THE IMPLEMENTATION AND MANAGEMENT OF SUPPLY CHAIN FLEXIBILITY: CONCEPTUAL FRAMEWORK

This research develops a conceptual framework 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, namely Required Flexibility Identification, Implementation and Shared Responsibility, and Feedback and Control.

Introduction

Implementing and managing manufacturing flexibility is a complex task. This complexity is primarily due to the multi-dimensional nature of manufacturing flexibility and the lack of widely accepted and robust measurements. Manufacturing flexibility is comprised of many different types and can exist at different levels of the organization (i.e., strategic, tactical, operational), and each with various aspects (i.e., potential, actual, required), which can be measured in terms of its range, mobility, and uniformity. The multi-dimensional nature of manufacturing flexibility means that the flexibility required by one organization may not be of the type or level required by another organization. As a result, manufacturing flexibility is not generic and cannot simply be treated as a commodity that could be bought off-the-shelf and immediately applied; rather, it should be justified, planned, and managed carefully in order for its potential benefits to be fully realized (Gustavsson 1984).

To attain the level of flexibility that customers value, organizations must look beyond manufacturing flexibility. Since Skinner's (1969) landmark paper, researchers have advocated direct interaction between operations and customers, implying that manufacturing should not be insulated from customers by buffers such as finished goods inventory and marketing tactics (Nemetz and Fry 1988). From the perspective of filling customer orders, no single part of the value chain working alone can significantly reduce customer lead-time (Zhang et al., 2002). Only cross-functional and cross-company efforts to increase flexibility and eliminate uncertainties can create the level of performance needed to create competitive advantage (Hamel and Prahalad 1989, Blackburn, 1991).

By the 1990's, firms recognized the necessity of looking beyond the borders of their own firm to their suppliers, suppliers' suppliers, and customers to improve overall customer and consumer value. This movement, called supply chain management or demand chain management, changed companies' focus from internal management of business processes to managing across the enterprise. As companies have improved their internal operations by increasing product quality while reducing costs, firms have achieved parity on these dimensions in many industries. These companies are looking to develop competitive advantages in areas such as delivery, flexibility, and innovation. All of these emphasize the importance of time (Vokurka et. al 2003). Firms have found that a successful initiative to accomplish this objective is through supply chain. The academic forum (1999) suggests that the traditional competition of company versus company is changing towards supply chain competes against supply chain.
As the basis of competition expands to the supply chain and time becomes increasingly important, a critical issue will be the flexibility of the supply chain (Vokurka et. al 2003). Overall, the literature on the topic is new and needs to provide answers to basic questions that supply chain managers need to address: What is the required supply chain flexibility taxonomy? How can supply chain partners implement and share the responsibility of the required supply chain flexibility? What is the impact of the required supply chain flexibility on supply chain performance? This paper develops a new conceptual framework for the implementation and management of supply chain flexibility, based on a synthesis of the strengths and weaknesses of existing frameworks in manufacturing flexibility as well as the little existing research dealing with relationship between flexibility and supply chain management. Supply chain flexibility taxonomy so far in literature has been identified based on previous operations literature we believe it should be examined from the integrative, customer-oriented perspective. Hence, supply chain flexibility taxonomy is defined in this research as encompassing those flexibilities that directly impact a firm’s customers (i.e., flexibilities that add value in customers’ eyes). Further, making use of the existing frameworks in manufacturing flexibility literature, this new conceptual framework proposes 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.

**Supply Chain Flexibility Defined**

A great deal of research into defining various types of flexibilities in manufacturing has occurred over the last two decades. Despite this, there is no general agreement on how to define flexibility. The most basic definitions of flexibility are concerned with the ability to effectively adapt to changing circumstances (Mandelbaum, 1978). However, this rather popular definition of flexibility does not explain what “ability” means and is hard to operationalize. Various researchers have modified the basic definition to consider the manufacturing system, process, product, or part in an attempt to develop a definition of flexibility more applicable to manufacturing activities. Within this context, manufacturing flexibility has been defined as the ability of the manufacturing system to produce a wide variety of parts or assemblies, without intervention from outside to change the system (Buzacott, 1982). The major weaknesses of these definitions are that they consider manufacturing flexibility solely as an adaptive response to uncertainty and fail to consider flexibility performance criteria such as cost, time, and quality. Upton (1994), who considered flexibility as being the result of various dimensions, each of which appears in different time intervals and with three distinct ‘elements’ or ways of being flexible: range, mobility, and uniformity. Considering various elements researchers define manufacturing flexibility as the “ability of the manufacturing system to change or react with little penalty in time, effort, cost, or performance” (Upton, 1994; De Toni and Tonchia, 1998). Although such definitions do consider performance criteria such as quality, cost, and time, they suffer the drawback of not considering the strategic or competitive importance of manufacturing flexibility. A few definitions move beyond manufacturing as simply the capability to adapt to uncertainty to consider strategic, market, or management issues. Hyun and Ahn (1992) state that strategic flexibility refers to the ability of firms “to reposition themselves in a market, change their game plans, or dismantle their current strategies when the customers they serve are no longer as attractive as they once were.”

The definitions of manufacturing flexibility play an important role in defining supply chain flexibility. However, as the supply chain extends beyond the enterprise, supply chain flexibility must also extend beyond one firm’s internal flexibility. Based on the supply chain
definitions and concepts, supply chain flexibility should be viewed from the perspective of the entire value-adding system, i.e., total system flexibility (Hyun and Ahn, 1992). The definition of supply chain flexibility for this research considers the definitions just described, flexibilities that directly impact a firm’s customers. The operational definition of supply chain flexibility for this research is “the ability of supply chain partners to reconfigure their assets and operations and share the responsibility to react to emerging customer trends (product, volume, new product, delivery, and responsiveness) at each node of the chain to produce a variety of products in the quantities, cost, and qualities that customers demand, while still maintaining high performance.”

The Need for New Supply Chain Flexibility Framework

Various researchers have attempted to develop frameworks for implementation and management of manufacturing flexibility. The existing implementation and management manufacturing flexibility frameworks also have individual strengths, which can play an important role in developing implementation and management supply chain flexibility frameworks. However, to-date there is no attempt in the literature to develop a framework for implementation and management of supply chain flexibility. Supply chain flexibility is a crucial factor at the strategic level. Since successful supply chain management has become an order winner, the flexibility of the supply chain may determine the survival of a firm (Vastag et al., 1994). However, most research on manufacturing flexibility has overlooked supply chain management issues in general. This is surprising considering that the integration of the supply chain into design and management decisions is critical to the success of responsive manufacturing strategy (Fawcett, 1992). For example, the integration of the internal capabilities of firms, suppliers, and customers can enhance manufacturing performance and the flexibility of an organization (Youssef, et al., 1999). Clearly, we need to investigate the limitations of supply chains to offer advice to firms on how to limit their vulnerability.

Unfortunately, the literature does not give helpful advice on how to deal with supply chain vulnerability (Prater et al., 2001). Moreover, the literature does not give guidance on how much uncertainty and complexity should be reduced. Or, in other words, what aspects of supply chain flexibility types and levels should a firm limit in order to reduce the complexity and uncertainty of its supply chain? Current guidelines are insufficient in proposing the kind of flexibility required by an organization. Expecting a system to acquire the many different types of flexibility may not be feasible, or possible (Narain et al., 2000). In today’s competitive business environment, a supply chain flexibility framework is not only desired, but becoming an urgent necessity to provide guidance for supply chain organizations to deal with this uncertain complex environment.

Developing the Components for a Supply Chain Flexibility Framework

The major components of the proposed framework are based on current review researches in the manufacturing flexibility literature as well as the Zhang et al. (2002) framework and the Vickery et al. (1999) empirical study. The strengths and weaknesses of these frameworks and the empirical study are analyzed to identify the important issues that must be considered when implementing and managing supply chain flexibility, and those components that need to be incorporated into a new integrated framework. In total ten frameworks are introduced and examined independent of one another. The frameworks developed by Swamidass and Newell (1987), Kumar and Kumar (1988), Sethi and Sethi (1990), are considered along with those progressed by Suarez et al. (1991), Hyun and Ahn (1992), Gerwin (1993), Narain et al. (2000).
Vokurka and O’Leary Kelly (2000), and Zhang et al. (2002) complete the literature review with the inclusion of the empirical study of Vickery et al. (1999). The flexibility components, derived from the existing framework that have been incorporated in constructing the new supply chain flexibility framework outlined in Table 1 and summarized in Appendix A. Some of the frameworks analyzed in this section such as Suarez et al. (1991), Gerwin (1993), and Narian et al. (2000) can be used for implementing and managing supply chain flexibility. These frameworks have a number of strengths and weaknesses that must be addressed by any new framework that is to be developed. However, the remaining frameworks address important issues in constructing supply chain flexibility taxonomy and therefore must be considered in any new framework. In this section an examination of the strengths and weaknesses of four frameworks out of ten are discussed.

Gerwin’s (1993) framework examines manufacturing flexibility in the context of five variables: specifically identifying environmental uncertainties, developing a manufacturing strategy, determining the required manufacturing flexibility, implementing the required flexibility, and developing performance measurements. Based on this framework, author proposes a sequence of four steps or phases for implementing and managing manufacturing flexibility, identifying flexibility dimensions requiring investigation, measuring gaps, selecting methods for closing gaps, and continuous assessment. This framework provides various feedback loops, suggesting the need for continually monitoring flexibility to ensure that the manufacturing strategy is being achieved. This framework highlights the need for continual management of manufacturing flexibility, by suggesting that managers must ensure that required flexibility will be periodically measured, as well as measured and evaluated as organizational strategies and uncertainty change. The main weaknesses of this framework are: i.) no relationship is stated between manufacturing flexibility and business performance; ii.) the framework does not consider technological capabilities or organizational attributes; and iii.) the framework emphasizes that manufacturing flexibility must be stated in terms of range and speed (i.e., mobility); however, it does not consider uniformity.

Suarez et al. (1991) suggest a three-stage approach for achieving manufacturing flexibility. These three stages are the need for flexibility, the implementation of flexibility, and the flexibility fit between required and observed flexibility. The first stage is focused on determining the types and levels of flexibility needed to adequately address uncertainty. To determine the specific flexibility types and levels required, managers must first identify the factors that affect the need for flexibility. These factors are referred to as flexibility need factors and are found both within and external to the organization. The flexibility need factor in the internal realm of the organization is the product strategy. In the external realm, the organization must consider, demand characteristics, competitor behavior, product life cycle, and end-product characteristics. Based on these flexibility need factors managers will determine the required types and levels of manufacturing flexibility to implement. The required types and levels of flexibility are achieved by implementing various flexibility source factors. The first two stages of this framework allow managers to implement the required types and levels of flexibility. During stage three, flexibility fit, managers review the required configuration of flexibility, as identified in stage one, to the observed configuration of flexibility, as implemented in stage two. If a gap exists between the required and the actual flexibility, then, via a feedback mechanism, the flexibility sources factors are reexamined and adjusted. However, as suggested by Gerwin (1993), this framework does not adequately differentiate between market uncertainty and strategy. However, there is no feedback loop extending from Stage III to Stage I (i.e., Need for Flexibility). As a result, this framework does not consider that unexpected performance may be the result of managers inaccurately determining flexibility needs (e.g., the types and levels of flexibility to pursue).
Vickery et al.’s (1999) does not propose a framework instead; this empirical research focuses on flexibility in the supply chain. This research addressed several issues such as whether greater uncertainty, as perceived by managers, would be associated with a greater emphasis on supply chain flexibility. The second research question examines whether greater strategic emphasis or performance on one dimension of supply chain flexibility is associated with a greater emphasis or performance on another dimension. The next question addressed whether high performance on supply chain flexibility helps the bottom line (i.e., overall firm performance). Finally, responsibility assignments for supply chain flexibility are investigated by comparing top performers versus the rest. Overall, manufacturing has dominant responsibility for volume flexibility, and marketing has dominant responsibility for access flexibility. The major limitation of the research was that it focused only on internal functional areas’ responsibilities for supply chain flexibility performance and did not examine the possible contributions of suppliers and/or channel members. However, by focusing on these flexibilities from an internal perspective, much of the contribution of a supply chain perspective is lost (Vokurka et al., 1999).

Narain et al. (2000) suggest the first steps in implementing and managing manufacturing flexibility is the identification of the uncertainties that exist as a result of the organization’s competitive situation. These uncertainties are then evaluated against the capability of the organization to address such uncertainties. This evaluation is performed using a SWOT (i.e., Strengths, Weakness, Opportunities, Threats) analysis. Based on this SWOT analysis, the competitive strategy for the organization is formed which, in turn, dictates the manufacturing, marketing, and other functional strategies. The manufacturing, marketing, and organizational strategies are then used to determine the strategic level flexibility. The strategic flexibility is then used to identify the operational and tactical flexibility needed to achieve the organizational strategies. The authors suggest that some flexibility types and levels chosen may conflict with or overlap one another. As a result, the strategic, operational, and tactical flexibility types and levels must be reconciled by determining what flexibility is necessary, sufficient, and competitive. Further, managers may not have the resources to implement all the required flexibility types and levels at once, and therefore the required flexibility types must be prioritized. As the competitive environment and organizational strategies often change, audits are needed to ensure the tools selected are achieving the required flexibility types and levels and that the required flexibility type and levels are still meeting the organizational strategies. This framework outlines the link between manufacturing, marketing, and organizational strategies, suggesting that the needs of marketing, and organization as a whole, must be considered when implementing manufacturing flexibility. The authors emphasize that non-technical means can be used to achieve manufacturing flexibility, such as facility layout and multi-skilled employees. However, this framework suffers from a number of weaknesses. First, while this framework partially outlines the relationship between uncertainty, strategy, and manufacturing flexibility, the framework fails to consider the direct influence that uncertainty plays on manufacturing strategy. Second, this framework does not suggest the relationship between manufacturing flexibility and business performance.

### Required Supply Chain Flexibility Taxonomy

Before we discuss the three stages for achieving supply chain flexibility, we will review the reasons for choosing these particular dimensions, and provide a working definition for each dimension. All the companies in the chain, their staff, buildings and equipment would not exist without the end consumer(s) buying their products or services. Therefore, all activities within a supply chain should be directed or focused towards satisfying consumers’ need. Supply chain flexibility taxonomy should be viewed from the perspective of the entire value chain-adding system, i.e., total system flexibility (Hyun and Ahn, 1992). This viewpoint suggests that supply
chain flexibility should be examined from an integrative, customer-oriented perspective. Therefore, required supply chain flexibility taxonomy encompasses those flexibilities that directly impact a firm’s customers. In addition, these chosen flexibilities taxonomy appear to include other kinds of flexibility, both of a general nature and those related to specific manufacturing or operation problems (Suarez et al., 1991). Table 2 presents a working definition of the five basic types of required supply chain taxonomy.

The first of these is **product flexibility**. Product flexibility is a value-adding attribute that is immediately visible to the customer. Carter (1986), and Gerwin and Tarondeau (1989) suggest product flexibility allows the company to be responsive to the market by enabling it to bring newly designed products quickly to the market. We have defined product flexibility as the ability of the supply chain system to produce customized product or upgrade existing ones to meet special customer specifications. A second required flexibility discussed in operations literature is **volume flexibility.** Volume flexibility directly impacts customers’ perceptions by preventing out-of-stocking conditions for products that are suddenly in high demand. Hays and Wheelwright (1984) have described the importance of this capability in a highly cyclical industry such as furniture, emphasizing the necessity of being able to accelerate or decelerate production very quickly and juggle orders so as to meet demands for unusually rapid delivery. We have defined volume flexibility as the ability of the supply chain system to control production levels (increasing or decreasing) profitably to meet customer demand. Another critical supply chain flexibility with high customer impact is **delivery flexibility.** In an environment where instant appreciation is becoming the norm, the ability to make a product widely available and easily accessible is critical (Vickery et al., 1999). This flexibility captures a company’s proficiency at getting the product “close to customer.” We have defined delivery flexibility as the ability of the integrated logistic system to distribute and deliver the product from the raw material source to the final customer.

As product life cycles dramatically decrease, increasing strategic emphasis is being placed on bringing many new products to market as quickly as possible. The innovation literature abounds with examples of companies that have gained a variety of competitive advantages by being first to the market (e.g., Chrysler Minivans introduced in the 1980s). Our definition of new product flexibility is the ability of supply chain partners to collaborate to produce new products in response to the market demand. The final required flexibility related to a supply chain focus is "response to the market." The need to make operations more flexible and thereby increase corporate responsiveness has been well documented within the literature (De Toni et al., 2001). Gerwin (1993) stated, “If market uncertainties continue to intensify over the next few years flexibility responsiveness may become the most significant dimension”. We define responsive flexibility as the capability of a supply chain system to respond quickly to the market change to satisfy customer demand.

**A conceptual Framework for Implementing Supply Chain Flexibility**

Figure 1, which represents the schematic diagram for the new conceptual framework, proposes that supply chain flexibility should be implemented and managed using a three-stage approach, specifically: required flexibility identification, implementation and shared responsibility, and feedback and control.
Stage I Required Flexibility Identification

The stage one of the framework suggests that the competitive strategy will determine the functional strategies, such as those for manufacturing and marketing (Narain, et al., 2000). In order to develop the manufacturing strategy, manufacturing managers will be required to analyze the current and potential internal and external uncertainty faced by their department (Swamidass and Newell, 1987), and the potential impact of this uncertainty in achieving the competitive strategy of the organization. Thus, to make sense of these environmental uncertainties, Porter (1985) recommends defining the weaknesses, opportunities, strengths, and threats (SWOT analysis) of an organization and its market. This analysis involves identifying the uncertainty that surrounds the organization and analyzing the organization’s general capability to address this uncertainty. Vokurka and O’Leary-Kelly (2000) suggest that manufacturing managers must examine the technological capabilities and organizational attributes that exist within the organization in general. Supply chain managers will also need to analyze their supply chain characteristics and customer characteristics. These two types of characteristics encompass the following dimensions: supply chain characteristics which include Number of supplier, Average size of the suppliers, Asset specificity, Information linkage, and Nature of contracts; and customer characteristics which includes Information required for products, Product life cycle and maintenance, and Verifications for pre-purchase. Within this competitive analysis, the supply chain organization needs to develop its overall corporate mission and strategy.

Therefore, once the supply chain strategy has been identified, the role of flexibility, if any, in achieving this strategy must be stated as a flexibility strategy. This strategy is derived from both the manufacturing and marketing strategies and is focused on adapting, redefining, or banking strategy, or as emphasized by Gerwin (1993), a combination thereof. From the flexibility strategy, the required supply chain flexibility types, measurements, and levels needed to achieve this flexibility strategy are identified.

The required flexibility types and measurements must be carefully selected and justified due to the potentially large impact (e.g., financial, time, employee changes, customer perception) on the supply chain system, resulting from implementing supply chain flexibility. Also critical to this is an analysis of the potential and actual flexibility for each required type of supply chain flexibility. This analysis is needed to determine the extent of change that must occur to achieve the required flexibility and will therefore influence the selection of organizational and technological tools. For example, suppose an organization already has some excess volume flexibility, achieved by a combination of multi-skilled employees and long relationships with subcontractors. However, this potential flexibility is less than the required flexibility needed to achieve the flexibility strategy. In this case, the potential flexibility may influence the decision to try to increase the level of these organizational tools (multi-skilled employees and agreement with sub-contacts) to meet the required volume flexibility, versus using other tools, such as in this example, the implementation of a flexible manufacturing system. Finally, examining the current capabilities of the supply chain characteristics will also prevent managers from over investing in supply chain flexibility, as well as prevent the potential, required, and actual flexibility misalignments, identified by Gerwin (1993).

Stage II Implementation and Shared Responsibility

Knowing the required types and levels of flexibility to monitor, attention then turns to implementing these flexibility types and levels. This is achieved by implementing the required organizational and technological tools into the supply chain system. An issue that must be
carefully selected during the implementation and shared responsibility stage is the organizational and technological tools (e.g., FMS, employees with broad skills, integrated information technology) needed to achieve the required supply chain flexibility types. Such tools need to be identified and prioritized (Narain et al., 2000). In addition, information technology as an enabling factor is considered fundamental to the realization of manufacturing flexibility (Sethi and Sethi 1990; Gerwin 1993; and Suarez et al., 1991). Lau (1996) argues that strategic flexibility is supported through the use of advanced information technologies. Rapid advances in information technology (IT) are having a major impact on the management of supply chains. To achieve the required supply chain flexibility types, sophisticated information technologies such as an electronic data interchange (EDI) and Internet-based technology (SCM, ERP, and CRM) must be considered for the implementation supply chain flexibility.

Further in this critical stage, supply chain partners must share the responsibility for implementing the required supply chain flexibility. Vickery et al. (1999), in their empirical study of supply chain flexibility, found that manufacturing is generally responsible for volume flexibility, marketing is generally responsible for distribution flexibility, and research and design is responsible for new product introduction flexibility, etc. By focusing on these flexibilities from an internal perspective much of the contribution of a supply chain perspective is lost (Vokurka et al., 2003). Consequently, we believe that the responsibility in achieving each type of required supply chain flexibility should be shared by various stakeholders. For instance, product flexibility we believe that close cooperation between manufacturers and key customers is essential for product flexibility achievement. Customer desires and competitive threats are the drivers for product flexibility (Swink et al., 1996). To achieve long-term relationships, firms foster direct customer contact, collect customer information, and use this information to design and deliver enhanced products and services (Schneider, 1994). Hence in the supply chain environment, manufacturers are generally responsible for implementing and managing product flexibility, with close communication with their key customers. In another example volume flexibility, we believe that in achieving volume flexibility, both suppliers and manufacturers must share the responsibility in implementing and managing this type of flexibility.

For delivery flexibility, integrated logistic has a strong link with distribution and delivery flexibility. We conclude that the logistics function within the supply chain system must be fully responsible for implementation and management of delivery flexibility. Furthermore, new product flexibility, much of the supply chain literature has demonstrated that both suppliers and customers can benefit from engaging in closer working relationships and partnerships in developing a new product. We imply here that all supply chain players must share the responsibility for implementation and management of new product flexibility. The final required flexibility in our framework relevant to a supply chain focus is “responsiveness to target markets.” Companies are seeking to become more responsive to changing market conditions by streamlining and restructuring their organizations, making use of knowledge work teams, and simplifying their work organization (Christiaanse, E., et al., 2000). We imply here that responsibility for achieving market response flexibility is spread throughout the supply chain and individual players must participate and take their share of responsibility in implementation and management of market response flexibility.

Stage III Feedback and Control

Finally, Stage III at the bottom of Figure 1 illustrates the importance of feedback and control to ensure continuous assessment. The feedback and control stage focuses on the following activities i) periodically measuring the required and observed flexibility to ensure that the required flexibility is still being achieved; ii) changing the required flexibility when needed to
correspond to changing uncertainty and competitive, manufacturing, and marketing strategies, and iii) ensuring that the required supply chain flexibility continues to help achieve the competitive, manufacturing, and marketing strategies, and positively influences supply chain performance.

The first goal of controlling the required supply chain flexibility is to periodically measure the observed flexibility to determine if, and why, a gap exists. The observed flexibility is created from the implementation of the required supply chain flexibility, and, hence, the implementation of the required organizational technical tools. However, the flexibility types and levels implemented (i.e., observed flexibility) may not be the flexibility types and levels required (i.e., required flexibility). As a result, and suggested by Suarez et al. (1991), the observed and required flexibility must be compared to ensure that there is adequate “fit.” If a proper fit exists between the observed supply chain flexibility and the required supply chain flexibility (i.e., they are equal), then it is expected that there will be an improvement in supply chain performance. A number of researchers have emphasized that business performance will improve as a result of achieving manufacturing flexibility. The feedback and control stage also addresses issues such as why the observed and the required flexibility, albeit equally, are not helping to improve supply chain performance or to achieve the competitive, marketing, or manufacturing strategy. Possible reasons for a lack of business improvement are highlighted by the feedback loops in the framework and include i) inaccurately analyzing the uncertainty faced by supply chain system; ii) developing an ineffective competitive strategy; iii) developing a supply chain strategy that does not match the competitive or marketing strategy; iv) implementing incorrect flexibility types and levels, and v) the uncertainty facing the supply chain organization and/or manufacturer has changed since the required supply chain flexibility types were identified. As a result, the required flexibility types or levels are not those needed to address this new environmental uncertainty or achieve the new competitive, manufacturing, marketing, or flexibility strategy.

Framework Implications, Limitations, and Further Research

The conceptual framework has a number of implications for managers and researchers. For managers, this framework is easy to understand, and highlights five critical points that should be considered when implementing and managing supply chain flexibility. First, this framework emphasizes to managers that the supply chain strategy should be developed by considering competitive and functional strategies, environmental uncertainty, supply chain characteristics, customer characteristics, and the capability of the entire supply chain to address these uncertainties. Second, this framework emphasizes that supply chain flexibility may only form part of the supply chain strategy and, therefore, managers should develop a flexibility strategy to determine how flexibility will be used to meet the supply chain manufacturing, marketing or competitive strategies. Third, the framework suggests to managers that supply chain flexibility taxonomy should be examined from an integrative, customer-oriented perspective; therefore, the required supply chain flexibility taxonomy encompasses those flexibilities that directly impact a firm’s customers (i.e., flexibilities that add value in customers’ eyes). Fourth, this framework suggests to managers that the responsibility for achieving the required supply chain flexibility types lies as follows: i) manufacturers and suppliers are the prime responsible groups for achieving volume flexibility, ii) integrated logistics partners are responsible for achieving distribution and delivery flexibility, iii) the manufacturer is generally responsible for product flexibility with close communication and coordination with their key customers, and iv) the entire supply chain partners are responsible for achieving new product flexibility and responsive flexibility. Fifth, this framework emphasizes that the flexibility of the supply chain system includes flexibility in establishing relationships with partners.
This framework is constructed by synthesizing the strengths and weaknesses of other conceptual frameworks. As a result, the major components of the framework are supported by the current research on the implementation and management of manufacturing flexibility, as well as the current literature on supply chain management. Various conceptual relationships are identified by the presence of arrows in the framework. As a result, the implications of this new conceptual framework for researchers is that it provides a very good starting point for conducting exploratory and confirmatory research on the process of implementing and managing supply chain flexibility. This framework has three major weaknesses. First, the framework has not been empirically tested. Consequently, and similar to other implementation and management frameworks presented, the actual robustness of this framework in supply chain organizations, at this time, remains unknown. Second, although five types of flexibility taxonomy are defined in the framework, additional research is needed to examine the specific issues that managers may encounter when executing the various types of flexibilities outlined in the framework. Third, although this framework introduces for the first time the assignment of responsibility to the supply chain partners, additional examination is needed to investigate the level of responsibility for each partner within the supply chain system. The issues underlying supply chain flexibility as organizations try to improve supply chain performance is an appropriate area to research. Based on the weaknesses of this framework and the research gap there are several future research issues that can be raised to develop the understanding of supply chain flexibility. Some of these are outlined below:

Empirical research is needed which gives deeper insights into what constitutes flexibility taxonomy in supply chain in various industries. Case and field research studies can be used to generate knowledge that supports the flexibility taxonomy and sharing the responsibility links with different partners suggested in this framework.

Are the types of required supply chain flexibility taxonomy as defined in this research the relevant types? Have all the relevant types been identified? How can dimensions for the supply chain flexibility taxonomy be measured as the on-going research has proposed for manufacturing flexibility? What specific elements can be used to measure the dimensions? Performance measures must be identified which measure supply chain performance across supply chain nodes to determine if real change in customer value has been added.

Considerable effort has been directed at the operational aspects of flexibility without much attention being given to the methods of delivery. Much more needs to be known about the contribution made by key enablers, such as information technology and communication, process technology, and training and labor skills, make towards the acquisition of supply chain flexibility.
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| 1  | Swamidass and Newell (1987)     | - Manufacturing flexibility as an effective strategy to address uncertainty  
|    |                                 | - Manufacturing flexibility is only one dimension of manufacturing strategy  
|    |                                 | - The framework highlights the relationship between manufacturing flexibility and business performance.                                                                                                          |
| 2  | Kumar and Kumar (1988)          | - Identifies four sources of uncertainty (environmental uncertainty, input, output, and processes).  
|    |                                 | - This framework highlights that each type of uncertainty in its turn requires a different and particular type of flexibility to accommodate it.                                                             |
| 3  | Sethi and Sethi (1990)          | - Identifying eleven manufacturing flexibility types, classifying them in three levels: component, (or basic), system, and aggregate.  
|    |                                 | - Information technology and Organizational structure are essential enablers to achieve the identified flexibility types.                                                                                     |
| 4  | Suarez (1991)                   | - The framework identifies internal and external flexibility source factors  
|    |                                 | - The fit between the required and observed types and levels of flexibility when implementing and managing manufacturing flexibility in organizations.                                                             |
|    |                                 | - Non-technical means in achieving manufacturing flexibility.                                                                                                                                                    |
| 5  | Hyun and Han (1992)             | - The framework classifies various types of manufacturing flexibility from three viewpoints: systems, environmental-associated, and decision hierarchical.  
|    |                                 | - The dynamic perspective of flexibility must be emphasized in the management of manufacturing flexibility.                                                                                                  |
|    |                                 | - Highlights that manufacturing flexibility exists at different levels of the organization.                                                                                                                        |
| 6  | Gerwin (1993)                   | - This framework examines five variables, specifically identifying environmental uncertainties, developing a manufacturing strategy, determining the required manufacturing flexibility, implementing the required flexibility, and developing performance measurements.  
|    |                                 | - Considers the relationship between actual, potential and require flexibility.                                                                                                                                  |
|    |                                 | - The framework identifies four generic strategies: adaptation, reduction, banking, and reduction.                                                                                                                |
| 7  | Vickery et al. (1999)           | - This empirical study examines the dimensions of supply chain flexibility and their relationships with the environmental uncertainty, business performance, and functional interfaces.                           |
| 8  | Vokurka and O’Leary Kelly (2000)| - This framework identifies four exogenous variables that are believed to influence the firm’s choice of manufacturing flexibility types, which will in turn influence business performance.  
|    |                                 | - These variables are organizational strategy, environmental factors, organizational attributes and technology.                                                                                                 |
| 9  | Narain et al. (2000)            | - This framework outlines the link between manufacturing, marketing, and organizational strategies, suggesting that the needs of marketing, and organization as a whole, must be considered when implementing manufacturing flexibility  
|    |                                 | - Highlights that manufacturing flexibility exists at different levels of the organization.                                                                                                                       |
| 10 | Zhang et al. (2002)             | - This model applies competence and capability theory to value chain flexibility, and it explores the relationships among environmental uncertainty, value chain flexibility and competitive advantage. |
## Appendix A

Contribution of Each Framework in Constructing Supply Chain Framework

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**Legend Key:** (Selected Components used for Constructing the New Supply Chain Framework)

1-Environmental Uncertainty  
2-Supply Chain Characteristics  
3-Customer Characteristics  
4-Manufacturing Strategy & Marketing Strategy  
5-Mission and Organizational Competitive Strategies  
6-Flexibility Fit  
7-Control Mechanism  
8-Observed flexibility  
9-Business Performance  
10-Sharing Responsibility  
11-Supply Chain Flexibility Taxonomy  
12-Technical Tools
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<th>Flexibility Type</th>
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<td>Product flexibility</td>
<td>The ability of the supply chain system to produce customized product or upgrade existing ones to meet special customer specifications</td>
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<td>Volume flexibility</td>
<td>The ability of the supply chain system to control production levels (increasing or decreasing) profitably to meet customer demand</td>
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<tr>
<td>Delivery flexibility</td>
<td>The ability of the integrated logistic system to distribute and deliver the product from the raw material source to the final customer</td>
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<td>New product flexibility</td>
<td>The ability of supply chain partners to collaborate to produce new products in response to the market demand</td>
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<tr>
<td>Responsive flexibility</td>
<td>The capability of supply chain system to respond quickly to market changes to satisfy customer demand</td>
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Figure 1
Conceptual Framework for the Implementation and Management of Supply Chain Flexibility

Stage I
Required Flexibility Identification

Stage II
Implementation & Shared Responsibility

Stage III
Feedback & Control

Supply Chain Characteristic

Environmental Uncertainty

Customer Characteristic

Mission and Organizational Competitive Strategies

Marketing Strategy

Manufacturing Strategy

New Product Flexibility

Volume Flexibility

Product Flexibility

Suppliers

Manufacturers Information Technology

Logistics

Customers

Responsive Flexibility

Control Mechanism

Flexibility Types Implemented

Flexibility Fit

Observed

Supply Chain Performance
References