

A comprehensive conceptual model for supply chain flexibility- network perspective

Ehsan Salavatihesari

Faculty of Management and Human Resource Development
Universiti Teknologi Malaysia (UTM), 81310 Johor Bahru, Johor, Malaysia

E-mail: ehsan.salavati@yahoo.com

Tel: +60-11-2899-7004

Inda Sukati

Faculty of Management and Human Resource Development
Universiti Teknologi Malaysia (UTM), 81310 Johor Bahru, Johor, Malaysia

E-mail: indasukati@utm.my

Tel: +60-17-660-5148

ABSTRACT

Supply chain flexibility has become a focus of organizations faced with the need to survive in a highly uncertain and turbulence business environment. This study develops a conceptual framework of supply chain flexibility through flexibility classification schemes and flexibility typologies of the published literature, and recent literature on supply chain flexibility. The developed model in this study is based on a network perspective that considers all firms and activities in the supply chain. The conceptual model suggests five dimension of supply chain flexibility including: manufacturing flexibility (volume and mix flexibility), product development flexibility (modification and new product flexibility), logistic flexibility and supply flexibility, following by a detailed explanation for each dimension and the underlying rationale. This study will provide opportunities for researchers who are interesting in supply chain flexibility studies.

KEYWORDS: flexibility, conceptual, supply chain, network model

Introduction

As a response to increasing environmental dynamism and uncertainty, organizations are reshaping themselves in order to become more efficient, more innovative and more flexible (Young - Ybarra & Wiersema, 1999; Mouritsen, 1999; Golden & Powell, 1997). Flexibility is arguably the most important strategic capability that managers should consider when designing operations for volatile environments (Hayes and Pisano 1994). Flexibility allows firms in this network era to quickly sense and respond to evolving customer needs, adapt to shifts in technologies, and recover from competitor actions and capital market downturns. With customers requiring highly diverging products in the market, it becomes extremely difficult for the supply chain to accommodate customer needs into a product design and to predict the level of demand for a certain product. In response, supply chain organizations are seeking to increase flexibility, which is the organization's ability to

meet an increasing variety of customer expectations without excessive costs, time, organizational disruptions, or performance losses (Zhang *et al.*, 2003). Flexibility in supply chains may well represent a potential source to improve the company's efficiency and may be a significant measure of supply chain performance.

Research into supply chain flexibility falls into a number of categories, and has been heavily influenced by flexibility dynamics within manufacturing businesses, which has tended to concentrate interest at the functional and operational levels of the organization (Avittathur and Swamidass, 2007). The characteristics of flexibility have been addressed by a number of researchers, which has led to the development of a variety of differing taxonomies (Lucas and Kirillova, 2011; Stevenson and Spring, 2007), frameworks (Duclos *et al.*, 2003; Ivens, 2005; Kumar *et al.*, 2006; Pujawan, 2004), as well as measures/perspectives (Giachetti *et al.*, 2003; Sawhney, 2006; Verdu´-Jover and G_omez-Gras, 2009).

While a great deal of previous research on the topic of flexibility has been done and the importance of it has been recognized for a long time, most of this work concentrates on intra-organization flexibility concerning the scales for manufacturing flexibility (Gerwin, 1993; Koste and Malhotra, 1999; Slack, 1983; Upton, 1994; Vokurka and O'Leary-Kelly, 2000), research on supply chain flexibility is still sparse (Ulf Merschmann, Ulrich W. Thonemann, 2011) and remains in its infancy and the topic is yet to be fully explored and its dynamics explained (Sa´nchez and Pe´rez 2005, Stevenson and Spring 2007, More and Subash Babu (2008), Christopher and Holweg 2011).

Researchers generally agree that flexibility is a multidimensional concept. However, they differ on what the underlying dimensions of supply chain flexibility should be (Fantazy, 2007). Current guidelines are insufficient in proposing the kinds of flexibility that could be required by an organization. Hence, in this research we are going to clarify the constructs and dimensions of supply chain flexibility and propose a comprehensive conceptual model for supply chain flexibility by taking a network perspective. This conceptual model encompasses all partners and their activities across the supply chain from raw material to the end customer.

Literature Review

Manufacturing flexibility to Supply chain flexibility

In the area of operations management, flexibility was initially proposed for manufacturers to help them deal with unexpected changes in their manufacturing systems, such as equipment breakdowns, variable task times, and re-works (Sethi and Sethi, 1990). In this regard, flexibility concerns the degree to which an organization possesses a variety of actual and potential procedures, and the rapidity with which it can implement these procedures to increase the control capability of the organization over its environment (Leeuw and Volberda, 1996). 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. Dimensions of manufacturing flexibility are widely discussed as the adaptive response to environmental uncertainty in manufacturing strategy (Gupta and Goyal, 1989; Gerwin, 1993).

In the era of manufacturing flexibility, some authors stated that 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 and they argued that all resources in a system contribute the flexibility. 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 (Liao, 2006). With inter-firm competition being extended to inter-chain competition in which both upstream suppliers and downstream distributors cooperate to deliver customer value, the concept of manufacturing flexibility needs to be expanded to supply chain scenarios. Several studies have adopted the approach of relating components

found in the manufacturing flexibility literature to a wider context of the supply chain. In 1995, Jordan and Graves demonstrated that flexibility initiatives carried out over a chain of plants (external flexibility) substantially outperform flexibility initiatives carried out within a single plant (internal flexibility). Similarly, Olhager and West (2002) have recognized the importance of extending the notion of flexibility beyond the factory floor linking it to market requirements and customer needs.

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. Lummus *et al.*(2003, p2) state that supply chain flexibility refers to "(the capability of) promptness and the degree to which the supply chain can adjust its speed, destinations and volume in line with changes in customer demand".

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.

Das (1996) concludes that, since every manufacturing facility experiences different changes to different degrees and the diversity of these possible changes is large, several different types of flexibilities may be appropriate. From the previous definitions of SCM, those activities include delivering a product from raw material through to the customer, including sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, delivery to the customer, and the information systems necessary to monitor all of these activities (Duclos *et al.*, 2003). Flexibility should, therefore, be pursued by a supply chain, or at least by every function related to supply chain activities. 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.

Classifications of supply chain Flexibility

Although the research articles available on the specific subject of supply chain flexibility are not very numerous, it is possible to find some classifications of the various types of supply chain flexibility, usually associated with correspondent types of manufacturing flexibility. However, as the supply chain extends beyond the enterprise, supply chain flexibility must also extend beyond one firm's internal flexibility (Duclos *et al.*, 2003). In addition, some researchers have added new dimensions that are more relevant to the supply chain environment. In the following we discuss about a few studies which had a great impact on supply chain flexibility literature.

Vickery *et al.* (1999) focused on flexibility in the supply chain and defined five supply chain flexibilities based on previous operations literature. The authors state that supply chain flexibility "should be examined from an integrative, customer-oriented perspective." The five defined flexibilities are: (1) product flexibility, defined as the ability to customize a product to meet specific customer demand; (2) Volume flexibility, defined as the ability to adjust capacity to meet changes in customer quantities; (3) New product flexibility, defined as the ability to launch new or revised products; (4) Distribution flexibility, defined as the ability to provide wide dispread access to products; and (5) Responsiveness flexibility, defined as the ability to respond to target market needs. While these descriptions of flexibility are appropriate, most of the responsibility for one of the types of flexibility lies with one functional area of a particular firm. Manufacturing is generally responsible for volume flexibility; marketing is generally responsible for distribution flexibility; research and design is responsible for

new production introduction flexibility, etc. By focusing on these flexibilities from an internal perspective much of the contribution of a supply chain perspective is lost (Duclos, *et al.*, 2003).

Duclos *et al.* (2003) presented an integrated conceptual model of supply chain flexibility and examined flexibilities classification schemes and the commonalities of flexibility typologies in the literature to create a theoretical foundation for analyzing the components of supply chain flexibility. They identified six components of supply chain flexibility from the literature on manufacturing flexibility, strategic flexibility and the limited writings on supply chain flexibility. 1) Operations system flexibility which is the ability to configure assets and operations to react to emerging customer trends (product changes, volume, and mix) at each node of the supply chain, 2) Market flexibility, defined as the ability to mass customize and build close relationships with customers (designing and modifying new and existing products). 3) Logistics flexibility, which is the ability to cost effectively receive and deliver product as sources of supply and customers change (customer location changes, globalization, and postponement). 4) Supply flexibility, or the ability to reconfigure the supply chain, altering the supply of product in line with customer demand. 5) Organizational flexibility, defined as the ability to align labor force skills to the needs of the supply chain to meet customer requirements. 6) Information system flexibility is the ability to align information system architectures and systems with the changing information needs of the organization as it responds to changing customer demand.

Pujawan's (2004) designed a framework in such a way that a supply chain can compare the desired level of flexibility and the current capability in various elements of supply chain flexibility. The four main parts of supply chain flexibility are identified as: product delivery system flexibility (ability of the supply chain to deliver different types of products to the customers with a wide range of volume at an acceptable cost and time), production system flexibility (ability to produce products of different types and different volume at an acceptable speed and cost), product development flexibility (ability to produce various new designs in a timely and cost-effective), and sourcing system flexibility (supplier ability to deliver materials in different speed options, mix different items into a delivery load). This dimension is similar to the supply flexibility dimension suggested by Duclos *et al.* (2003).

Lummas *et al.* (2005) explored the characteristics of flexible supply chains by conducting a Delphi study. The results of the Delphi study provided a set of characteristics important to practitioners for improving overall supply chain flexibility. After refining 112 characteristics/capabilities, they suggested five components of supply chain flexibility including: 1) operations system (reconfigure equipment, rapid process change, dynamic capacity), 2) logistics processes (adjust to global requirements, adjust to customer location changes, vary warehouse space, vary transportation carriers), 3) supply network (add and remove suppliers, select suppliers with fast ramp up, vary supplier relationships, select supplier with variable capacity), 4) organization design (organization structure, human resource practices, work force capability, personnel linkages, change culture), 5) information system (synchronize hardware and software, internal process interfaces, share information with partners), and the considered customer satisfaction and supply chain assets as the result of flexible supply chain.

Kumar *et al.* (2006) have developed a framework as a starting point for implementing and managing supply chain flexibility in supply chain organizations. The framework suggests that supply chain flexibility should be implemented and managed using a three-stage approach: required flexibility identification, implementation and shared responsibility, and feedback and control. Kumar *et al.* (2006) define the five supply chain flexibilities dimensions based on previous operations literature: product flexibility (defined as the ability of the supply chain partners to produce a customized product or upgrade existing ones to meet customers' specifications), sourcing flexibility (defined as the ability of the supply chain partners to control the supply levels increasing or decreasing), delivery flexibility (is defined as the ability of the integrated logistic system to distribute and deliver the product economically and with no additional time from the raw material source to the final customer), new product flexibility (is defined as the ability of supply chain partners to collaborate and

coordinate to produce completely new products economically and with no additional time), responsive flexibility (is defined as the capability of supply chain partners to respond economically and with no additional time to the market changes to satisfy customer demand). This framework provides various feedback loops, suggesting the need for continually monitoring flexibility to ensure that the supply chain flexibility is being achieved.

Sanchez et.al (2005) developed a framework of supply chain flexibility following the work of Duclos et al. (2003) and Vickery et al. (1999). Their framework includes both process flexibility and logistics flexibility. Based on the bottom-up classification of flexibility as in manufacturing systems – basic, system and aggregate types – they suggest different types of supply chain flexibility dimensions, which concern mainly the context of supply/demand relations. According to Figure 1, the first three flexibility dimensions are shop floor capabilities that impact on supply chain (basic flexibility); the following three dimensions are hierarchically located at company level (system flexibility); the top four flexibility dimensions are linked to the customer-supplier relationships in the supply chain (aggregate flexibility).

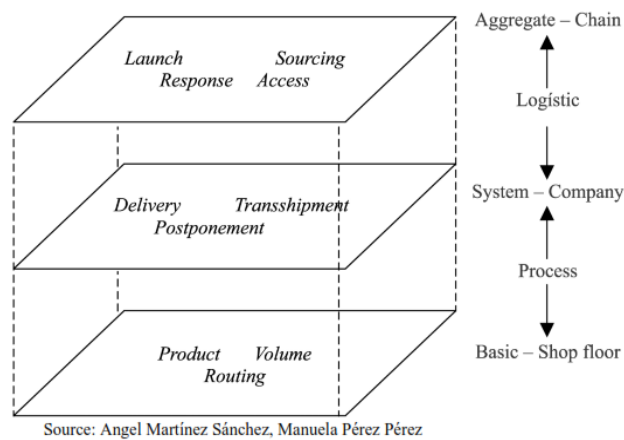


Figure1. Hierarchical model of supply chain flexibility

(1) Product flexibility is defines as the ability to handle difficult, non-standard orders, to meet special customer specification, and to produce products characterized by numerous features, options, sizes, and colors. (2) Volume flexibility is defined as the ability to effectively increase or decrease aggregate production in response to customer demand (Cleveland et al., 1989). (3) Routing flexibility is the capability of processing a part through varying routes by using alternative machines, flexible material handling, and flexible transporting network. (4) Delivery flexibility is the company's capability to adapt lead times to the customer requirements. (5) Trans-shipment flexibility involves movement of stock between locations at the same echelon level where physical distances between the demand locations and the supply locations are small (Barad and Sapir, 2003). (6) Postponement flexibility implies the capability of keeping products in their generic form as long as possible, in order to incorporate the customer's product requirements in later stages (Barad and Sapir, 2003). (7) Sourcing flexibility is related to the company's ability to find another supplier for each specific component or raw material. (8) Response to market flexibility captures the overall ability of the firm to respond to the needs of its target markets (McDonald, 1993). (9) Launch flexibility is the ability to rapidly introduce many new products and product. (10) Access flexibility is the ability to provide widespread or intensive distribution coverage.

In summary, each author may use different dimensions to identify supply chain flexibility similar to the manufacturing flexibility literature. However, in the supply chain context the dimensions should be related to supply chain functions. As we can see in supply chain flexibility literature some researchers used different name

or different category, some of the dimensions may overlap each other, or some dimensions maybe are just applicable in some special conditions. Table1 summarizes the conceptual and empirical studies on dimensions of supply chain flexibility.

Authors/ year	Focus of the study	Research type	Flexibility dimension
Zhang et al. (2002)	The relationships among environmental uncertainty, value chain flexibility and competitive advantage	Empirical study	product development, manufacturing, logistics and spanning
Gosain et al (2005)	The effects of information infrastructure characteristic on SCF	Empirical study	Offering flexibility, partnering flexibility
Ying Liao (2006)	Relationships among the antecedents, driving forces, supply chain flexibility, and its impacts on performance.	Conceptual and Empirical study	Market-oriented Flexibility, Supply Flexibility, Logistics Flexibility, Spanning Flexibility
Sanchez and perez (2006)	relationship between supply chain characteristics and the dimensions of supply chain flexibility and firm performance	Empirical study	Product, volume, routing, delivery, transshipment, postponement, response to market, access, lunch
Fantazy et al. (2009)	relationships among strategy, flexibility, and performance in the supply chain context- small and medium-sized Canadian manufacturing	Empirical study	New product, sourcing, product, information system, delivery
Stevenson and Martin Spring (2009)	The effects of inter-firm practices on achieve increased flexibility in buyer-supplier relationship	Empirical study	Configuration flexibility(ability to change counterparts), planning and control flexibility(ability to change time, volume, design)
Merschmann and Thoneman n (2010)	relationship between environmental uncertainty, supply chain flexibility, and firm performance	Empirical study	manufacturing lead-times, new product, product development, customization, delivery capacity/capability, customer service, responsiveness to changing market needs , delivery reliability,
Yi Ying (2010)	The effects of market orientation and supply chain partnership orientation on supply chain flexibility	Conceptual and Empirical study	Sourcing, operation system, distribution, information system
Shukla et al. (2010)	The relationship between flexibility of supply chains and sustainability	Empirical study	Product, volume, delivery, transshipment, sourcing, response to market, new product, distribution

Malhotra and Mackelprang (2012)	utilization of both internal and external flexibilities on creating synergies of firm's delivery performance	Empirical study	Supplier flexibility, logistic flexibility, modification flexibility, mix flexibility, new product flexibility
Moon et al. (2012)	develop a multifaceted scale for SCF	Empirical study	sourcing, operating system, distribution, information system
Blome et al. (2013)	The effects of knowledge transfer on supply chain flexibility- moderating role of complexity	Empirical study	order adjustability, customer deliveries, throughput time reduction, reduction of ramp up time, adjustment of production processes, production capacity, new product launches
Nagarajan et al. (2013)	relationship between environmental uncertainty, information quality, and proactive logistics practices on supply chain flexibility	Empirical study	Volume, product improvements, new products
Jin et al. (2014)	The links among IT-enabled sharing capability, supply chain flexibilities, and competitive performance.	Empirical study	product development, production, logistics, suppliers, supply base
Thomé et al.(2014)	effects of flexible SC at various tiers on SC's ability to provide products to end-customers in automotive industry	multiple case study	Sourcing, product (mix and volume), relational, delivery, postponement, new product, responsiveness

Supply chain flexibility: Network perspective design

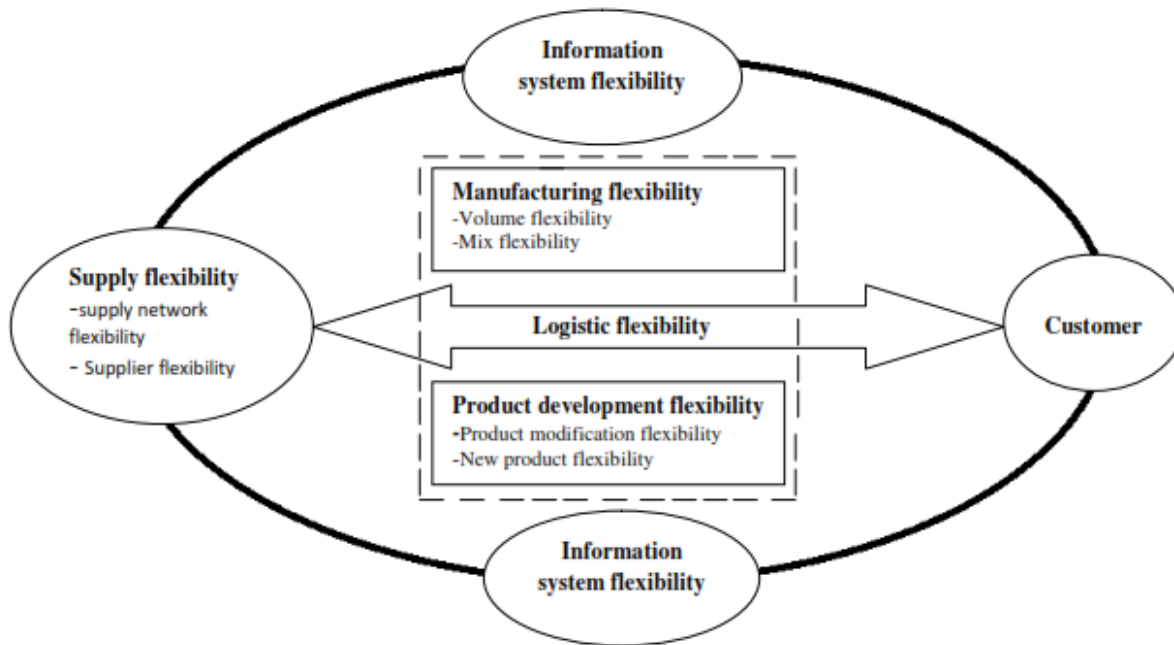
Das (1996) concludes that, since every manufacturing facility experiences different changes to different degrees and the diversity of these possible changes is large, several different types of flexibilities may be appropriate. A number of taxonomies have been developed to describe supply chain flexibility as illustrated in previous section. From the definitions of SCM, those activities include delivering a product from raw material through the customer, including sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, delivery to the customer, and the information systems necessary to monitor all of these activities (Duclos *et al.*, 2003). Flexibility should, therefore, be pursued by a supply chain, or at least by every function related to supply chain activities. To a world-class organization, a happy and satisfied customer is of the utmost importance. With this concept in mind, supply chain flexibility should be viewed from the perspective of the entire value chain-adding system, i.e., total system flexibility (Hyun and Ahn, 1992).

Therefore, the types of supply chain flexibility used for this research have been selected based on two important criteria. Firstly, the supply chain flexibility dimension encompasses those flexibilities that directly impact a firm's customers (i.e., flexibilities that add value in customers' eyes), secondly those flexibility types that are more frequently used in the supply chain flexibility literature and commonly cited in operations management

literature. In addition, this chosen flexibilities taxonomy appears to include other kinds of flexibility, both of a general nature and those related to specific manufacturing or operation problems.

Hence, five dimensions of supply chain flexibility are considered in this research: manufacturing flexibility, product development flexibility, logistic flexibility, supply flexibility and information systems flexibility.

Figure2. Conceptual model of supply chain flexibility



Manufacturing Flexibility

Manufacturing flexibility or operating system flexibility is the ability of the organization to quickly and effectively adjust production processes and manufacturing resources to meet various customer requests 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). A manufacturing firm's flexibility, in a dynamic supply chain, is important to successfully sustaining the firm's competitive positions and long-term profitability (Stevenson and Spring, 2007). 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.

Volume flexibility is the ability of the organization to operate at various batch sizes and/or at different production output levels economically and performance-effectively, given a certain product mix (Carlsson 1989, Gerwin 1993). volume flexibility, defined as the ability to effectively increase or decrease aggregate production in response to customer demand (Cleveland et al., 1989). Volume flexibility may require close coordination between a manufacturer and its suppliers, especially in the face of increasing demand. Volume

flexibility directly impacts supply chain's performance by preventing out-of-stock conditions for products that are suddenly in high demand or by preventing high inventory levels (obsolete stock).

Mix flexibility is the ability of the organization to produce different combinations of products economically and performance-effectively given certain capacity (Boyer and Leong 1996). Mix flexibility must be evaluated within the current production system configuration without considering facility modifications (Sethi and Sethi 1990, Dixon 1992, Gupta and Somers 1992). 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).

Product Development Flexibility

Product development flexibility is the ability to introduce and launch new products and to modify existing products with fewer resources and shorter development cycle time with respect to market changes (Slack 1987, Sethi and Sethi 1990, Hyun and Ahn 1992, Dixon, 1992; Gerwin, 1993; Upton, 1994; Iansiti, 1995; Viswanadham and Raghavan, 1997; Singh and Sushil, 2004). 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).

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 be examined as having two sub-dimensions: new product flexibility and modification flexibility (Koste and Malhotra, 1999; Klassen and Angell, 1998; Ellie and Penner-Hahn, 1994; Hyun and Ahn, 1992). 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).

Product modification flexibility is the ability to respond to customer needs for design changes quickly and performance-effectively. Vickery et al. (1997) define product modification flexibility in a supply chain framework as the ability to handle difficult, non-standard orders, to meet special customer specifications, and to produce products characterized by numerous features, options, sizes, and colors. A product is considered modified if its functional characteristics are maintained, but other aspects of the product are changed to meet customer needs. Product modification flexibility is responsible for upgrading or modifying existing products based on the emerging technologies and changing customer expectations.

New product flexibility is the ability to introduce and launch new products quickly and performance-effectively (Sethi and Sethi 1990, Gupta 1993). A product is new if its characteristics differed from other products the plant made previously (Dixon 1992). Vickery et al. (1999) defined new product introduction (i.e., launch flexibility) as the ability to rapidly introduce large numbers of product improvements/variations or completely new products. An organization that develops and introduces products very different from each other should be considered more flexible than one that introduces similar products.

Logistic flexibility

Logistics and distribution management include all the processes of transporting goods from suppliers to manufacturers, to distribution centers and to the final consumption point (Ricker and kalakota, 1999). These processes include packing and shipping, preparing documentation, inventory and warehouse management, transportation planning and management, customer transactions, reverse logistic, and tracking and delivery. In some previous research logistic flexibility was defined as the ability to move planned delivery dates (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 (). 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 and logistics must be able to accommodate dynamic and diverse delivery requirements from customers.

By taking into account a number of considerations, logistic flexibility is defined as the ability of a company to effectively deliver products to customers in response to changes in planned delivery dates, volume and destination (Pagell and Krause, 2004; Pujawan, 2004). Based on the above discussion, logistic flexibility is reflected in terms of the ability that a company can accommodate special or non-routine 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).

Supply flexibility

Generally, sourcing activities are the pre-activities of an enterprise's core business. They provide crucial links between suppliers and manufacturers, and are responsible for the upstream procurement of suitable material, components, products, or services to support material requirements (Lummus *et al.*, 2003; Swafford *et al.*, 2006). Duclos *et al.* (2003) defined supply flexibility as the ability to meet the changing needs of customers that requires changing the supply of product, including mix, volume, product variations, and new products. Meeting these needs in the supply chain requires flexibility in sourcing products from raw materials to the outsourced finished product. In another definition Supply flexibility is described 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).

As mentioned above, one definition of Supply flexibility is the, "availability of a range of options and the ability of the purchasing function to effectively exploit them to respond to changing requirements for the supply of purchased components" (Swafford *et al.*, 2006) that we call supplier flexibility. Another definition of Supply flexibility is related to the company's "ability to find another supplier for each specific component or raw material" (Sanchez and Perez, 2005) that we call supply network flexibility. Given the above discussion, supply network flexibility and supplier flexibility are viewed as supply flexibility in responding to environmental uncertainty. Suppliers' flexibility and supply network flexibility correlate with each other and are associated to the firm's flexibility. These two types of flexibilities are an asset specific to the manufacturing firm, which both adds value to the supplier–manufacturer relationship (Dyer and Singh, 1998).

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). 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, adding a new supplier and changing the closeness of the relationship effectively and rapidly. Some researchers have expressed the importance of taking a flexible perspective in designing supply network (Lummus et al. 2003, Pujawan 2004, and Duclos et al. 2003). In this regard, a firm who has more and greater variety of supply sources, has wider range of materials/components/products available from the major suppliers, and has the ability to add and remove suppliers freely; it might be more competent to secure a smooth supply flow to support their daily operations (Lummus et al., 2003; Swafford et al., 2006).

In the current environment, where the level of vertical integration is limited, it is difficult to imagine that a firm could accommodate customer demand for product variety without the assistance of flexible suppliers (Das and Abdel-Malek, 2003). Suppliers' flexibility is the ability of suppliers to efficiently and effectively adjust their operations to cope with a manufacturer's requests for components needed to meet the final

customers' demands (Das and AbdelMalek, 2003; Pujawan, 2004). To a manufacturer, the most important elements of suppliers' flexibility are order quantity and product variety, (Tachizawa and Thomsen, 2007). Because a manufacturer is striving to satisfy its customers on multiple competitive dimensions simultaneously, it views suppliers' flexibility as a way of integrating both its needs and those of the customers. 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).

Information system flexibility

Information systems generally provides the tools for organizations to effectively gather, store, access, share, and analyze data so as to facilitate operations for help in making better decisions (Swafford, 2003). With the physical flow of products moving across different supply chain nodes, relevant information should also be transferred across the nodes fluently and efficiently. To facilitate information flow in the supply chain, it is essential for the organization to set up an efficient and flexible information system. Without accurate information about supply and demand conditions, even a supply chain that is physically capable of high flexibility cannot respond efficiently to real-time changes.

Information system flexibility or spanning flexibility refers to the ability of a firm to efficiently and effectively distribute various information and manage information sharing connectivity along the supply chain with respect to environmental changes (Lummus et al., 2003; Aranda, 2003; Zhang et al., 2002). Information system flexibility encompasses two actions: first, 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, so supply chain participants share knowledge about plans, requirements, and status on a timely basis (Duclos et al., 2003; Zhang et al., 2004), second, is Information dissemination flexibility which involves the number of ways and variety of data can be shared seamlessly across the supply chain (Aranda, 2003; Zhang et al., 2002) in a manner that is flexible, cost effective, manageable, and reliable (Sanders and Premus, 2002; Heinrich and Betts, 2003).

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.

Discussion and Conclusion

Nowadays, firms must enhance their flexibility abilities from an operational perspective to a strategic, cross-organizational perspective to be successful. Companies must realize that real competition is not firm-to-firm anymore, but supply chain-to-supply chain. The development from individual organization flexibility to supply chain flexibility results in the requirement that all entire supply chain should be flexible. This paper begins with the importance of flexibility and the vital needs of firms to move towards a flexible supply chain in current turbulence and changing business environment, and the importance of supply chain flexibility as a competitive advantage for the firms to satisfy their customers' needs. Afterwards, we addressed the issues in current supply chain flexibility studies and a review on the development of supply chain flexibility constructs. At the end, we proposed a conceptual model of supply chain flexibility based on a network perspective, following by the dimensions and definitions of each dimension.

The purpose of this study was to create a conceptual model of supply chain flexibility based on a network perspective. The proposed supply chain flexibility model in this study is based on a vast review on the literature of manufacturing flexibility, operation management, supply chain management and supply chain flexibility. As we mentioned in this paper many researchers examined different aspects and different

dimensions of supply chain flexibility. We stated earlier, there are some gaps and theoretical problems relating to the current studies on supply chain flexibility which stems from the following issues: First, most of the literature and development of supply chain flexibility are adapted from manufacturing flexibility literature; meanwhile some of the researchers used the dimensions of manufacturing flexibility in the context of supply chain without adapting to the wider concept of supply chain. Second, some of the research is confined to evaluating one aspect of supply chain flexibility, while researchers highlighted that flexibility is a multidimensional concept (Fantazy, 2007), and other dimensions are relating to and may affect each other, so concerning just one dimension will not manifest the real function. Third, focusing on the plant or firm as the unit of analysis and examining the impact of supply chain flexibility on the firm, rather than the supply chain, thus failing to explore the full inter-organizational impact of supply chain flexibility. Authors in the wider Operations Management field have acknowledged the benefits to be gained by companies that treat the supply chain as a single entity, compete as a chain and focus on satisfying end-customer demand (Tan et al., 1998; Croom et al., 2000; Hill and Scudder, 2002), leading to the belief that the unit of analysis for researchers should be the supply chain or the network (Harland et al., 1996; Frohlich and Westbrook, 2001; Van Hoek et al., 2001). Hence, in order to develop a more complete understanding of supply chain flexibility, it is important to take a network perspective and assess the impact on the wider supply chain across groups of inter-related entities. In light of the above, it is argued here that there is a particular need to conduct further empirical research into supply chain flexibility; this is supported by authors such as Lummus et al. (2003), Aprile et al. (2005), Holweg (2005), Lummus et al. (2005) and Kumar et al. (2006). This could help not only to develop a broader and more complete understanding of this emerging phenomenon but also increase the number of factors incorporated in measurements of flexibility and advance the sophistication of analytical models.

Implications for future research

The proposed model in this research presents an opportunity for researchers interested in supply chain flexibility improvement. Researchers may find interest in examining the following issues. First, this paper moves away from the more traditional views of flexibility that are based on flexibility dimensions (e.g product flexibility, volume flexibility, launch flexibility, access flexibility, responsiveness flexibility) which comes from manufacturing flexibility by considering a network perspective which count all nodes in supply chain. So researchers may use this model in empirical research to realize the strength and weakness of the proposed model. Second, we suggest for more research about the inter-relationships between the dimensions of supply chain flexibility, as they can affect each other. Third, many research are done on the relationship between supply chain flexibility and supply chain performance, or the drivers of supply chain flexibility, but there is a shortage of research to show the relationship between supply chain practices and supply chain flexibility that how a firm can achieve flexibility.