



Theme - IV

Flexibility in Supply Chain Management

33.	Flexibility in Global Supply Chain: A Review of Perspectives	377-385
34.	Modeling Bullwhip Effect and Understanding Role of Information Sharing	386-397
35.	A Flexible Framework to Evaluate Supply Chain Performance	398-402
36.	Reverse Supply Chain - Current Practices in India and Developed Countries : A Detailed Study	403-428
37.	E-Business in Supply Chain Management	429-434
38.	Global Financial Supply Chains – An Integer Programming Formulation	435-440
39.	Analysing Supply Chain Configuration of Food and Drink Retail Company	441-451
40.	Problems, Challenges and Opportunities of Logistics with Special Reference to Indian Economy	452-463
41.	Sales Promotion Practices in Apparel Retail Sector & Challenges Ahead	464-470
42.	Flexible Strategic Framework for Managing Continuity and Change in Reverse Supply Chain in the Battery Industry- Study of Lead Acid Batteries and Ni Cd batteries for automotive computers and mobile phones	471-492



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FLEXIBILITY IN GLOBAL SUPPLY CHAIN: A REVIEW OF PERSPECTIVES

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ABSTRACT

All the activities in a supply chain are seeking to enhance flexibility to respond to an environment of uncertainty. It measures a system's ability to accommodate and schedule fluctuations from suppliers, manufacturers and customers. One of the biggest challenges in global supply chain is to manage the smooth flow of materials and information. In this paper, various ranges, dimensions and types of flexibility are investigated. The available literatures on flexibility deals mainly with manufacturing systems while researches on flexibility in distribution channels and supply chains have been very limited. The agility of global supply chain is a function of four flexibility components: product development flexibility, sourcing flexibility, manufacturing flexibility, and logistics flexibility. All such flexibilities are composed of two dimensions which we call range and adaptability. The influence of flexibility on supply chain performance and profitability has also been analyzed. This paper may help the supply chain manager to synchronize the system with various types of fluctuations and changes in global market.

Keywords: Flexibility, Range, Adaptability, Agility

Introduction

Flexibility reflects the ability of a system to respond rapidly to changes inside and outside the system (Garavelli, 2003). According to Charles H. Fine (1998) a company's real core capability lies in its ability to design and manage the supply chain in order to gain maximum advantage in a market where competitive forces are changing. Flexibility is critical to the success of supply chain and it must be achieved without excessive costs, time, organizational disruption or performance losses. Flexibility becomes particularly relevant when the whole supply chain is considered, consisting of a network of supply, production, and delivering firms (Garavelli, 2003; Christofer, 1992). In a supply chain, flexibility plays a critical role which is considered as crucial weapon to increase competitiveness in a turbulent market place (Upton, 1994). There are many sources of uncertainty in supply chain such as customer demand, supply quality and lead time, product models and information delays.

A growing interest in flexibility in supply chain management has occurred due to the increasing global competition caused by recent trade agreements, removal of trade barriers, and increased accessibility to global customers via the internet. The trend toward global companies mandates advanced research in the area to provide competitive advantages in terms of low cost, high quality, and fast delivery. Flexibility allows switching production among

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different plants and suppliers, so that management can cope with internal and external variability (Chen et al., 1994).

Slack (1983) defines flexibility in terms of range, cost, and time where range is the number of states the system can adopt, and both cost and time are associated with a change in the number of states. Flexibility is classified as range flexibility and response flexibility. Range flexibility is concerned with the extent to which the operations can be changed. Response flexibility is defined as the ease with which the operation can be changed. Koste and Malhotra (1999) divided range into two categories, range-heterogeneity and range-number. Range-heterogeneity measures the difference among the existing manufacturing options, while the range-number measures the number of options. Along with the two range measures, they defined manufacturing flexibility in terms of mobility and uniformity. Uniformity measures the similarity of outcomes in terms of cost, quality and time which could represent the effective use of agility.

Swafford et al., (2006) defined flexibility using two dimensions called range and adaptability. They defined range as the number of different positions, or flexible options that could be achieved with existing resources. An organization with a higher number of range states will be more flexible than an organization with fewer range states. For example, an organization with multiple production facilities for the same product has more flexibility than an organization with single production facility. This higher level of flexibility exists because the organization with multiple production facilities is capable of relocating or otherwise adjusting its production in response to environmental changes such as labor disputes.

Bordoloi, Cooper and Matsuo (1999) define adaptability as the ability to change within a given state. They define a state as the collection of capabilities together with the conditions that can facilitate or impede their realization by actuating a set of administrative or mechanical processes.

The remaining part of the paper briefly reviews the flexibility of various activities in supply chain, flexibility ranges and its dimensions, and influences of flexibility on supply chain performance. The last section of the paper presents the conclusion.

Flexibility in Supply Chain

Flexibility is a complex and multidimensional concept, difficult to summarize (Upton, 1994; Gupta and Buzacott, 1996). If we consider a broad definition of flexibility, it reflects the ability of a system to properly and rapidly respond to changes, coming from inside as well as outside the system.

Beamon (1999) divided the flexibility into four classes: volume flexibility, delivery flexibility, mix flexibility, and new product flexibility. Volume flexibility is ability to change the production output to meet the market demand. Delivery flexibility is ability to change the planned delivery dates. Mix flexibility is ability to change the variety of products produced. New product flexibility is ability to introduce and produce new products. At operational level, the interesting aspect of flexibility is the object of change i.e., flexibility of product, mix, volume, etc. (Gerwin, 1993, Browe et al., 1984, D'Souza and Williams, 2000; Hyun and Ahn, 1992; Sethi and Sethi, 1990; Vokurka and O' Leary-Kelly, 2000).

Vickery et al. (1999) and Swafford et al., (2006), proposed the following dimensions of supply chain flexibility: product, volume, launch, access, target market, while Viswanadham and Raghavan (1997) considered volume, mix, routing, delivery time, and new product flexibility. Various aspects of flexibility that can be outlined from literatures are: flexibility in operations,

marketing, and logistics (Kim, 1991; Lynch and Cross, 1991), flexibility at different levels like shop, plant, and company (Gupta, 1993; Koste and Malhotra, 1999;), global flexibility vs. specific ones (Gupta and Somers, 1992; Sarker et al, 1994; Chung and Chen, 1990; De Groote, 1994), Long term vs., short term flexibility (Zelenovich, 1982).

Garavelli (2003) measured the flexibility as 'no flexibility', 'limited flexibility' and 'total flexibility'. He also measured the influences of flexibility on the profitability of supply chain. Both manufacturing flexibility and supply chain flexibility are now accepted themes in research and practice (Avittathur and Swamidass, 2007).

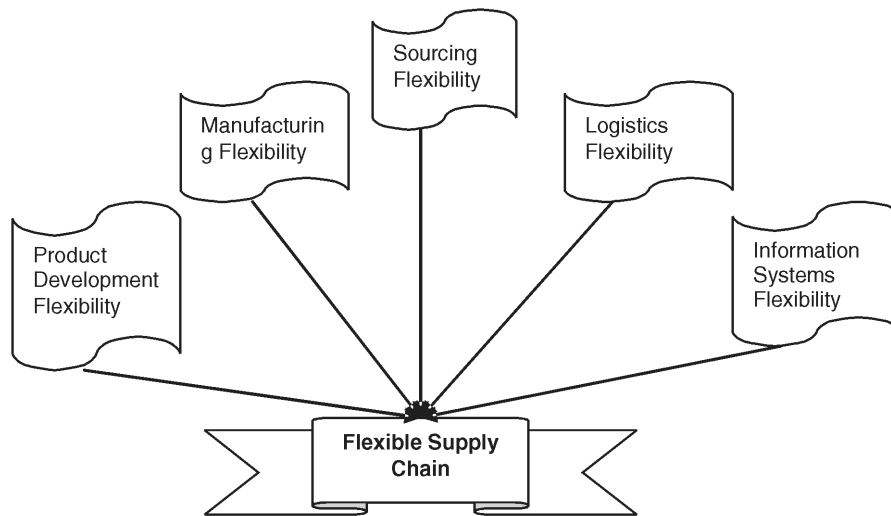


Figure 1: Different types of flexibility in supply chain

In this paper, authors have considered following types of flexibility for investigation as shown in figure 1: product development flexibility, manufacturing flexibility, sourcing flexibility, logistics flexibility, information systems flexibility

Product Development Flexibility

Product development flexibility can be defined as the ability to develop diversified products and to enhance the product's design in a timely and cost effective manner in response to customer or market change and to employ technological enhancements. With higher flexibility in product development, the organization will be in a better position to introduce products in response to changing customer expectations or technology (Swafford et al., 2006)

To meet the complexity range in product development, there is requirement of a number of technologies and knowledge from various fields of science and technology. The multi-product announcements are influenced by the number of different platforms in design, the number of product generations in design, and the number of development of projects in progress. A company simultaneously producing multiple generations of a product would have a better opportunity to effectively incorporate new customer expectations into the design.

Commonality and the use of existing technology are important concepts of design for manufacturing. Higher levels of part commonality simplify the product. Adaptability of product development flexibility is the ability to increase or decrease the number of states based on resources and technologies. This dimension of flexibility makes multiple projects possible as

well as change within any specific project (Thomas, 1993).

Pagh and Cooper's (1998) studied the impact of product postponement strategies on inventories. If product differentiation is performed later in supply chain, the cost of adapting can be lowered. Thus, the ability to postpone product differentiation in the global supply chain is one measure and to postpone design decisions until improved product information is available is another measure of adaptability.

In an apparel industry, traditionally, the manufacture of clothing starts with the dyeing of the yarn followed by the knitting of the garment. This process may result in out of stock of desired colour and over inventory of unpopular colour. In a market characterized by very short product life cycles, this mismatch of inventory and customer demand cannot be corrected using a traditional manufacturing approach. The typical result is the end of season mark-down. Benetton uses the bleached yarn and delay dyeing until information on the preferred colours became available through EDI to reduce the inventory size.

Manufacturing Flexibility

Manufacturing flexibility continues to be a concern for companies as they strive to meet the changing demands of their customer (Krause et al., 2007). Suppliers must be able to meet changes in volume requirement on short notice. They should have the ability to produce smaller batch size production runs at frequent intervals (Dyer, 1996; Liker and Wu, 2000; Meredith, 2000; Womack et al, 1990).

Sethi and Sethi (1990) defined manufacturing flexibility as the ability to reconfigure manufacturing resources so as to efficiently produce different products of acceptable quality. Swafford et al. (2006) defined manufacturing flexibility as the ability of manufacturing to adapt its capabilities to produce quality products in a time and cost effective manner in response to changing product characteristics, material supply, and demand, or to employ technological process enhancements.

Avittathur and Swamidass (2007) divided the evolution of manufacturing flexibility concept into four phases. Phase I (during eighties) is concerned with conceptualization of flexibility in manufacturing equipments, manufacturing systems, and manufacturing strategies (Wheelwright, 1978; Browne et al., 1984; Swamidass, 1988; Gerwin, 1987; Slack, 1983).

In Phase II (during and before nineties), manufacturing flexibility received more attention from researchers and practitioners. Manufacturing Flexibility was declared as multidimensional. Gerwin (1993) identified 7-core dimensions of flexibility: mix, changeover, modification, volume, rerouting, material, and flexibility responsiveness. Vokurka and O'Leary-Kelly (2000) defined 15 dimensions of manufacturing flexibility. Koste and Malhotra (2000) proposed a hierarchy of flexibility dimensions.

In phase III (during and recent nineties), supply chain flexibility became the focus of interest of researchers. This subject is still evolving. The importance of supply chain flexibility has grown due to recent rise in mass customization, which calls for increased supply chain flexibility without addition of cost (Gilmore and pine, 1997; Lummus et al., 2003; Pine, 1997).

In phase IV (recently), the interest of researchers has turned toward the matching of buyer and supplier flexibilities. Choi and Hartley (1996) observed that the ability of suppliers to meet the requirement of volume changes became one of the factors for supplier selection.

Various research articles on manufacturing flexibility describe several types of flexibility such as machine, labor, material handling, routing, operation, expansion, volume, mix, new

product, market, and modification (Gupta and Somers, 1992; Sethi and Sethi, 1990; Gupta and Goyal, 1989). Most of these flexibilities are defined at the shop floor or individual resource level.

The available method to increase capacity also affects range and represents part of expansion flexibility (Koste and Malhotra, 1999). Sethi and Sethi (1990) mentioned several methods such as building smaller production units, having cellular manufacturing systems, and multipurpose machinery to enhance expansion flexibility. Sethi and Sethi (1990) combined new product flexibility and modification flexibility together as market flexibility which they defined as the ease with which the manufacturing system can adapt to a changing market environment.

The number of product changeovers (per month/ per facility) is one measure of process flexibility (Ettlie, 1998) and is also used as the measure of flexibility range. The other measure is workforce capabilities and is similar to the range-number element of labor flexibility (Koste and Malhotra, 1999). A workforce with higher levels of cross training facilitates more possible job assignment combinations to adapt the changing production schedules.

Sourcing Flexibility

Integrated sourcing flexibility in supply chain management improves the organization's ability to deliver products and services in a timely and effective manner (Tan et al., 1996). Sourcing flexibility is the ability to change sourcing decisions such as the number of suppliers per part and delivery schedule. Sourcing flexibility facilitates a faster response when there is uncertainty; therefore, sourcing flexibility has a positive impact on manufacturing flexibility (Gupta and Somers, 1996). Sourcing flexibility may support the arms-length relationship with suppliers, but strategic partnership with flexibility is more beneficial to cover various uncertainties in supply chain. Manufacturers always try to find the reliable suppliers and establish a strategic relationship. According to survey done by Capgemini, Georgia Institute of Technology and FedEx (2005) number of 3PL providers used by 70 to 80 percent manufactures prefer to have less than five logistics service providers. Similarly, the number of supplier used by vehicle manufacturers has been reduced.

The first measure of sourcing flexibility is range of order sizes used by the purchasing department. This is analogous to volume flexibility used in manufacturing. Another measure is range of delivery frequencies that captures the time between the earliest and latest delivery dates achievable by the supplier i.e. slack time. Sourcing has greater flexibility if it can increase or decrease order sizes without incurring extra costs. It has been observed that ability to change delivery schedules are positively related to delivery flexibility (Narasimhan and Das, 1999).

Logistics Flexibility

Logistics flexibility can be defined as the ability to control the flow and storage of raw materials, finished goods, services, and related information from origin to destination in response to changing environmental conditions. The logistics function is a critical dimension of time-based competitive strategies for companies (Fawcett and Clinton; 1996). Changes in overall warehouse locations, distribution of products among warehouses, transportation network, and mode of transportation impact the supply chain performance significantly (Kopczak, 1997). If the organization has higher logistics flexibility, it will have an opportunity to be more customer-responsive with respect to product delivery.

Mode of transportation is first measure of logistics flexibility. A product which can be delivered through multiple modes provides more logistics flexibility than a product which can be transported

via single delivery mode. For example, small electronics components can be shipped by land, sea, or air while a heavy machine may only be shipped by sea due to its size.

The number of delivery policies is the second measure of logistics flexibility. This measure is based on the time between customer order receipt and product delivery i.e. lead time for delivery. The third measure is the number of carriers per delivery mode, which is also analogous to another manufacturing flexibility measure called process flexibility.

The fourth and fifth measures are the number of customers served per facility and the number of distribution channels respectively that deal with the strategy of delivering product. A facility that can fill orders for a large number of different customers, then it demonstrates higher flexibility, and an organization which utilizes multiple channels through which a customer can purchase the product displays greater logistics flexibility.

The last two measures of logistics flexibility are ability to change total storage capacity and the ability to change delivery capacity, represent capabilities to change the overall capacity of the logistics network which includes material in storage and in transit.

Information Systems Flexibility

Lee and Ng (1997) mentioned three types of flow through a supply chain in their special issue on global supply chain management: material, finance, and information. Several research articles have been written on the use of information technology (IT) within an organization (Katayama and Bennett, 1999; Powell and Dent-Micallef, 1997; Palvia, 1997). Information systems flexibility can be defined as the ability of an organization's collective information system to adapt and support changing requirements of the business functions such as product development, sourcing, manufacturing and logistics and other strategic goals.

Sethi and King (1994) developed a concept called CAPITA (Competitive Advantage Provided by and Information Technology Application), which measures the firm's competitive benefits gained through the use of a single information technology application. Li and Ye (1999) used interactive regression to analyze the individual and collective effects of Information Technology (IT) investment, environmental, strategic, and management factors on firm performance.

The first measure of range and adaptability of information technology flexibility is the percentage of the global supply chain directly supported by the IT system. Higher the percentage of the global supply chain supported by IT, higher is the impact on performance. Higher levels of commonality among IT systems support worldwide transfer of knowledge between similar functions within the supply chain.

Supply Chain Performance with Flexibility

Garavelli (2003) used two extreme degrees of flexibility namely, no flexibility and total flexibility with an intermediate flexibility (limited flexibility) for performance evaluation of various flexibility configurations in supply chain. Each situation was configured with same number of suppliers, assemblers, markets, and products. His study is based on mainly process and logistics flexibility and their impacts on supply chain performance.

In general, the limited process flexibility at either supplier or assembler stage gives better result. In fact, an increase in degree of process flexibility from *limited* to *total* does not improve supply chain performance in the case of demand volume variability, while the improvement is not relevant in the case of demand mix variability. Distribution of process flexibility at supplier stage or assembler stage is another important question. In case of higher capacity variability, higher process flexibility at assembler stage is more beneficial. Also, an increase in degree of

logistics flexibility is always beneficial. The limited logistics flexibility is very effective in both cases of limited and total process flexibility.

Avittathur and Swamidass (2007) observed the relationships between the supplier and plant flexibility and their impacts on profitability and work-in-process inventory. There must be compatibility between supplier flexibility and plant flexibility to improve the profitability, since highly flexible supplier with not flexible plant may result in high material cost and low profitability. Similarly, work-in-process inventory is drastically reduced when less flexible suppliers are used by flexible plants. Work-in-process inventory remains unchanged when suppliers are flexible and plant flexibility increases from low to high because a flexible supplier helps to reduce work-in-process inventory regardless of plant flexibility.

Sourcing flexibility is the most important factor for success of global supply chain. Flexibilities in selection of sources, volume and delivery have positive impacts on market uncertainty in terms of variability in product mix and demand size. Material cost and transportation cost with market location plays an important role in deciding the selection of supplier. For example, India has become an outsourcing hub for auto-components due to low steel cost, low labour cost, and being a big car market. Sourcing flexibility may support the arms-length relationship with suppliers, but strategic partnership with flexibility is more beneficial to cover various uncertainties in supply chain.

Revolution in information technology is one of the facilitators for globalization of world economy and businesses. A global supply chain covers wider geographical area and for coordinating various activities in the supply network an integrated information system is required. To reduce the information delay, a centralized data warehouse and (EDI) electronic data interchange are used. In inventory and storage control RFID (radio frequency identification) is very helpful. Not only in supply chain even in manufacturing system, information technology is very helpful in providing software support for automated design, manufacturing, and various business functions.

Conclusion

In the paper, various characteristics of flexibility in global supply chain have been discussed. Different views of researchers about the flexibility have been highlighted. The concept of individual flexibility is linked with overall flexibility of supply chain. It has been observed that flexibility in every aspect in supply chain is possible, but there is requirement of cost analysis for different degree of flexibility; so that the degree of flexibility of one activity can be interrelated with other activities considering the cost- benefit analysis.

Supply chain performance with flexibility in various activities has been analyzed and it is observed that compatibility of flexibility of one activity with the other is very important. For example, supplier capacity flexibility must be compatible with plant flexibility to improve the supply chain profitability and work-in-process inventory. Logistics flexibility should be compatible with suppliers and plant flexibility to meet the demand variability.

This study has shown how the flexibility configurations of supply chain activities are important to respond to the environment of uncertainty. Also, the range of flexibility and its impacts on supply chain performance has been analyzed properly.

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Flexibility in Global Supply Chain: A Review of Perspectives

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