A Model of Global Supply Chain Agility

and its Impact on Competitive Performance

Patty Swafford
The DuPree College of Management
Georgia Institute of Technology
Atlanta, GA 30332-0520
(404) 894-3899
pswaffor@bellsouth.net

Dr. Soumen Ghosh
The DuPree College of Management
Georgia Institute of Technology
Atlanta, GA 30332-0520
(404) 894-4927
soumen.ghosh@mgt.gatech.edu

Dr. Nagesh Murthy
The DuPree College of Management
Georgia Institute of Technology
Atlanta, GA 30332-0520
(404) 894-8714
nagesh.murthy@mgt.gatech.edu

Abstract

During the past few years, organizational agility has gained prominence as a competitive weapon in both the academic and business communities. Although much discussion has taken place, little research exists which explains the relationship between organizational agility, organizational strategies and performance. Using sound theory-building methods, this study proposes related constructs and a model of global supply chain agility. For this study, global supply chain agility is defined as a measure of the supply chain's ability to efficiently adapt to a rapidly changing global competitive environment to provide products and/or services. We posit that global supply chain agility is determined by four flexibility components; product development flexibility, sourcing flexibility, manufacturing flexibility, and logistics flexibility. Each flexibility is composed of two dimensions which we call range and adaptability. We also posit that an organization's information technology flexibility and its industry's global competitive environment influence its level of global supply chain agility. To study the effects of global supply chain agility on performance, two additional constructs called supply chain performance and global competitive performance are included in the model. Our primary goal is the development of a framework for future research on global supply chain agility.

1. Introduction and Motivation

This research investigates determinants of global supply chain agility and agility's impact on competitive performance. In his recent book, Charles H. Fine (1998) states, "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." From a more organizational perspective, the Agility Forum (1998) defines agility as, "the ability of an organization to thrive in a continuously changing, unpredictable business environment." In a more recent study, the Next Generation Manufacturing (NGM) Project (1997) states, "competitive companies of the future will have the ability to sustain continuous change and to prepare the organization to respond to calls for dramatic change." Goldman, Nagel, and Preiss (1994) present a qualitative analysis of agility in their book, Agile Competitors and Virtual Organizations : Strategies for Enriching the Customer. These sources point to the critical need for organizations to enhance their ability to appropriately react and adapt to the ever changing global competitive environment. Also, the abundance of literature identifies the increasing desire of organizational leaders to understand the characteristics and impacts of global supply chain agility.

A growing interest in supply chain management has occurred due to the increasing global competition (Li and O.Brien, 1999) caused by recent trade agreements, removal of trade barriers, and increased accessibility to global customers via the Internet. A supply chain provides the framework for the movement of raw materials through manufacturing and distribution to the customer. In 1989, Digital Equipment Corporation recognized the importance of supply chain management and invested in the development of a Global Supply Chain Model (GSCM) (Arntzen, Brown, Harrison, and Trafton, 1995). GSCM is a large mixed-integer program which is used to evaluate different supply chain designs for making worldwide manufacturing and distribution strategy decisions. About the same time, Hewlett Packard formed a group for Strategic Planning and Modeling (SPaM). In 1990, this group developed its Worldwide Inventory Network Optimizer (WINO) to assess the impact of demand uncertainty on inventory within the supply chain (Lee and Billington, 1995).

With increasing accessibility to global markets, many organizations are expanding beyond the boundaries of their own country (Fliedner & Vokurka, 1997). Not only are they expanding through the sales of products to other countries, they also are locating their facilities in other countries (Murray, Kotabe, & Wildt, 1995). Some organizations have realized improvements in their marketing efforts when development and manufacturing is located close to the target customers. Also, the higher level of global competition motivates organizations to focus on the potential economic benefits of locating in countries with lower labor costs or by locating close to suppliers who offer lower cost, higher quality material (Murray, Kotabe, & Wildt, 1995). The trend toward global organizations mandates more research in those areas that provide competitive advantages such as lower cost, high quality, and faster delivery. Global supply chain agility provides an organization with the ability to adapt in order to pursue or maintain these advantages. Goldman, Nagel and Preiss (1994) state, "Agility is the competency that sustains world class performance over time."

There is a growing need for research on agility because of its prevalence in certain literature as a competitive advantage. The Agility Forum (1998) mentions several reasons (market fragmentation, shrinking product lifetimes, and true global competition) for an organization to increase its agility. The increasing global nature of supply chains and the need for a framework to analyze global supply chain agility provides the motivation to develop a model for global supply chain agility. While recent literature addresses the general issue of organizational agility (Nagel and Bhargava, 1994; Fleidner and Vokurka, 1997; Meade and Sarkis, 1999; Mason-Jones and Towill, 1999), no research has broached the study of global supply chain agility from a theory building perspective.

The broad research question addressed in this study is, "Is an organization's global supply chain agility defined by elements of flexibility and does global supply chain agility impact competitive performance?" We define global supply chain agility as a measure of the supply chain's ability to efficiently adapt to a rapidly changing global competitive environment to provide products and/or services. This paper presents a model of global supply chain agility by addressing three important issues. First is the development of psychometrically sound constructs of flexibility elements that are proposed as components of global supply chain agility. To answer the second part of the research question, we will examine the relationship between the newly developed construct of global supply chain agility and two dimensions of performance. Third, we will examine the effect of the global competitive environment on global supply chain agility.

The next section presents the theory-building approach and the global supply chain agility model with propositions along with the definitions, item measures and literature support of each construct. Section 3 presents the proposed methodology for addressing the research questions. In closing section 4 provides a summary of the article and its contribution to the area of global supply chain management.

2. A Model of Global Supply Chain Agility

2.1 Theory Building Approach

Articles containing good theory-building research methods (i.e. Wacker, 1998; Amundson, 1998; Malhotra and Grover, 1998; Meredith, 1993,1998;) were reviewed to ensure the best practices were used to develop our global supply chain agility model. Theoretical models are essential to sound theory-building because they provide the framework for analysis, a method for field development and a clear explanation (Wacker,1998). Wacker (1998) quotes Van de Ven who wrote, "Good theory is practical precisely because it advances knowledge in a scientific discipline, guides research toward critical questions and enlightens the profession of management." Theory is, "an ordered set of assertions about a generic behavior or structure assumed to hold throughout a significantly broad range of specific instances"(Weick, 1989). Essentially, theory explains the relationships between concepts and constructs. According to Wacker (1998), the four components of good theory are, "(1) definitions of terms or variables, (2) a domain where the theory applies, (3) a set of relationships of variables, and (4) specific predictions." Based on Weick's (1989) perspective, the model presented here represents a middle range theory because it contains a limited number of assumptions, considerable detail in the problem specification, and a scope of manageable size.

As a first step, we developed definitions for each construct in our global supply chain agility model. Based on these constructs and the global characteristic of the model, the domain has been defined to include organizations within manufacturing industries with an established global supply chain. Numerous brainstorming sessions were used to discuss the propositions related to the relationships among the constructs and to identify appropriate measures for each construct. Multiple items were used to develop each construct because the averaging of the individual item errors can reduce measurement error (Stratman and Roth, 1999). Once we developed the initial model, an extensive literature review was conducted to support the relationships within the model; however some of the constructs have not been fully developed and tested. Since content validity is required (O'Leary-Kelly and Vokurka; 1998) and similar constructs do not yet exist in the literature; content validity was evaluated via the literature review. Content validity deals with how well the item measures represent the construct domain (Kerlinger, 1986).

Whetton (1989) discusses four elements of a complete theoretical contribution. First, the researcher must explain what factors are considered in the model. The model should exhibit both, "comprehensiveness (are all relevant factors included ?) and parsimony (should some factors be deleted because they add little additional value to our understanding?)" (Whetton, 1989). Next, the researcher must explain how the factors are related. Usually, relationships are depicted visually within a graphical presentation of the model. Further explanation is necessary to explain why each factor is considered. Here the researcher presents the underlying arguments for the proposed factors and relationships within the model. As Whetton (1989) explains, "What and How describe; only Why explains." The fourth element answers the questions of Who, Where, and When. For this research, Who describes the unit of analysis and the survey respondent, Where describes the geographical boundaries of this survey and When describes the timeline for performing the survey. In the next section, we answer these questions by presenting our model, propositions, and constructs.

2.2 The Model

Our proposed model for global supply chain agility is shown in Figure 1. For brevity, we will refer to global supply chain agility as GSC agility throughout the remainder of this paper.

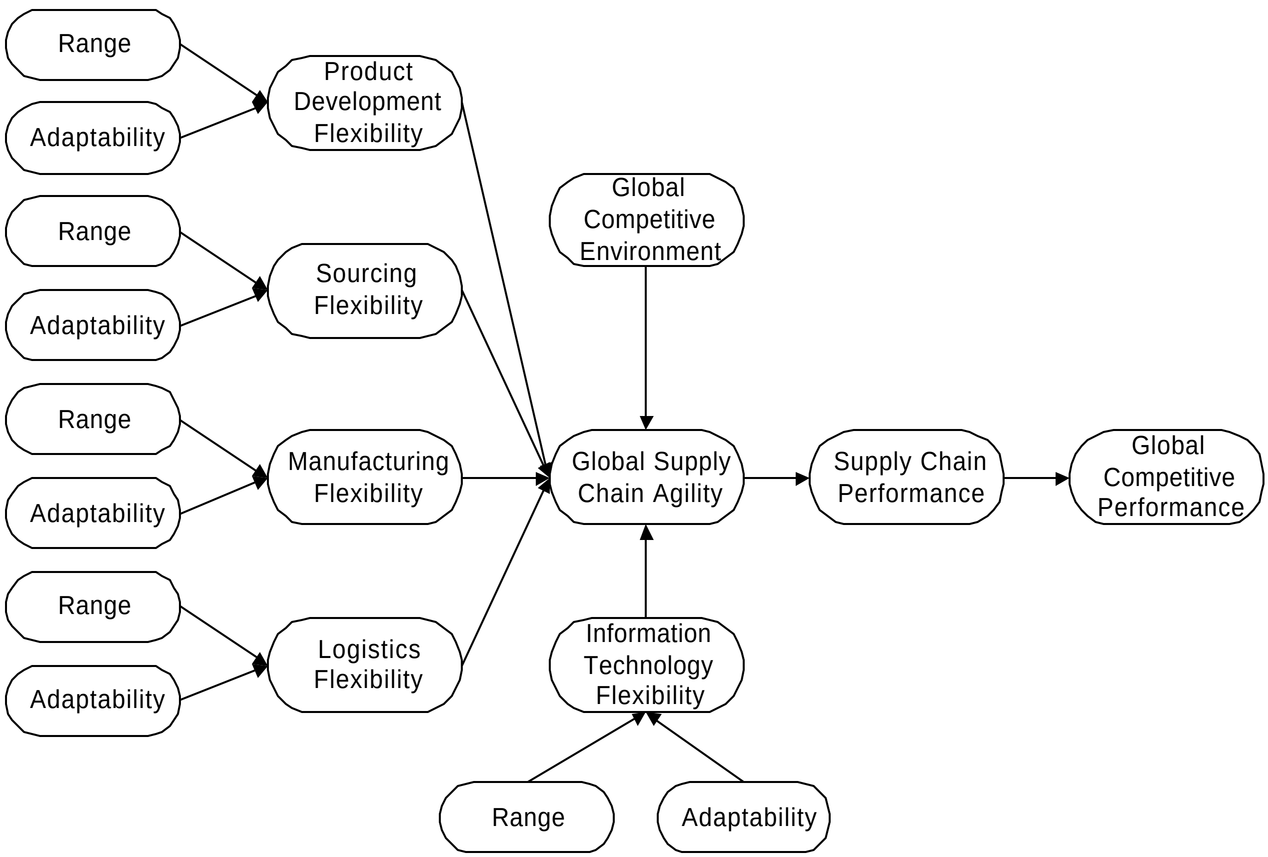

Figure 1 : Global Supply Chain Agility Model

Cohen and Lee (1989) argue that a firm's performance is determined, to a great extent, by its international resource deployment decisions concerning supply, manufacturing, and distribution facilities. Yusuf, Sarhadi, and Gunasekaran's (1999) study mentions the impact of manufacturing flexibility on agility but also warned that equating agile manufacturing with agility forms a narrow understanding thus the creation of four additional flexibility constructs. Based on supply chain literature, the constructs of flexibility identified to impact GSC agility are product development flexibility, sourcing flexibility, manufacturing flexibility, and logistics flexibility.

The model posits that GSC agility consists of four component flexibilities : product development flexibility, sourcing flexibility, manufacturing flexibility and logistics flexibility. Each component flexibility in turn consists of two dimension, range and adaptability. GSC agility is impacted by the global competitive environment and information technology flexibility, and in turn is theorized to impact SC performance and finally global competitive performance.

Based on the proposed model, we present the following propositions regarding the relationships between the dimensions of flexibility and GSC agility:

Proposition 1a : An organization's global supply chain agility is obtained through the coalignment of the four component flexibilities called product development flexibility, sourcing flexibility, manufacturing flexibility and logistics flexibility.

Proposition 1b : Range and adaptability are positive drivers of flexibility and thereby global supply chain agility.

A critical imperative for organizations is an ability to adapt to a rapidly changing global competitive environment (Next Generation Study, 1997). Also, the Agility Forum (1998) lists true global competition as a driver of increased agility. In their literature review of supply chain articles, Cohen and Mallik (1997) contend that the level of agility is impacted by the competitive environment just as a firm's competitive scope impacts its level of globalization. All of these arguments are intuitive. A company within an intense global competitive industry would require more agility than its competitors in order to announce products earlier as well as deliver products faster. This supports the next proposition.

Proposition 2 : The intensity of the global competitive environment in which an organization operates positively influences its global supply chain agility.

Information technology also impacts an organization's GSC agility. According to Jeffrey James (1999), "Information technology not only enhances the ability of a multinational corporation to coordinate their intra-firm activities on a global scale, but it facilitates inter-firm network relationships of various kinds." Stratman and Roth (1999) state, "Information processing theory posits that uncertainty drives the need for information processing competencies." Also, the effective use of information technology can provide information to allow an organization to effectively respond to the affects of market uncertainty (Stratman and Roth, 1999). This supports our next proposition.

Proposition 3 : The flexibility offered by an organization's information technology infrastructure through its range and adaptability attributes is a positive enabler of its global supply chain agility.

Two dimensions of supply chain performance are flexibility and time (Beamon, 1999). Since flexibility is hypothesized to impact agility then agile supply chains should exhibit higher performance with respect to flexibility and time than non-agile supply chains. This supports proposition three.

Proposition 4 : An organization's global supply chain agility has positive influence on its supply chain performance.

Along with measures of supply chain performance, there are financial and market measures of performance. Just as supply chain performance measures should improve with higher agility, the performance of the organization with respect to competitors should also improve thus the final proposition.

> **Proposition 5 : An increase in an organization's global supply chain agility is a positive driver of its global competitive performance through its supply chain performance.**

2.3 Dimensions of Flexibility

Within literature, flexibility has been defined as having multiple dimensions. Slack (1983) defines flexibility in terms of range, cost, and time where range was the number of states the system could adopt, and both cost and time were associated with a change in the number of states. Using Upton's (1994) concept of "extent of differentiation", Koste and Malhotra (2000) divide 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, Koste and Malhotra (2000) use mobility and uniformity to define manufacturing flexibility. Mobility measures the ability of the organization to change from one manufacturing state to another state. Uniformity measures the similarity of outcomes in terms of cost, quality and time which could represent the effective use of agility. Based on Slack's (1983) concept that flexibility is defined as two dimensions, we defined flexibility using two dimensions called range and adaptability.

Slack (1983) defines range as the number of states the system could adopt. In this paper we use Slack's expanded definition, *"range is defined as the number of different positions, or flexible options, that can be achieved with existing resources."* Stated another way, range can be measured in terms of the bandwidth of a continuous characteristic or the number of a states of a discontinuous characteristic. The bandwidth of the volume capacity is continuous (ie. 5000 to 8000 units per month) while the number of products manufactured per plant is discontinuous (ie. 3 products per plant); however, both represent range. 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 only one production facility. This higher level of flexibility exists since the organization with multiple production facilities can relocate or otherwise adjust 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." Mixing Slack's (1983) concept of changing states with Bodoloi, Cooper and Matsuo's (1999) definition, we define *adaptability as the ability to change the existing number of states*. This change may require an increase or decrease in resources. Using the previous example of production location, an organization with the ability to add additional production facilities has more flexibility than an organization which does not have financial capability to add additional facilities.

2.4 Construct Development

Product Development Flexibility

Ettlie's (1998) study shows research and development intensity to be associated with increases in market share as well as increased agility. Higher product design flexibility increases the ability to make changes later in the development cycle (Thomke,1997) thus increasing agility. In this paper, we define *product development flexibility as the ability to develop diverse products and/or product enhancements in a timely and cost effective manner in response to customer or market requirement, or to exploit market opportunities or to employ technological enhancements.* The NGM study's (1997) attribute of customer responsiveness such as ability to meet customer needs is supported by an increase in product development flexibility. With higher flexibility in product development, the organization will be better able to introduce products in response to changing customer expectations or technology.

The hypothesized model of product development flexibility is shown in Figure 2.

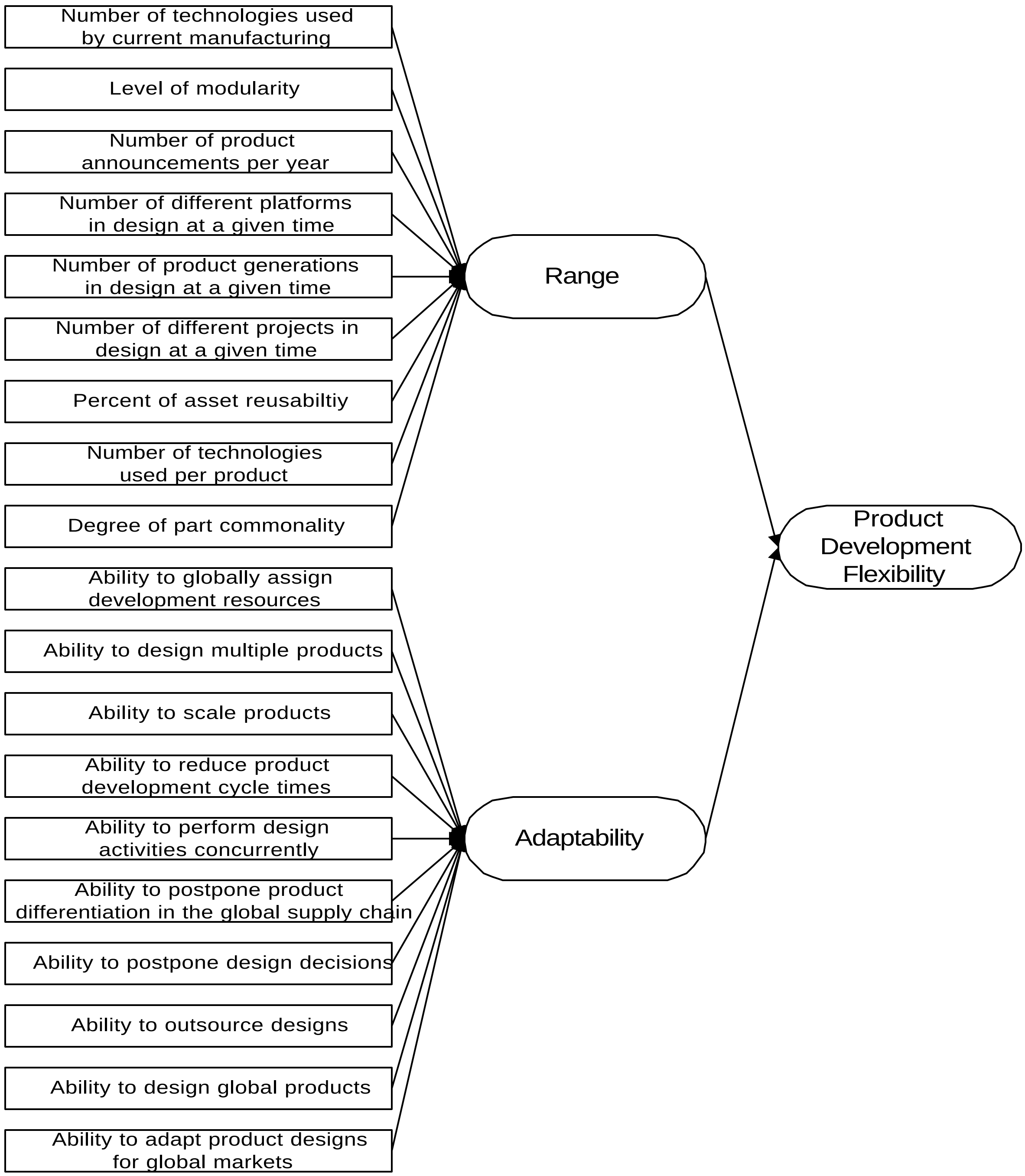

Figure 2: Product Development Flexibility

The first dimension, range, measures the possible number of states that product development can achieve as a function of its product characteristics and existing development resources. One characteristic of a development project that impacts development cycle time is the level of complexity of the project (Griffin, 1993). Griffin

(1993) defines complexity in terms of how difficult and time-consuming development might be due to project size. Das (1998) uses the complexity of new processes utilized in product design, prototying, and manufacturing as a measure of new product flexibility. To capture product complexity range, the first item is the number of technologies used per product. The development of an automobile requires knowledge in numerous process areas such as hydraulics, electronics, metallurgy, etc., thus development requires a wider range of states. The development concept of modularity impacts flexibility and is included in our range construct. A higher level of modularity allows design changes to be localized within the modular units (Thomke, 1997) which may reduce the impact of the changes on overall development time. This leads to the next item of range which is the level of modularity utilized in product development.

A higher number of product announcements demonstrates higher product development flexibility and is included in range as the number of new products introduced per year (Das,1998). The types of product announcements are impacted by the next three measures; the number of different platforms in design, the number of product generations in design, and the number of development projects in progress. An organization simultaneously developing multiple generations of a product would have a greater opportunity to effectively incorporate new customer expectations into the design.

The next item is the percent of asset reusability. Griffin (1993) defines asset reusability as the amount of change across a project. An example of asset reusability can be drawn from the tire industry. If a tire is developed on a small scale and the knowledge is transferable to a design project of a tire on a large scale then asset reusability exists. This is related to the concept of part commonality. Higher levels of part commonality simplify the product design (Loch, Stein, & Terwiesch, 1996). This is an important concept for design for manufacturability. Another concept of design for manufacturability is the use of existing manufacturing technology. The next two items, the number of current technologies used in manufacturing (Das, 1998) and the degree of part commonality, capture the effects of design for manufacturability.

Adaptability of product development flexibility measures 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). Thomas also states that slack resources improve organizational flexibility and enable an organization to better adapt to internal and external demands. The first item of adaptability of product development flexibility is the ability of a firm to globally assign resources as needed. A development group with this capability can reassign developers to a project which is being accelerated due to an increased customer demand forecast. Thus the higher this capability, the higher the flexibility. In accordance with the number of different products, the next two items of adaptability are the ability to design multiple products and the ability to scale products.

The Agility Forum (1998) lists the ability to quickly deliver products to market as an attribute of an agile organization. The ability to deliver products to market is impacted by the length of the development cycle time. Das (1998) and Griffin (1993) show that the ability to reduce the product development cycle time captured aspects of product development flexibility, therefore it is the next item in adaptability. The reduction of development cycle time would be aided by the ability to perform design activities concurrently and any ability to outsource design stages. Pagh and Cooper's (1998) study shows the impact on inventories by postponement strategies. If development designs products where differentiation is performed late in the supply chain, the cost of adapting is lowered. Thus we include the measure for the ability to postpone product differentiation in the global supply chain. Another measure of adaptability is the ability to postpone design decisions until improved product information is available.

The last two items are applicable to corporations with global supply chains and not applicable to localized supply chains. First, the ability to design global products measures the extent to which development can design products for the same global market niche but with different characteristics to match geographically different customer requirements. A product development group which designs washing machines for North America and Europe displays more adaptability. An extension of this prior concept is that product development displays greater adaptability if the designers can adapt existing product designs for global markets.

Sourcing Flexibility

Integrating sourcing flexibility with supply chain management supports an organization's ability to deliver products and services in a more timely, effective manner (Tan, Kannan, and Handfield, 1996); thereby increasing the organization's agility. Sourcing flexibility measures the ability to change sourcing decisions (i.e. the number of suppliers per part, and delivery) to optimize effects of changing requirements. Sourcing flexibility facilitates a faster response when there is uncertainty; therefore sourcing flexibility has a positive impact on manufacturing flexibility (Gupta and Somers, 1996). The NGM study's (1997) attribute of teaming as a core competency is supported by purchasing's ability to form relationships with suppliers that improve the NGM study's

(1997) attribute of global market responsiveness. In order to provide global support responsiveness, the purchasing function must form relationships with suppliers that enhance organizational ability to respond to uncertainty thus increasing sourcing flexibility.

Based on the literature, we define *sourcing flexibility as the ability of the purchasing function to respond in a timely and cost effective manner to changing requirements of purchased components*. Narasimhan and Das (1999) link supply chain management practices within purchasing to achieving manufacturing agility. The practices used were supplier responsiveness capabilities, early supplier involvement, and internal purchasing practices. The ability of purchasing to adapt to satisfy changing material requirements provides an organization with a higher level of responsiveness, and thus higher agility.

The items used to measure the range and adaptability constructs of sourcing flexibility are shown in Figure 3.

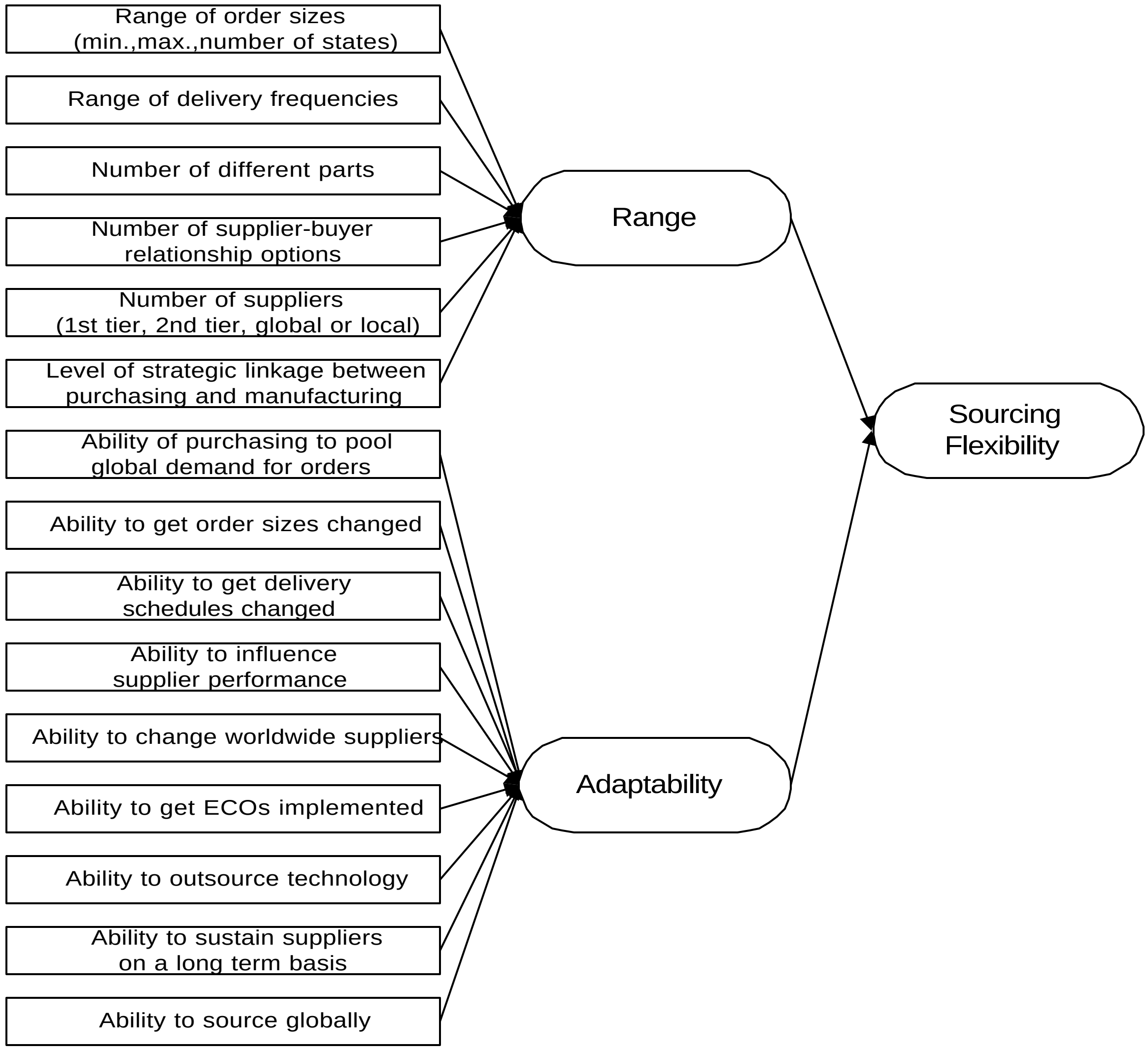

Figure 3: Sourcing Flexibility

There are six measures of the range of sourcing flexibility. The first item is the range of order sizes used by the purchasing department. This is analogous to volume flexibility used in manufacturing since it refers to the range of purchase order sizes versus the range of volume which is used in manufacturing. The wider the range of possible purchase order methodologies, the higher the flexibility for the buyer to select the best purchasing solution to maintain supply continuity. The range of delivery frequencies captures Corbett's (1992) concept of time between the earliest and latest delivery dates achievable by the supplier. The number of different parts measures the magnitude of range. The larger the number of parts to be sourced then the lower the sourcing flexibility unless grouping of parts with one supplier provides purchasing power.

The number of supplier-buyer relationship options used is another measure of sourcing range. A higher number of options supports a wider range of relationships with suppliers which could be tailored to benefit both parties. Types of supplier-buyer relationships include forming partnerships, signing contracts for manufacturing capacity or placing individual purchase orders as needed. Stuart (1993) concludes that supplier partnerships lead to both short term and long term benefits especially in the areas of product development.

The number of capable suppliers per part based on technology also impacts flexibility. A part that can be provided by several suppliers provides more sourcing flexibility than a part that is sole-sourced. If supply from the sole source is interrupted, the buyer has no alternative. The number of suppliers per tier is also important for flexibility. Tiers refer to the level of the supplier within the supply chain. A first tier supplier provides material directly to the organization while a second, third, etc. tier supplier provides materials to the next higher tier in the supply chain. If there are fewer first tier suppliers then coordination requirements are lower which results in higher coordination per supplier to handle changing requirements. Kekre, Murthi, and Srinivasan's (1995) study shows a positive impact on product quality when there were fewer suppliers. The final measure of range is the level of strategic linkage between purchasing and manufacturing strategies.

Adaptability of sourcing flexibility measures purchasing's ability to impact supplier delivery. The first measure is the ability of purchasing to pool demands from multiple sources. If demand can be pooled, order sizes are increased leading to increased purchasing power which can be used to negotiate delivery changes. Also, the larger purchase orders created by pooling leads to lower prices from volume discounts offered by the supplier (Tan, Kannan, and Handfield, 1996). This ties directly into the next measure, the ability to get order sizes changed. Sourcing has greater flexibility if it can increase or decrease order sizes without incurring extra costs. The ability to change order volumes has a positive impact on expansion flexibility within manufacturing (Narasimhan and Das, 1999) thus increasing overall agility. Just as important is the ability to get delivery schedules changed. An organization has more flexibility if purchasing can expedite or delay delivery so delivery can more closely match when the materials are needed. Narasimhan and Das (1999) found ability to change delivery schedules was positively significant related to delivery flexibility. Along with the ability to influence supplier delivery there is the ability to influence supplier performance. This is usually related to the supplier-buyer relationship or purchasing power. If the organization can influence supplier performance, it can provide higher quality products at lower cost for the consumer. Another measure of adaptability is the ability to change suppliers. If an organization can quickly change its supplier base, it will have more flexibility if supply problems are encountered.

The ability to get engineering change orders (ECOs) implemented in a time and cost effective manner is the next measure. Quicker implementation of ECOs reduces cost of obsolete inventory for the organization and provides a better quality or less expensive product to the consumer. This is closely related to Narasimhan and Das's (1999) measure, supplier ability to modify product, which also had a positive and significant relationship to volume flexibility. The ability to outsource technology with suppliers also impacts sourcing flexibility. If an organization can outsource assemblies or packaging, it can focus on its core capabilities which add value to the product.

Another measure of sourcing adaptability is the ability to sustain suppliers on a long term basis. Long-lasting relationships with suppliers have more positive effects on an organization's performance than a short relationship. These benefits occur because long-lasting relationships enhance the other measures of sourcing flexibility. The supplier will have more accumulated information on the product and processes which should improve their performance in the areas of cost, quality, and delivery. Also, the supplier will have more information for assisting in new product development. The last measure of sourcing adaptability is the ability to source globally. This measure captures the ability of the purchasing department to identify and develop relationships with globally located suppliers. An organization whose purchasing departments can procure materials from global suppliers will possess higher adaptability to pursue the competitive benefits of cost, delivery, and quality.

Manufacturing Flexibility

Sethi and Sethi (1990) define manufacturing flexibility as the, "ability to reconfigure manufacturing resources so as to efficiently produce different products of acceptable quality". Several recent articles (Sharifi and Zhang,1999; Narasimhan and Das, 1999; Yusuf, Sarhadi, and Gunasekaran,1999) link the concepts of flexible manufacturing and agility. Sharifi and Zhang (1999) define agile manufacturing as the, "ability to cope with unexpected changes in order to survive unprecedented threats of business environment and to take advantage of changes as opportunities". Narasimhan and Das (1999) describe manufacturing agility as the, "ability to produce a broad range of low-cost, high-quality products with short lead times in varying lot sizes, built to individual customer specifications."

In this paper, we define *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*. The NGM study's (1997) attribute of physical plant and equipment responsiveness and global market responsiveness within an organization is determined by its level of manufacturing flexibility. Manufacturing flexibility enables an organization to adapt its manufacturing strategy to environmental changes.

Numerous articles on manufacturing flexibility (e.g. Gupta and Somers, 1992; Sethi and Sethi, 1990; Gupta and Goyal, 1989) describe several types of flexibility such as machine, labor, material handling, routing, operation, expansion, volume, mix, new product, market, and modification. Most of these flexibilities are defined at the shop floor or individual resource level. This study uses flexibilities defined at the plant level (volume, modification, expansion, new product, and mix) to capture a strategic business unit's overall agility in a global environment. However, aggregate measures of labor and machine flexibility will be used to represent flexibiltities due to changes in resources within the strategic business unit. Many of these flexibilities possess both range and adaptability measures. For example, expansion flexibility has two components, the number of methods for expansion as well as the ability to expand; thus it will be presented in both the range and adaptability constructs. The manufacturing flexibility construct is shown in Figure 4.

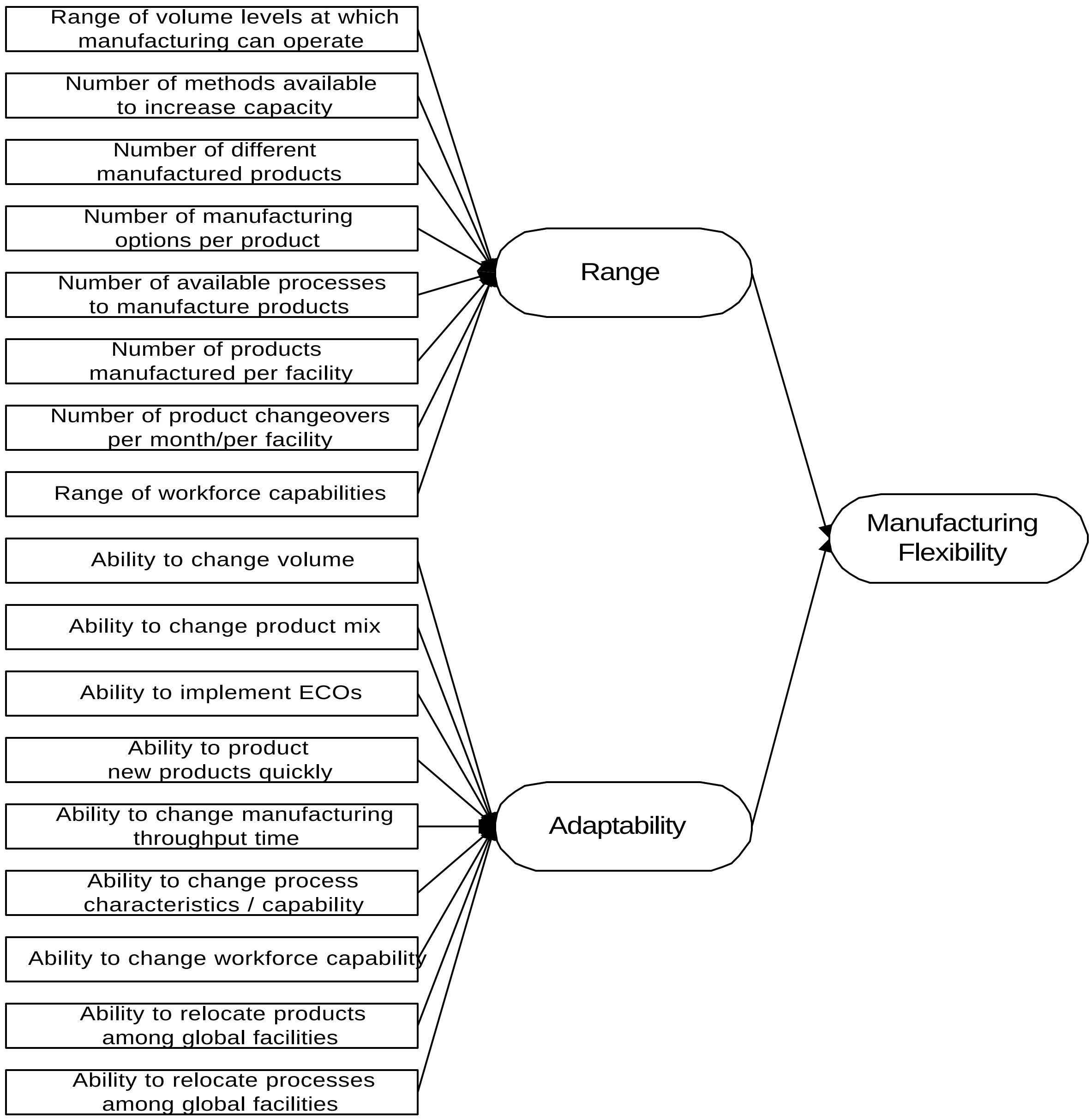

Figure 4: Manufacturing Flexibility

The range of manufacturing flexibility captures the possible combinations within the manufacturing facilities. The first measure is the range of volume levels at which manufacturing can currently operate. This measure represents volume flexibility which is the, "extent of change and the degree of fluctuation in aggregate output level which the system can accommodate"(Koste and Malhotra, 1999). Gupta and Somers (1992) define volume flexibility as the, "ability of a manufacturing system to be operated profitably at different overall output levels." An organization with more operating capacity levels has more flexibility than an organization with only one operating capacity, because it can accommodate a higher range of demand fluctuations. The number of available methods to increase capacity affects range and represents part of expansion flexibility (Koste and Malhotra, 1999). Sethi and Sethi (1990) mention several methods such as building smaller production units, having modular flexible manufacturing systems, and multipurpose machinery to enhance expansion flexibility.

The next measure of range is the number of different manufactured products. Koste and Malhotra (1999) call this mix flexibility while Sethi and Sethi (1990) call it process flexibility. Mix flexibility with respect to range is defined as the, "number of products which can be produced."(Koste and Malhotra, 1999) Manufacturing with the ability to economically produce a wide variety of low volume products in small batches gains a competitive advantage (Berry and Cooper, 1999).

The number of different manufacturing options per product is an adaptation of Sethi and Sethi's (1990) routing flexibility and is another range measure. In a global market, the organization with the ability to move products around different production lines at different locations has greater flexibility than an organization with a single production facility per product. The number of available processes to produce new products is a range measure. This captures new product flexibility and measures its impact on manufacturing caused by product announcements. Sethi and Sethi (1990) group 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." This flexibility is important in constantly changing environments like high technology industries and industries with short product life cycles (Sethi and Sethi, 1990).

The next measure is the number of products produced per facility. This item captures the ability of a line to produce multiple products and is called process flexibility in some articles (Sethi and Sethi, 1990; Gupta and Goyal, 1989); while Suarez, Cusumano and Fine (1995) call it mix flexibility. The greater the number of products per facility then the higher the number of profitable combinations which can be scheduled to adjust to demand changes, component shortages or labor issues. The number of product changeovers (per month/ per facility) is also a measure of process flexibility (Ettlie, 1998) and is used as the last measure of flexibility range. The final measure of range is the range of workforce capabilities. This is similar to the range-number element of labor flexibility used by Koste and Malhotra (1999) which captures the extent of cross training. A workforce with higher levels of cross training provides more possible job assignment combinations for adapting to changing production schedules.

There are several measures of manufacturing flexibility adaptability to capture the system's ability to change the existing number of states. The first is the ability to change volume which captures a system's expansion flexibility. "Expansion flexibility is the ease with which capacity and capability can be increased when needed"(Sethi and Sethi, 1990). Manufacturing with an ability to readily change its volume demonstrates more flexibility to respond to product demand.

The ability to change product mix has been used to measure product flexibility (Gupta and Goyal ,1989). They define product flexibility as the, "ability to change over to produce a new product." Slack (1983) defines product mix flexibility as the, "ability to manufacture a particular mix of products within a given time period," and measures response as the, "time required to produce a new product mix." The ability to implement engineering change orders is a measure of adaptability which was labeled as process flexibility by Roth, Demeyer and Alano (1989). The next measure is the ability to produce new products quickly which Suarex, Cusumano and Fine (1995) refer to as new product flexibility. The previous three measures are interrelated. When manufacturing has the ability to change product mix, it has some of the same characteristics that aid in implementing engineering change orders and manufacturing new products. An organization with the ability to adapt manufacturing to different product specifications can exhibit faster product completion thereby reducing the overall delivery time.

Another measure is the ability to change manufacturing throughput time which is similar to Slack's (1983) delivery flexibility measure. This ability supports the concept of delivery time compression which is an important aspect of agility. The ability to change process capabilities and workforce capabilities are the next two measures. Manufacturing can quickly adapt to changing requirements when it possesses the ability to change the process or the job assignments of the employees.

The last two measures capture the organization adaptability on a global scale. An organization whose manufacturing facilities have the ability to move products and/or processes among global facilities possesses higher adaptability for adapting to changing global market requirements.

Logistics Flexibility

The logistics function is a critical dimension of time-based competitive strategies for companies (Fawcett and Clinton; 1996). Changes in overall warehouse structure, distribution of product among warehouses, and transportation network and mode impact supply chain significantly (Kopczak; 1997). Logistics is defined by the Council of Logistics Management as, "the process of planning, implementing and controlling the efficient, effective flow and storage of materials, finished goods, services and related information from origin to the location where they are used" (Fawcett and Clinton, 1996).

For this study, *logistics flexibility is defined as the ability to adapt, in a timely and cost effective manner, the process of controlling the flow and storage of materials, finished goods, services, and related information from origin to destination in response to changing environmental conditions*. The NGM study's (1997) attribute of customer responsiveness is impacted by logistics flexibility. If the organization has higher logistics flexibility, it will have an opportunity to be more customer responsive with respect to product delivery.

The range and adaptability constructs of logistics flexibility are shown in Figure 5.

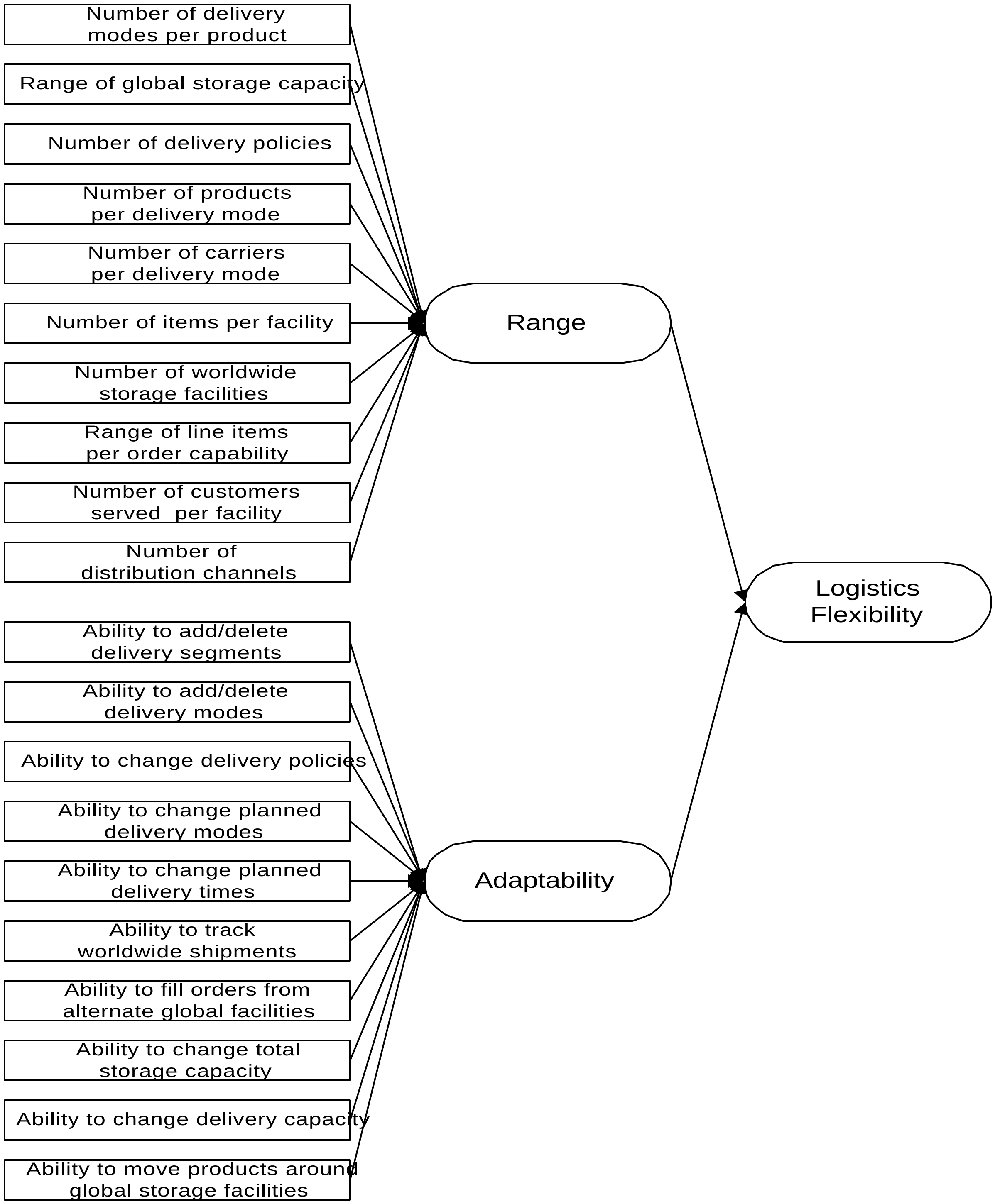

Figure 5: Logistics Flexibility

The first measure of range is the number of delivery modes per product which is analogous to the range-number measure of material handling flexibility in manufacturing.

Koste and Malhotra (1999) define this flexibility in manufacturing as the number of existing paths between processing centers. A product which can be delivered through multiple modes provides more logistics flexibility than a product which can be transported via only one delivery mode. For example, transistors can be shipped by land, sea, or air while a flexible manufacturing cell may only be shipped by sea due to its size. Using another analogy, the measure of the range of total storage capacity is based on the same concept as volume flexibility. An organization with a wider range of flexibility can accommodate more levels of product delivery as required by customer demands. The number of delivery policies is the next measure. This measure is based on Corbett's (1992) concept of delivery windows which represents the quoted time between customer order receipt and product delivery.

The fourth measure is the number of products per delivery mode. This measure is analogous to the range heterogeneity measure of material handling flexibility used by Koste and Malhotra (1999). They define flexibility as the variety of material which can be transported along the delivery routes. This measure captures the flexibility of the logistics network to handle a variety of materials. The higher the number of products the network can transport then the higher the flexibility. The next measure, the number of carriers per delivery mode, is also analogous to another manufacturing flexibility measure called process flexibility. An organization with a number of possible carriers per delivery mode can better respond if a carrier is unable to provide quick response to a delivery request.

The next two measures of range, the number of items managed at each facility and the number of worldwide storage facilities, impact flexibility. A facility with few items may have faster response time for picking and shipping than a facility with many items. Also related to delivery speed, an organization with multiple storage facilities may have closer proximity to more customers thus faster delivery. However, the relationship between facility and items has another impact on flexibility thus the next measure, the range of line items per order capability, is included in the model. If the facility manages many products, the range of line items per order must be wider in order to have the same level of flexibility as a facility which manages a few items.

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

Adaptability is determined by ten measures which capture the ability of the logistic network to change additional capabilities or track current network flow. The first is the ability to add or delete delivery segments. This provides options for changing the overall delivery route in response to customer requirements. Along this same line of reasoning is the ability to add or delete delivery modes. An example is the speed through which a relationship with a new sea freight carrier can be established to carry Robert Bosch product from Germany to Charleston, SC for BMW.

The ability to change delivery policies is the third measure. An example is the ability of Reebok to change the usual delivery time of 5 weeks via sea freight to 2 weeks via air freight in order to satisfy a customer with an inventory shortage. This is related to the next two measures, the ability to change planned delivery mode and the ability to change planned delivery time. The ability to change planned delivery time represents Slack's (1983) delivery flexibility concept for manufacturing. The ability to track worldwide shipments is the next measure since it reduces the response time for customer inquiries and identification of shipments problems.

Along with the range measures, number of customers served per facility and the number of distribution channels, is the adaptability measure of the ability to fill orders from alternate global facilities. The flexibility provided by the range measure is compounded if those same customers can also have orders filled by multiple facilities. The next two measures, 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. These measures are important since they capture the same dimension as expansion flexibility which is represented in the manufacturing adaptability construct. The final measure of logistics flexibility is the ability to move product around global storage facilities. This captures the organization's ability to relocate product based on changing global market demands.

Information Technology Flexibility

In their introduction to a special issue on global supply chain management, Lee and Ng (1997) mention three types of flow through a supply chain : material, finance, and information. Several articles (Katayama and Bennett, 1999; Powell and Dent-Micallef, 1997; Palvia, 1997) have been written on the use of information technology (IT) within an organization. Katayama and Bennett (1999) label three different activities within a manufacturing business unit as being related to agility. These activities are using CAD/CAE, integrating information systems within manufacturing, and integrating information systems across functions within the business unit. For this paper, we define *information technology flexibility as the ability of an organization's collective information technology system to adapt and support changing requirements of the business with respect to the flexibility dimensions of product development, sourcing, manufacturing and logistics as well as other strategic goals.*

Although an organization may have IT, it may not recognize the benefits of the technology due to the human factors such as CEO commitment or the level of open communications within the organization (Powell and Dent-Micallef, 1997). However, if the organization does effectively utilize its IT, information is more accessible thus improving decision making processes and providing a competitive advantage.

Several articles have been written that address the link between different ITs and performance (Sethi and King, 1994; Li and Ye, 1999; Stratman and Roth, 1999). Sethi and King (1994) developed a construct 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) use interactive regression to analyze the individual and collective effects of Information Technology (IT) investment, environmental, strategic, and management factors on firm performance. Based on their sample of 513 firms, the interactive terms of IT investment and environmental dynanism had a significant impact on the return of sales performance.

Stratman and Roth (1999) propose a construct called enterprise resource planning competence in order to study its relationship with performance. They propose that higher IT competence provides better information faster to aid response to the effects of market uncertainty. Stratman and Roth (1999) define IT competence based on Roth and Jackson's definition, "competencies refer to localized production expertise, such as the bundle of people skills, system integration, or specific production technologies, that can be linked to a specific point in the value chain or to specific strategic design choices that create competitive capabilities." Since the need for higher IT competence and higher GSC agility are both driven by higher levels of uncertainty, we posit that higher IT flexibility supports higher levels of GSC agility. Our construct of IT flexibility is also defined by range adaptability. The item measures for both range and adaptability of IT flexibility are shown in Figure 6.

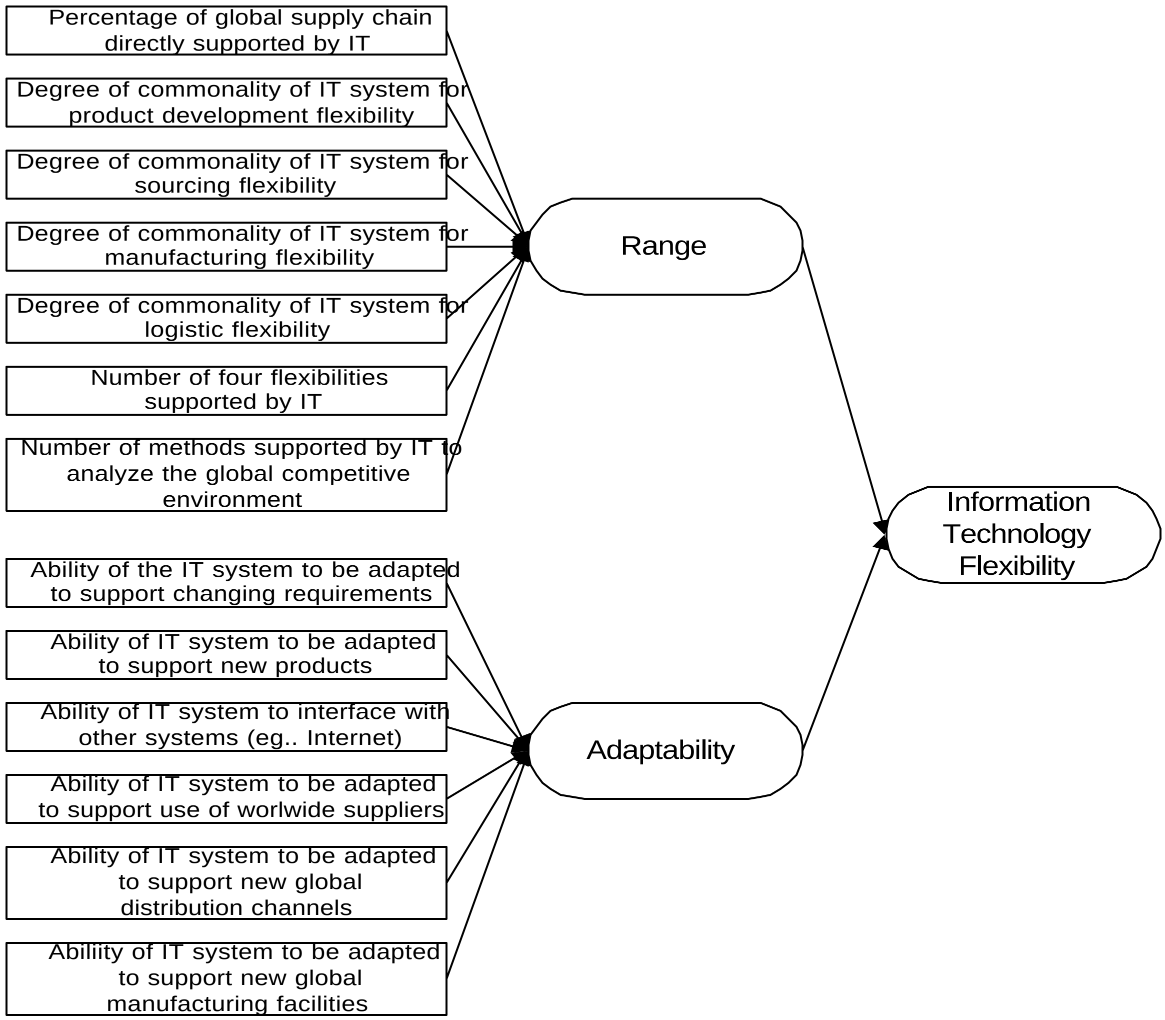

Figure 6 : Information Technology Flexibility

The first item is the percentage of the global supply chain directly supported by the IT system. Since IT impacts global performance (Jeffrey James, 1999), the higher the percentage of the global supply chain supported by IT, the higher its impact on performance. The next four items measure the amount of commonality of the IT systems used at the different locations for each activity within a supply chain such as product development, sourcing, manufacturing and logistics. Higher levels of commonality among IT systems supports worldwide transfer of knowledge between similar functions within the supply chain. Palvia (1997) uses this item as a measure of his learning curve and knowledge transfer construct. For example, higher levels of commonality among inventory IT systems at different locations expedites the transfer of product information when products are relocated due to changes in global markets.

Along the same thought pattern of first measure is the number of four flexibilities supported by IT. This reveals if one activity, say product development, is not supported by IT when eighty percent of the entire supply chain is considered to be supported by IT. The last item is the number of methods supported by IT to analyze the global competitive environment. The higher the number of methods then the organization has more information for making strategic global decisions regarding its competitors. Two questions in Palvia's (1997) survey related to the number of methods are, "To what extent does IT identify worldwide market trends?" and "To what extent does IT discovers and develop new and profitable worldwide markets?".

Six items exist to measure the adaptability of IT flexibility. All refer to different levels of the ability of the IT system to be adapted to changing requirements of the global supply chain. The first item is the overall ability of the IT system to be modified per changing requirements. At a deeper level, the next few items look at the ability of the IT system to be adapted to support new products, use of worldwide suppliers, new global distribution channels, and new global manufacturing facilities. Palvia (1997) also addresses these issues with survey questions such as, "To what extent does IT allow the manufacture of different parts in different locations?" and "To what extent does IT provide for rapid adjustments to the firm's logistics/distribution network?".

Global Competitive Environment

For this study, an existing construct of competitive environment is adopted with some minor changes. The construct from Tan, Kannan, Handfield, and Ghosh's article (1999) is chosen since it exhibits internal consistency with a Cronbach's alpha equal to 0.803. Powell and Dent-Micallef's (1997) entry barrier construct is added as an additional measure of the global competitive environment along with the number of worldwide competitors in the industry and degree of difficulty to become the worldwide industry leader. An organization in an industry with high barriers to entry and few competitors may be successful with a lower level of GSC agility. However, an organization in an industry with low barriers to entry and many competitors must possess a higher level of GSC agility for long term competitiveness and financial success. If the degree of difficulty for becoming an industry leader is high, an organization with higher global supply chain agility will have a better advantage to become the leader. The measures of competitive environment are shown in Table 1.

Item	Global Competitive Environment
1	Time, effort, resources and managerial attention required to keep pace with global competitors
2	Importance of potential global competitors reaction to business unit announcements
3	Number of competencies required to survive in the global industry
4	Amount of time spent in analyzing major global competitors' strategies and actions
5	Aggressiveness of major global competitors
6	Overall global competitiveness of associated industry
7	Level of barriers to industry
8	Number of worldwide competitors in the industry
9	Degree of difficulty to become the worldwide industry leader

Table 1: Measures of Global Competitive Environment

Global Supply Chain Agility

An agile organization has both structure and processes which enable fast and fluid changes to provide customer-enriching business activities (Goldman, Nagel, and Preiss, 1994). Since flexibility is a measure of the organization's ability to adapt (Goldman, Nagel, and Preiss,1994) and agility is a measure of the time required to adapt; flexibility can exist without agility but agility can not exist without flexibility. The GSC agility construct includes time and cost related measures since agility's purpose is to provide the supply chain with an ability to effectively respond quickly (Mason-Jones and Towill, 1999). Many of these measures represent the speed of adaptability within the flexibility constructs. Other measures capture the speed to pursue other competitive advantages such as quality and cost. Table 3 shows measures of GSC agility.

Item	Global Supply Chain Agility
1	Effectiveness in time and cost to reduce manufacturing leadtime
2	Effectiveness in time and cost to change global manufacturing capacity
3	Effectiveness in time and cost to change manufacturing's worldwide process capabilities
4	Effectiveness in time and cost to change global workforce capabilities
5	Effectiveness in time and cost to manufacture new product
6	Effectiveness in time and cost to reduce development cycle time
7	Number of times an innovative product was first to market
8	Effectiveness in time and cost to reduce delivery time
9	Effectiveness in time and cost to change worldwide delivery capacity
10	Effectiveness in time and cost to improve product quality
11	Effectiveness in time and cost to reduce product cost
12	Effectiveness in time and cost to reduce delivery cost

Table 3 : Item Measures of Global Supply Chain Agility

Supply Chain Performance

Several of Beamon's (1999) supply chain performance measures are used to represent the supply chain performance constructs. An organization with global supply chain agility should have faster response time; thus it should have shorter delivery time, shorter supply chain cycle time and shorter time to market. Also it would be able to respond faster to demand thus having higher percent of on-time deliveries, lower backorder level, fewer stockouts, and higher capacity utilization. The items used to measure supply chain performance are shown in Table 4.

Item	Supply Chain Performance
1	Average lateness of orders
2	Average earliness of orders
3	Percent of on-time worldwide deliveries
4	Average global backorder level
5	Number of worldwide stockouts
6	Amount of time between order and delivery
7	Manufacturing lead time
8	Average global supply chain cycle time
9	Average global supply chain capacity utilization
10	Time to market (product development to product announcement)

Table 4 : Item Measures of Supply Chain Performance

Global Competitive Performance

A number of constructs for financial and marketing performance have been used in academic articles (Tan, Kannan, Handfield, 1996; Smith and Reece, 1999; Hendricks and Singhal, 1997; Beamon, 1999; and Easton and Jarrell, 1998). The construct used by Tan, Kannan, and Handfield (1996) had a Cronbach alpha of .809 and the measures correlated with financial indicators from the Dun and Bradstreet database. The measures used in their construct are market share, return on assets (ROA), production costs, customer service, product quality, competitive position, growth in market share, growth in sales and growth in ROA. Two cost based measures of global competitive performance are volume of sales and profit margin (Beamon, 1999). The measures for the global competitive performance construct are shown in Table 5.

Item	Global Competitive Performance
1	Return on global assets (%)
2	Global market share (%)
3	Volume of worldwide sales ($)
4	Profit margins (%)
5	Global operating income ($)
6	Total worldwide cost / Total worldwide sales ($)
7	Total worldwide sales / Global total number of employees ($/employee)

Table 5 : Item Measures of Global Competitive Performance

3.0 Proposed Methodology

For this research, the sample survey strategy will be applied. Sample surveys typically exhibit high levels of generalizability since they tend to study larger universal systems (Kerlinger, 1986). Also, sample surveys are typically used for exploratory research in new areas (Kerlinger, 1986). According to Malhotra and Grover (1998), sample surveys have three characteristics. First, surveys involve the collection of data by asking respondents to answer structured questions. Second, surveys are usually quantitative. Third, survey data represents a selected population by using accepted sampling techniques to identify a smaller but "identical" sub-group of the population as respondents. In this study, the unit of analysis for the survey includes manufacturing industry organizations with an established global supply chain.

A fundamental component of the sample survey strategy is the development of the measurement scale. Malhotra and Grover (1998) discuss a framework for developing measurement scales which is based on Churchill's model and is shown in Figure 7.

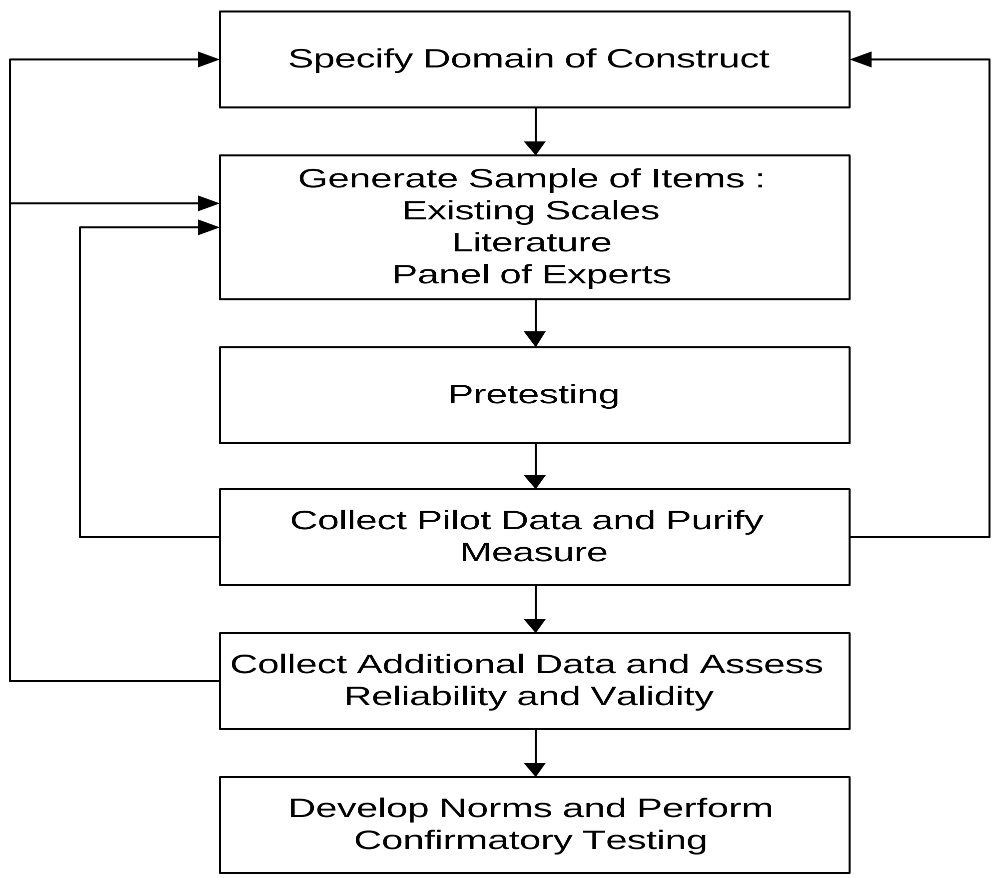

Figure 7 : Framework for developing measurement scales

The first few steps, addressed in this paper, are specifying construct domain and the use of literature to establish content validity. After an initial list of item measures is developed, pre-testing of the item measures begin. The Q-sort method will be used to test the linkage between item measures and constructs (Hensley,1999). In this method, respondents match each item measure in a randomized list to the appropriate construct given the definitions of the constructs. The respondents also note any confusing or ambiguous wording of the item measures and construct definitions. Several techniques including inter-respondent agreement statistics and item placement ratios exist to assess item measure reliability based on the respondents' matching (Stratman and Roth, 1999). The item placement ratio technique also assesses construct validity. The item measures will then be modified based on respondents' remarks and the construct's reliability level. Item measure modifications and additional iterations of the Q-sort method will be performed until acceptable reliability and validity levels are obtained for each construct.

Once item measures exhibit acceptable reliability and validity levels, development of the survey instrument begins. The survey will consist of self-report questions using a 6-point Likert scale (i.e. For the following items, rate your ability from Very High to Very Low relative to your competition). Using Sudmand and Bradburn's (1982) advice, six response categories are used to eliminate the cumulative responses from piling up at a center response. For example, the overall response curve for a five category question may exhibit a normal distribution but have a high peak at the center point. Providing response categories simplifies the respondent's task of answering the survey questions but can lead to lower measurement precision of the constructs. (Sudmand and Bradburn, 1982)

After the survey is developed, it is pilot tested before distribution. Approximately 30 respondents will complete the survey and indicate any ambiguity in the questions. The pilot survey responses will be used to evaluate construct reliability using Cronback's alpha (Cronbach, 1951). Survey questions will be modified until acceptable reliability levels are obtained and to reduce ambiguity.

The survey will be distributed to supply chain managers within the defined unit of analysis. The sample of respondents will be developed from several sources. First, mailing lists from journals which publish articles pertaining to supply chains will be obtained. Second, additional companies will be identified through the use of Fortune 500 type lists for the United States and Canada. Lastly, we are requesting Cranfield University in England to assist with distributing and collecting the survey in Europe.

Since response can be less than 40 or 50 percent (Kerlinger, 1986) and the study requires at least 200 responses (Hinkin, 1995), several techniques will be used to motivate respondents to participate. A cover letter will accompany each survey describing the overall intent of the study and the potential toward development of application tools for analyzing global supply chain agility. Also, a signed endorsement letter by a recognized leader in supply chain academic and practitioner circles will be enclosed with the survey. On the survey itself will be a box for the respondent to mark to request a copy of the final analysis report. Follow-up reminder postcards and phone calls will also be used to encourage participation.

Once the survey data is collected, exploratory and confirmatory factor analysis will be used to assess convergent and discriminate validity of the constructs. After validating the constructs, structural equation modeling will be used to test the viability of the propositions of the global supply chain agility model.

4. Summary

This article has presented a framework for analyzing GSC agility and its potential impact on two dimensions of performance. Several constructs of flexibility have been developed along with constructs for the global competitive environment, supply chain performance, and global competitive performance. Each construct has been defined and arguments provided for each measure of the constructs.

The result of the empirical study using this model will provide valuable information regarding GSC agility. Based on the coefficients, one will be able to determine which flexibility dimension has the greatest impact on GSC agility. Also it will show which environmental factors influence GSC agility. The third important aspect of examining this model will show the impact of GSC agility on performance. More information would be gained if organizations' supply chains were classified as being global or local along with being classified as high or low agility. This will provide information on how a local company with a local level of agility could change to have global agility in order to expand its supply chain globally.

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