# A Conceptual Framework for Assessing Supply Chain Flexibility

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### Abstract

Flexibility has been considered as a major determinant of competitiveness in an increasingly intense competition in the marketplace. A large body of literature has been addressing various issues of flexibility in the last two decades. However, the discussions have mainly been from the viewpoint of a manufacturing company as a single entity in a supply chain. The flexibility related to machine, process, routing, part, worker, and the like are all associated with a manufacturing or a production system. With the advent of the supply chain management concepts, business communities have been realizing that being flexible in a production system only is not sufficient. To be competitive, flexibility must be pursued by a supply chain. Thus, flexibility concepts should be broaden from the perspective of a production system into a supply chain system. However, there is limited study to date addressing flexibility of a supply chain.

This paper presents a framework for supply chain flexibility assessment. Four main parts of flexibility are identified including flexibility of the product delivery system, production system, product development, and sourcing or supplier system. In each of these parts, four flexibility measures are defined: volume, types, speed, and cost The framework can be used to assess in each of the flexibility elements **the need** and **the ability** of the supply chain to be flexible. Hence, a supply chain could identify whether there is a match between the need and the ability to be flexible. A flexibility map is then used to provide a clear picture on the areas where the supply chain needs improvement in flexibility.

Key words: supply chain, flexibility assessment, framework.

#### 1. Introduction

Today's customers are smart and clever. They are not anymore accepting standard products as were the case of many years ago. To a supply chain, such diverging customer needs represent two things. Firstly, it is a source of intense competition. Suarez, et al (1995) stated that high competition means highly volatile markets, short product life cycle, and highly sophisticated buyers. Secondly, it is a cause of uncertainty. With customers requiring highly diverging products in the market, it becomes highly difficult for the supply chain to accommodate the customer's aspiration into product design and to predict the level of demand for a certain product.

These all contribute to difficulty in managing the operations of a supply chain. In addition, high product variability increases the costs associated with production and delivery of products to the customers. This is logical since, when the variety of products demanded by the customers is high, the supply chain will loss the opportunity to exploit the economic of scale in many of its activities. The cost implication for this situation is clear: the unit price to be paid by the customer is higher, especially when the supply chain is not flexible enough to manage products with high variety. A study conducted by Berry and Cooper (1999) has shown that productivity of a production system decreases when the product variety is increased. Consequently, to stay competitively in the marketplace, a supply chain is required to be able to produce various different products and deliver to the market in an acceptable speed and cost. This implies that flexibility is an important competitive advantage a supply chain should pursue to win an intense competition.

Despite the unquestioned importance of flexibility, there should be an assessment on how much flexibility a supply chain should have. In many types of products, such as salt, sugar, and mineral water, the need for flexibility is much less than for innovative products such as fashion and computers. Fisher (1997) provides a nice classification of products into two types: functional and innovative. Functional products are characterized by relatively long life cycle, few product variations, and easy to predict demand, thus error in forecasts at the time production is committed is less than 10%. On the other extreme, the innovative products are characterized by short product life cycle, wide variety of products, and consequently, the forecast errors are normally high.

The focus of the supply chain in responding to these two types of products should certainly be different. A supply chain supplying innovative products should pursue responsiveness while for functional products, cost should be the primary focus. Based on this classification, innovative products certainly require higher supply chain flexibility than

the functional products do. It is important therefore that the assessment of flexibility for a manufacturing company as well as for a supply chain should relate the ability and the requirements for being flexible. Suarez et al (1995) argued that a company's competitiveness is determined by the ability of a company to answer the need from the market in terms of quality, efficiency, and flexibility. It implicitly implies that a company does not need to be very flexible if the market does not require it. This notion is important because, as stated by Bengtsson (2001), investment for flexibility is often costly and thus, high flexibility should be pursued only if the market indicated the need for it.

In this paper, a framework for supply chain flexibility assessment is presented. The framework is designed in such as a way that a supply chain can compare between the need and the capability of a supply chain to be flexible in various elements of supply chain flexibility. Before describing the flexibility assessment model, a review of manufacturing flexibility and supply chain flexibility will be presented in the following two sections.

### 2. Manufacturing Flexibility

In the last two decades, manufacturing flexibility has been an issue that attracts much attention of the academics. A large body of literature have been addressing flexibility as an important competitive advantage. D'souza and Williams (2000) classified manufacturing flexibility into externally-driven and internally-driven manufacturing flexibility where each has two elements. The externally-driven manufacturing flexibility includes two dimensions, volume and variety flexibility while the internally-driven flexibility includes process and material handling flexibility. Each of the dimensions has two elements: range and mobility. The authors offer a quite general definition on the two elements. Range is defined as the range of output volumes at which the firm can run profitably. The mobility on the other hand was measured in terms of cost implication and the time required to increase or decrease the volume of output.

Koste and Malhotra (1999) presented a comprehensive review on manufacturing flexibility. Ten dimensions of flexibility were identified from a large number of previous literature addressing flexibility. The dimensions include flexibility in machine, labor, material handling, routing, operations, expansion, volume, mix, new product, and modification. The ten dimensions were then mapped into four elements: range-number, range-heterogeneity, mobility, and uniformity. While the dimensions seem to cover a wide definition of flexibility, they are merely addressing the elements of flexibility internal to a manufacturing system.

Chang et al (2001) conducted an empirical study on the relationships between business strategy and manufacturing flexibility. Six dimensions of manufacturing flexibility were used: product, product mix, product modification, volume, delivery, and service. They suggested that companies should select appropriate dimensions of manufacturing flexibility and related those dimensions with the strategy of the firm. Their survey on machine tool and machinery industries in Taiwan suggested that developing manufacturing flexibility and business strategy will provide firms with competitive advantages and better business performance from the aspects of successful new product introduction, net profit, and sales. Hence, firms should invest on resources and time to develop manufacturing flexibility to fit into their business strategies.

### **3.** Supply Chain Flexibility

In the context of a supply chain, where the overall performance is determined by a network of companies, being flexible as a manufacturing system alone is inadequate. A manufacturing system is only one element of a supply chain. In other words, when flexibility is required, not only a single manufacturing company needs to be flexible, the whole chain does. Thus, the flexibility should consider elements that deal with interrelationships between channels of a supply chain. In their review of empirical research on manufacturing flexibility, Vokurka and O'Leary-Kelly (2000) presented 15 dimensions of manufacturing flexibility where many are the same with those identified in Koste and Malhotra (1999) which focused on elements of manufacturing flexibility. Although the latter identified other types of flexibility such as market and delivery flexibility, it seems that the focus is not specifically focused on the interface between channels in the supply chain.

A limited number of recent papers have extended the focus of flexibility from a manufacturing system to a supply chain. The notion that flexibility should be supported by the whole channel in a supply chain seems to have been the main motivation for the authors addressing supply chain flexibility. As stated by Duclos et al (2001) supply chain flexibility should be extended beyond one firm's internal flexibility. For example, when a manufacturing firm introduces a new product which requires different specification of materials, not only its production system needs to be flexible, but also the production system of the supplier. Likewise, when there is a sudden large demand arriving at a manufacturing company, there should be flexibility in allocating purchases of raw materials to different suppliers if one supplier is not able to provide the whole requirements. Thus, many dimensions of flexibility outside of a manufacturing system should be taken into account.

In an attempt to develop a supply chain flexibility model, Duclos et al (2001) considered six elements of flexibility: production system, market, logistics, supply, organizational, and information system. Swafford et al (2001) developed a similar model on supply chain flexibility and agility. They defined that global supply chain agility is a measure of the supply chain's ability to adapt in a timely and cost effective manner to a rapidly changing global competitive environment in providing products and services. The agility of a supply chain, according to the authors, is impacted by flexibility in product development, procurement, manufacturing, and logistics. Each dimension of flexibility is defined by range and adaptability. Similar to the elements proposed by Slack (1983) and D'souza and

Williams (2000), range is defined as the number of different states, such as levels, options, and positions, that can be achieved with existing resources and adaptability is the ability to change from one state to another in a timely and cost effective manner.

In a recent paper, Prater et al (2001) stated that supply chain agility is determined by speed and flexibility of sourcing, manufacturing, and delivery. Speed is a measure of the time it takes to ship or receive a good. Flexibility on the other hand is the degree to which the firm is able to adjust the time in which it can receive or ship the goods. According to the authors, the degree of agility of a firm's supply chain is determined by the configuration of the three dimensions (sourcing, manufacturing, and delivery) to incorporate speed and flexibility.

#### 4. The Model

We present a model for supply chain flexibility assessment in this paper. The model is based on a notion that each supply chain requires different degree of flexibility. As stated in an earlier part of this paper, there are products that should be managed with high flexibility while others require lower flexibility. Many functional products do not need various types of flexibility defined in many earlier papers on manufacturing and supply chain flexibility. This implies that a supply chain should identify the characteristic of products and the degree of flexibility required in various dimension of flexibility. In other word, the competitiveness of a supply chain is determined by how much a supply chain match the required flexibility in each of the relevant dimensions.

Figure 1 illustrates a general framework showing the relationship between the degree of flexibility required and the capability of the supply chain to satisfy such a requirement. A supply chain is well matched if the capability for being flexible in any dimension is about equal to the requirement. A supply chain is under-designed if the requirement for flexibility is significantly higher that the corresponding capability. Conversely, it is over-designed if low flexibility requirement is dealt with high capability. In case of under-designed, a supply chain may need some types of investment to increase flexibility capability.



Figure 1 A general framework for assessing supply chain flexibility

The above framework should be used to identify where each flexibility dimension lies in the diagram. A one to five likert scale may be used to map both the requirements and the capability for being flexible. In a supply chain, not all dimensions are of the same degree of importance, hence, the requirements are not the same for each flexibility dimension. Similarly, a supply chain may have high capability in one dimension but low capability on another. Using this framework, a supply chain should be able to identify in which dimension the improvement should be prioritized.

The assessment should be made on each dimension of flexibility. We propose that flexibility of a supply chain is much determined by the flexibility of the supply chain function as an integrated element. In principle, each function within a supply chain should pursue for flexibility. As in Swafford (2001), four dimensions of supply chain flexibility

are considered in this paper: souring, product design, production / manufacturing, and delivery. For each of the four dimensions, flexibility is assessed by the range of volume and variety as well as speed and cost. Table 1 presents the functional dimensions and measures of supply chain flexibility.

<b>Functional Dimensions</b>	Measures Dimensions				
	Volume	Variety	Speed	Cost	
Sourcing	1.1	1.2	1.3	1.4	
Product Development	2.1	2.2	2.3	2.4	
Production	3.1	3.2	3.3	3.4	
Delivery	4.1	4.2	4.3	4.4	

 Table 1 Functional dimensions and measures of supply chain flexibility

Sourcing flexibility is flexibility of any activities related to procurement of materials and outsourcing of activities not to be performed in house. Volume flexibility in sourcing is a measure of how easy the company changes the quantity of materials to be delivered from the supplier. In many instances a manufacturing company requires only a small quantity of materials. In other instances, the manufacturing company requires a significantly larger quantity of materials than normally ordered. The sourcing system is said to be flexible if any quantity required (volume) can be satisfied by the supplier. This capability may be obtained by having a single flexible supplier or a number of suppliers with different focus of operations. One supplier may requires a large minimum order quantity and could satisfy large quantity in an acceptable time and cost. Another supplier may be operating on flexibility focus but charging the company a higher price. Hence, sourcing system flexibility is determined by various different sourcing schemes. In terms of variety, a company which often introduces new products requires flexibility of the supplier in supplying different types of materials. Such flexibility should be achieved with minimum time and cost. Table 2 provides the description of the flexibility dimensions for a supply chain.

Product development flexibility is determined by the ability of the company to produce various new designs (variety) in a timely (speed) and cost effective (cost) manner. When a supply chain is supplying a large number of different products, the ability to produce new design quickly in a cost effective manner is important. Activities related to product design are not solely the responsibility of the manufacturing company. When a new product is developed, the ability of the supplier to supply the required materials is necessary. The supplier also often provides technical assistance in developing new products. On the other hand, when the responsibility of developing new products is on more than one organizations' shoulder, there should be a mechanism to easily communicate design ideas, including files, prototypes, etc. Product development flexibility assessment should take into account such linkages in the context of a supply chain.

Manufacturing or production flexibility is related to the ability of the manufacturing system to produce products of different types (variety), different quantities (volume) at an acceptable speed and cost. In the previous section, it has been described that manufacturing flexibility has been an issue for academics and practitioner for more than two decades. Achieving manufacturing flexibility means investing in technology and human resources. For example, to obtain volume flexibility in production, the manufacturing system should be able to produce economically small as well as large production batch. In this context, the manufacturing flexibility is much determined by the machine and worker flexibility. A manufacturing system which possesses general purpose machine and multi-skilled workers will be able to provide variety flexibility, that is, they are able of producing products with a wide variety of specifications.

No	Description	Require-	Current	Gap
		ments	State	
1.1	The availability of the suppliers who are able to			
	supply materials with flexible quantity			
1.2	The availability of the suppliers who are able to			
	supply materials with flexible specification or			
	types			
1.3	The time required to change the volume and/or			
	the type of materials ordered			
1.4	The cost incurred when the company require to			
	change the quantity and/or types of items			
2.2	The ability of the company to produce a wide			

 Table 2 A framework for supply chain flexibility mapping

	variety of designs		
2.3	The time required to produce a new design		
2.4	The cost incurred to produce a new design		
3.1	The ability of the production system to produce flexible quantity of outputs		
3.2	The ability of the production system to produce various types of outputs		
3.3	The time required to change the quantity and/or types of output		
3.4	The cost implication of changing the quantity and/or types of output		
4.1	The ability to deliver various different quantity of products		
4.2	The ability to deliver products of various types		
4.3	The time required to increase or decrease the quantity and/or to change the types of products to be delivered		
4.4	The cost implication of changing the quantity and/or the types of products to be shipped to the customers		

The last element of supply chain flexibility is delivery flexibility. This is a measure of the ability of the supply chain to deliver products to the customers with a wide range of volume, types (variety) at an acceptable costs and time. Delivery flexibility is a difficult issue due to complexity of elements interrelated in a distribution system. When assessing a distribution system flexibility, one needs to consider whether it is possible to schedule different routes in each day of the delivery, the range of size of trucks owned by the company, the ability to rent trucks from different sources, and whether or not a distribution system allows a transshipment system to work where a product can be delivered from another parallel channel in addition to shipment from an upstream channel of the supply chain. In addition, the customers may frequently require small quantity of products to be delivered immediately. To satisfy such requirements, a delivery system should have the capability to either mix different products into a truckload and/or uses different mode of transportation.

### 5. Performing an Assessment

To perform a supply chain flexibility assessment, the above framework may need to be decomposed into smaller elements of flexibility. For example, when assessing 4.1: The ability to deliver various different quantity of products for example, one may need to define the elements of volume flexibility of a delivery system. This may include the availability of vehicle with different capacities, the fixed transportation cost, and the capability of the system to deliver a mix of different products into one vehicle. For each element, there should be a clear definition on the scoring scheme to be applied to both the current state and the requirements. A likert scale of 1 to 5 may be applied where, for requirements, the definitions may be as follows:

- 1 The corresponding flexibility element is virtually not relevant and thus, not important to be considered.
- 2 The corresponding flexibility element has low importance
- 3 The corresponding flexibility elements has moderate importance
- 4 The corresponding flexibility elements has high importance
- 5 The corresponding flexibility elements has very high importance

Similarly, for the current state column, the same likert scale may be applied where the scores are defined as follows:

- 1 The supply chain is very inflexible in the corresponding flexibility element
- 2 The supply chain has low flexibility in the corresponding flexibility element
- 3 The supply chain has moderate flexibility in the corresponding flexibility element
- 4 The supply chain has high flexibility in the corresponding flexibility element
- 5 The supply chain has very high flexibility in the corresponding flexibility element

The gap is then obtained by subtracting the score for current state from the score for requirement. A positive gap represents a need for improvement of flexibility in the corresponding flexibility element. The results should then be mapped into a diagram like that shown in Figure 1. The results of the analysis will provide the management with an insight on what aspect of the supply chain needs improvement and/or investment in order to increase flexibility.

The assessment may be performed by a group of relevant persons in the supply chain. The relevant persons should include Procurement manager, R & D manager, Production manager, as well as Marketing or Distribution manager.

### 6. Concluding Remarks

A general framework for supply chain flexibility assessment has been presented in this paper. The paper extends the current literature on flexibility which focuses on manufacturing flexibility. This extension is important with the advent of supply chain management concepts in the last two decades. There are two important notions as impetus of this paper. First, flexibility for a supply chain can not be created merely by a single manufacturing company within the chain, thus assessment should also include inter-organizational flexibility. Second, the degree of flexibility should match the requirements, otherwise a supply chain maybe too low (under-design) or too high (over-designed). The framework proposed in this paper enable a supply chain to compare between the requirement and the current capability of a supply chain for being flexibility dimensions.

We are in the process of applying the framework to a number of manufacturing companies in Indonesia, but the results are yet to be compiled. When applied to a real company or supply chain, several modifications may be required in the model, taking into account that each supply chain will need emphasis on different flexibility elements.

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