fit of the independence model. The independent model is one of the most restrictive models that can be fit. The greater the discrepancy between the overall fit of the two models the larger the values of CFI. NFI is the normed-fit index, which varies from 0 to 1, with 1 equals to perfect fit. NFI is a relative comparison of proposed model to the null model. Many researchers interpret these index scores (GFI, AGFI, CFI, NFI) in the range of .80-.89 as representing reasonable fit; scores of .90 or higher are considered as evidence of good fit (Hair et al., 1998; Joreskog and Sorbom, 1989; Bentler and Bonett, 1980). RMR, the root mean square residual, indicates the average discrepancy between the elements in the sample covariance matrix and the model-generated covariance matrix. RMR values range from 0 to 1, with smaller values indicating better model (Byrne, 2001). The RMSEA has only recently been recognized as one of the most informative criteria in covariance structure modeling. It takes into account the error of approximation in the population and is expressed per degree of freedom, thus making the index sensitive to the number of estimated parameters in the model. Values below .05 signify good fit and the most acceptable value is .08 (Browne and Cudeck, 1993; Bryne, 1989).

As recommended by Joreskog and Sorbom (1989), only one item was allowed to be altered at a time to avoid over-modification of the model. Therefore, following Sethi and King (1994), iterative modifications were made for first-order and second-order factor models by examining modification indices along with coefficients to improve key model fit statistics. An item could be eliminated due to nonsignificant or low path coefficient. Specifically, for each fixed parameter specified, AMOS provides a modification index (MI), the value of which represents the expected drop in overall χ^2 value if the parameter were to be freely estimated in a subsequent run (Byrne, 2001). One arbitrary rule of thumb is to consider eliminating paths associated with parameters whose modification index exceeds 100. However, another common path is simply to eliminate the parameter with the largest MI, and then see the effect as measured by the chi-square fit index and goodness-of-fit indices. The deletion of an item must be on the basis of enough evidence, both theoretically and empirically. This iterative process continued until all model parameters and key fit indices met recommended criteria.

Finally, the reliability of the items comprising each dimension was examined using Cronbach's alpha. Reliability is an assessment of the degree of internal consistency between multiple measurements of a variable. The generally agreed upon lower limit for Cronbach's alpha is .70 (Robinson et al., 1991; Robinson and Shaver, 1973).

5.5 Large-scale Measurement Results

The following section will present the large-scale instrument validation results on each of the four new constructs in the study: outsourcing, supply flexibility, logistics flexibility, and spanning flexibility. For each construct, the instrument assessment methodology described in the previous section was applied. In presenting the results of the large-scale study, the following acronyms were used to number the questionnaire items in each sub-construct.

Outsourcing (OU)	
OU/COR	Core Outsourcing
OU/PER	Peripheral Outsourcing
Supply Flexibility (SF)	
SF/NET	Supply Network Flexibility
SF/SPL	Supplier Flexibility
Logistics Flexibility (LF)	
LF/DIS	Physical Distribution Flexibility
LF/CHL	Logistics Channel Flexibility
Spanning Flexibility (PF)	
PF/INF	Information Dissemination Flexibility
PF/CHL	Spanning Channel Flexibility

5.5.1 Outsourcing (OU)

The Outsourcing (OU) construct was initially represented by two dimension and 8 items, including Core Outsourcing (OU/COR) (3 items) and Peripheral Outsourcing (OU/PER) (5 items). The analysis began with purification using CITC analysis. For the OU/COR dimension, items OU/COR3 had CITC scores of 0.37, far below 0.50. Thus they were removed at this stage. The CITC for each item and its corresponding code name are shown in Table 5.5.

An exploratory factor analysis was then conducted using principal components as means of extraction and varimax as method of rotation. The ratio of respondents to items is 29 and thus, meets the general guideline. The factor results are shown in Table 5.6. The KMO score of 0.73 indicated an acceptable sampling adequacy. The cumulative variance explained by the two factors is 61.85%. All items loaded on their respective factors and there were no items with cross-loadings greater than .40.

The first-order factor model for Supply Flexibility was then tested using AMOS. The initial model of Supply Flexibility was tested indicating an acceptable model fit indices: $\chi^2 / df = 2.13$; RMR = .07, GFI = .96, AGFI = .92, NFI = .93, RMSEA = .07, and CFI = .96. Since the initial model was in very good fit, there was no need of any further modifications. The first-order model for Outsourcing (OU) is shown in Figure 5.12. The factor loadings (λ) were all above .50 and significantly important.

Coding	**Items**	**Initial CITC**	**Alpha if Deleted**	**Final CITC**	**Cronbach's Alpha**
	Core Outsourcing (OU/COR)				
OU/COR1	We outsource manufacturing	.62	.48	.62	α= .77
OU/COR2	We outsource assembly	.58	.52	.58	
OU/COR3	We outsource research and development	.37	Item dropped after purification		
	Peripheral Outsourcing (OU/PER)				
OU/PER1	We outsource sales	.54	.71	.54	α= .76
OU/PER2	We outsource information systems	.50	.73	.50	
OU/PER3	We outsource logistics and distribution	.50	.75	.50	
OU/PER4	We outsource marketing	.63	.69	.63	
OU/PER5	We outsource customer service	.60	.71	.60	

Table 5.5 Purification for Outsourcing (OU)

In the next step, the second-order model was tested to see if these two sub-constructs (OU/COR and OU/PER) underlie a single higher-order construct – Outsourcing (OU). The second-order model for Outsourcing is shown in Figure 5.13. The model showed very good model fit indices: χ^2 / df=1.376; RMR = .07, RMSEA = .04, GFI = .96, AGFI = .93, NFI = .93, and CFI = .98. The standardized coefficients (γ) were .67 for OU/COR, and .51 for OU/PER and both were statistically significant, hence, the higher-order construct (OU) can be considered.

Item	Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.73		
	Supply Network Flexibility	Supplier Flexibility	α
OU/PER1	.71		.77
OU/PER2	.65		
OU/PER3	.65		
OU/PER4	.82		
OU/PER5	.78		
OU/COR1		.89	.76
OU/COR2		.89	
Eigenvalue	2.96	1.37	
% of Variance	38.08	23.77	
Cumulative % of variance	38.08	61.85	

Table 5.6 Purification for Outsourcing (OU)

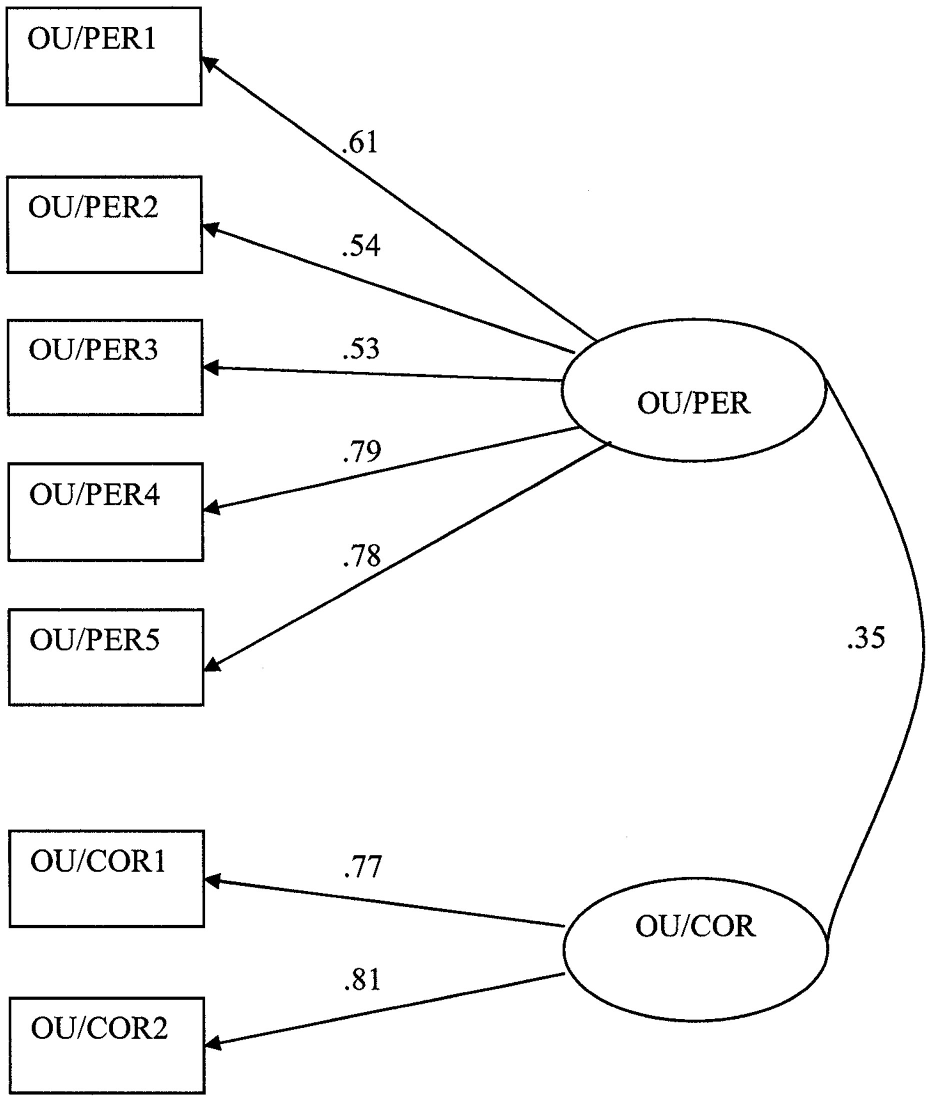


Figure 5.12 The First-order Model for Outsourcing (OU)

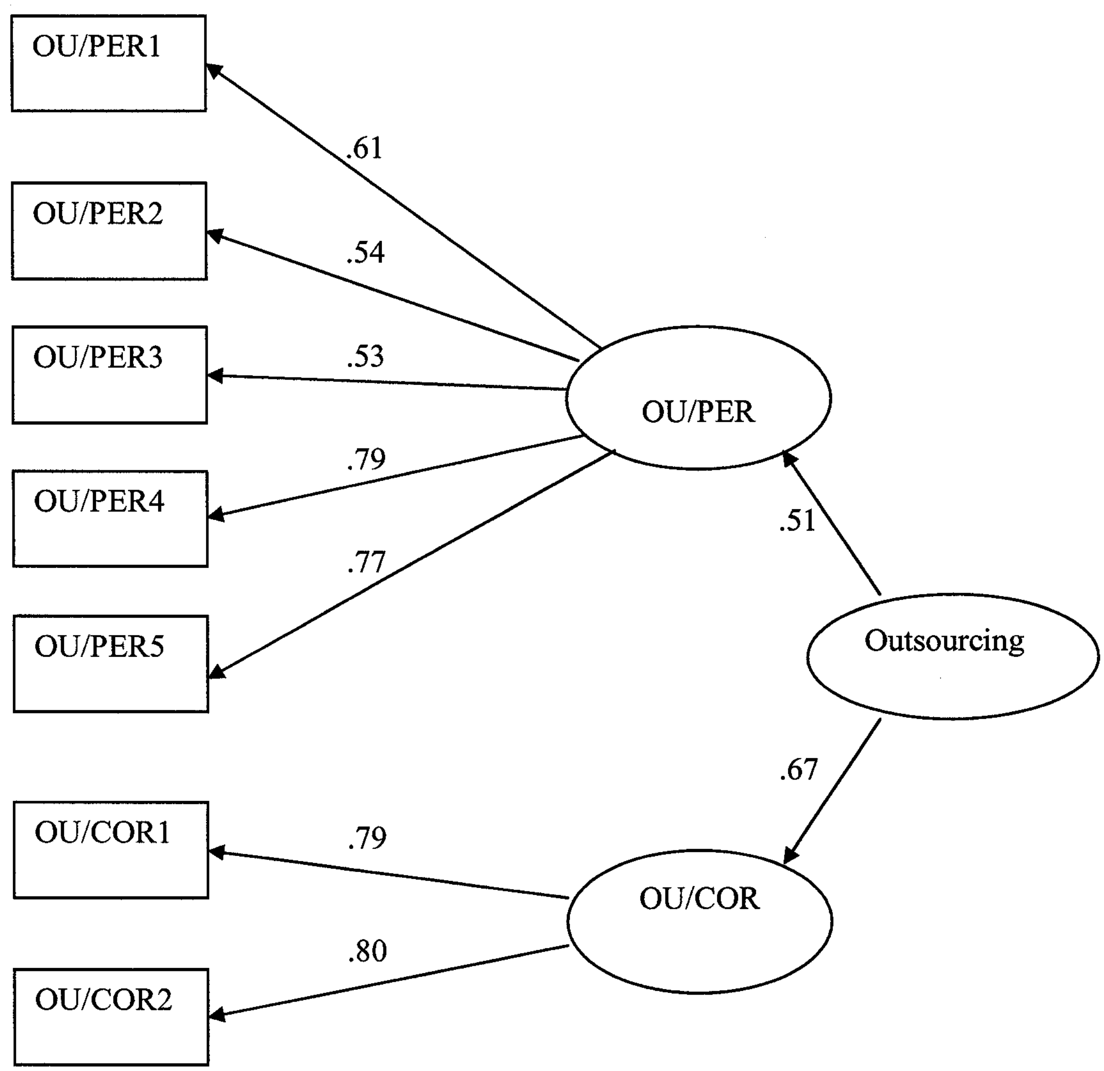


Figure 5.13 The Second-order Model for Outsourcing (OU)

5.5.2 Supply Flexibility (SF)

The Supply Flexibility (SF) construct was initially represented by two dimension and 6 items, including Supply Network Flexibility (SF/NET) (4 items), and Supplier Flexibility

(SF/SPL) (2 items).The analysis began with purification using CITC analysis. The CITC for each item and its corresponding code name are shown in Table 5.7.

An exploratory factor analysis was then conducted using principal components as means of extraction and varimax as method of rotation. The ratio of respondents to items is 34 and thus, meets the general guideline. The factor results are shown in Table 5.8. The KMO score of 0.80 indicated very good sampling adequacy. The cumulative variance explained by the two factors is 82.31%. All items loaded on their respective factors and there were no items with cross-loadings greater than .40.

The first-order factor model for Supply Flexibility was then tested using AMOS. The initial model of Supply Flexibility was tested indicating an acceptable model fit indices: χ^2/df=.754 with a p-value of .644; RMR = .017, GFI = .99, AGFI = .974, NFI = .993, and CFI = 1.0. Since the initial model was in very good fit, there was no need of any further modifications. The first-order model for Supply Flexibility (SF) is shown in Figure 5.14. The factor loadings (λ) were all above .70.

In the next step, the second-order model was tested to see if these two sub-constructs (SF/NET and SF/SPL) underlie a single higher-order construct – supply flexibility (SF). The second-order model for Supply Flexibility is shown in Figure 5.15. The model showed very good model fit indices: χ^2/df=1.124 with a p-value of .306; RMR = .037, GFI = .971, AGFI = .946, NFI = .976, and CFI = .997. The standardized coefficients (γ) were .84 for SF/NET, and .58 for SF/SPL and both were statistically significant, hence, the higher-order construct (SF) can be considered.

Coding	Items	Initial CITC	Alpha if Deleted	Final CITC	Cronbach's Alpha
	Supply Network Flexibility (SF/NET)				
SF/NET1	We have multiple supply sources for most purchased items	.71	.91	.71	α= .91
SF/NET2	We are able to replace one supply source for another with low cost	.86	.86	.86	
SF/NET3	We are capable to replace one supply source for another in a short time	.85	.86	.85	
SF/NET4	We can switch supply source with little negative effect on component quality and design	.76	.89	.76	
	Supplier Flexibility (SF/SPL)				
SF/SPL1	Our major suppliers are willing to accommodate changes that we have requested	.80		.80	α= .89
SF/SPL2	Our major suppliers are able to accommodate changes that we have requested	.80		.80	

Table 5.7 Purification for Supply Flexibility (SF)

Item	Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.80		
	Supply Network Flexibility	Supplier Flexibility	α
SF/NET1	.82		.91
SF/NET2	.90		
SF/NET3	.89		
SF/NET4	.83		
SF/SPL1		.92	.89
SF/SPL2		.92	
Eigenvalue	3.72	1.22	
% of Variance	62.02	20.29	
Cumulative % of variance	62.02	82.31	

Table 5.8 Exploratory Factor Analysis for Supply Flexibility

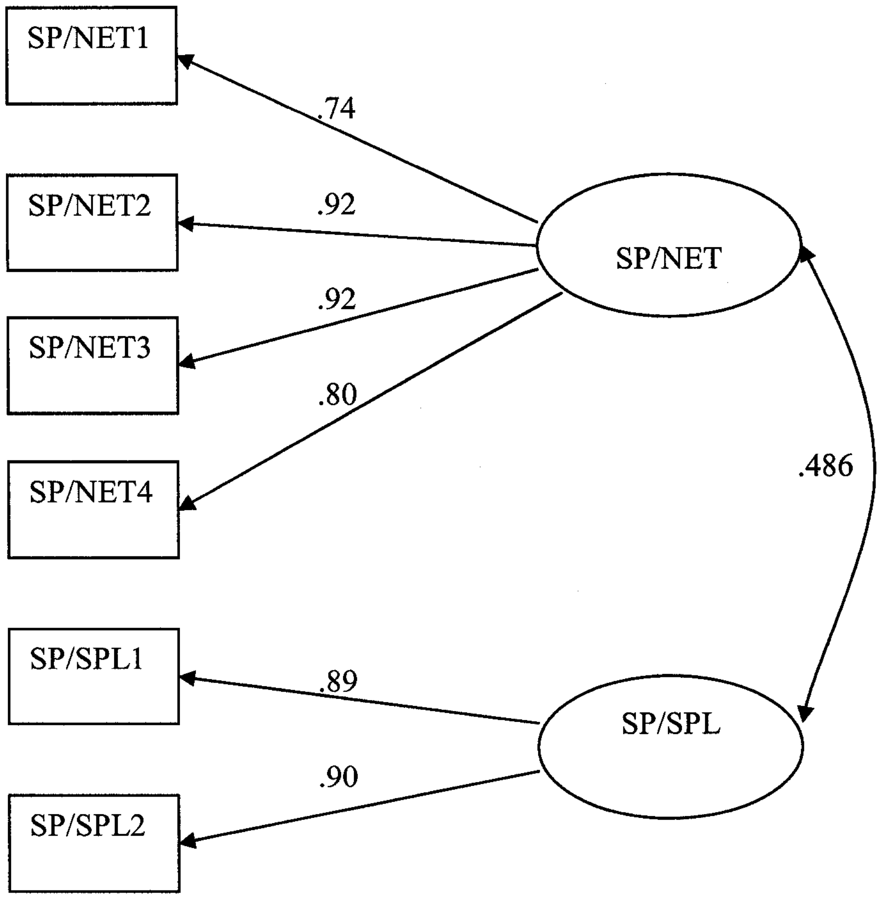


Figure 5.14 The First-order Model for Supply Flexibility (SF)

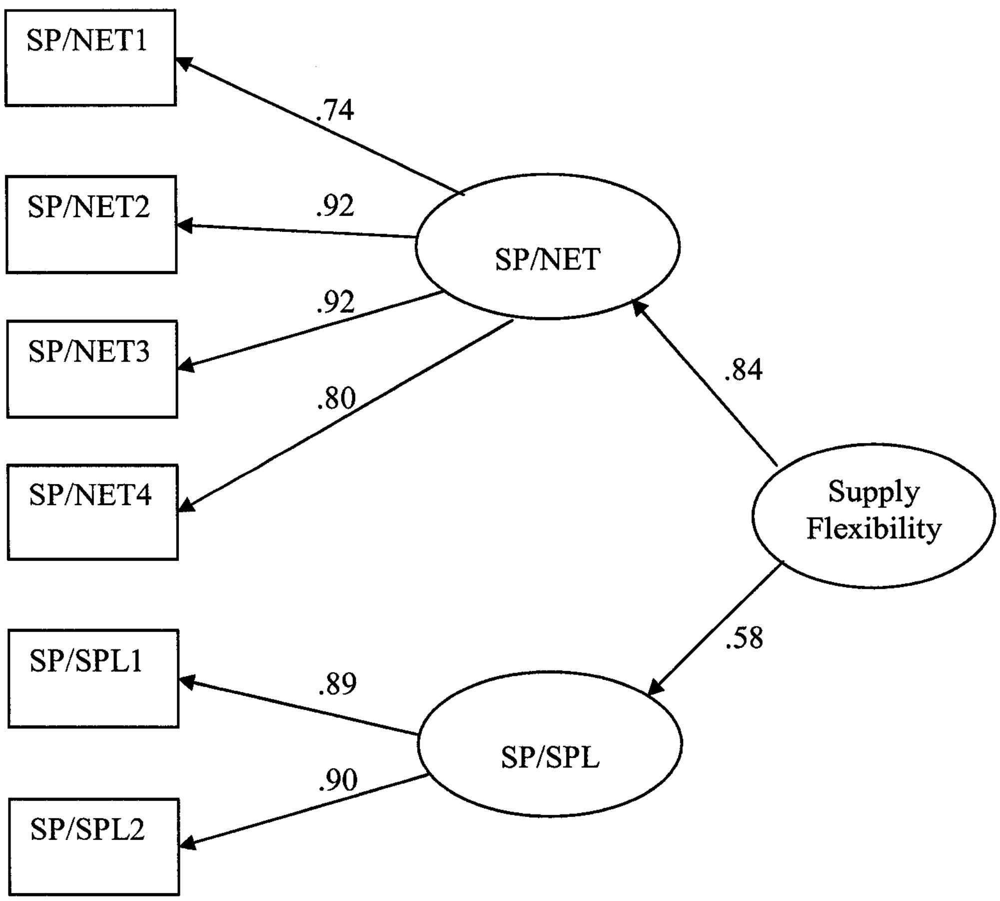


Figure 5.15 The Second-order Model for Supply Flexibility (SF)

5.5.3 Logistics Flexibility

The Logistics Flexibility (LF) construct was initially represented by two dimensions and 10 items, including Physical Distribution Flexibility (LF/DIS) (5 items), and Logistics Channel Flexibility (LF/CHL) (5 items). The analysis began with purification using CITC analysis. The CITC for each item and its corresponding code name are shown in Table 5.9.

An exploratory factor analysis was then conducted using principal components as means of extraction and varimax as method of rotation. The ratio of respondents to items is 20 and thus, meets the general guideline. The factor results are shown in Table 5.10. The KMO score of 0.88 indicated very good sampling adequacy. All items load on their respective factors and there are no items with cross-loadings greater than .40. Corbach's alpha's for the two sub-constructs are .94 and .88 respectively. The cumulative variance explained by the two factors is 74.85%.

Coding	Items	Initial CITC	Alpha if Deleted	Final CITC	Cronbach's Alpha
	Physical Distribution Flexibility (LF/DIS)				
LF/DIS1	We can receive items from suppliers with multiple transportation modes	.67	.86	.67	α= .88
LF/DIS2	We are able to deliver items to customers with multiple transportation modes	.69	.86	.69	
LF/DIS3	We are capable to change transportation modes quickly	.82	.83	.82	
LF/DIS4	We have capability to switch transportation modes with low cost	.71	.71	.71	
LF/DIS5	We can switch transportation modes with little negative effect on logistics performance	.68	.68	.68	
	Logistics Channel Flexibility (LF/CHL)				
LF/CHL1	We have multiple distribution channels for a variety of products/services	.61	.96	.61	α= .94
LF/CHL2	We can easily restructure physical distribution channels in response to changes in market demand	.93	.91	.93	
LF/CHL3	We are able to easily restructure physical distribution channels in response to changes in competition	.90	.91	.90	
LF/CHL4	We are capable to easily restructure physical distribution channels in response to changes in business condition	.90	.91	.90	
LF/CHL5	We can restructure distribution channels with little negative effect on logistics performance	.84	.92	.84	

Table 5.9 Purification for Logistics Flexibility (LF)

Item	Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.88		
	Logistics Channel Flexibility	**Physical Distribution Flexibility**	α
LF/CHL1	.67		.94
LF/CHL2	.95		
LF/CHL3	.94		
LF/CHL4	.92		
LF/CHL5	.89		
LF/DIS1		.82	.88
LF/DIS2		.83	
LF/DIS3		.88	
LF/DIS4		.74	
LF/DIS5		.72	
Eigenvalue	5.36	2.12	
% of Variance	53.61	21.24	
Cumulative % of variance	53.61	74.85	

Table 5.10 Exploratory Factor Analysis for Logistics Flexibility

The detailed model fit statistics of iterative process in the first-order model for Logistics Flexibility (LF) is shown in Table 5.11. The initial model was tested indicating acceptable λ coefficients being greater than .6. The model fit was very poor with χ^2 / df=5.4, RMR = .094, GFI = .823, AGFI = .714, NFI = .898, and CFI = .915. The following is a description of each of the modifications for first-order Logistics Flexibility (LF) model in the 4 trials.

1. Although all λ coefficients were good, the AGFI (.714) was low indicating possibility of error correlation. The modification index indicated high error

correlation between LF/DIS1 and LF/DIS2 (48.19). It was decided to drop item LF/DIS1 since, on an examination of the description of the two items, it appeared that item LF/DIS2 is a more important measure of physical distribution flexibility than item LF/DIS1.

2. Model fit indices were improved; however, not good enough. Given the indicated high error correction between items LF/DIS2 and LF/DIS3 (24.06), it was decided to drop item LF/DIS2 since, on an examination of the description of the two items; it appeared that item LF/DIS3 subsumes LF/DIS2.
3. The model required further refinement. LF/CHL4 and LF/CHL5 presented high error correlation with MI = 19.87. Item LF/CHL5 was deleted since the statement about "logistics performance" is too general and this item showed error correlations with other several items. The fit indices indicated acceptable model fit. No further modifications were done.

The final first-order model for Logistics Flexibility (LF) is shown in Figure 5.16. The factor loadings (λ) were acceptable with the lowest λ being .64 and they were all statistically significant.

The next step was to test if these two sub-constructs (LF/DIS and LF/CHL) underlie a single higher-order construct – Logistics Flexibility (LF). The second-order model is shown in Figure 17. The model showed acceptable model fit indices: χ^2/df =1.76; RMR = .05, GFI = .94, AGFI = .91, NFI = .96, and CFI = .98. The standardized coefficients (γ) were .62 for LF/DSI, and .76 for LF/CHL and both were statistically significant, hence, the higher-order construct Logistics Flexibility (LF) can be considered.

The final set of measurement items for Logistics Flexibility (LF) and resulting reliabilities as measured by Cronbach's alpha are listed in Table 12. The Cronbach's alphas are both above .85, indicating the reasonable reliability of constructs.

Trials		**1**	**2**	**3**	**4**
Path Coefficients	LF/DIS1	.73			
	LF/DIS2	.74	.64		
	LF/DIS3	.90	.83	.78	.78
	LF/DIS4	.77	.85	.86	.86
	LF/DIS5	.74	.82	.85	.85
	LF/CHL1	.63	.63	.63	.64
	LF/CHL2	.97	.97	.97	.98
	LF/CHL3	.94	.94	.94	.94
	LF/CHL4	.94	.94	.94	.92
	LF/CHL5	.88	.88	.88	
χ^2		183.89	103.15	69.32	31.11
df		34	26	19	13
χ^2 / df		5.41	3.96	3.65	2.39
p-value		.000	.000	.000	.003
RMR		.09	.07	.06	.05
GFI		.82	.89	.91	.96
AGFI		.71	.80	.83	.92
NFI		.90	.94	.95	.97
CFI		.92	.95	.97	.98
RMSEA		.15	.12	.11	.08

Table 5.11 First-order Model Refinement Process for Logistics Flexibility (LF)

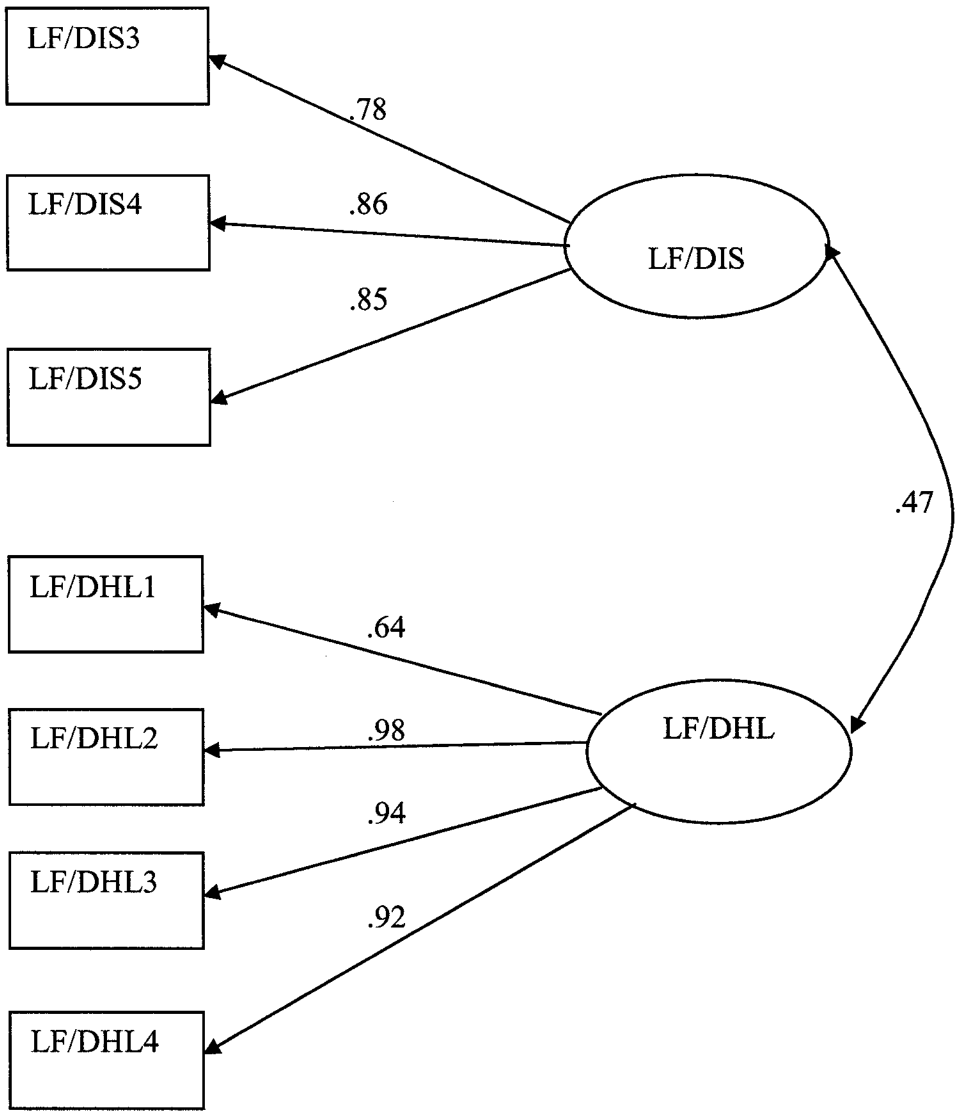


Figure 5.16 The First-order Model for Logistics Flexibility (LF)

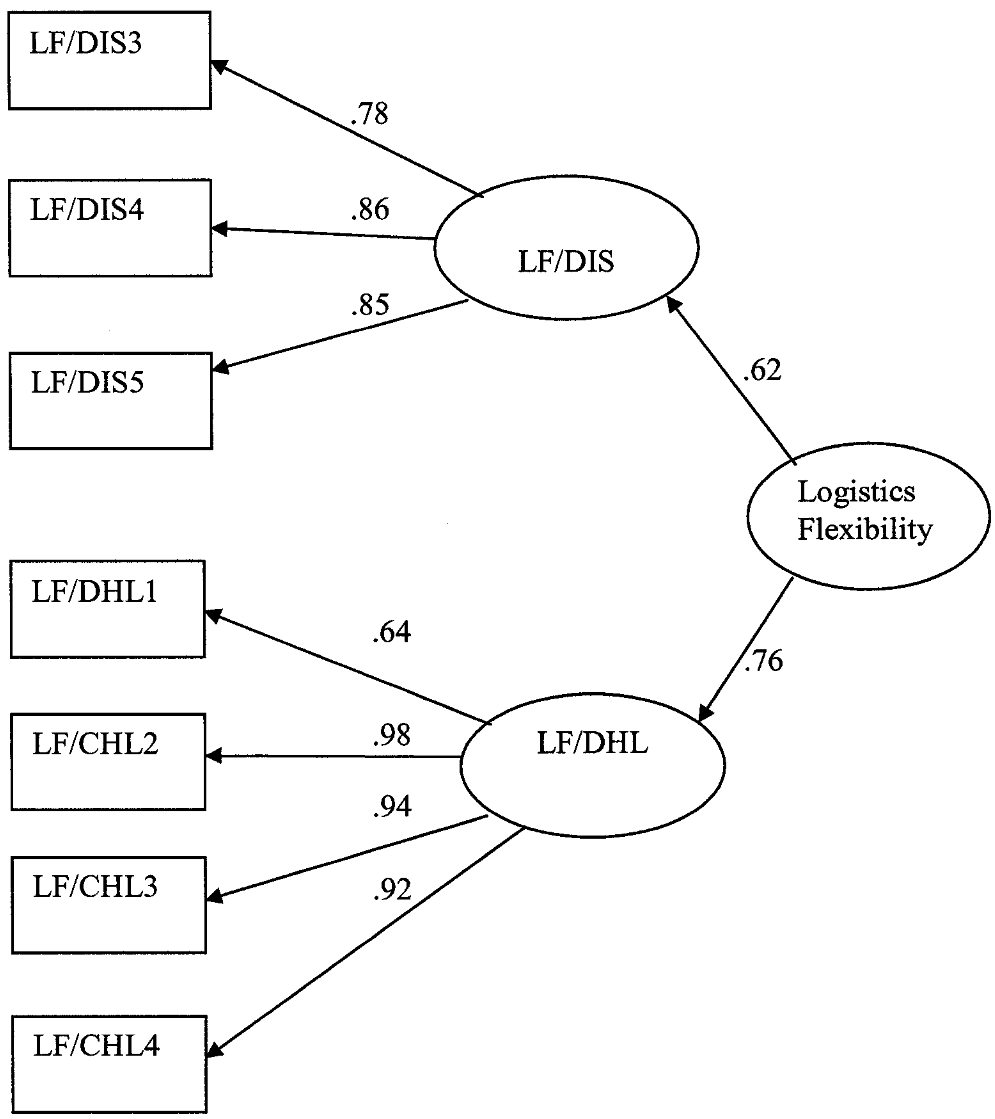


Figure 5.17 The Second-order Model for Logistics Flexibility (LF)

Coding	Items	α
	Physical Distribution Flexibility (LF/DIS)	.87
LF/DIS3	We are capable to change transportation modes quickly	
LF/DIS4	We have capability to switch transportation modes with low cost	
LF/DIS5	We can switch transportation modes with little negative effect on logistics performance	
	Logistics Channel Flexibility (LF/CHL)	.92
LF/CHL1	We have multiple distribution channels for a variety of products/services	
LF/CHL2	We can easily restructure physical distribution channels in response to changes in market demand	
LF/CHL3	We are able to easily restructure physical distribution channels in response to changes in competition	
LF/CHL4	We are capable to easily restructure physical distribution channels in response to changes in business condition	

Table 5.12 Logistics Flexibility (LF) - Final Construct Items

5.5.4 Spanning Flexibility

The Spanning Flexibility (SF) construct was initially represented by two dimensions and 10 items, including Information Dissemination Flexibility (PF/DIS) (5 items) and Spanning Connectivity Flexibility (PF/CON) (5 items). The analysis began with purification using CITC analysis. The CITC for each item and its corresponding code name are shown in Table 5.13.

Coding	Items	Initial CITC	Alpha if Deleted	Final CITC	Cronbach's Alpha
	Information Sharing Flexibility (PF/INF)				
PF/INF1	We have many ways to share information with our major suppliers	.73	.86	.73	α= .88
PF/INF2	We can share many kinds of information (e.g., text, video, database, etc.) with our major suppliers	.75	.85	.75	
PF/INF3	We are able to exchange information with major suppliers in a short time	.69	.87	.69	
PF/INF4	Information can be exchanged automatically with our major suppliers using information systems	.72	.86	.72	
PF/INF5	We are able to share real time information with major suppliers	.74	.85	.74	
	Spanning Channel Flexibility (PF/CHL)				
PF/CON1	We can establish new information sharing channels in a short time	.70	.86	.70	α= .88
PF/CON2	We are able to set up new information sharing channels with low cost	.71	.85	.71	
PF/CON3	Information is shared seamlessly across our Supply chain regardless of the information sharing channels	.75	.84	.75	
PF/CON4	Our major suppliers are willing to share information to accommodate changes that we request	.68	.86	.68	
PF/CON5	Our major suppliers are able to share information to accommodate changes that we request	.72	.85	.72	

Table 5.13 Purification for Spanning Flexibility (PF)

An exploratory factor analysis was then conducted using principal components as means of extraction and varimax as method of rotation. The ratio of respondents to items is 20 and thus, meets the general guideline. The factor results are shown in Table 5.14. The KMO score of 0.87 indicated very good sampling adequacy. The results were presented in Table 5.14. Two factors emerged from the factor analysis with all factor loadings above 0.50 and most above 0.70. Serious cross-loading occurred on items. Hence items PF/CON1 and PF/CON2 were dropped. Corbach's alpha's for the two sub-constructs are .88 and .85 respectively. The cumulative variance explained by the two factors is 73.28%.

Item	**Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy = 0.87**		
	Information Sharing Flexibility	**Spanning Channel Flexibility**	α
PF/INF1	.76		.88
PF/INF2	.73		
PF/INF3	.76		
PF/INF4	.78		
PF/INF5	.84		
PF/CON1	.57	.52	.85
PF/CON2	.51	.57	
PF/CON3		.69	
PF/CON4		.87	
PF/CON5		.92	
Eigenvalue	4.73	1.14	
% of Variance	42.09	31.19	
Cumulative % of variance	42.09	73.28	

Table 5.14 Exploratory Factor Analysis for Spanning Flexibility

The detailed model fit statistics of iterative process in the first-order model for Spanning Flexibility (PF) is shown in Table 5.15. The initial model was tested indicating acceptable λ coefficients being greater than .6. The model fit was very poor with χ^2 / df=5.8, RMR = .13, GFI = .881, AGFI = .774, NFI = .897, and CFI = .912. The following is a description of each of the modifications for first-order Spanning Flexibility (LF) model in the 4 trials.

1. Although all λ coefficients were good, the AGFI (.774) was low indicating possibility of error correlation. The modification index indicated high error correlation between PF/INF4 and PF/INF5 (37.85). It was decided to drop item PF/INF5 since, on an examination of the description of the two items, it appeared that item PF/INF4 subsumes PF/INF5; and item PF/INF5showed error correlations with other several items.
2. Model fit indices were improved; however, not good enough. Item PF/CON3 presented lowest path coefficient and high modification indexes, it was decided to drop item PF/CON3 since it might be interpreted to be included in other items.

As seen in Table 5.15., the last trial is an accepted model fit. χ^2 / df is .992; all GFI, AGFI, NFI, and CFI are above .90; RMR and RMSEA are both below .05, proving evidence that the model has been significantly improved. The final first-order model for Spanning Flexibility (PF) is shown in Figure 5.18. The factor loadings (λ) were acceptable with the lowest λ being .68 and they were all statistically significant.

Trials		**1**	**2**	**3**
Path Coefficients	PF/INF1	.81	.83	.83
	PF/INF2	.84	.90	.90
	PF/INF3	.73	.69	.69
	PF/INF4	.76	.68	.68
	PF/INF5	.75		
	PF/CON3	.64	.64	
	PF/CON4	.94	.94	.97
	PF/CON5	.91	.91	.89
χ^2		183.89	37.55	9.043
df		34	13	8
χ^2 / df		5.41	2.88	1.13
p-value		.000	.000	.339
RMR		.09	.11	.03
GFI		.82	.95	.99
AGFI		.71	.89	.96
NFI		.90	.96	.99
CFI		.92	.97	1.00
RMSEA		.15	.09	.03

Table 5.15 First-order Model Refinement Process for Spanning Flexibility (PF)

The next step was to test if these two sub-constructs (PF/INF and PF/CON) underlie a single higher-order construct – Spanning Flexibility (PF). The second-order model is shown in Figure 5.19. The model showed acceptable model fit indices: χ^2 / df=.992; a p-value for the hypothesis stating that the model fits perfectly in the population of .48; RMR = .05, GFI = .97, AGFI = .95, NFI = .98, and CFI = 1.00. The standardized coefficients (γ) were .92 for PF/INF, and .66 for PF/CON and both were statistically significant, hence, the higher-order construct Spanning Flexibility (LF) can be considered.

The final set of measurement items for Logistics Flexibility (LF) and resulting reliabilities as measured by Cronbach's alpha are listed in Table 5.16. The Cronbach's alphas are both above .85, indicating the reasonable reliability of constructs.

All the final retained measurement items for supply flexibility (SF), logistics flexibility (LF), spanning flexibility (PF), and outsourcing (OU) are listed in Appendix D.

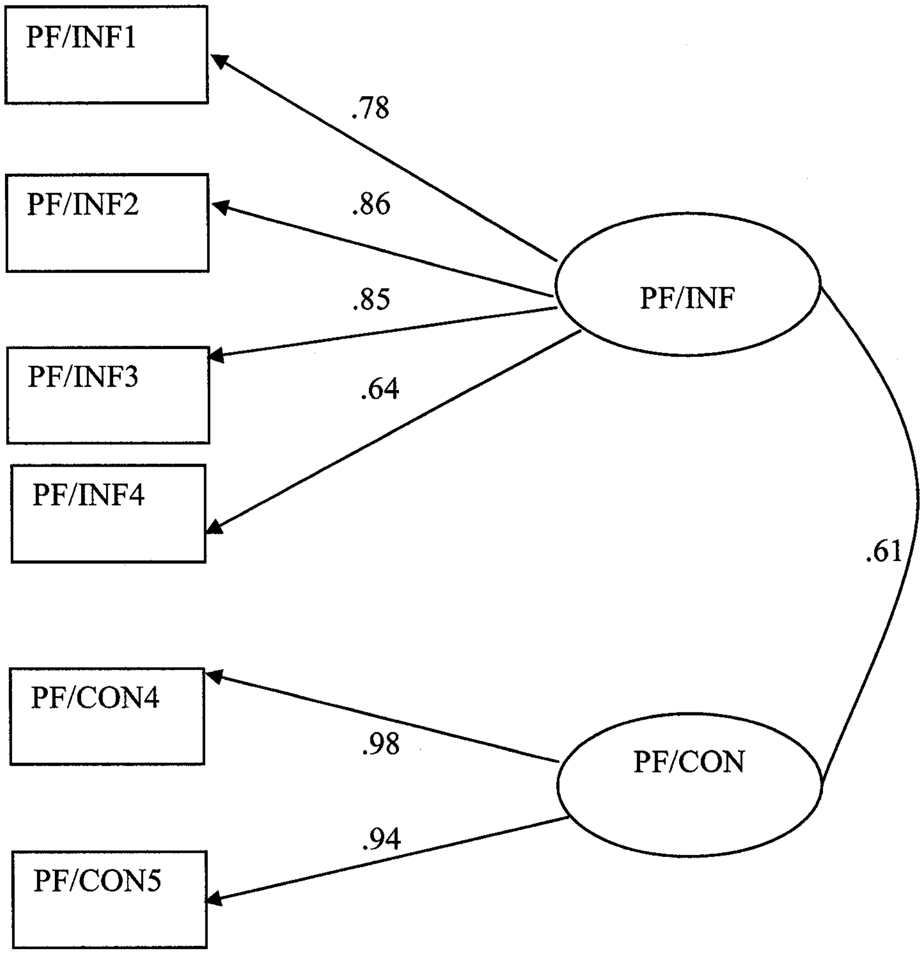


Figure 5.18 The First-order Model for Spanning Flexibility (PF)

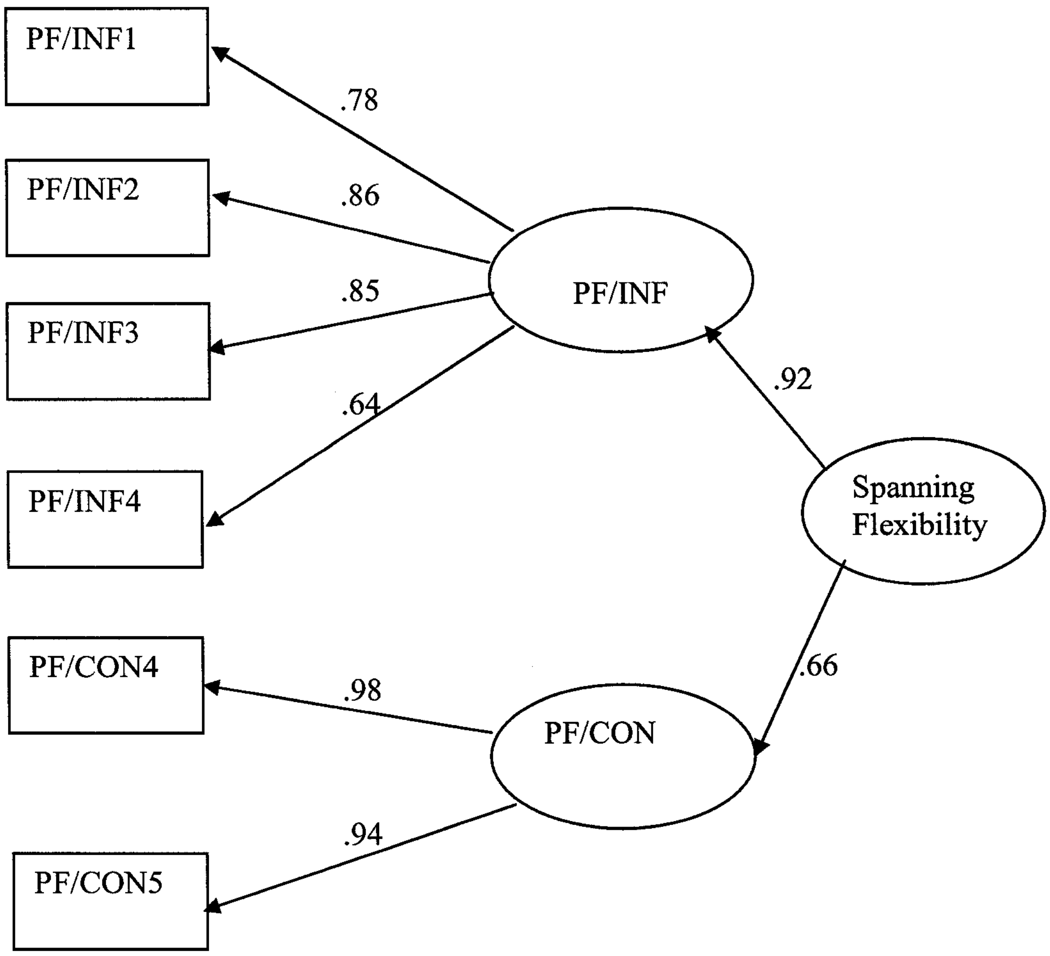


Figure 5.19 The Second-order Model for Spanning Flexibility (PF)

Coding	Items	α
	Information Dissemination Flexibility (LF/DIS)	.88
PF/INF1	We have many ways to share information with our major suppliers	
PF/INF2	We can share many kinds of information (e.g., text, video, database, etc.) with our major suppliers	
PF/INF3	We are able to exchange information with major suppliers in a short time	
PF/INF4	Information can be exchanged automatically with our major suppliers using information systems	
	Spanning Connectivity Flexibility (PF/CON)	.85
PF/CON4	Our major suppliers are willing to share information to accommodate changes that we request	
PF/CON5	Our major suppliers are able to share information to accommodate changes that we request	

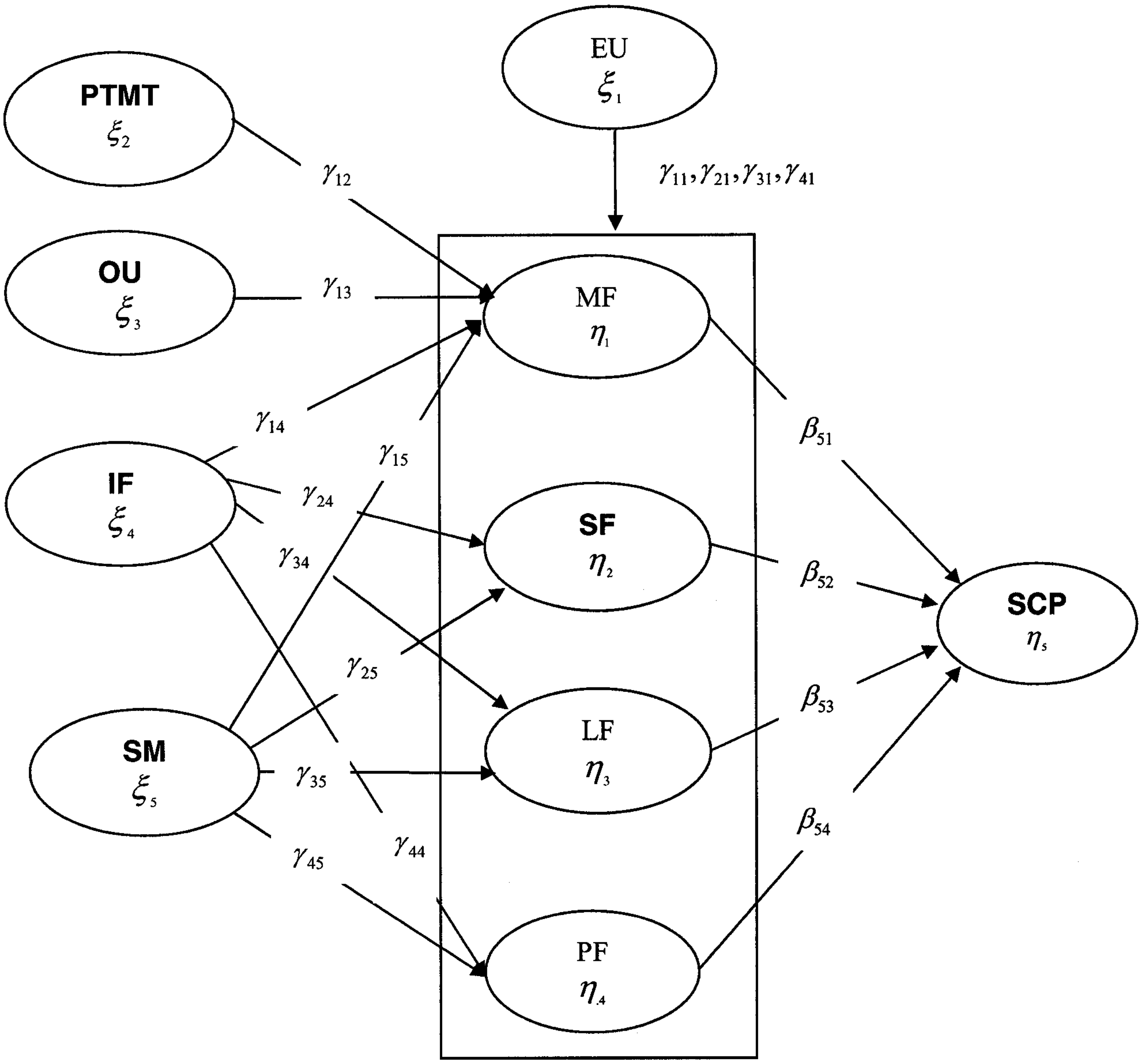
Table 5.16 Spanning Flexibility (PF) - Final Construct Items

6. CAUSAL MODEL AND HYPOTHESES TESTING

A major methodological breakthrough in the study of complex interrelations among variables has been the development and application of structural equation modeling (SEM) (Joreskog, 1977). SEM is a family of statistical techniques which incorporates and integrates the *measurement* model (a sub-model in SEM that specifies the indicators of each construct and assesses the reliability of each construct for later use in estimating the causal relationships) and the *structural* model (the set of dependent relationships linking the model constructs). Since the measurement instruments have been carefully assessed in the previous chapter with necessary adjustments. The SEM model described in this chapter will focus on path analysis using the AMOS software. The significance of each path in the proposed structural model will be tested and the overall goodness-of-fit of the entire structural equation model will be assessed as well.

6.1 The Structural Equation Model

The proposed structural model depicted in Figure 6.1 is a replication of the framework presented in Figure 3.1 using the mathematical notation in the structural equation model.



PTMT:	Postponement	MF:	Market-oriented Flexibility
OU:	Outsourcing	SF:	Supply Flexibility
IF:	Information Facility	LF:	Logistics Flexibility
SM:	Supplier Management	PF:	Spanning Flexibility
EU:	Environmental Uncertainty	SCP:	Supply Chain Performance

Figure 6.1 Proposed Structural Equation Model

There are ten variables in the model: Environmental Uncertainty (EU) - ξ_1, Postponement (PTMT) - ξ_2, Outsourcing (OU) - ξ_3, Information Facility (IF) - ξ_4, Supplier Management (SM)- ξ_5, Market-oriented Flexibility (MF) - η_1, Supply Flexibility (SF) - η_2, Logistics Flexibility (LF) - η_3, Spanning Flexibility (PF) - η_4, and Supply Chain Performance (SCP) - η_5. EU, PTMT, OU, IF, and SM are regarded as independent (exogenous) variables, and all others are dependent (endogenous) variables. Endogenous latent variables are affected by the exogenous variables in the model, either directly or indirectly. They are explained by the model because their causal antecedents are specified within the model under consideration.

The general structural equation model relating the above latent exogenous and endogenous variables is

$$\eta = \beta\, \eta + \tau\, \xi + \varsigma$$

where η is a (5×1) vector of latent endogenous variables; ξ is a (5×1) vector of the latent exogenous variable; τ (gamma) is a (5×5) vector of coefficients relating the 5 exogenous variables to 5 endogenous variables; β is a (5×5) matrix of coefficients of relating the 4 endogenous variables to one another. ς is a (5×1) vector of errors in the structural equations.

The 18 hypotheses proposed in Chapter 3 are represented by the 18 causal relationships in the model. Hypothesis 1a is represented in Figure 6.1.1 by the relationship γ_{11}(EU → MF); Hypothesis 1b is represented by the relationship γ_{21} (EU

→ SF), Hypothesis 1c is represented by the relationship γ_{31} (EU → LF); Hypothesis 1d is represented by the relationship γ_{41} (EU → PF); Hypothesis 2 is represented by the relationship γ_{12} (PTMT → MF); Hypothesis 3 is represented by the relationship γ_{13} (OU → MF); Hypothesis 4a is represented by the relationship γ_{14} (IF → MF); Hypothesis 4b is represented by the relationship γ_{24} (IF → SF), Hypothesis 4c is represented by the relationship γ_{34} (IF → LF); and Hypothesis 4d is represented by the relationship γ_{44} (IF → PF). Hypothesis 5a is represented by the relationship γ_{15} (SM → MF); Hypothesis 5b is represented by the relationship γ_{25} (SM → PF), Hypothesis 5c is represented by the relationship γ_{35} (SM → LF); and Hypothesis 5d is represented by the relationship γ_{45} (SM → PF). Hypothesis 6a is represented by the relationship β_{51} (MF→ SCP); Hypothesis 6b is represented by the relationship β_{52} (SF → SCP), Hypothesis 6c is represented by the relationship β_{53} (LF → SCP); and Hypothesis 6d is represented by the relationship β_{54} (PF → SCP).

6.2 Structural Equation Model Results Using AMOS

The structural equation model showed a good fit between the theoretical model and the data. Measures of absolute fit of the model to the data show an acceptable degree to which the overall model predicts the observed covariance matrix: χ^2/df=2.52; RMR = .07, RMSEA = .05, GFI = .94, AGFI = .88, NFI = .91 and CFI = .96. The findings for the structural equation model are presented in Table 6.1 and Figure 6.2 Out of the 18 hypothesized relationships, 15 were found to be significant at the 0.05 level.

The results support the following research hypotheses presented in Chapter 3: Environmental uncertainty is a driving force of market-oriented flexibility, supply flexibility and spanning flexibility. Market-oriented flexibility is related to environmental uncertainty, postponement, supplier management, and information facility (causal path represented in the structural equation 1 below); supply flexibility is affected by environmental uncertainty, supplier management, and information facility practices (causal path represented in the structural equation 2 below); logistics flexibility is related to supplier management (causal path represented in the structural equation 3 below); spanning flexibility is affected by environmental uncertainty, supplier management and information facility practices (causal path represented in the structural equation 4 below); and supply chain performance is related to market-oriented, logistics, and spanning flexibilities (causal path represented in the structural equation 5 below).

$$\eta_1 = \gamma_{11}\xi_1 + \gamma_{12}\xi_2 + \gamma_{14}\xi_4 + \gamma_{15}\xi_5 + \zeta_1 \quad (1)$$

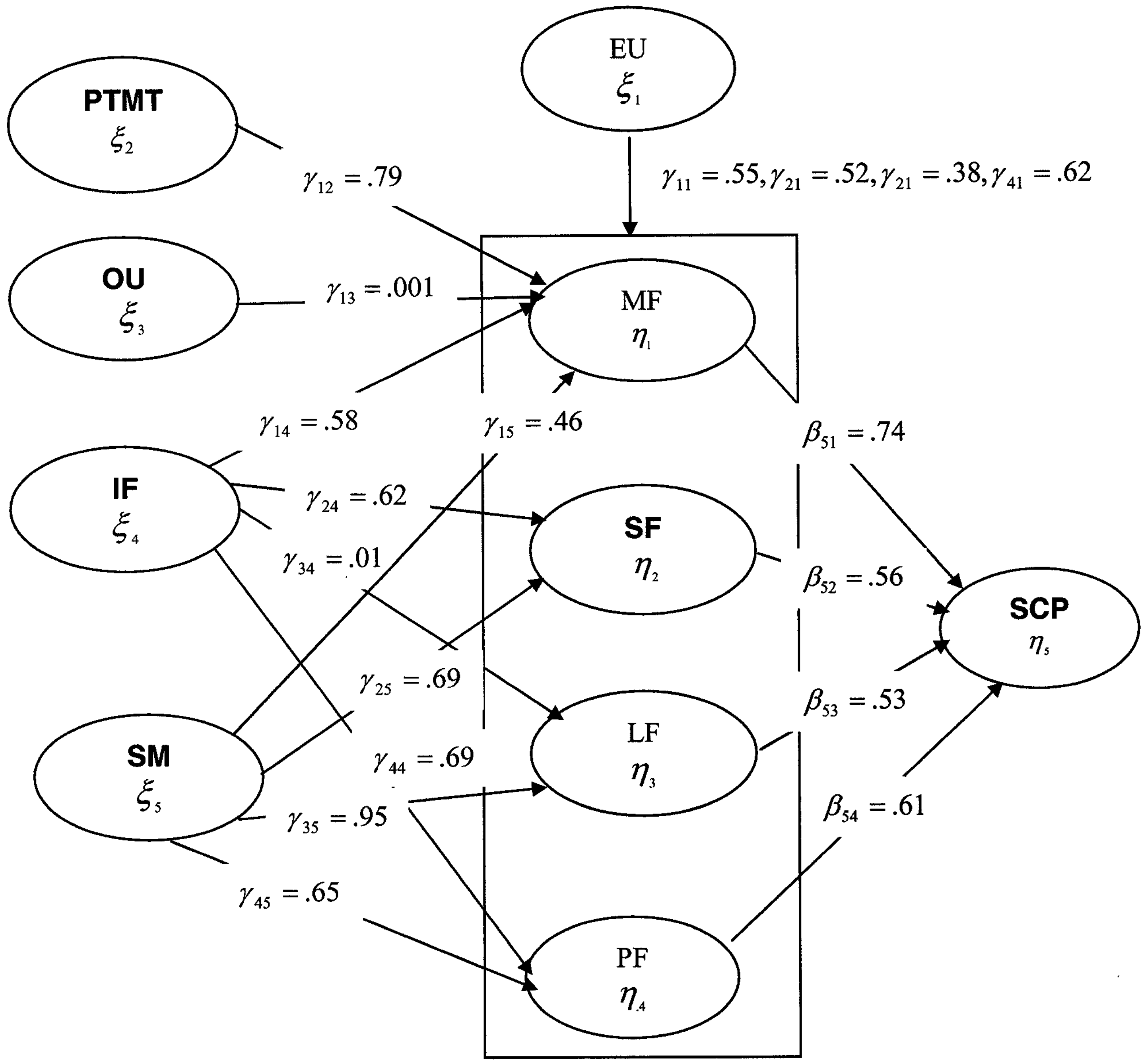
$$\eta_2 = \gamma_{21}\xi_1 + \gamma_{24}\xi_4 + \gamma_{25}\xi_5 + \zeta_2 \quad (2)$$

$$\eta_3 = \gamma_{35}\xi_5 + \zeta_3 \quad (3)$$

$$\eta_4 = \gamma_{41}\xi_1 + \gamma_{44}\xi_4 + \gamma_{45}\xi_5 + \zeta_4 \quad (4)$$

$$\eta_5 = \beta_{51}\eta_1 + \beta_{53}\eta_3 + \beta_{54}\eta_4 + \zeta_5 \quad (5)$$

The results indicate that there are no significant, direct relationships between environmental outsourcing and market-oriented flexibility or between information facility and logistics flexibility. And there are partially significant relationships between environmental uncertainty and logistics flexibility, and between supply flexibility and supply chain performance.



PTMT:	Postponement	MF:	Market-oriented Flexibility
OU:	Outsourcing	SF:	Supply Flexibility
IF:	Information Facility	LF:	Logistics Flexibility
SM:	Supplier Management	PF:	Spanning Flexibility
EU:	Environmental Uncertainty	SCP:	Supply Chain Performance

Figure 6.2 Results - Structural Equation Model

Hypotheses	Relationship	Path	t-value	p-value	Significant? ($\alpha = .05$)
H1a	EU → MF	γ_{11}	2.340	.019	Yes
H1b	EU → SF	γ_{21}	2.069	.039	Yes
H1c	EU → LF	γ_{31}	1.847	.065	No
H1d	EU → PF	γ_{41}	2.474	.013	Yes
H2	PTMT → MF	γ_{12}	4.096	.000	Yes
H3	OU → MF	γ_{13}	0.010	.995	No
H4a	IF → MF	γ_{14}	7.679	.000	Yes
H4b	IF → SF	γ_{24}	8.059	.000	Yes
H4c	IF → LF	γ_{34}	.101	.920	No
H4d	IF → PF	γ_{44}	8.495	.000	Yes
H5a	SM → MF	γ_{15}	6.658	.000	Yes
H5b	SM → SF	γ_{25}	8.931	.000	Yes
H5c	SM → LF	γ_{35}	10.245	.000	Yes
H5d	SM → PF	γ_{45}	8.448	.000	Yes
H6a	MF → SCP	β_{51}	6.367	.000	Yes
H6b	SF → SCP	β_{52}	8.434	.000	Yes
H6c	LF → SCP	β_{53}	4.063	.000	Yes
H6d	PF → SCP	β_{54}	2.507	.012	Yes

Table 6.1 Summary of Structural Equation Model Results for Hypothesis Testing

6.3 A Summary of Hypotheses Testing Using SEM

The previous section reported the AMOS structural modeling and hypotheses testing results on the proposed model. The results from this research can be used not only by academicians in further exploring and testing causal linkages in supply chain flexibility, but also by practitioners for guiding the implementation of supply chain management practices and the evaluation of supply chain flexibility. This section will discuss the theoretical and practical implications of the test of each hypothesis.

Hypothesis 1a: *The higher the level of environmental uncertainty, the higher the level of market-oriented flexibility.*

This relationship was found to be significant ($\gamma = .55, p = .019$), which indicates that there is positive relationship between environmental uncertainty and market oriented flexibility. Theoretically, this hypothesis shows that in a highly uncertain environment, companies must improve the ability to respond quickly to changes in the market and to deliver new customer values. In other words, environmental uncertainty should be considered and combined with the potential flexibility options including manufacturing, product development, and delivery flexibility. For instance, radically customer preferences changes, technology development, and competition evolution will drive firms to develop ability to quickly introduce and launch new product or to make design changes in responding to a variety of environmental uncertainties. The results also confirm the supply chain management and flexibility literature developed by Sethi and Sethi (1990) and Chen et al. (1992) and other researchers about the importance of developing the capability of adjusting the level and mix of production for responding to highly uncertain market demands.

Hypothesis 1b: *The higher the level of environmental uncertainty, the higher the level of supply flexibility.*

It was postulated that environmental uncertainty has significant positive relationship with supply flexibility. From the results, hypothesis 1b is supported with the significant, direct positive effect ($\gamma = .52, p = .039$). This can be explained by the nature of supply chain management and flexibility. Supply chain management endorses a supply chain orientation and involves coordination of activities and flows that extend across boundaries. Similarly, an integrative perspective is taken to examine the supply chain flexibility, which emphasizes the importance of the linkages with supply side and demand side. Therefore, in responding to environmental uncertainty, the ability to adjust supply sources effectively and rapidly is required. In other words, enough architectural flexibility should be built up into the supply chain structure in adapting to the changes. On the other hand, with supply base optimization, companies are relying on limited but manageable supply base. The results also imply that unless companies are able to bring suppliers who are capable of achieving responsive performance objectives into their supply base, they are at the mercy of competitors who have taken-supplier flexibility capabilities seriously.

Hypothesis 1c: *The higher the level of environmental uncertainty, the higher the level of logistics flexibility.*

This relationship is found to be not significant ($\gamma = .38, p = .065$) at .05 significant level, which indicates that there is no direct, positive relationship between environmental uncertainty and logistics flexibility. This partially significant relationship may be explained by the following: First, because some of the customers' desired value changes appear to require logistics competencies, environmental uncertainty seems to predict a company's reliance on responsive and reliable logistics process. However, more and more companies are now outsourcing logistics functions to third-party logistics providers, who are capable of offering professional and flexible services. The logistics network, therefore, is becoming more complex, involving alliances with third-party logistics providers, and will have to be more flexible than the traditional network regardless of business environment. Second, logistics flexibility involves the management of transportation and distribution channel. Organizations may have been pursuing logistics flexibility, not simply out of the pressure from the external environment, but by the motivation for gaining competitive advantage. For example, the study of Anderson et al. (1997) finds that for many companies, tailoring logistics assets could be a source of differentiation for a manufacturer, more so than the product itself. O'Conner and Rawlinson (1993) suggest that the logistics systems are one of the key areas for bringing distinct value to distinct customers. Many companies include multiple logistics and distribution partners across the chain and are able to provide specifying logistics functions to specific requirements. Therefore, an organization in a relative stable environment may have a high level of logistics flexibility too.

Hypothesis 1d: *The higher the level of environmental uncertainty, the higher the level of spanning flexibility.*

This relationship is found to be significant ($\gamma = .62, p = .013$). It demonstrates that environmental uncertainty affects not only market-oriented and supply flexibility but also spanning flexibility directly. The significance of Hypothesis 1d empirically confirmed that in this increasingly information-intensive and uncertain environment, a company has to have the ability of leveraging information in a manner that is flexible, cost effective, manageable, and reliable. Spanning flexibility enables companies to get timely and accurate response from customers and supply chain partners. Specifically, uncertainty may exist for level of demand, product prices, product mix, resources availability, and technological innovation, supply chain partners that share information on a timely basis are able to work as a single entity. Together, they are better able to respond to changes in the marketplace. Therefore, for companies facing higher level of environmental uncertainty, efforts of achieving quick and accurate information disseminating along the supply chain is very critical for building up competitive advantages.

Combining the results of Hypothesis 1a through 1d show that building flexibility into the supply chain is an effective response to continuously changing, unpredictable business environment. These findings are very important since there has been doubt among researchers and practitioner about investment and putting management efforts on supply chain flexibility. Prater et al. (2001) even suggests that as external vulnerability increases, supply chain flexibility should decrease to limit supply chain complexity. But the results from this study verify that higher level of environmental uncertainty result in a greater emphasis on supply chain flexibility.

Hypothesis 2: *The higher the level of postponement practice, the higher the level of market-oriented flexibility.*

As expected, this relationship is found to be significant ($\gamma = .79, p = .000$), which indicates that the implementation of postponement has a direct and positive effect on market-oriented flexibility. This result confirms the literature about the adoption of postponement balancing efficiency and responsiveness across the supply chain (Van Hoek et al., 1999a, Yang et al., 2004). The main benefit related to postponement stems from the fact that one can delay the decision point for differentiation. By postponing both production and delivery decisions to after demand realization, companies can better respond to the changes in the marketplace. Specifically, to achieve market-oriented flexibility, semi-product manufacturing, assembly, packaging, and labeling postponement are most commonly adopted options in production process with the intent to delay customization until the nearest positions to the customers or until specific customer orders are received. Or in logistics system, the delay of the forward movement of goods downstream to the customer until orders are received can also improve the market-oriented flexibility.

Hypothesis 3: *The higher the level of outsourcing, the higher the level of market-oriented flexibility.*

The relationship is found to be no significant (γ=0.35, t=4.32). This is unexpected by the researcher since some previous studies and practical experience have showed that greater flexibility enabled by outsourced manufacturing allows companies to be highly responsive to market conditions and evolving opportunities (Billington and Johnson, 2005). A plausible explanation for this result could the found in the lwo percentage of outsourcing practice. Only 30%, 21%, and 3% of the respondents answered that their companies implemented outsourcing in manufacturing, assembly, and product development activities respectively. Therefore, the relationship between outsourcing and flexibility could be weak at this point. Another reasonable explanation is that outsourcing usually associated with a variety of risks (i.e., loss of control over suppliers, internal conflicts) (Quinn and Hilmer, 1994; Gilley and Rasheed, 2000). Therefore, outsourcing impacts supply chain flexibility associated with other supply chain actions such as outsourcing risks management and knowledge management on supply market.

Hypothesis 4a: *The higher the level of information facility practices, the higher the level of market-oriented flexibility.*

The relationship is found to be significant ($\gamma = .58, p = .000$).This finding reveals the critical role of effective information facility practices in the improvement of market-oriented flexibility. It empirically confirms the theoretical notion that a well-managed and well-executed information chain directly leads to improved flexibilities which are market-oriented. The implementation of information facility practices will directly improve a company's ability of responding to market changes on an effective and efficient basis. For example, suppliers continuously exchange information about their problems and emerging requirements and actively participate in the firm's development processes before product specifications are established. Such information sharing practices help to coordinate all the functions, anticipate needs across the supply chain and further demonstrate responsiveness. Therefore, managements should seriously consider and implement information facility practices to affect the firm's efficient and effectiveness in distributing and sharing information along the supply chain to respond quickly to various customer needs.

Hypothesis 4b: *The higher the level of information facility practices, the higher the level* *of supply flexibility.*

The relationship is found to be significant ($\gamma = .62, p = .000$). Although some previous researchers have proposed that information technology utilization and information sharing practices has become a fundamental enabler in creating and maintaining flexible supply networks, there is no empirical evidence has been provided (Venkatraman, 1994; Aranda, 2003). The statistical significance of Hypothesis 4b confirms that information facility practice, indeed, has a bottom-line influence on the supply side flexibility. Great sharing of information would also allow collective knowledge and consensus on action to emerge faster with new partners (i.e., component suppliers or logistics service providers), yielding supply network flexibility. Therefore, if organizations want to develop a flexible supply base, it will be necessary for them to be aware of the importance of using specific IT based support for order processing and invoicing, for materials and resource planning, for real time information sharing with suppliers, exchanging information needed to support changes in product features or volumes with major suppliers, and so on.

Hypothesis 4c: *The higher the level of information facility practices, the higher the level of logistics flexibility.*

The path coefficient between information facility practices and logistics flexibility was .01 with a p-value of .92. This result did not support the hypothesis that information facility positively affects logistics flexibility, which is not expected by the researcher. Information flow has been viewed as extremely important in the context of logistics flexibility. Theoretically, this hypothesis shows that firms with real-time information availability are able to make distribution operations and logistics channels more flexible. However, the finding implies that there is no significant impact of information facility practices on logistics flexibility. A plausible explanation for this result could be found in the fact that it is now the logistics service providers who specialize in tailoring solutions to fit the company's unique requirements and to grow with changing needs. The third-party logistics providers have utilized flexible processes and technology to maximize the efficiency of logistics services. An additional explanation could be based on the fact that information facility is only part of the solution to high level of logistics flexibility. To achieve a high level of logistics flexibility, the information facility must be accompanied by other factors, such as qualified logistics providers and good partnership with them.

Hypothesis 4d: *The higher the level of information facility practices, the higher the level of spanning flexibility.*

The relationship is found to be significant ($\gamma = .69, p = .000$). The significant positive relationship between information facility practices and spanning flexibility empirically demonstrated to managers, that upgrading information technology application is a key to efficient and effective information distribution and dissemination along the supply chain with respect to environmental changes. In addition, as suggested by Gosain et al., (2004), with information being considered as an integral part of a supply chain network, the ability to collect and disseminate quickly the various data needed along a value chain to respond resourcefully to various customer needs can also be improved by higher quality of information sharing with supply chain partners.

Hypothesis 5a: *The higher the level of supplier management practices, the higher the level of market-oriented flexibility.*

The relationship is found to be significant ($\gamma = .46, p = .000$). The result is consistent with the conclusions from the studies of Narasimham and Das (2000) and Singh and Sushil (2004) that the selection, development, and integration of suppliers with flexibility are key determinants of flexibility in the context of manufacturing and new product development. This finding also empirically confirms the assertion in the literature that firms use a variety of activities in supplier selection and development to improve suppliers' performance and/or capabilities for achieving capabilities of responding to marketplace changes. Therefore, managers should regard supplier management as a means for continuously improving the market-oriented flexibility.

Hypothesis 5b: *The higher the level of supplier management practices, the higher the level of supply flexibility.*

As expected, supplier selection, development and partnership have direct and strong positive effect on supply flexibility. The path coefficient of this relationship is .69 with a p-value of .000. The importance of supplier management in striving toward a flexible supply base has received considerable support in the literature (Van Hoek et al., 2001; Christopher, 2000; Christopher et al., 2004). However, no empirical evidence has been shown. The statistical significance of hypothesis 5b verified that better supplier management will improve the level of supply flexibility. Therefore, purchasing managers should take a more strategic view of what they do, moves beyond the typical transaction focus of purchasing and towards evolution to a strategic focus of procurement. For instance, the ability and willingness of responding to the company's changes should be one criterion of supplier selection. Efforts must be made to build up partnership with major suppliers so that they would like to coordinate with changes if it is necessary.

Hypothesis 5c: *The higher the level of supplier management practices, the higher the level of logistics flexibility.*

The relationship is found to be significant ($\gamma = .95, p = .000$). This is a very valuable finding in that many firms are outsourcing logistics functions to third parties, but not putting enough emphasis on continuous third-party logistics provider's performance improvement and relationship maintenance. Over 40% of the respondents (41.7%) answered their companies outsource logistics functions to at least moderate extent. According to Huppertz (1999), distinctive third-party logistics providers can offer transportation mode alternative and quicker entry into a new distribution environment with minimal impact to the existing fulfillment network. However, not all of the outsourcing projects are successful. For example, a lack of effective communication could lead to problems of quality and to delays, as well as to misunderstandings and lack of visibility of shipment and demand schedules; and further deteriorate the flexibility performance. In the long run, if a company wants to maintain its comprehensive competitive competences, it will have new ways of providing logistics services for the business. External sourcing might not have ability or willingness of innovation. A successful example is Mercedes in Germany, who has established a long-term partnership with logistics providers allowed for being flexible and creative in developing customized services (Cunningham, 1996). Therefore, managements need to constantly monitor logistics performance, recognize their achievement, and to build successful partnerships with logistics providers.

Hypothesis 5d: *The higher the level of supplier management practices, the higher the level of spanning flexibility.*

Supplier management practices affect directly spanning flexibility, as supported by the structural equation model. The path coefficient of this relationship is .65 with a p-value of .000. This means that higher supplier management practice will improve the level of flexibility in information dissemination. Since suppliers have a profound and direct impact on responsiveness of the buying firms, better management of supply base and relationships with other supply chain members can build more effective information sharing channels to accommodate changes, and therefore greater flexibility in information exchange and sharing between buyer and suppliers can be achieved.

Hypothesis 6a: *The higher the level of market-oriented flexibility, the higher the level of supply chain performance.*

The relationship is found to be statistically significant ($\beta = .74, p = .000$) and it establishes the direct relationship between market-oriented flexibility and supply chain performance. This finding also empirically confirms the assertion in the literature that higher level of market-oriented flexibility could lead to better performance along the supply chain (Duclos et al., 2003; Lummus et al., 2003). Specifically, as suggested by Wadhwa and Rao (2003) and Nair (2005), the companies can attain significant improvements in lead time performance with flexibility in manufacturing, product development, and delivery. By being flexible in terms of customer-faced values, the supply chain can meet specific customer needs and influence the responsiveness in an effective and efficient manner.

Hypothesis 6b: *The higher the level of supply flexibility, the higher the level of supply chain performance.*

The relationship is found to be statistically significant ($\beta = .56, p = .000$). It supports believes that the suppliers with higher degree of flexibility and flexible supply base both contribute to the supply chain performance. Supply link improves as supply flexibility increases because the integration of flexibility enables better cross-functional collaboration and inter-organizational coordination. In addition, the ability to change the supply networks over time and in response to competition changes provides the network participants take advantage of opportunities to improve their individual positions and performance. As a result, one would expect improvements on each node with a flexible supply chain and further better supply chain performance can be achieved. Supply network flexibility also enable companies tap into a responsive supply base to ensure reliable supply of the products. Therefore, companies can restructure the supply flows of their materials to gain efficiency. Time-based performance improvement comes from supply flexibility since the volume and mix variations with respect to market changes can be absorbed by the supply side.

Hypothesis 6c: *The higher the level of logistics flexibility, the higher the level of supply chain performance.*

The relationship is found to be statistically significant ($\beta = .53, p = .000$). The significantly important relationship between logistics flexibility and performance should be concerned by the management. Observed by Closs et al. (2005), logistics flexibility has not received the same level of attention as other dimensions of flexibility (i.e., manufacturing flexibility). This finding empirically confirms the assertion in the literature that logistics flexibility could provide a supply chain with competitive advantage in terms of cost, time, and quality etc.; and can give the company a defensible position over its competitors by enabling the company to respond to customer needs and overcome unforeseen contingencies. This result is also consistent with the results of research conducted by Closs et al. (2005), which conclude that logistics flexibility has direct and positive impact on responsiveness, reliability, and cost.

Hypothesis 6d: *The higher the level of spanning flexibility, the higher the level of supply chain performance.*

The relationship is found to be statistically significant ($\beta = .61, p = .012$) and it establishes the direct relationship between spanning flexibility and supply chain performance. Flexible information dissemination will support the information interchange between the customer and the entire supply chain, so that firms can use the information to support diverse strategies for design, manufacturing, and distribution on a timely basis, resulting in the enhancement of supply chain performance (Lau and Lee, 2000). This finding is also supported by Zhang's study (2001), which shows a strong causal relationship between spanning flexibility and customer satisfaction. Therefore, it can be concluded that spanning flexibility will affect a supply chain's overall performance, such as cost, delivery competence, and so on.

6.4 Summary of Results

The environmental changes require company to view flexibility from a supply chain perspective rather than a process or functional perspective (Day, 1994). This research represents one of the large-scale empirical efforts to systemically investigate the issue of supply chain flexibility. It aims at figuring out relationship between environmental uncertainty, various supply chain management practices, supply chain flexibility, and supply chain performance. Overall, the results indicate that environmental uncertainty drives market-oriented, supply, and spanning flexibility. The results also show that higher levels postponement, supplier management, and information facility practices will lead to improved market-oriented flexibility; supply and spanning flexibility are not only influenced directly by supplier management practice, but also through information facility practice; and logistics flexibility can be improved by implementing good supplier management practice. Moreover, the findings reveal that market-oriented, supply, and spanning flexibility will enhance supply chain performance. However, the findings did not support the positive relationship between outsourcing and market-oriented flexibility, the influence of information facility practice on logistics flexibility, and the direct impact of supply flexibility on SCM practice. The environmental uncertainty as a driving force of logistics flexibility seems to be moderate.

The following chapter helps in understanding in detail the implications of the structural equation modeling results. It goes to a dimension-level analysis to explore which supply chain management practices affect which supply chain flexibility and supply chain performance dimensions.

7. DIMENSION-LEVEL ANALYSIS

Structural equation modeling allows the researcher to prove causal relationships proposed in Chapter 3. In the last chapter, the researcher showed positive relationships between supply chain practices, supply chain flexibility, and supply chain performance. However, the researcher could not provide further conclusions on which specific supply chain management practice dimension are producing better results; in addition, each of the supply chain flexibility dimensions may affect one or more supply chain performance dimensions with varying degrees of importance. Therefore, a dimension-level analysis to further explore these relationships was conducted and the results are shown in this chapter.

Dimension-level analysis was first performed using MANOVA. MANOVA is used to assess (1) whether an overall differences in sets of supply chain flexibility dimensions (MF – market-oriented flexibility, SF – supply flexibility, LF - logistics flexibility, and PF – spanning flexibility) are found between groups formed by dimension-level supply chain management practices (PTMT – postponement, OU/COR – core outsourcing, OU/PER – peripheral outsourcing, IF/IT – information technology utilization, IF/IS – information sharing, SM/SEL – supplier selection, SM/DEV – supplier development, and SM/PTN – partnership; and (2) whether an overall differences in sets of supply chain performance dimensions (SCP/REL – reliability, SCP/COS – cost, SCP/TIM – time-based performance, and SCP/SLK – supply link performance) are found between groups formed by dimension-level supply chain flexibility dimensions. If multivariate significance was found, univariate tests (ANOVA) tests were employed to address (1) the individual supply chain management practices significant importance for each supply chain flexibility dimensions; and (2) the individual supply chain flexibility significant importance for each supply chain performance dimensions. The classifications between low and high levels of individual supply chain management practice and supply chain flexibility were done by using the median. The following describe in detail the results obtained for each of the dimension-level supply chain management practice and dimension-level supply chain flexibility.

7.1 Dimension Level Analysis of Supply Chain Practice and Supply Chain Flexibility

By substantially improving multiple dimensions of implementations in supply chain management, such supply chain practices have enabled a range of more flexible and responsive methods of doing business. In the previous data analysis, composite measures are used to represent each construct of supply chain practices and flexibility, and only the structural model was tested using AMOS. It is certain that supply chain practices play critical roles in affecting supply chain flexibility. However, the strength and nature of relationships among dimensions across variables may vary. That is, more detailed question such as which supply chain practice (i.e., information technology utilization, supplier development, partnership, etc.) has more impact on which dimension of supply chain flexibility (i.e., market-oriented flexibility, supply flexibility, etc.) can be raised. This section documents the evaluations of the significance of mean differences on all dimensions of supply chain flexibility between groups defined by various levels of supply chain practice dimensions.

7.1.1 Postponement

Postponement is a set of practices of delaying activities in the supply chain as late as possible until actual customer orders are received. In other words, with postponement strategy, one can delay the decision point for differentiation in operations processes, and it further enables much flexibility in an effective and efficient manner. The dimension-level analyses were first done between the practice of postponement and supply chain flexibility including market-oriented, supply, logistics, and spanning flexibility.

Role of Postponement in Market-oriented Flexibility

Market-oriented flexibility is a set of abilities to adjusting operational process across the supply chain including production, product development, and delivery. In other words, the set of market-oriented flexibility dimensions are directly related to customer value creation of the whole supply chain. The MANOVA results indicated significant differences among the high/low postponement categories on the dependent variables (MF/MFG – manufacturing flexibility, MF/PD – product development flexibility, and MF/DEL – delivery flexibility), Pillai's Trace = .067, $F_{(3, 197)} = 4.735$, $p < .05$.

Analysis of variance (ANOVA) was then conducted on each market-oriented flexibility dimension as a follow-up test to MANOVA. Table 7.1 presents means and standard deviations for manufacturing flexibility, product development flexibility, and delivery flexibility by levels of postponement category. Levels of postponement category differences were significant for manufacturing flexibility ($F_{(1,199)} = 8.90, p < .01, \eta^2 = .043$), product development flexibility ($F_{(1,199)} = 9.64, p < .01, \eta^2 = .046$), and delivery flexibility ($F_{(1,199)} = 5.96, p < .05, \eta^2 = .029$).

The practice of postponement is proven to differentiate between high and low levels when analyzing its impact on all dimensions of market-oriented flexibility. This result is very positive for those companies that have already implemented or are thinking about implementing postponement in various operations such as production and delivery, since it reinforces the fact that postponement positively affects market-oriented flexibility.

	Market-oriented Flexibility (MF) Dimensions					
Level of PTMT	MF/MFG**		MF/PD**		MF/DEL***	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Low	3.51	.86	3.34	.96	4.10	.75
High	3.91	1.04	3.83	1.23	4.34	.64

* Difference significant at $\alpha = .001$
** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.1 ANOVA Results for Differences in Market-oriented Flexibility among Levels of Postponement

Role of Postponement in Supply Flexibility

Supply flexibility refers to the ability of adjusting supply base and the ability of the suppliers to respond to changes. As discussed in previous chapters, supply flexibility is conceptualized by two dimensions: supply network flexibility (SF/NET) and supplier flexibility (SF/SPL). The MANOVA results show significant differences among both dimensions for supply flexibility Pillai's Trace = .038, $F_{(2, 198)} = 3.88$, $p < .05$. And the follow-up ANOVA analysis revealed significant differences among the level of postponement categories on supplier flexibility ($F_{(1,199)} = 5.09, p < .01, \eta^2 = .038$). Differences in supply network flexibility were not significant ($F_{(1,199)} = 1.098, p = .296, \eta^2 = .005$). Table 7.2 presents means and standard deviations for supply network flexibility and supplier flexibility by levels of postponement category.

	Supply Flexibility (SF) Dimensions			
	SF/NET		SF/SPL**	
Level of PTMT	Mean	Std. Dev.	Mean	Std. Dev.
Low	3.22	.96	3.88	.73
High	3.39	1.32	4.20	.90

* Difference significant at $\alpha = .001$
** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.2 Differences in Supply Flexibility among Levels of Postponement

Role of Postponement in Logistics Flexibility

The ability of accommodating changes in logistics process is essential in today's business by playing a crucial role in seamless supply chain physical distribution. It is captured by physical distribution flexibility (LF/DIS) and logistics network flexibility (LF/CHL). The MANOVA results show no significant differences among both dimensions for logistics flexibility Pillai's Trace = .020, $F_{(2, 198)} = 2.044$, p = .132.

Role of Postponement in Spanning Flexibility

Spanning flexibility involves aligning suppliers' connection and disseminating information along the supply chain quickly and accurately. Through spanning flexibility, companies and other participants in the supply chain are able to respond resourcefully to various changes. The MANOVA results indicated significant differences among the high/low postponement categories on the dependent variables (PF/INF – information dissemination flexibility, and PF/CON – spanning connectivity flexibility), Pillai's Trace = .032, $F_{(2, 198)} = 3.282$, $p < .05$. Analysis of variance (ANOVA) was then conducted on each market-oriented flexibility dimension as a follow-up test to MANOVA. Table 7.3 presents means and standard deviations for information dissemination flexibility (PF/INF), and spanning connectivity flexibility (PF/CON) by levels of postponement category. Levels of postponement category difference was significant for information dissemination flexibility ($F_{(1,199)} = 6.57, p < .05, \eta^2 = .032$); but the difference was not significant for spanning channel flexibility ($F_{(1,199)} = 1.60, p = .207, \eta^2 = .008$).

	Spanning Flexibility (PF) Dimensions			
	PF/INF		PF/CON***	
Level of PTMT	Mean	Std. Dev.	Mean	Std. Dev.
Low	3.41	.88	3.55	.96
High	3.77	1.07	3.74	1.15

* Difference significant at $\alpha = .001$

** Difference significant at $\alpha = .01$

*** Difference significant at $\alpha = .05$

Table 7.3 Differences in Spanning Flexibility among Levels of Postponement

7.1.2 Information Facility

Many studies have inferred that information is a resource enhancing operational effectiveness, efficiency and flexibility across the supply chain. Supply chain flexibility is hard to achieve without instantaneous visibility into information. Both information technology utilization (IF/IT) and information sharing (IF/IS) are widely recognized as practices to facilitate information flows including demand information flowing up the supply chain and supply information that flows down the supply chain. In the subsequent section, dimension-level analyses between different levels of information facility practices and supply chain flexibility are explained.

Role of Information Facility in Market-oriented Flexibility

The path analysis in Chapter 6 has discussed the impact of information facility practice on market-oriented flexibility. However, in order to make further conclusions on what type of information facility practice is better for achieving higher performance in different dimensions of market-oriented flexibility, a MANOVA was conducted to determine the effect of IT utilization (IF/IT) and information sharing (IF/IS) on the combined dependent variable of market-oriented flexibility. The MANOVA model tests not only for the main effects of both independent variables but also their interaction or joint effects on the dependent variables. The main effects of IF/IT (Pillai's Trace = .086, $F_{(3, 195)} = 6.142$, $p < .01$) and IF/IS (Pillai's Trace = .070, $F_{(3, 195)} = 4.885$, $p < .01$) are both significant. However, the factor interaction was nonsignificant (Pillai's Trace = .010, $F_{(3, 195)} = .625$, $p = .599$).

Then, the ANOVA results showed a main effect for IT utilization (IF/IT) on delivery flexibility (MF/DEL) ($F_{(1,197)} = 18.58, p < .001, \eta^2 = .086$), and a main effect for information sharing (IF/IS) for manufacturing flexibility (MF/MFG) ($F_{(1,197)} = 10.85, p < .001, \eta^2 = .059$), and product development flexibility (MF/PD) ($F_{(1,197)} = 10.87, p < .005, \eta^2 = .044$).

Table 7.4 presents multiple comparisons performed by using t-test after ANOVA. The t-tests confirm the all dimensions of market-oriented flexibility (MF) are positively influenced by information sharing (IF/IS). The examples vary in the degree of information sharing that occurs and consequently, in the ability to react to changes in the marketplace. However, only delivery flexibility (MF/DEL) is significantly affected by IT utilization (IF/IT). Manufacturing flexibility (MF/MFG) and product development flexibility (MF/PD) can be improved by doing better in information sharing even the utilization of information technology level is low. It is noted that IT utilization (IF/IT) does not directly relate to manufacturing flexibility and product development flexibility. Manufacturing and product development involve more engineering changes and process modifications than delivery flexibility. Information visibility across the supply chain is therefore more important to achieve manufacturing flexibility (MF/MFG) and product development flexibility (MF/PD). Such visibility cannot be realized with information technology only, but effective management of information flow is a must for achieving these two aspects of flexibility.

	Market-oriented Flexibility (MF) Dimensions					
	MF/MFG		MF/PD		MF/DEL	
Level of IF/IT	Mean	t-value	Mean	t-value	Mean	t-value
High	3.81	1.81	3.70	1.72	4.41	4.51*
Low	3.56		3.42		3.97	
Level of IF/IS						
High	4.07	3.98*	3.95	3.41*	4.37	2.30***
Low	3.50		3.38		4.12	

* Difference significant at $\alpha = .001$
** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.4 Differences among Levels of Information Facility Dimensions by Market-oriented Flexibility Dimensions

Role of Information Facility in Supply Flexibility

In order to investigate the impact of information facility practice on supply flexibility at the dimensional level, a MANOVA was run with supply network flexibility (SF/NET) and supplier flexibility (SF/SPL) as the dependent variables and IT utilization (IF/IT) and information sharing (IF/IS) as the independent variables. The MANOVA shows a main effect of information sharing (IF/IS) (Pillai's Trace = .046, $F_{(2, 196)} = 4.675$, $p < .01$), and an interactive effect across IT utilization (IF/IT) and IF/IS (Pillai's Trace = .025, $F_{(2, 196)} = 2.533$, $p < .1$) on combined dependent variables. However, the main effect of IT utilization (IF/IT) on supply flexibility is not significant (Pillai's Trace = .017, $F_{(2, 196)} = 1.694$, $p = .186$).

The follow up ANOVA revealed that neither IT utilization (IF/IT) nor information sharing (IF/IS) significantly differ for supply network flexibility (SF/NET). The ANOVA results also indicate that information sharing (IF/IS) significantly differs for supplier flexibility (SF/SPL) ($F_{(1,197)} = 8.894, p < .005, \eta^2 = .043$) and the interactive effect between IT utilization (IF/IT) and information sharing (IF/IS) on supply network flexibility (SF/NET) is significantly important ($F_{(1,197)} = 5.007, p < .05, \eta^2 = .025$).

The comparison results in Table 7.5 indicate the interactive effect that when there is a high level of IT utilization (IF/IT), supply network flexibility (SF/NET) and supplier flexibility (SF/SPL) are better when the information sharing (IF/IS) level is high than is low. Conversely, if IT utilization (IF/IT) level is low, supply network flexibility (SF/NET) and SF/SPL are not benefited from information sharing (IF/IS). The results imply that the effect of information sharing on supply network flexibility depends on the level of information technology utilization. In order to establish flexible supply base, information sharing should be implemented on the basis of good utilizations of information technology. Information infrastructure should be designed to be able to accommodate a constantly changing pool of suppliers and customers at varying stages of relationship

(Yucesan and Wassenhove, 2005). As a result, manufacturers are able to switch suppliers on a timely and effective manner. Since the IT utilization (IF/IT) and information sharing (IF/IS) interaction was found significant, inferences drawn from the main effects are limited. Table 7.6 presents the main effect of IT utilization (IF/IT) and information sharing (IF/IS) on SF/SPL but no effect on supply network flexibility (SF/NET) is found.

	Supply Flexibility (SF) Dimensions			
	SF/NET		SF/SPL	
Level of IF/IT and IF/IS	Mean	t-value	Mean	t-value
Low level of IF/IT				
High level of IF/IS	3.28	1.062	4.12	1.425
Low level of IF/IS	3.00		3.83	
High level of IF/IT				
High level of IF/IS	3.67	2.234***	4.40	3.018**
Low level of IF/IS	3.15		3.94	

* Difference significant at $\alpha = .001$
** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.5 Interactive Effect of Information Facility on Supply Flexibility (Dimension Level)

	Supply Flexibility (SF) Dimensions			
	SF/NET		SF/SPL	
Level of IF/IT	Mean	t-value	Mean	t-value
High	3.37	.93	4.14	2.10***
Low	3.22		3.89	
Level of IF/IS				
High	3.45	1.33	4.32	3.59***
Low	3.22		3.88	

* Difference significant at $\alpha = .001$
** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.6 Differences among Levels of Information Facility Dimensions by Supply Flexibility Dimensions

Role of Information Facility in Logistics Flexibility

In Chapter 6, the hypothesis which posits the positive relationship between information facility practice and logistics flexibility was not supported. Therefore, it is not surprised that IT utilization (IF/IT) (Pillai's Trace = .002, $F_{(2, 196)} = .241$, $p = .786$) and information sharing (IF/IS) (Pillai's Trace = .002, $F_{(2, 196)} = .164$, $p = .849$) as well as the interaction between IT utilization (IF/IT) and information sharing (IF/IS) (Pillai's Trace = .028, $F_{(2, 196)} = 2.794$, $p = .064$) do not significantly affect the combined dependent variables of physical distribution flexibility and logistics network flexibility from MANOVA results.

Role of Information Facility in Spanning Flexibility

As expected, in the investigation of relationship between IT utilization (IF/IT) and information sharing (IF/IS) as independent variables and information dissemination flexibility (PF/INF) and spanning connectivity flexibility (PF/CON) as dependent variables, there are significant differences between low and high levels of IT utilization (IF/IT) and information sharing (IF/IS) for the combination of information dissemination flexibility (PF/INF) and spanning connectivity flexibility (PF/CON). The results of multivariate tests reveal significant main effects of IT utilization (IF/IT) (Pillai's Trace = .035, $F_{(2, 196)} = 3.553$, $p < .05$) and information sharing (IF/IS) (Pillai's Trace = .084, $F_{(2, 196)} = 9.027$, $p < .001$). However, MANOVA result shows that the interaction effect of IT utilization (IF/IT) and information sharing (IF/IS) is not significant (Pillai's Trace = .009, $F_{(2, 196)} = .925$, $p = .398$).

The univariate tests confirm that these findings hold for each dependent variable separately. The ANOVA results indicate that IT utilization (IF/IT) significantly differs for information dissemination flexibility (PF/INF) ($F_{(1,197)} = 7.045, p < .01, \eta^2 = .035$); and information sharing (IF/IS) significantly differ for information dissemination flexibility (PF/INF) ($F_{(1,197)} = 18.14, p < .001, \eta^2 = .084$) and spanning connectivity flexibility (PF/CON) ($F_{(1,197)} = 4.82, p < .05, \eta^2 = .024$).The comparison results presented in Table 7.7 indicate that with high information technology utilization level, companies can improve the spanning connectivity flexibility but no information dissemination flexibility. Effective management of information flow across members of the supply chain benefits both information dissemination flexibility and spanning connectivity flexibility. These results imply that investing in information technology infrastructure does not differ for responsive connectivity among supply chain partners. Companies should dedicate management efforts to transmit timely and accurate information because the combination of the information's precision, reliability, and outcome influences the efforts that are undertaken (Kulp, 2002). For example, sharing information on inventory levels should reduce the demand distortion experienced upstream at the supplier level. Such information sharing leads to better operational performance and improved coordination. Therefore, the ability to create a more flexible infrastructure for capturing, disseminating, and monitoring information assets can be greatly increased.

	Spanning Flexibility (PF) Dimensions			
	PF/INF		PF/CON	
Level of IF/IT	Mean	t-value	Mean	t-value
High	3.83	4.06^{***}	3.75	1.54
Low	3.28		3.52	
Level of IF/IS				
High	4.04	4.86^{***}	3.92	2.64^{**}
Low	3.35		3.50	

* Difference significant at $\alpha = .001$

** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.7 Differences among Levels of Information Facility Dimensions by Spanning Flexibility Dimensions

7.1.3 Supplier Management

Note that since suppliers have a profound and direct impact on cost, quality, time and responsiveness of the buying firms and the whole supply chain, the management of supply base and relationships with other members of the supply chain is increasingly being emphasized by both practitioners and academicians. In other words, one of the keys to achieving agile response to fast-changing markets lies upstream of the company in the quality of supply base. Therefore, by effectively managing suppliers, a powerful opportunity for achieving flexible supply chain can be created. The companies surveyed in this research showed significant relationship between supplier management and for all sub-construct of supply chain flexibility including market-oriented, supply, logistics, and spanning flexibility. The details on which flexibility dimensions are more affected by the level of supplier management practice, including supplier selection (SM/SEL), supplier development (SM/DEV), and partnership (SM/PNT), are explained below.

Role of Supplier Management in Market-oriented Flexibility

In conducting a MANOVA, we first test how manufacturing flexibility (MF/MFG), product development flexibility (MF/PD), and delivery flexibility (MF/DEL) differ as a whole across the groups. The MANOVA results indicate significant groups differences in SM/SEL (Wilks' Λ=.957, $F_{(3, 191)} = 2.848$, $p < .05$), SM/DEV (Wilks' Λ=.947, $F_{(3, 191)} = 3.588$, $p < .05$), and SM/PNT (Wilks' Λ=.953, $F_{(3, 191)} = 3.109$, $p < .05$) with respect to the combined dependent variables of all dimensions of market-oriented flexibility.

Since the overall multivariate test is significant, the univariate ANOVA results were then used to indicate the degree to which groups differ for each market-oriented flexibility dimensions. The ANOVA results reveal that supplier selection significantly differs for only manufacturing flexibility ($F_{(1,193)} = 4.91, p < .05, \eta^2 = .025$) and not product development flexibility ($F_{(1,193)} = .007, p = .933, \eta^2 = .000$) or delivery flexibility ($F_{(1,193)} = 3.24, p = .074, \eta^2 = .016$). Supplier development (SM/DEV) does not significantly differ for manufacturing flexibility ($F_{(1,193)} = .157, p = .693, \eta^2 = .001$) or delivery flexibility ($F_{(1,193)} = .301, p = .43, \eta^2 = .003$); but there is difference between high and low level of supplier development for product development flexibility ($F_{(1,193)} = 9.85, p < .005, \eta^2 = .047$). A positive result suggests that there are significant differences between high and low level of partnership (SM/PTN) for all dimensions of market-oriented flexibility. This means that those companies engaging in partnership with suppliers gain improvements in manufacturing, product development, and delivery flexibility. In addition, interactive effects for all three supplier management practices on both manufacturing flexibility ($F_{(1,193)} = 3.902, p < .05, \eta^2 = .020$) and product development flexibility ($F_{(1,193)} = 6.29, p < .05, \eta^2 = .032$) were observed. Therefore, the main effects

The planned contrasts for interactive analysis (Table 7.8) suggest that when both supplier selection (SM/SEL) and supplier development (SM/DEV) implementations are low, all the dimensions of market-oriented flexibility are better in the group with high level of partnership than with low level of partnership. That is, if the companies' management level of supplier selection and development are not high, companies should strive to maintain partnership for gaining market-oriented flexibility benefits. That is, strategic supplier partnership (SM/PTN) plays a dominant role in improving market-oriented flexibility. Conversely, in the group with low level of supplier selection (SM/SEL) and high level of supplier development (SM/DEV), establishing partnership relationship does not significantly differ for performance of all market-oriented flexibility. Additionally, even supplier selection is well-managed, the supplier development and partnership do not significantly differ for all dimensions of market-oriented flexibility.

As shown in Table 7.9, partnership relationship significantly impacts all market-oriented flexibility, indicating the most influence compared with supplier selection (SM/SEL) and supplier development (SM/DEV). This result is very positive for those companies that have already put efforts on or are thinking about building strategic partnership with suppliers if they are seeking ways to improve market-oriented flexibility. In case of product development flexibility (MF/PD) and delivery flexibility (MF/PD), there is a significant difference between high and low implementation of supplier selection (SM/SEL) and supplier development (SM/DEV) shown in Table 7.9. However, because of the existence of interactions among supplier management practices, the inferences drawn from the main effects are limited.

Level of SM/SEL, SM/DEV, and SM/PTN	Market-oriented Flexibility (MF) Dimensions					
	MF/MFG		MF/PD		MF/DEL	
	Mean	.t-value	Mean	t-value	Mean	t-value
Low level of SM/SEL						
Low level of SM/DEV						
High level of SM/PTN	4.04	3.064**	3.95	3.841*	4.40	2.191***
Low level of SM/PTN	3.30		2.86		3.97	
Low level of SM/SEL						
High level of SM/DEV		.93		.405		.707
High level of SM/PTN	3.38		3.82		4.20	

Low level of SM/PTN	3.60		3.86		4.04	
High level of SM/SEL						
Low level of SM/DEV						
High level of SM/PTN	3.91	.837	3.34	.142	4.31	.616
Low level of SM/PTN	3.62		3.29		4.15	
High level of SM/SEL						
High level of SM/DEV						
High level of SM/PTN	4.32	1.348	3.99	.020	4.55	.790
Low level of SM/PTN	3.80		3.38		4.41	

* Difference significant at $\alpha = .001$
** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.8 Interactive Effect of Supplier Management on Market-oriented Flexibility (Dimension Level)

	Market-oriented Flexibility (MF) Dimensions					
	MF/MFG		MF/PD		MF/DEL	
Level of SM/SEL	Mean	t-value	Mean	t-value	Mean	t-value
High	3.99	3.63^{***}	3.73	1.69	4.38	2.80^{**}
Low	3.49		3.46		4.09	
Level of SM/DEV						
High	3.82	1.86	3.94	5.08^{***}	4.29	1.69
Low	3.56		3.19		4.12	
Level of SM/PTN						
High	3.95	3.39^{***}	3.94	4.26^{***}	4.39	3.31^{***}
Low	3.49		3.28		4.06	

* Difference significant at $\alpha = .001$
** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.9 Differences among Levels of Information Facility Dimensions by Market-oriented Flexibility Dimensions

Role of Supplier Management in Supply Flexibility

A MANOVA was conducted to determine the effect of SM/SEL, SM/DEV, and SM/PTN on the two dependent variables of supply network flexibility and supplier flexibility. NANOVA results indicate that SM/SEL (Pillai's Trace = .112, $F_{(2, 192)} = 12.11$, $p < .001$)

and SM/PTN (Pillai's Trace = .077, $F_{(2, 192)} = 7.97$, $p < .001$) significantly affect the combined dependent variables of SF/NET and SF/SPL.

Univariate ANOVA was conducted as follow-up tests. ANOVA results indicate that only the dependent variable of SF/NET is significantly affected by supplier selection ($F_{(1,193)} = 23.96, p < .001, \eta^2 = .11$). The ANOVA results also indicate significant effect of supplier selection ($F_{(1,193)} = 6.618, p < .05, \eta^2 = .033$) and partnership on SF/SPL ($F_{(1,193)} = 14.1, p < .001, \eta^2 = .068$). No significant interaction among supplier management dimensions was found.

	Supply Flexibility (SF) Dimensions			
	SF/NET		SF/SPL	
Level of SM/SEL	Mean	t-value	Mean	t-value
High	3.99	3.63^{***}	3.73	1.69
Low	3.49		3.46	
Level of SM/DEV				
High	3.82	1.86	3.94	5.08^{***}
Low	3.56		3.19	
Level of SM/PTN				
High	3.95	3.39^{***}	3.94	4.26^{***}
Low	3.49		3.28	

* Difference significant at $\alpha = .001$
** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.10 Differences among Levels of Supplier Management Dimensions by Supply Flexibility Dimensions

As shown in Table 7.10, benefits of supplier flexibility come more from supplier development and partnership. Companies should be active in supplier development (SM/DEV) and partnership (SM/PTN) to improve a supplier's performance and/or capabilities to meet the flexibility needs. When analyzing differences among supply network flexibility performance, it is significantly different for the levels of supplier selection (SM/SEL) and strategic partnership (SM/PTN). This implies that SM/SEL and SM/PNT are helping organizations to identify the best suppliers who are capable of accommodating changes and have willingness to get involved in further joint improvement efforts.

Role of Supplier Management in Logistics Flexibility

Traditionally, companies have taken a uniform approach to design and manage their logistics process and network to meet a single service standard. Facing more and more pressure from changing business environment, logistics network and process have been designed to provide flexible and responsive solutions and serve differentiated demands in a cost effective and efficient fashion. Such solutions require a number of supplier management practices to facilitate coordination between supply chain parties.

The MANOVA results show group differences in supplier selection (Wilks' Λ=.946, $F_{(2, 192)} = 5.531$, $p < .01$) with respect to physical distribution flexibility (LF/DIS) and logistics network flexibility (LF/CHL). No significant interactive effect was found. The results from ANOVA show the strong impact of supplier selection practice on physical distribution flexibility ($F_{(1,193)} = 9.968, p < .01, \eta^2 = .049$). And the planned contrasts performed after ANOVA (Table 7.11) show that the physical distribution flexibility (LF/DIS) has a strongest influence from higher levels of supplier selection (SM/SEL) management. On the other hand, neither supplier development (SM/DEV) nor partnership (SM/PTN) showed significant influence on each of logistics flexibility (LF) dimensions. The results show no differences between high and low level of supplier development and strategic partnership. A plausible explanation could be that the use of third-party logistics (3PL) providers to take over some or all of a company's logistics responsibilities is becoming more prevalent. It has been discussed that third parties may provide greater flexibility in logistics processes and networks (Harrington, 1996; Troyer and Cooper, 1995). Provider selection and whether an agreement should be entered into with a particular 3PL provider are major and complex business decisions. Therefore, selection has dominant effect on logistics flexibility, and effects inferred from other two supplier management practices are limited.

	Logistics Flexibility (LF) Dimensions			
	LF/DIS		LF/CHL	
Level of SM/SEL	Mean	t-value	Mean	t-value
High	3.98	3.88^{*}	3.85	1.02
Low	3.46		3.68	
Level of SM/DEV				
High	3.70	.40	3.86	1.34
Low	3.64		3.64	
Level of SM/PTN				
High	3.67	.04	3.82	.80
Low	3.67		3.69	

* Difference significant at $\alpha = .001$
** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.11 Differences among Levels of Supplier Management Dimensions by Logistics Flexibility Dimensions

Role of Supplier Management in Spanning Flexibility

Supplier management facilitates the quickly and accurate sharing of information on demand, inventory levels, consumer research and so on across the supply chain. From the MANOVA results, different levels of supplier management practice affect all dimensions of spanning flexibility (supplier selection - Pillai's Trace = .026 $F_{(2, 192)} = 2.595$, $p < .1$;

supplier development - Pillai's Trace = .043, $F_{(2, 192)} = 4.269$, $p < .05$; partnership - Pillai's Trace = .05, $F_{(2, 192)} = 5.068$, $p < .01$).

ANOVA and detailed multiple comparisons were performed to identify between which groups of supplier management practices those differences exist. The ANOVA results indicate that supplier selection significantly differs for PF/INF ($F_{(1,193)} = 4.443, p < .05, \eta^2 = .023$); supplier development's impacts on both PF/INF ($F_{(1,193)} = 7.87, p < .01, \eta^2 = .039$) and PF/CON ($F_{(1,193)} = 4.522, p < .05, \eta^2 = .023$) are indicated as significantly important; and the significant effect of partnership on PF/CON is also shown important ($F_{(1,193)} = 10.098, p < .01, \eta^2 = .05$). Again, no interaction among supplier management practices was found.

	Spanning Flexibility (PF) Dimensions			
	PF/INF		PF/CON	
Level of SM/SEL	Mean	t-value	Mean	t-value
High	3.82	2.98**	3.84	2.22***
Low	3.40		3.50	
Level of SM/DEV				
High	3.88	4.58*	3.84	2.68**
Low	3.27		3.44	
Level of SM/PTN				
High	3.95	4.96*	3.92	3.40*
Low	3.28		3.42	

* Difference significant at $\alpha = .001$
** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.12 Differences among Levels of Supplier Management Dimensions by Spanning Flexibility Dimensions

As shown in Table 7.12, the dimension of supplier management practice has the strongest influence on spanning flexibility is strategic partnership. It is positively related both information dissemination flexibility (PF/INF) and spanning connectivity flexibility (PF/CON) at the significance level of .001. Companies focus on develop strategic partnership relationship concern open communication infrastructure, and flexible, precise, and reliable information transfers. Also, when analyzing differences between high and low level of supplier development (SM/DEV) and strategic partnership (SM/PTN), both PF/INF and PF/CON show significant differences with varied degrees. These imply that supplier management is helping organizations in improving their flexibility in information flow, which is expected, since supply chain partners would work together to create more reliable, faster, and easy access and connectivity to information.

7.1.4 Outsourcing

Although the causal relationship between outsourcing and market-oriented flexibility has been shown nonsignificant by using structural equation modeling in the last chapter, a dimension level analysis was conducted to provide further conclusions on which outsourcing practice are producing better performance in supply chain flexibility.

First, multivariate significance is found in core outsourcing with respect to market-oriented flexibility (Pillai's Trace = .073, $F_{(3,\ 195)} = 5.136$, $p < .005$). However, outsourcing category does not significantly differ for supply flexibility, logistics, or spanning flexibility.

Then, an ANOVA was performed for each dimension of market-oriented flexibility with core outsourcing as independent variable. The results of ANOVA indicate that the only strong effects are core outsourcing's effect on both manufacturing flexibility ($F_{(1,197)} = 6.17, p < .05, \eta^2 = .03$) and product development flexibility

($F_{(1,197)} = 8.98, p < .005, \eta^2 = .044$).

Since significant effects were found, planned contrast analyses were done in order to see different impact of core outsourcing on all the dimensions of market-oriented flexibility across groups (see Table 7.13). Companies trying to improve their production and product development flexibility should seek ways of implementing and managing outsourcing in manufacturing, assembly, and product development activities.

Level of OU/COR	Market-oriented Flexibility (MF) Dimensions					
	MF/MFG**		MF/PD**		MF/DEL	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Low	3.52	.81	3.33	.92	4.16	.71
High	3.86	1.07	3.80	1.24	4.25	.72

* Difference significant at $\alpha = .001$
** Difference significant at $\alpha = .01$
*** Difference significant at $\alpha = .05$

Table 7.13 Differences among Levels of Core Outsourcing by Market-oriented Flexibility

7.2 Dimension Level Analysis of Supply Chain Flexibility and Supply Chain Performance

There is an emerging requirement to focus on the performance of the extended supply chain or network in which the company is a partner. To maintain and encourage supply chin improvement we need to go beyond traditional functional and business performance measures. The supply chain flexibility will directly improve a supply chain's performance has been approved in the path analysis in Chapter 6 through structural equation modeling. However, there is still no clear consensuses about which are the exact benefits of flexibility implementation according to every dimension. In this section, the researcher provides a detailed examination the effects of various types of supply chain flexibility on all dimensions of supply chain performance.

7.2.1 Role of Market-oriented Flexibility in Supply Chain Performance

First, MANOVA was conducted and the main effect of market-oriented flexibility on all dimensions of supply chain performance as a whole (Pillai's Trace = .219, $F_{(4,196)} = 7.657$, $p < .001$). Then ANOVA results show all dimensions of supply chain performance are significantly affected by the level of market-oriented flexibility (all p-values < .001). Finally, planned contrasts analysis was conducted and the results are shown in Table 7.14. The contrast values confirm that supply chain performance in reliability, cost, time, and supply link are highly improved through ability of accommodating changes in product features, mix, production volumes and delivery requirements.

	Supply Chain Performance (SCP) Dimensions							
	SCP/RL*		SCP/CT*		SCP/TB*		SCP/SLK*	
Level of MF	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Low	4.10	.74	2.89	.70	3.53	.75	3.71	.63
High	4.51	.58	3.56	.84	4.16	.63	4.11	.70

* Difference significant at $\alpha = .001$

Table 7.14 Differences in Supply Chain Performance among Levels of Market-oriented Flexibility

7.2.2 Role of Supply Flexibility in Supply Chain Performance

This part considers the effect of supply flexibility on different aspects of supply chain performance. MANOVA was conducted and the main effect of supply flexibility on all dimensions of supply chain performance as a whole was determined with Pillai's Trace = .219, $F_{(4,196)} = 7.915$, and $p < .001$. Thus, supply chain performance is significantly affected by supply flexibility, which is consistent with the results from path analysis.

Then ANOVA results show all dimensions of supply chain performance are significantly affected by the level of supply flexibility (all p-values $< .001$), and the effect is shown in the contrast tests (see Table 7.15). All the contrast tests are significant, indicating that the performance of the supply chain will increasingly depend on their ability to tap into a responsive supply base.

	Supply Chain Performance (SCP) Dimensions							
	SCP/RL*		SCP/CT*		SCP/TB*		SCP/SLK*	
Level of SF	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Low	4.19	.72	3.05	.90	3.69	.82	3.74	.72
High	4.51	.60	3.53	.74	4.13	.60	4.16	.62

* Difference significant at $\alpha = .001$

Table 7.15 Differences in Supply Chain Performance among Levels of Supply Flexibility

7.2.3 Role of Logistics Flexibility in Supply Chain Performance

The testing process was repeated here, but with the logistics flexibility. First, MANOVA was conducted and the main effect of logistics flexibility on all dimensions of supply chain performance as a whole was determined with Wilks' Λ=.917, $F_{(3, 191)} = 4.456$, $p < .005$. Thus, supply chain performance is significantly affected by logistics flexibility. Then ANOVA results show only cost ($F_{(1,199)} = 11.09, p < .001, \eta^2 = .076$) and time-based ($F_{(1,199)} = 7.37, p < .01, \eta^2 = .036$) performance are significantly affected by the level of logistics flexibility. And the effect is shown in the contrast tests (see Table 7.16). Thus, there is no effect of logistics flexibility on reliability and supply link performance; and the extent of performance in cost and supply link are not significantly different among different levels of logistics flexibility.

	Supply Chain Performance (SCP) Dimensions							
	SCP/RL		SCP/CT*		SCP/TB**		SCP/SLK	
Level of LF	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Low	4.28	.69	3.03	.80	3.75	.74	3.85	.63
High	4.41	.66	3.51	.84	4.04	.72	4.04	.74

* Difference significant at $\alpha = .001$

** Difference significant at $\alpha = .01$

Table 7.16 Differences in Supply Chain Performance among Levels of Logistics Flexibility

7.2.4 Role of Spanning Flexibility in Supply Chain Performance

The process of comparing supply chain performance was continued with spanning flexibility. The MANOVA test showed the significant impact of spanning flexibility on all dimensions of supply chain performance as a whole with Pillai's Trace = .139, $F_{(4,196)}$ = 7.893, and p < .001. The follow up ANOVA results reveal that spanning flexibility significantly differs for all performance dimensions including reliability ($F_{(1,199)} = 20..96, p < .001, \eta^2 = .093$), cost, ($F_{(1,199)} = .4.572, p < .05, \eta^2 = .022$), time-based performance ($F_{(1,199)} = 17.79, p < .001, \eta^2 = .082$), and supply link ($F_{(1,199)} = 20.98, p < .001, \eta^2 = .095$). The positive contrast values shown in Table 7.17 also confirm the relationships between spanning flexibility and all dimensions of supply chain performance such that those maintaining high spanning flexibility have a better performance in reliability, cost, time, and supply link compared to those who are with low spanning flexibility.

Level of PF	Supply Chain Performance (SCP) Dimensions							
	SCP/RL*		SCP/CT**		SCP/TB*		SCP/SLK*	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Low	4.13	.75	3.17	.82	3.69	.79	3.73	.71
High	4.55	.53	3.43	.86	4.12	.64	4.17	.63

* Difference significant at $\alpha = .001$

** Difference significant at $\alpha = .01$

Table 7.17 Differences in Supply Chain Performance among Levels of Spanning Flexibility

The next chapter will conclude with the summary of research findings and major contributions, implications for managers, limitations of the research, and recommendations for future research.

8. SUMMARY AND RECOMMENDATIONS FOR FUTURE RESEARCH

Flexibility is often seen as a reaction to environmental uncertainty. Recent studies have proposed that flexibility should be viewed from the perspective of the entire supply chain. (Duclos et al., 2003; Zhang et al., 2002; Vickery et al., 1999). This study focuses on dimensions of supply chain flexibility and the research framework depicts their relationships with environmental uncertainty, supply chain practice, and supply chain performance. In this chapter, the research findings, major contributions, and implications to practitioners are summarized; and the limitations of the research and recommendations for future research are also discussed.

8.1 Summary of Research

The current research represents one of the first large-scale empirical efforts to systemically investigate the complex causal relationships in the supply chain flexibility. It aims to answer the following important questions: 1) what are the key dimensions of supply chain flexibility, 2) what are the forces driving companies to build flexibility into supply chain, and 3) what supply chain practices influence the supply chain flexibility. As we have mentioned in the introduction section, there is still a lack of definition of constructs and conceptual frameworks on supply chain flexibility in the current literature. The empirical investigation simultaneously explains the causal relationships among these constructs: driving factors for supply chain flexibility, supply chain practices, supply chain flexibility, and supply chain performance has been scarce in the literature. The research model developed here considers the flexibility of whole (upstream and downstream side) supply chain, explores the antecedents and consequences of supply chain flexibility, and represents an attempt to build a theoretical framework in the area of supply chain flexibility research. Based on the data collected from 201 supply chain/purchasing/operations/logistics managers, the model is tested using structural equation modeling methodology. The study contributes to our knowledge of supply chain flexibility in a number of ways.

First, the methodology of data collection for testing the measurement model and casual relationship was using on-line survey. To do the questionnaire on-line in a usual way, the link that would take the respondents to the online questionnaire is sent with the invitation email to the sample. This research provides an iterative revised approach on the methodology to effectively reach eligible and cooperative respondents and improve the response rate.

Second, the concept and dimension of supply chain flexibility are clarified. Most of the existing studies are functionally focused and fail to show the cross-functional, cross-business nature of supply chain flexibility (Lummus et al., 2003). What makes the current study more valuable is that the dimensions of supply chain flexibility are identified by following the SCOR model, cover both upstream and downstream supply chain, and capture both functional entities responsiveness and network characteristics. . In summary, this study has anchored in a comprehensive understanding of flexibility and its various dimensions across the whole supply chain, which forms a foundation for research in supply chain flexibility.

Third, measurement models for four new constructs not empirically validated or tested for reliability in previous literature were developed and tested (outsourcing, supply flexibility, logistics flexibility, and spanning flexibility). All the scales have been tested through rigorous statistical methodology including purification, factorial validity, unidimensionality, reliability, and the validation of second-order construct. All the scales are shown to meet the requirements for reliability and validity and thus, can be replicated by other researchers in the development of new models in supply chain flexibility. Outsourcing practice is a construct with a multi-dimensional nature, and it was defined as a second-order factor with two first-order factors (core outsourcing and peripheral outsourcing). Three new supply chain flexibility constructs also showed multi-dimensional nature and they were defined as second-order factors with certain first-order factors: Such valid and reliable scales have been otherwise lacking in the literature of empirical supply chain flexibility research. The evidence of the reliability and validity of supply chain flexibility instruments represent substantial progress towards the establishment of the groundwork for the future.

Fourth, built on previous research, a theoretical framework is provided, which identifies the salient dimensions of supply chain flexibility, environmental uncertainty, supply chain practice, and supply chain performance. Little research has been directed towards understanding how the supply chain flexibility can be achieved (Lummus et al., 2003). Although benefits of flexibility (i.e., manufacturing flexibility, product development flexibility) in enhancing performance are documented in literature (Singh and Sushil, 2004; Zhang et al., 2003; Kara and Kayis, 2004), the mechanism by which flexibility can improve performance is not fully developed in the context of supply chain.

This framework provides a foundation for research by identifying some of the significant relationships between environmental uncertainty and supply chain flexibility; supply chain practices and supply chain flexibility; and finally supply chain flexibility and supply chain performance.

Overall, this research provides a methodological guide for supply chain management researchers who are undertaking empirical research in the field of flexibility. It offers a step-by-step procedure to conduct an empirical research through on-line survey. The findings verify the strategic role of supply chain practice for achieving supply chain flexibility, and further improve supply chain performance. The findings also indicate the significant role of environmental uncertainty as driving forces for the implementation of supply chain flexibility strategy.

8.2 Implications for Practitioners

In recent years, competition is moving from among organizations to between supply chains, more and more organizations are increasingly adopting supply chain practice, in the hope for securing competitive advantage. The globalization of business, the proliferation of product variety, and the shortening of the product life cycles have necessitated companies to work on new supply chain strategies, which enable a supply chain to meet customer requirements without adding significant cost. Building flexibility into supply chain is such a strategy that has emerged as a key enabler. This study has lead to the following important managerial insights and contributions.

First, the ever-changing environment in which companies find themselves requires rapid new product introduction, quick response to customer requirements, responsive logistics network, and capable suppliers. This finding is very important since there has been disagreement on supply chain flexibility as a reaction of environmental uncertainty. It also represents a motivation for organizations, which are in industries with fast changes in product, technology, and competition, to seriously considering implementing supply chain strategy to maintain competitive advantages.

Second, from a more integrative perspective, this research helps executives to develop a better understanding of dimensions of supply chain flexibility. The identified dimensions emphasize both the functional and network characteristics of flexibility in the context of supply chain. With the proposed supply chain flexibility model, managers are able to evaluate which flexibility capabilities are critical to their performance. The model framework developed in this study includes both upside and downside flexibility. If executives have a partial rather than a comprehensive view of flexibility, they limit themselves to a particular source of flexibility. Additionally, the instruments of supply chain flexibility developed in this study have several applications in practice. It can be utilized to evaluate supply chain flexibility, and further benchmark and compare supply chain flexibility performance across different organizations. The measurements developed in this research capture the different aspects of supply chain flexibility, and, thus, can be used to identify which aspect of supply chain flexibility is more problematical. It can also be used to compare flexibility dimensions rather than overall flexibility performance across organizations. The results can in turn be used in developing the supply chain strategy. In fact, most of the respondents are holding job tiles of CEO/President, Director or Manager and 115 out of 201 respondents have indicated that they would like to receive results.

Third, there exist doubts about the worth of investment in flexibility in the context of potential benefits from supply chain flexibility. Overall, the findings of this research assure the practitioners that instead of spend money on flexible hardware and/or infrastructure, supply chain practice is an effective way of competing, and the implementation of supply chain practice does have strong impact on supply chain performance. The model developed in this study includes some key practical features such as postponement, supplier management, and outsourcing, which have not been previously addressed in empirical studies. The findings demonstrate to the practitioners that implementing postponement, improving information facility, and encouraging supplier management lead to significant improvement in supply chain flexibility. From an in-depth dimension level analysis, this study also implicitly provides a valuable tool for executives to make decisions on which supply chain practice dimension should be focused to affect one or more flexibility dimensions with varying degrees of effects. For instance, in the area of purchasing, supplier selection often requires evaluating of quality and delivery performance. Supply network flexibility requires supplier selection that goes beyond focusing on quality and delivery. As companies make efforts of building a flexible supply base, it is important that the supplier's abilities of responding to changes in volume, mix, and delivery are assessed.

Fourth, the findings highlight the importance of devoting substantial resources to develop both Information technology infrastructure and information sharing competencies that facilitate market-oriented flexibility, supply flexibility, and spanning flexibility. Although organizations have tended to focus on the applications of information technology and effective information sharing supply chain practice, they have not given enough attention to the hierarchical effect of these two practices on each dimension of supply chain flexibility. This phenomenon may be reflected by the observation from dimension level analysis that when the level of information technology utilization is low, effective management of information flow across members of supply chain will not help to achieve delivery, supplier, and spanning connectivity flexibility. These results imply to the practitioners that to achieve higher levels of supply chain flexibility in terms of most dimensions, good IT utilization is a must.

Fifth, the research also supports some previous publications in practitioners' journals that supplier management practices help to achieve flexibility. Better supplier management practices will positively benefit the flexibility outcomes. Specifically, strategic partnership has dominant effect on market-oriented flexibility and supply flexibility. Therefore, it would be worthwhile for organizations that are contemplating the adoption of supply chain flexibility strategy in market-oriented and supply aspects to spend time and effort to build long-term and strategic relationships with their supply chain partners. And to be successful all supply chain partners must incorporate the flexibility characteristics across the supply chain to maximize performance and provide value to customers.

Sixth, as product variety increases and the capability to quickly deliver customized products becomes more important, companies may find that postponement holds the key to success. These results are important for managers because postponement may require changes to the traditional business processes and information technology functions, and managers would fully like to understand its implications.

Seventh, the findings help executives understand that flexible supply chains will outperform those that are less flexible. By using the insights from dimensional level analysis, managers can understand which supply chain flexibility dimensions would contribute to supply chain performance in terms of cost, time, supply-link and reliability.

8.3 Limitations of Research

First, three sub-constructs (supplier flexibility, spanning connectivity flexibility, and core outsourcing) in this research were measured by two items after item purification, confirmatory factor analysis, and measurement model analysis. Because of this limitation, the relationships between the corresponding second-order variables and other variables in the research model may be doubt. There is a need to revise this construct from the measurement angle and then re-explore the relationships.

Second, because of the limited number of observations (201), the revalidation of constructs was not carried out in this research. Lack of systematic confirmatory research, impedes general agreement on the use of instrument. This needs to be addressed in future research.

Third, the interactive effect of environmental uncertainty and supply chain flexibility on performance has not been examined. There is still a need to link supply chain flexibility to the benefits they carry and to determine which flexibility dimensions are the most critical responses to environmental uncertainty across industries. It could be interesting to perform an invariance analysis across different levels of environmental uncertainty; or a moderating regression analysis to examine the moderate effect of environmental uncertainty on the relationship between supply chain flexibility and performance. Additionally, government issues as part of environmental uncertainty is missing in this study. Government issues are part of the organization's general environment and consist of government regulation of business and the relationship between business and government. This dimension of uncertainty is important since the legal system and political stability influence business activity due to the impact of changing policies, long-standing drafting practices, the local disregard for national laws and policies, and the wide discretion of bureaucrats (Daft, 2000).

Fourth, this research fail to show that outsourcing practice as a whole has significantly direct impact on supply chain flexibility, which is inconsistent with some real business experience. It could be the result of not well-developed instruments of outsourcing practice; or it is because outsourcing impacts supply chain flexibility associated with other supply chain actions such as outsourcing risks management and knowledge management on supply market.

Fifth, this research limited the industries to the following SIC classifications: 23 "Apparel and other textile products", 30 "Rubber and Plastics", 34 "Fabricated Metal Products", 35 "Industrial and Commercial Machinery", 36 "Electronic and Other Electric Equipment", 37 "Transportation Equipment". The results can be cautiously generalized to other industries, especially those involving rapidly changing business environment.

Sixth, in order to keep the study at a manageable size, this research did not consider the interrelationship among supply chain flexibility dimensions. The answers to the question of "do improvements in one supply chain dimensions affect improvements in another?" will be meaningful to practitioners when they design their supply chain flexibility strategy. The interrelationship might also differ across different industries.

Seventh, the potential barriers to flexibility (i.e., people and their work behaviors, and organizational structures) are not considered in this research.

Eighth, the supply chain performance measures are subjective including cost, reliability, time-based performance, and supply link performance. Other performance aspects could be affected by supply chain flexibility, but it is not proposed in this research. On the other hand, examining the relationships between supply chain flexibility and objective measurements (i.e., order fulfillment lead time, on-time delivery rate, and inventory days of supply etc.) will provide more powerful evidence of benefits from implementing flexibility strategy.

Finally, supply chain flexibility is not always good news to industries. Potential risks and disadvantages also exist if it is not well implemented and managed. For instance, some companies may indulge in information technology overkill in the name of flexibility. This may be wasteful expenditure for unneeded flexibility. This research area is not concerned by this study.

8.4 Recommendations for Future Research

This study has extended past research in several ways, by making significant contributions from both a theoretical and practical point of view. However, the research limitations present opportunities for researchers interested in supply chain flexibility and supply chain performance improvement. The issues underlying supply chin flexibility strategy is an appropriate area to research as firms today try to improve supply chain performance by revising existing industry practices. Therefore, in the following section the recommendations for future research will be discussed.

8.4.1 Measurement Issues

First, better construct definition and measurement items should be developed for outsourcing construct. As pointed out previously, outsourcing suffered from measurement issues in this study and may not be appropriate for supply chain flexibility research. Future research should attempt to verify this understanding by developing better definition and sub-dimensions for this construct. A possible solution may be to measure outsourcing from the orientation perspective (i.e., operational oriented vs. strategic oriented).

The definition and measurement items of supplier flexibility and spanning connectivity flexibility should be refined. There are only two items for each dimension after instrument validation in this study. It is recommended to refer supplier flexibility to market-oriented flexibility since buyers are regarded as customers of suppliers and market-oriented flexibility is defined as customer-faced. For spanning connectivity flexibility, it could be refined by taking information system infrastructure into account.

Third, future research should conduct factorial invariance tests. Generalizability of measurement scales can further be supported by factorial invariance tests. Using the instruments developed in this research, one may test for factorial invariance across industries, across different organization size, and across organizations with different supply chain structure (such as supply chain length, organization's position in the supply chain, and so on).

8.4.2 Structural Issues

First, future research should examine the hypothesized structural relationships across industries. Future investigation will determine which flexibility dimensions are the most critical responses to environmental uncertainty across industries; in addition, each of the supply chain flexibilities dimension is related to at least one aspect of overall supply chain performance. Nevertheless, further work is needed to examine the relationship between supply chain flexibility and overall supply chain performance in a variety of industry settings to confirm a global flexibility – performance linkage. The same hypothesized structural relationships across countries can also be tested in the future research. This will allow the comparison of practice-flexibility linkage in different countries, and the identification of country-specific supply chain practices to facilitate supply chain flexibility.

Second, future research should incorporate the factors inhibiting the implementation of supply chain flexibility strategy. The studies of the impacts of such inhibiting factors and solutions to reduce or even eliminate such negative influence on SCM practice are critical for further understanding supply chain flexibility issues and improving overall performance of supply chain.

Third, future research should test hypothesized structural relationships at a specific supply chain flexibility and performance level. This analysis may provide important insights into determinants of high and low performers of supply chain flexibility. The analysis can also uncover the relationship between levels of performance and dimensions of supply chain flexibility (such as manufacturing flexibility, supply network flexibility, physical distribution flexibility, and so on).

Fourth, future studies can also examine the proposed relationships by bringing some contextual variables into the model, such as organizational size, industry, and supply chain structure. For example, it will be intriguing to investigate how relationship between supply chain practice and flexibility differ across organization size. The implementations of postponement have been highly successful in firms in the electronics and fashion apparel industries by appropriately locating the differentiation points of customized products. However, for firms in relative stable business environment, would postponement be useful for achieving flexibility? It will also be very interesting to examine the impact of supply chain structure (supply chain length, organization's position in the supply chain, and so on) on supply chain flexibility and performance.

Fifth, this study indicates that supplier management plays an important role in improving supply chain flexibility. Supplier management is a multi-dimensional construct including supplier selection, development, and strategic partnership. Future research can expand the current theoretical model by adding hierarchical effect. For instance, it would in interesting to investigate to improve the logistics flexibility, if supplier selection should be the first management effort to put; or if devote resources to develop the existing suppliers' capabilities is the most important determinant.

Sixth, a number of studies related to logistics partnerships have sought to describe the recent trend toward an increased use of logistics partnerships (Bardi and Tracey, 1991; Lieb, 1992; LaLonde, 1992; Lieb et al., 1993; Skjoett-Larsen, 2000). Therefore, a supply chain consists of a set of activities including material suppliers and logistics providers as well. The functions performed by the logistics providers can encompass the entire logistics process or selected activities within that process. The definition and content reflect the necessary of implementation of different managerial practices to establish logistics partnership. For instance, when choosing a logistics provider, it is important to check quality image, stability, and service reliability of the third party's strategic alliance partners (Skjoett-Larsen, 2000). In previous studies, flexibility was emphasized as the primary benefit from logistics partnership (Lieb et al., 1993). Therefore, logistics partnership could be studied as one of the supply chain practices for achieving logistics flexibility.

Seventh, although the hypothesized direct relationship between outsourcing and market-oriented flexibility was not supported, the impact of outsourcing on network related flexibility such as logistics and/or supply flexibility could be proposed. The idea of outsourcing logistics activities as warehousing, transportation, and even some value-adding services such as final assembly, packaging, quality control, and information services is not a new phenomenon (Kopczak, 1997). Increased market coverage, improved service level and increased flexibility towards the changing requirements of customers are consequences associated with logistics outsourcing. Similarly, outsourcing some production activities will make it easier for companies to restructure their supply base. This suggests companies think that they may be able to deal with new technology and fluctuating customer demand easier through outsourcing.

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APPENDIX A: SAMPLE INVITATION EMAIL FOR DATA COLLECTION

Dear John Wilson,

My Name is Ying Liao. I am from The University of Toledo, and I am conducting a research on ***Supply Chain Flexibility: the Driving Forces, Antecedents, and Impacts on Performance*** as a part of my dissertation. This survey is part of an on-going study of The University of Toledo to investigate methods, tools, and managerial practices that contribute to supply chain flexibility. Knowledge gained from this research will help practitioners focus on critical supply chain management practices which help organizations respond effectively and quickly to environmental turbulence.

I invite you to participate in this research project by filling out a questionnaire. The completion time for the questionnaire is ***15 to 20 minutes.***

The information collected will be used for research purposes only. It will be stored in a secure place and will be treated with the **utmost confidentiality**. The collected information will only be used at the aggregate level so that information about any particular company cannot be ascertained or deduced by readers.

If you agree to participate, please reply to me with a blank email thus implying your consent of participation to the study. I will use your blank email to send you a link which will lead you to the questionnaire.

Your response is extremely valuable for my dissertation. I thank you in advance for taking your valuable time to complete the questionnaire. As a token of my appreciation for your time, I will be pleased to provide you with a summary of the results if you indicate so.

Sincerely,

Ying Liao
PhD Candidate in Manufacturing Management
College of Business Administration
The University of Toledo
Toledo, OH 43606
Email: yliao@utnet.utoledo.edu

This email was sent personalized to each of the individuals in the database.

APPENDIX B: SAMPLE FOLLOW-UP EMAIL DIRECTING TO ON-LINE SURVEY

Dear Mr. Wilson,

I greatly appreciate your willingness to help with the research on **Supply Chain Flexibility: the Driving Forces, Antecedents, and Impacts on Performance** as a part of my dissertation.

Again, let me assure you that data collected in this research will be treated with the **utmost confidentiality** and will be only used in this research and in related reports.

Please visit http://uac.utoledo.edu/uacsurveys/SupplyChainFlexibility.asp to complete the questionnaire.

I thank you for taking your valuable time to complete the questionnaire. (You may leave your contact information at the end of the questionnaire. I will be pleased to provide you with a copy of results afterward).

Sincerely,

Ying Liao
PhD Candidate in Manufacturing Management
College of Business Administration
The University of Toledo
Toledo, OH 43606
Email: yliao@utnet.utoledo.edu

This email was sent personalized to each of the individuals in the database.

APPENDIX C: SAMPLE FOLLOW-UP EMAIL FOR REMINDING

Dear Mr. Wilson,

On April 27, you received an e-mail from Ying Liao at the University of Toledo asking for your participation in a Supply Chain Flexibility survey. You responded with your willingness to participate. I greatly appreciate that.

I thank you if you have filled out either the on-line questionnaire or the hard copies. Your responses have been very valuable! You will receive a copy of results as long as the research is completed.

If you have not filled out the questionnaire yet, I would be very thankful if you could please take 15 minutes of your time and fill out the questionnaire for this Supply Chain Flexibility Research. Your response is extremely valuable to my dissertation research.

Please visit **http://uac.utoledo.edu/uacsurveys/SupplyChainFlexibility.asp** to review and complete the questionnaire.

I thank you in advance for taking your valuable time to complete the questionnaire. This will be the last email sent to you.

Sincerely,

Ying Liao
PhD Candidate in Manufacturing Management
College of Business Administration
The University of Toledo
Toledo, OH 43606
Email: yliao@utnet.utoledo.edu

This email was sent personalized to each of the individuals in the database.

APPENDIX D: LARGE-SCALE QUESIONNAIRE

Supply Chain Flexibility: the Driving Forces, Antecedents, and Impacts on Performance
By
The College of Business Administration
The University of Toledo

In an increasingly turbulent marketplace, supply chain flexibility is crucial to build sustainable competitiveness. This questionnaire is part of an on-going study to complete a PhD dissertation on investigating methods, tools, and managerial practices that contribute to supply chain flexibility. Knowledge gained from this research will help practitioners focus on critical supply chain management practices which help organizations respond effectively and quickly to environmental turbulence.

The data gathering process of the study requires the input of experts in the field and that is why I kindly ask you to fill out this questionnaire. Most questions in this survey ask your opinions about the major supply chains of major product families in your company. The information collected will be used for research purposes only. It will be stored in a secure place and will be treated with the **utmost confidentiality**. The collected information will only be used at the aggregate level so that information about any particular company cannot be ascertained or deduced by readers.

Your response is extremely valuable for my dissertation. I thank you for taking your valuable time to complete this questionnaire. You can either submit the completed questionnaire by fax (419-530-2290), or send it to the address below. **As a token of my appreciation for your time, I will be pleased to provide you with a summary of the best practices and managerial methods which are key contributors for improving supply chain flexibility. This summary of research results can be a handy and concise guide for benchmarking. Simply provide the information requested on the last page of the questionnaire.** If you have any comments or would like to qualify your answers, please feel free to write them in the space in the margins.

If you have any questions, please contact:

Ying Liao
College of Business
The University of Toledo
Toledo, OH 43606
Phone: (419) 450-7659
Fax: (419) 530-2290
Email: yliao@utnet.utoledo.edu

Unless otherwise specifically requested, please use the following scale to answer each item:

1	2	3	4	5	6
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable

Section I: Environmental Uncertainty of the Company

Environmental uncertainty is defined as the attributes of internal and external changes that influence supply chain strategy, structure, and performance.

In this section, we would like to know the perceived environmental uncertainty of your company. Please circle the number that corresponds to the extent to which you agree or disagree with each statement regarding the environmental uncertainty of your company.

We have a high rejection rate of incoming critical materials from suppliers	1	2	3	4	5	6
The suppliers don't consistently meet our delivery requirements	1	2	3	4	5	6
We have extensive inspections of incoming critical materials from suppliers	1	2	3	4	5	6
The suppliers don't produce consistent quality materials	1	2	3	4	5	6
Our demand fluctuates drastically from week to week	1	2	3	4	5	6
The volume of demand of our customers is difficult to predict	1	2	3	4	5	6
The composition of demand of our customers is difficult to predict	1	2	3	4	5	6
Change of customer preference in product features is difficult to predict	1	2	3	4	5	6
Entry of new competitors into the market is difficult to predict	1	2	3	4	5	6
Changes in competitors' strategies are difficult to predict	1	2	3	4	5	6
Changes in the markets served by competitors are difficult to predict	1	2	3	4	5	6
Changes in competitors' prices are difficult to predict	1	2	3	4	5	6
Our industry is characterized by rapidly changing technology	1	2	3	4	5	6
The production technology in our industry changes frequently	1	2	3	4	5	6
The rate of process obsolescence is high in our industry	1	2	3	4	5	6
If we don't keep up with changes in technology, it will be difficult for us to remain competitive	1	2	3	4	5	6

Section II: Supply Chain Management Practice

In this section, we would like to know about the supply chain management practices currently applied in your company. Please circle the number that corresponds to the extent to which your company engages in the following supply chain management practices.

1	2	3	4	5	6
Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent	Not Applicable

INFORMATION TECHNOLOGY (IT) UTILIZATION

IT utilization refers to the extent of information technology applications in supporting efficient business processes and effective decision making.

We use specific IT based support for order processing and invoicing	1	2	3	4	5	6
We use specific IT based support for shipment and delivery tracking	1	2	3	4	5	6
We use specific IT based support for materials and resource planning	1	2	3	4	5	6
We use specific IT based support for real time information sharing with suppliers	1	2	3	4	5	6

INFORMATION SHARING WITH SUPPLIERS

Information sharing with suppliers refers to the practices of capturing and disseminating timely and accurate information for efficient business processes and effective decision making.

We exchange future plans with major suppliers (i.e. promotion and marketing plans, long-term production plans, and capital investment etc.)	1	2	3	4	5	6
We exchange information related to market demand trends and forecasts with major suppliers	1	2	3	4	5	6
We exchange information needed to support changes in product features or volumes with major suppliers	1	2	3	4	5	6
We exchange information related to product changes with major suppliers (i.e. technical specification, part numbers)	1	2	3	4	5	6

OUTSOURCING

Outsourcing refers to the extent of practices of transferring internal business activities and functions to external parties.

We outsource manufacturing	1	2	3	4	5	6

Unless otherwise specifically requested, please use the following scale to answer each item:

1	2	3	4	5	6
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable

We outsource assembly	1	2	3	4	5	6
We outsource research and development	1	2	3	4	5	6
We outsource sales	1	2	3	4	5	6
We outsource information systems	1	2	3	4	5	6
We outsource logistics and distribution	1	2	3	4	5	6
We outsource marketing	1	2	3	4	5	6
We outsource customer service	1	2	3	4	5	6

SUPPLIER SELECTION

Supplier selection refers to the practices to define the criteria used to evaluate and select suppliers in order to configure and establish a responsive supply base.

Please circle the number that corresponds to the extent to which you agree or disagree with each statement regarding the supplier selection practices of your company.

The ability to change production volumes rapidly is one of our supplier selection criteria	1	2	3	4	5	6
The ability to set up for new products on short notice is one of our supplier selection criteria	1	2	3	4	5	6
The ability to change the mix of ordered items is one of our supplier selection criteria	1	2	3	4	5	6
The ability to consistently meet delivery deadlines is one of our supplier selection criteria	1	2	3	4	5	6
Cost increases from delivery changes is one of our supplier selection criteria	1	2	3	4	5	6
Prompt response to requests is one of our supplier selection criteria	1	2	3	4	5	6
Willingness to share information is one of our supplier selection criteria	1	2	3	4	5	6

SUPPLIER DEVELOPMENT

Supplier development refers to the practices to improve supplier's performance and capabilities in efficiently and effectively responding to environmental changes.

Please circle the number that corresponds to the extent to which you agree or disagree with each statement regarding the supplier development practices of your company.

We have strategic goals of investing in major suppliers to increase their capabilities	1	2	3	4	5	6
We co-locate engineers to major supplier facilities to increase their performance or capabilities	1	2	3	4	5	6
We assess our suppliers' performance regularly through established guidelines and procedures	1	2	3	4	5	6
We recognize suppliers' achievements/performance in the form of awards	1	2	3	4	5	6

STRATEGIC SUPPLIER PARTNERSHIPS

Strategic supplier partnerships refer to the practices to establish long-term relationships with suppliers for a lasting competitiveness of the entire supply chain.

Please circle the number that corresponds to the extent to which you agree or disagree with each statement regarding the strategic supplier partnerships practices of your company.

We regularly solve problems jointly with our major suppliers	1	2	3	4	5	6
We include our major suppliers in our planning and goal-setting activities	1	2	3	4	5	6
We have continuous improvement programs that include our major suppliers	1	2	3	4	5	6
We share extensive information with major suppliers	1	2	3	4	5	6
We strive to maintain long-term relationships with major suppliers	1	2	3	4	5	6
We actively involve our major suppliers in new product development processes	1	2	3	4	5	6

POSTPONEMENT

Postponement refers to the practices of delaying activities in the supply chain as late as possible until actual customer orders are received.

Please circle the number that corresponds to the extent to which you agree or disagree with each statement regarding the postponement practices of your company.

We delay components/semi-finished product manufacturing until the position nearest to the customers	1	2	3	4	5	6
Components/semi-finished product manufacturing will not be started until customer orders have actually been received	1	2	3	4	5	6
We perform final product assembly activities until the position nearest to the customers	1	2	3	4	5	6

Unless otherwise specifically requested, please use the following scale to answer each item:

1	2	3	4	5	6
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable

We delay final product assembly activities until customer orders have actually been received 1 2 3 4 5 6

We perform packaging and labeling until the position nearest to the customers 1 2 3 4 5 6

Packaging and labeling will not be started until customer orders have actually been received 1 2 3 4 5 6

We differentiate product specifications until the last possible moment 1 2 3 4 5 6

Section III: Supply Chain Flexibility

In this section we would like to know the actual level of the capability of your supply chain in terms of flexibility. Please circle the number that corresponds to the extent to which you agree or disagree with each statement regarding the supply chain flexibility of your company.

MANUFACTURING FLEXIBILITY

Manufacturing flexibility is defined as the ability to quickly and effectively adjust production processes with respect to market changes.

We can operate profitably at different production volumes 1 2 3 4 5 6

We are able to change our production volume in a short time 1 2 3 4 5 6

We are capable to change our production volume with low cost 1 2 3 4 5 6

We are able to change our production volume without affecting production efficiency 1 2 3 4 5 6

We can produce an extensive variety of products in the plant 1 2 3 4 5 6

We can make products which are very different from each other in the plant 1 2 3 4 5 6

We can easily change the production of product mix in the plant 1 2 3 4 5 6

We are able to change our product mix without affecting the production efficiency 1 2 3 4 5 6

PRODUCT DEVELOPMENT FLEXIBILITY

Product development flexibility refers to the ability to rapidly and effectively introduce and launch new products with respect to market changes.

We can introduce a high number of new products into production each year 1 2 3 4 5 6

We have capability to design an extensive variety of new products 1 2 3 4 5 6

We are able to develop and introduce new products in a short time 1 2 3 4 5 6

We are capable to develop new products with low average cost 1 2 3 4 5 6

We can introduced new products into the production system without affecting the production efficiency 1 2 3 4 5 6

DELIVERY FLEXIBILITY

Delivery flexibility refers to the ability to effectively deliver products to customers in respond to changes in planned delivery dates, volume and destination.

We are able to accommodate varied delivery times in case specific customer requirements change 1 2 3 4 5 6

We can accommodate varied delivery destinations in case specific customer requirements change 1 2 3 4 5 6

We are capable to accommodate varied delivery volumes in case specific customer requirements change 1 2 3 4 5 6

Small delivery order quantities from the customer can be satisfied 1 2 3 4 5 6

We have capability to satisfy frequent delivery orders from the customer 1 2 3 4 5 6

We can handle an extensive variety of special customer requests for delivery 1 2 3 4 5 6

SUPPLY FLEXIBILITY

Supply flexibility refers to the ability of a firm to efficiently and effectively reconfigure the supply base with respect to environmental changes.

We have multiple supply sources for most purchased items 1 2 3 4 5 6

We are able to replace one supply source for another with low cost 1 2 3 4 5 6

We are capable to replace one supply source for another in a short time 1 2 3 4 5 6

We can switch supply source with little negative effect on component quality and design 1 2 3 4 5 6

Our major suppliers are willing to accommodate changes that we

Unless otherwise specifically requested, please use the following scale to answer each item:

1	2	3	4	5	6
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable

have requested 1 2 3 4 5 6

Our major suppliers are able to accommodate changes that we have requested 1 2 3 4 5 6

LOGISTICS FLEXIBILITY

Logistics flexibility refers to the ability of a firm to efficiently and effectively manage physical materials flow and physical distribution network with respect to environmental changes.

We can receive items from suppliers with multiple transportation modes 1 2 3 4 5 6

We are able to deliver items to customers with multiple transportation modes 1 2 3 4 5 6

We are capable to change transportation modes quickly 1 2 3 4 5 6

We have capability to switch transportation modes with low cost 1 2 3 4 5 6

We can switch transportation modes with little negative effect on logistics performance 1 2 3 4 5 6

We have multiple distribution channels for a variety of products/services 1 2 3 4 5 6

We can easily restructure physical distribution channels in response to changes in market demand 1 2 3 4 5 6

We are able to easily restructure physical distribution channels in response to changes in competition 1 2 3 4 5 6

We are capable to easily restructure physical distribution channels in response to changes in business condition 1 2 3 4 5 6

We can restructure distribution channels with little negative effect on logistics performance 1 2 3 4 5 6

SPANNING FLEXIBILITY

Spanning flexibility refers to the ability of a firm to efficiently and effectively distribute and share various information along the supply chain with respect to environmental changes.

We have many ways to share information with our major suppliers 1 2 3 4 5 6

We can share many kinds of information (e.g., text, video, database, etc.) with our major suppliers 1 2 3 4 5 6

We are able to exchange information with major suppliers in a short time 1 2 3 4 5 6

Information can be exchanged automatically with our major suppliers using information systems 1 2 3 4 5 6

We are able to share real time information with major suppliers 1 2 3 4 5 6

We can establish new information sharing channels in a short time 1 2 3 4 5 6

We are able to set up new information sharing channels with low cost 1 2 3 4 5 6

Information is shared seamlessly across our supply chain regardless of the information sharing channels 1 2 3 4 5 6

Our major suppliers are willing to share information to accommodate changes that we request 1 2 3 4 5 6

Our major suppliers are able to share information to accommodate changes that we request 1 2 3 4 5 6

<u>Section IV: Supply Chain Performance</u>

Supply chain performance refers to the extent to which a supply chain in meeting end-customer requirement, and operational efficiency in the supply chain to deliver that performance.

Please circle the number that corresponds to the extent to which you agree or disagree with each statement regarding your performance as compared to the INDUSTRY AVERAGE.

SUPPLY LINK

Our major suppliers provide high quality and reliable products 1 2 3 4 5 6

Our major suppliers provide high delivery performance 1 2 3 4 5 6

Our suppliers respond well to requests for changes 1 2 3 4 5 6

Overall, our major suppliers' performance is good 1 2 3 4 5 6

We feel that we can trust our major suppliers completely 1 2 3 4 5 6

The relationship our company has with major suppliers is something we are committed to 1 2 3 4 5 6

Our major suppliers are willing to provide assistance to us without exception 1 2 3 4 5 6

We are delighted with our relationships with our major suppliers 1 2 3 4 5 6

Unless otherwise specifically requested, please use the following scale to answer each item:

1	2	3	4	5	6
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable

RELIABILITY

We provide reliable delivery	1	2	3	4	5	6
We provide reliable products	1	2	3	4	5	6
We fulfill promises for customer orders	1	2	3	4	5	6

TIME-BASED PERFORMANCE

We introduce new products to the market quickly	1	2	3	4	5	6
We provide fast delivery	1	2	3	4	5	6
We provide on-time delivery	1	2	3	4	5	6
We have a short manufacturing lead time	1	2	3	4	5	6
We rapidly confirm customer orders	1	2	3	4	5	6
We rapidly handle customer complaints	1	2	3	4	5	6
We rapidly develop new ways of customer service	1	2	3	4	5	6
We respond well to customer demands for nonstandard features	1	2	3	4	5	6

COST

We have low inventory costs	1	2	3	4	5	6
We have low production costs	1	2	3	4	5	6
We have low transportation and handling costs	1	2	3	4	5	6
We have low costs associated with order entry, order follow/updating, and invoicing	1	2	3	4	5	6

Section V: General Information

Please provide the following background information for statistical purposes in this section. The information collected will be used for research purposes only and will be completely confidential.

1) Your job title
   - □ CEO/president
   - □ Director
   - □ Manager
   - □ Other (Please specify) ____________

2) Your present job function (mark all that apply)
   - □ Corporate executive
   - □ Purchasing
   - □ Transportation
   - □ Manufacturing/operations
   - □ Distribution
   - □ Supply chain management
   - □ Logistics
   - □ Sales
   - □ Other (Please specify) ____________

3) Please indicate your level of education
   - □ High school
   - □ Associate degree
   - □ Bachelor degree
   - □ Master degree
   - □ Doctorate
   - □ Other (Please specify): ____________

4) How many years have you been working for your current organization?
   - □ Less than 2 years
   - □ 2-5 years
   - □ 6-10 years
   - □ More than 10 years

5) Please indicate the extent of your understanding of other business functions/processes within your company

1	2	3	4	5	6
Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent	Not Applicable

6) Please indicate the extent of collaboration with other business functions within your company in your day-to-day work

1	2	3	4	5	6
Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent	Not Applicable

7) Please indicate the extent to which you jointly resolve operations problems with other business functions within your company.

1	2	3	4	5	6
Not at all	To a small extent	To a moderate extent	To a considerable extent	To a great extent	Not Applicable

8) Please indicate your SIC code ____________

9) Please indicate the category that best describes your primary business:
   - □ Automotive or parts
   - □ Fabricated metal products
   - □ Electronics or Electrical equipment
   - □ Furniture and fixtures
   - □ Appliances
   - □ Rubber and plastic products
   - □ Industrial machinery and equipment
   - □ Transportation equipment
   - □ Instruments and related products
   - □ Electronics
   - □ Other (please specify) ____________

10) Number of employees in your company:
   - □ 1-50
   - □ 51-100
   - □ 101-250
   - □ 251-500
   - □ 501-1000
   - □ over 1000

11) Average annual sales of your company in millions of $:
   - □ Less than $5 mil
   - □ $5 to $9 mil
   - □ $10 to $24 mil
   - □ $25 to $49 mil
   - □ $50 to $99 mil
   - □ More than $100 mil

6

12) Please indicate the position of your company in the supply chain (Mark all that apply).
   - □ Raw material supplier □ Component supplier
   - □ Sub-assembler □ Assembler
   - □ Manufacturer □ Distributor
   - □ Wholesaler □ Retailer

13) Please indicate the number of tiers across your supply chain.
   - □ Less than or equal to 3 □ 4-5
   - □ 6-7 □ 8-10
   - □ More than 10

THANK YOU FOR YOUR ASSISTANCE IN THIS PROJECT!

If you would like to receive the summary of results of this research, please complete the following details:

Your Name: ______________________

Business Name: ______________________

Address: ______________________

____

City: ____________ State: ____________

Zip Code: ____________

Tel: ____________ Fax: ____________

E-mail:

APPENDIX E: FINAL RETAINED MEASUREMENT ITEMS FOR SUPPLY FLEXIBILITY, LOGISTICS FLEXIBILITY, SPANNING FLEXIBILITY, AND OUTSOURCING

Acronyms	Items
Supply Network Flexibility (SF/NET)	
SF/NET1	We have multiple supply sources for most purchased items
SF/NET2	We are able to replace one supply source for another with low cost
SF/NET3	We are capable to replace one supply source for another in a short time
SF/NET4	We can switch supply source with little negative effect on component quality and design
Supplier Flexibility (SF/SPL)	
SF/SPL1	Our major suppliers are willing to accommodate changes that we have requested
SF/SPL2	Our major suppliers are able to accommodate changes that we have requested
Physical Distribution Flexibility (LF/DIS)	
LF/DIS3	We are capable to change transportation modes quickly
LF/DIS4	We have capability to switch transportation modes with low cost
LF/DIS5	We can switch transportation modes with little negative effect on logistics performance
Logistics Channel Flexibility (LF/CHL)	
LF/CHL1	We have multiple distribution channels for a variety of products/services
LF/CHL2	We can easily restructure physical distribution channels in response to changes in market demand
LF/CHL3	We are able to easily restructure physical distribution channels in response to changes in competition
LF/CHL4	We are capable to easily restructure physical distribution channels in response to changes in business condition
Information Sharing Flexibility (PF/INF)	
PF/INF1	We have many ways to share information with our major suppliers
PF/INF2	We can share many kinds of information (e.g., text, video, database, etc.) with our major suppliers
PF/INF3	We are able to exchange information with major suppliers in a short time
PF/INF4	Information can be exchanged automatically with our major suppliers using information systems
Spanning Channel Flexibility (PF/CHL)	
PF/CON4	Our major suppliers are willing to share information to accommodate changes that we request
PF/CON5	Our major suppliers are able to share information to accommodate changes that we request

Core Outsourcing (OU/COR)	
OU/COR1	We outsource manufacturing
OU/COR2	We outsource assembly
Peripheral Outsourcing (OU/PER)	
OU/PER1	We outsource sales
OU/PER2	We outsource information systems
OU/PER3	We outsource logistics and distribution
OU/PER4	We outsource marketing
OU/PER5	We outsource customer service