**An Impact of Manufacturing Flexibility and Technological Dimensions of Manufacturing Strategy on Improving Supply Chain Responsiveness: Business Environment Perspective**

**Minkyun Kim, Ph.D. (Corresponding Author)**

Affiliation: Assistant Professor, Department of Logistics/Supply Chain/Service Operations Management, Sogang Business School,

Sogang University, Seoul, Korea

E- mail: minkyunkim@sogang.ac.kr

Address: Department of Logistics/Supply Chain/Service Operations Management, Sogang Business School, 35 Baekbeom-ro, Mapo-gu, Seoul, Korea

Minkyun Kim is an Assistant Professor in Sogang Business School in Sogang University, Seoul, Korea. He received Ph.D from Department of Operations Management & Strategy in the School of Management, State University of New York at Buffalo. He graduated from University of Illinois at Urbana-Champaign with B.S. degree in Finance and SUNY at Buffalo with M.S degree in Finance. His research areas are strategic sourcing, supply chain risk management and e-business technology in supply chain management. His research has been published in Decision Support Systems, Behavior & Information Technology and International Journal of Information Management.

**Nallan C. Suresh, Ph.D.**

Affiliation: Professor, Department of Operations Management & Strategy

School of Management, The State University of New York at Buffalo

E-mail: ncsuresh@buffalo.edu

Address: Department of Operations Management & Strategy, 326F Jacobs Center

School of Management, SUNY at Buffalo, Buffalo, NY 14260 USA

Nallan C Suresh is a professor and Chair in the Department of Operations Management & Strategy in the School of Management, State University of New York at Buffalo. His research work has been in the areas of: 1) economic justification of flexible manufacturing systems (FMS) and robotics, 2) design of cellular manufacturing systems, 3) production planning, control &

scheduling systems, and 4) supply chains and e-commerce applications. His publications have appeared in leading research and professional journals such as: Decision Sciences, Management Science, Journal of Operations Management, International Journal of Production Research, International Journal of Production Economics, IIE Transactions, International Journal of Flexible Manufacturing Systems, European Journal of Operational Research, Computers and Industrial Engineering, and International Journal of Operations and Production Management.

**Canan Kocabasoglu-Hillmer, PhD.**

Affiliation: Senior Lecturer, Faculty of Management, Cass Business School, City University London

E-mail: Canan.Kocabasoglu-Hillmer.1@city.ac.uk

Address: Cass Business School, City University London, 106 Bunhill Row, London, EC1Y 8TZ, United Kingdom

Canan Kocabasoglu-Hillmer is a Senior Lecturer in Operations Management in Faculty of Management, Cass Business School, City University London. She also worked as an Assistant Professor in the University of Kansas before joining City University London. She received PhD in School of Management, SUNY at Buffalo. Her research areas are Corporate Social Responsibility, E-Business, Logistics and Distribution, Production & Operations Management, Supply Chain Management. Her research works are published in leading research journals such as Journal of Operations Management, Journal of Supply Chain Management, Quality Management Journal, and International Journal of Management Science.

# An Impact of Manufacturing Flexibility and Technological Dimensions of Manufacturing Strategy on Improving Supply Chain Responsiveness: Business Environment Perspective

The main objective of this research is to investigate the impact of manufacturing flexibility and technological dimensions of manufacturing strategy on responsiveness in the supply chain. Based on the theoretical background of dynamic capability, this study also examines the role of the business environment on the relationship between manufacturing flexibility and supply chain responsiveness. 144 structured surveys were collected and the partial least squares of structural equation modelling approach were utilized for data analysis. The result establishes relationships among various dimensions of manufacturing flexibility. Although the technological dimensions in manufacturing strategy such advanced manufacturing technology (AMT) and e-procurement do not have any direct impacts on new product and market flexibility, they increase supply chain responsiveness, which helps to react quickly against supply chain disruptions. More importantly, the business environment has a moderating effect on the relationship between market flexibility and supply chain responsiveness.

Keywords: Manufacturing flexibility; manufacturing strategy; supply chain responsiveness; business environment; dynamic capability;

## 1. Introduction

Recently, supply chain management is receiving much attention as a business tool to be used in dealing with challenges which are generated by competitive and dynamic markets. Current business trends lead to greater exposure to risks such as the increased use of outsourcing, the globalization of supply chains and the reduction in the supply base. Other potential risks include a more integrated process among supply chain members, a reduction in a buffer, an increased demand for on-time delivery within a limited time, shorter product life cycles and time-to-market, as well as capacity limitation and a heavy demand in the early product life cycle (Norrman and

Jansson, 2004). In recent years, the structure of supply chains has become more complex due to growing levels of risk and uncertainty in the market as well as within the supply chain itself. Managers are not able to control all aspects of the supply chain, which requires them to take a selective action in dealing with risk (Luhmann, 1995). According to the McKinsey Global Survey, executives are not prepared to manage supply chain risks. According to Mark Hillman in AMR research, 60% of organizations in the U.S do not have effective supply chain risk management policies. High risk generates inefficiency in the supply chain (Christopher and Lee, 2004). More importantly, tangible risks in the supply chain are proved to be one of causes for poor performances (Wilding, 1998). Therefore, mitigating risk in the supply chain emerges as a significant issue in academia as well as in the business world because of the unknown impact of risk in the supply chain.

In mitigating supply chain risks, previous literature introduces various strategies in supply chains. In order to respond with supply chain disruptions, establishing manufacturing strategy as well as manufacturing flexibility is considered as proper risk mitigating strategies in the supply chain. For establishing effective manufacturing strategy toward supply chain risks, assessing and evaluating the existing risk is very crucial (Kumar *et al.*, 2010). First of all, it is very important for researchers to identify and understand supply chain risk while minimizing the impact of the risk (Norrman and Jansson, 2004). In order to mitigate risk, prior studies present one common strategy. Leindorfer and Saad point out the significance of internal and external integrations in a supply chain for mitigating supply chain risks. (Kleindorfer and Saad, 2005). Faisal *et al.* indicate that information sharing and collaborative relationships in supply chain networks also lessen supply chain risks (Faisal *et al.*, 2006). Therefore, this research introduces the impact of manufacturing flexibility and manufacturing strategy in an effort to improve supply chain responsiveness against supply chain disruptions. In addition, this research focuses on supply chain risk management by finding ways of mitigating supply chain risks but without including supply chain risks as actual constructs.

Although the importance of supply chain risk management has been recognized in the industry as well as academic world, there is a lack of empirical studies in supply chain risk management so that more empirically grounded research is necessary for supply chain risk management (Juttner *et al*., 2003). This research is motivated to fill the gap of mitigating supply chain risk by adopting a synergy effect of manufacturing flexibility and manufacturing strategy and examining the role of business environment in the relationship between manufacturing flexibility and supply chain responsiveness with an empirical approach. This research investigates the role of business environments because it examines how manufacturing strategy and manufacturing flexibility implemented by supply chain members react toward changes of business environments leading to improvement of supply chain responsiveness.

Manufacturing strategy is highly associated with the business strategy. The research of Williams *et al* (1995) established the framework that business strategy affected manufacturing strategy which influences the performance. In that study, they defined manufacturing strategy in two dimensions: technology orientation including production planning and control systems, quality assurance programs, capacity planning, innovate manufacturing process, and special purpose equipment and market orientation including general purpose equipment, capacity slack, product quality, variety of final products offered, product customization, and facility focus (Williams *et al.,* 1995). This paper focusing on the technological dimensions of manufacturing strategy empirically examines the linkage between manufacturing flexibility and technological dimensions of manufacturing strategy and how these two dimensions influence supply chain responsiveness.

There are many dimensions on manufacturing flexibility. This research focuses on machine, labor, new product and market flexibility. This flexibility does not generate high penalties and outcome differences.  Machine and labor flexibility depends on machines and workers who can execute multiple operations (Koste and Malhotra, 1999). New product flexibility is the number and variety of new products that can be produced (Koste and Malhotra, 1999). Market flexibility is defined as an ability of adapting to market changes (Narasimhan and Das, 1999). Another important objective of this research strives to investigate the relationships among these dimensions of manufacturing flexibility: machine, labor, new product and market flexibility.

A major objective of this research is to investigate the joint impact of manufacturing flexibility and the technological dimensions of manufacturing strategy in improving the responsiveness in the supply chain. In addition, this study examines the role of the business environment as it affects manufacturing flexibility and supply chain responsiveness. Specifically, the following research questions are addressed:

- What impact do technological dimensions of manufacturing strategy have on manufacturing flexibility and supply chain responsiveness?
- What impact does manufacturing flexibility have on supply chain responsiveness?
- What impact does the business environment have on the relationship between market flexibility and supply chain responsiveness?
- What impact does a hierarchy of manufacturing flexibility make on supply chain responsiveness?

This paper is organized as follows. Section 2 includes the theoretical background and a review of relevant literature. Section 3 establishes a conceptual model and the constructs and hypothesis are developed for designing the research model. Section 4 presents a discussion of the samples and research methodology. Section 5 introduces results of data analysis. The paper ends with Section 6 conclusion and discussion.

## 2. Theoretical background and literature review

### *Dynamic Capability*

Dynamic capabilities, introduced by Teece et al. (Teece *et al*., 1997), has been developed from Resource Based View (Pandža *et al*., 2003). Compared to a resource based view, dynamic capabilities focus on the market and emphasize speed and unpredictable changes in the business environment. The dynamic capabilities approach also focuses on the dynamic process of developing capabilities while RBV identifies resources and capabilities as static (Pandža *et al*., 2003 ). The main idea presented by dynamic capabilities is how a firm can acquire or develop firm-specific resources or capabilities to achieve a competitive position in the dynamic business environment (Eisenhardt and Martin, 2000, Winter, 2003). For this reason, in dynamic capabilities, a firms' ability of configuring and relocating resources and its competence is regarded as a source of competitive advantage in rapidly evolving business conditions.

In the very competitive and dynamic business environments, organizations need to have the capability of incorporating and assembling all resources as well as competencies (Teece *et al*., 1997). In the dynamic capabilities model, ability is the source of the competitive advantage of firms (Eisenhardt and Martin, 2000). Based on the definition of Teece *et al*., and the research of Eisenhardt and Martin, dynamic capabilities are the firm's processes that use resources in their processes to integrate, reconfigure, gain and release resources—to match and even create market change. Dynamic capabilities, then, are the organizational and strategic practices by which firms achieve new resource allocations depending upon market conditions. (Eisenhardt and Martin, 2000). This research is based on dynamic capability as a theoretical background. Business environments are often neglected in the context of supply chain management. Thus, by adopting dynamic capability theory, this research considers changes of business environments such as dynamics and competition in the market in the relationships between manufacturing flexibility and supply chain responsiveness. This study investigates how the relationship between manufacturing flexibility and supply chain responsiveness has been changed by the impact level of business environments. It also focuses on how manufacturing flexibility and technological manufacturing strategy can react effectively toward dynamic business environment in the supply chain management. In order to reflect the time in the dynamic nature of dynamic capabilities theory, this research investigates the moderating effects of dynamic and competitive business environments on the relationship only between market flexibility and supply chain responsiveness. In this relationship between the market flexibility and supply chain responsiveness, we examine how dynamic business environments make an impact on the market flexibility as time passes by. Then, the research investigates how changes of market flexibility influence on the supply chain responsiveness.

***Supply Chain Risk Management***

There are two main definitions of supply chain risk management. It is defined as a process of collaboration with supply chain partners while applying risk management tools to deal with risks, in all related logistics activities (Norrman and Jansson, 2004). In a simple term, it is defined as the management of risks for the supply chain, through a coordinated approach among supply chain members, to reduce supply chain vulnerability as a whole' (Juttner *et al.*, 2003). This research focuses on how managers can mitigate the risk by implementing manufacturing flexibility as well as technological dimensions of manufacturing strategies in order to improve the responsiveness in the supply chain.

The research of Christopher and Lee suggests three strategies to remove the risk spiral in supply chain: making information accurate, visible and accessible, being alerted for out of control conditions and performing responsive corrective actions (Christopher and Lee, 2004). Christoper and Peck emphasize the importance of supply chain collaboration which encourages information exchange in supply chain networks and supply chain agility (Christopher and Peck, 2004).

Juttner *et al*. presents four points for mitigating strategies: avoidance, contingencies, cooperation and flexibility (Juttner *et al.*, 2003). Supply risk management uses very similar approaches as with supply chain risk management. Zsidisin *et al*. confirmed that reducing supply risk can be achieved byforming alliance relationship, making suppliers responsible for the development of risk mitigation plans, maintaining common platforms for the products, accessing directly to suppliers and establishing industry standards (Zsidisin *et al*., 2000).

Consistent with previous suggestions, Harland *et al*. also find similar supply risk management strategy. First, forming collaborative supply network strategy is very critical. Second, implementing supply network risk strategy is very significant for the organizations. (Harland *et al*., 2003). Based on the literature review of supply chain risk management, the common themes for supply chain risk mitigating strategy are flexibility and collaboration. By improving flexibility and collaboration in the supply chain, the supply chain members are able to develop quick response plans toward supply chain risk. This research applies both manufacturing flexibility and technological dimensions of manufacturing strategies on how to improve the supply chain responsiveness in order to help managers to set up risk mitigating strategies.

### *Manufacturing Strategy*

Implementing manufacturing strategy for firms is very crucial because it has a direct impact on a firm's performance. Das and Narasimhan established the framework of process environments and manufacturing technologies and examined their influence on manufacturing performance (Das and Narasimhan, 2001). The research of Devaraj *et.al*. examined which map area of product-process matrix and genetic manufacturing strategy framework could improve the performance as the research results support that the diagonal of product process matrix provides higher performance (Devaraj *et al*., 2001). Frohilch and Dixon examined the role of manufacturing strategy with different approach while they investigated the association between manufacturing strategy and competitive capabilities that is performance on price, flexibility, quality, delivery and service (Frohlich and Dixon, 2001). Although they measured the performance in a different manner, their research also emphasized the importance of manufacturing strategy which influences the performance positively. Product process matrix has been validated and it also confirmed that determining manufacturing strategy is very crucial to improve the performance (Safizadeh and Ritzman, 1996). According to Ward and Duray, they also investigated the role of manufacturing strategy on improving business performance while they align competitive strategy into manufacturing strategy in order to prove that integrating business strategy into manufacturing leads to the better performance (Ward and Duray, 2000).

Prior literatures regarding the concept and practice of manufacturing strategy have been growing for thirty years as different approaches and views emerge on investigating this research area. Formulating the best manufacturing strategy is difficult due to global competition, dynamic business environments and rapid changes of technology (Miltenburg, 2009). Voss mentioned that strategic choice aligns with business strategy and best practice is a linkage between manufacturing strategy and practice (Voss, 2005). The study of Devaraj *et al* confirmed that plants with a better fit between manufacturing objectives and actual manufacturing strategies generate superior outcomes in generic manufacturing strategy framework (Devaraj *et al*., 2004). The research of Ward *et al.* provided empirical evidences that the association exists between business strategy and investments on manufacturing (Ward *et al.*, 2007). Zhao *et al.* recognized taxonomy of manufacturing strategies in China and empirically investigated the relationship between manufacturing strategy and financial performance (Zhao *et al*., 2006). Sousa presented that a plant's overall manufacturing strategy affects strongly the pattern of usage of customer focus practices (Sousa, 2003). The research results by Paiva *et al* indicated that knowledge resources in the organization help manufacturing functions to look for higher integration with other functions in the environment (Paiva *et al*., 2008). The study of Swink *et al.,* showed that cost efficiency, process flexibility and new product flexibility have a significant relationship with workforce development and product-process development (Swink *et al*., 2005). Acquaah et al., 2011 empirically confirmed that the effectiveness of manufacturing strategy assists in establishing defense as well as resilience against economic disruption (Acquaah *et al*., 2011). Because this study investigates the role of advanced manufacturing technology and e-procurement it focuses on the impact of technological dimension of manufacturing strategy on manufacturing flexibility and supply chain responsiveness. By implementing advanced manufacturing technology and e-procurement, this research emphasizes the synergy impact of these two technological factors in manufacturing strategy with manufacturing flexibility in order to improve supply chain responsiveness.

***Manufacturing Flexibility***

The research of Koste and Malhotra proposed a hierarchy of flexibility dimensions which consider machine and labor flexibility as individual resource (tier 1), new product flexibility as plant (tier 3) and market flexibility as functional (tier 4) (Koste and Malhotra, 1999). Van Hop and Ruengsak proposed a model which includes dimensions of flexibility, capability and capacity in manufacturing (van Hop and Ruengsak, 2005). Rogers *et al*., 2011 establishes six dimensions of manufacturing flexibility: product mix flexibility, routing flexibility, equipment flexibility, volume flexibility, labor flexibility and supply management flexibility (Rogers *et al*., 2011). Narasimhan and Das empirically validated the relationship between tactical flexibilities and strategic flexibilities including new product flexibility (Narasimhan and Das, 1999). The study of Vokurka and O'Leary-Kelly reviewed the literatures on empirical research regarding manufacturing flexibility and described various factors affecting manufacturing flexibility (Vokurka and O'Leary-Kelly, 2000). Koste *et.al.* (2004) clarified dimensions of manufacturing flexibility and identified two underlying factors thatare scope and achievability (Koste *et al.*, 2004). The research of Chan *et al*., 2006 emphasized that adding flexibility in manufacturing systems influence the performance positively although an increase of flexibility becomes counterproductive in certain environments (Chan *et al.*, 2006). Zang *et al* (2003) also empirically validated that the flexible manufacturing competence has a positive impact on volume and mix flexibility, which influence customer satisfactions (Zhang *et al.*, 2003). This research depends on a proposed conceptual model which investigates the relationship between operational flexibilities including machine and labor flexibility and strategic flexibilities including new product and market flexibility following a hierarchy of flexibility dimensions.

## 3. Model Development

Machine flexibility is defined as the number of various operations that a machine can execute without generating penalties of production outcomes (Koste and Malhotra, 1999). Labor flexibility is defined as the number of various operations that a worker can perform without generating penalties of production outcomes (Koste and Malhotra, 1999). New product flexibility is defined as the number of various new products which are introduced without generating penalties of production outcomes (Koste and Malhotra, 1999). According to their study, machine and labor flexibility is located in tier 1 as an individual resource and new product flexibility is located in plant tier 3.

Market flexibility is defined as the ability of a manufacturing system to adapt to or influence market changes (Narasimhan and Das, 1999). According to their study, machine and labor flexibility are operational flexibility levels as a basic level of manufacturing flexibility hierarchy. New product and market flexibility are strategic flexibility levels as the highest level of manufacturing flexibility hierarchy. They also pointed out that market flexibility is an antecedent of new product flexibility in strategic flexibility level. In this study, market flexibility becomes the higher level of new product flexibility because new product flexibility can affect market flexibility based on dynamics and competition in market coming from dynamic capability theory.

The benefits of manufacturing flexibility are considered as better availability, predictability and dependability (Slack, 2005). The tier of manufacturing flexibility such as machine, labor, new product and market flexibility makes a significant impact on improving lead time performance (Wadhwa *et al*., 2005). More importantly, manufacturing flexibility is viewed as a coping mechanism against uncertainty in the organizational external environment (Sawhney, 2006). In other words, manufacturing flexibility improves agility so that it is very important to keep manufacturing flexibility in the supply chain in order to face uncertain environments (Lin, 2004). Moreover, market flexibility can help firms directly to react in the change of the business environments (Narasimhan and Das, 1999). In addition, flexibility in the supply chain has a significant positive relationship with responsiveness (Nair, 2005). Based on above discussions, this research hypothesizes that:

*H1:* Machine flexibility has a positive impact on new product flexibility.

*H2:* Labor flexibility makes a positive impact on new product flexibility.

*H3:* New Product flexibility positively affects on market flexibility.

*H4*: Market flexibility influences supply chain responsiveness positively.

There has also been a major technological transformation in supply chain management by way of e-business technologies, which provides supply chain members the establishment of communication networks between buyers and suppliers (Min and Galle, 1999, Deeter-Schmelz *et al.,* 2001). Information technology also helps suppliers to transfer their knowledge, leading to assisting on mass manufacturing (Henriksen and Rolstadås, 2010). E-business technology also enables firms to utilize real time information promoting enhanced collaborations among firms (Vakharia, 2002). Among these e-business technologies, e-procurementallows firms to purchase materials using the Internet (Presutti, 2003). Many studies have pointed out the potential benefits from e-procurement. Croom (2000) identified four main benefits: 1) lower procurement process cost, compared to manual procurement processes, 2) greater visibility on expenditure control, 3) increase in procurement control, and, 4) benefits from managing suppliers (Croom, 2000). E-procurement may also generate internal cost reduction in purchasing (e.g. transparency, order discounts and price efficiency) as well as external business innovation such as new market penetration (Benton, 2007). E-procurement promotes better management of information and knowledge of suppliers, better control of supplier operations, (Muffatto and Payaro, 2004). In addition, e-procurement may result in increased speed, quantity and quality of information processing, especially with international suppliers (Essig and Arnold, 2001. E-procurement also makes a positive impact on both buyer and supplier performance (Tai et al., 2010). To summarize advantages of e-procurement on manufacturing flexibility as well as supply chain responsiveness, implementing e-procurement encourages information sharing and collaboration with suppliers, leading to improvement on flexibility in introducing new product , flexibility towards changes in the market and responsiveness in the supply chain. Based on benefits of e-procurement in above discussion, this research hypothesizes that:

*H5:* E-Procurement has a positive impact on new product flexibility.

*H6:* E-Procurement makes a positive impact on market flexibility.

*H7:* E-Procurement positively affects supply chain responsiveness.

Advanced manufacturing technology (AMT) has two main benefits. One is that it gives the flexibility of that firms can produce various products at low volumes without high penalties. The other is that it increases manufacturing productivity (Swamidass and Kotha, 1998, Kotha and Swamidass, 2000). Advanced manufacturing technology also strengthen the relationship with the suppliers in the supply chain management (Rahman et al., 2009). Obviously, AMT has its objective to adopt improve flexibility but previous literature shows conflicting evidences. Because of various ways of using AMT in the production line, the impact of AMT on manufacturing flexibility has not been validated yet. More importantly, the broader impact of AMT on the firm's financial performance is also unclear (Swink and Nair, 2007). However, in this study, advanced manufacturing technology assume to generate flexibility in the supply chain so that it makes a positive impact on new product flexibility, market flexibility as well as supply chain responsiveness. Therefore, this study is approaching the impact of AMT in a positive side as it hypothesizes that:

*H8:* AMT has a positive relationship with new product flexibility.

*H9:* AMT has a positive relationship with market flexibility.

*H10:* AMT has a positive relationship with supply chain responsiveness.

In supply chain management, the business environment is often ignored although they are receiving some attentions recently. The business environment is a very important factor affecting performance directly or indirectly. The business environment influenced manufacturing flexibility and the role of operation managers in strategic decision makings (Swamidass and Newell, 1987). The environmental uncertainty directly affects new product flexibility, volume flexibility and product mix flexibility (Shih-Chia et al., 2002). Three dimensions of environment which are environmental munificence, environmental dynamism and environmental complexity made an impact on the performance although the effect of environmental complexity was neglected (Ward *et al.,* 1995). Three environmental factors such as competitive intensity, technological change and customer type were examined as a moderating effect on the relationship between supply chain relationship quality and supply chain performance (Fynes *et al.,* 2005). The impact of the business environment in strategic sourcing and buyer supplier relationships was also examined (Chen and Paulraj, 2004). The study of Kocabasoglu *et al* also investigated the relationship between business environment which consists of munificence, dynamism, hostility and heterogeneity and forward and reverse supply chain risk propensity (Kocabasoglu *et al*., 2007). Dynamism of the environment moderates the relationship between manufacturing flexibility and firms' strategic behavior (Tamayo-Torres *et al*., 2011). By conducting a longitudinal study, Corbett provied evidences that many firms changed their strategy against dynamic business environments (Corbett, 2008).Based on the above discussions, this research hypothesizes:

H11: Business environment has a moderating effect on the relationship between market flexibility and supply chain responsiveness.

Figure 1 describes our research model.

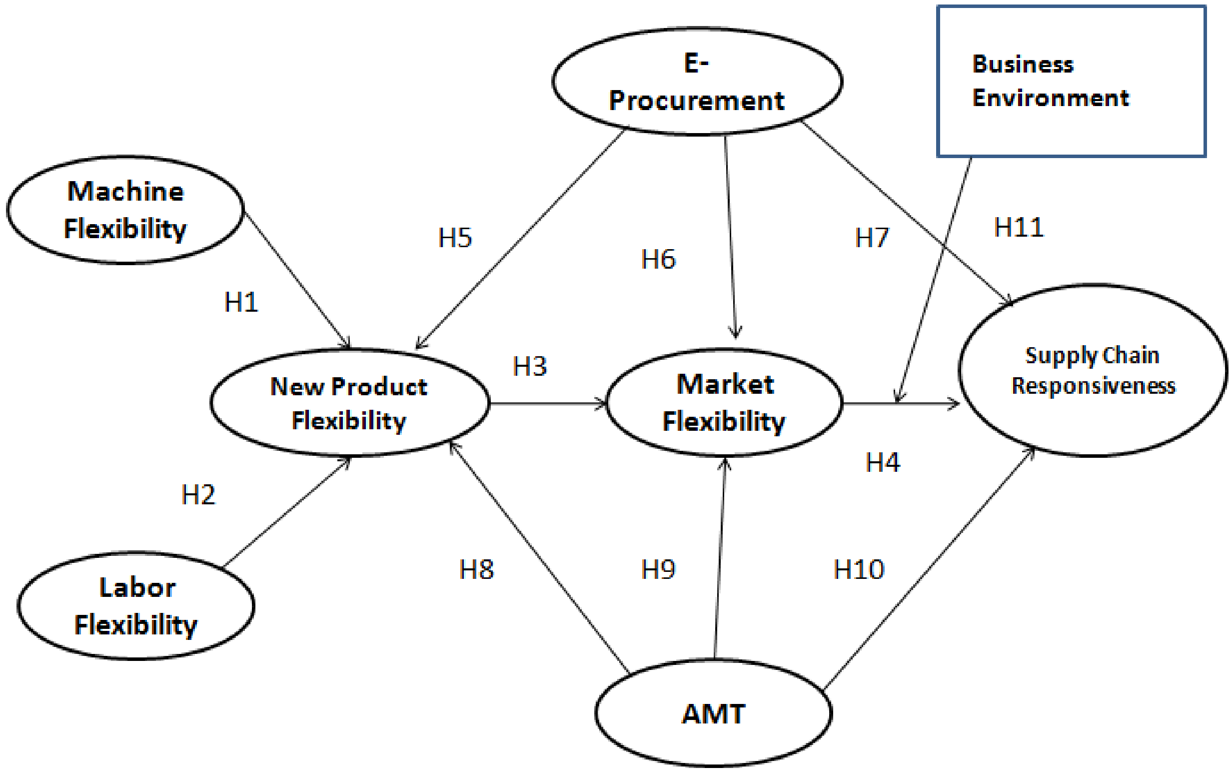


**Figure1. Research Model**

## 4. Methodology

This study utilized for data collection on the survey. The survey instruments have been developed from previous literatures. All items were assessed using a five-point Likert scale, except for the business environment variables. Labor flexibility measures the flexibility of labor workforces in the production line. Machine flexibility measures the flexibility of machines in the production line. New product flexibility measures flexibility of introducing new products in the market. Market flexibility measures flexibility of product mix. E-procurement measures impact of adopting e-business technologies. AMT measures intensive usage of AMT. Supply chain responsiveness measures the responsiveness toward customers. In other words, supply chain responsiveness indicates the ability of a supply chain to satisfy customers' needs. Three measurement items capture the extent to which companies and their suppliers can satisfy their customers by being responsive to their needs as well as their satisfactions. For business environments, the measures for degree of competitive intensity and market turbulence were based on a 1-to-7 Likert scale. The degree of competition indicates the level of competition which the firm's major products face in the market. The degree of turbulence represents the level of market contingency and the demand change in the market. The measurements of constructs have three items which are developed from previous literatures. Table 2 and Appendix describes indicators of measurements, survey questions, scale as well as sources.

The survey was first tested through semi-structured interviews with purchasing professionals, business consultants, and academics in the U.S. and Netherlands. Feedbacks were collected during 30 to 90 minute interviews. Professionals were asked for suggestions to improve the clarity of the survey as well as the format and the time required for completing the questionnaire. The survey was modified to reflect their feedbacks. The revised version, two hundred surveys was sent out to a random group of purchasing and supply management executives, who were members of the Buffalo chapter of the Institute for Supply Management (ISM). Twenty complete responses were received and the responses were reviewed to detect further potential problems with the questionnaire.

The respondents for the final survey were selected from purchasing and supply management executives of manufacturing firms in the U.S., who were members of ISM. In accordance with Dillman's (1978) guidelines for mail surveys, a mailing package which included a letter of support from ISM, a cover letter from the primary investigators of this study, the questionnaire, and a paid return envelope was sent,. The survey was sent to 1950 potential respondents. In order to improve the response rate, this research followed Frohlich's techniques, which are pre-paid postage envelops that the respondents can use for returning the survey and multiple mailings of the reminder postcard (Frohlich, 2002). In the end, 155 surveys were received and 144 usable and completed responses were obtained which makes 8% response rate.

All survey respondents are collected from manufacturing industries. 29 survey respondents are from SIC 34 Fabricated metal products except machinery and transportation, 25 survey respondents are from SIC 35 Industrial and commercial machinery and computing equipment, 27 survey respondents are from SIC 36 Electronic and other electronic equipment and components, 18 survey respondents are from SIC 37 Transportation and machinery items, and 9 survey respondents are from SIC 38 measuring and analyzing and controlling instruments, photographic, medical and optical goods. The rest of cases are unanswered.

The firm size depends on the annual sales in million dollars. 16 survey respondents have less than 20 million dollars of annual sales, 45 survey respondents have from 20 million dollars to 100 million dollars of annual sales, 37 survey respondents have from 100 million dollars to 500 million dollars of annual sales, 10 survey respondents have from 500 million dollars to 1000 million dollars of annual sales and 14 survey respondents have greater than 1000 million dollars of annual sales. The rest of cases are unanswered. Table 1 describes demographics of survey respondents.

Table 1. Demographics of Survey Respondents

| SIC | Number | Firm Size ($) | Number |
|---|---|---|---|
| SIC 34 Fabricated metal products except machinery and transportation | 29 | Less than 20 million dollars | 16 |
| SIC 35 Industrial and commercial machinery and computing equipment, | 25 | 20 million dollars to 100 million dollars | 45 |
| SIC 36 Electronic and other electronic equipment and components, | 27 | 100 million dollars to 500 million dollars | 37 |

| | | | |
|---|---|---|---|
| SIC 37 Transportation and machinery items | 18 | 500 million dollars to 1000 million dollars | 10 |
| SIC 38 measuring and analyzing and controlling instruments, photographic, medical and optical goods | 9 | Greater than 1000 million dollars | 14 |

## 5. Results

### *Measurement Model*

This study applied the partial least squares (PLS) technique of structural equation modeling (SEM) to investigate the structural model. There are two main reasons for using PLS. PLS, a variance-based approach to structural equation modeling, can be used to specify both the relationships among constructs as well as a measurement of constructs (Wold, 1989). Compared to LISREL or AMOS, PLS has an advantage of not making any assumptions about population or scale measurement and working with no distributional assumption (Haenlein and Kaplan, 2004). The other advantage of PLS is that it is less restrictive with regard to sample size with unbiased estimates (Falk and Miller, 1992).

For assessing reliability, this research has factor loadings and Cronbach's alpha. They are all acceptable as they are greater than 0.7 in order to establish strong reliability (Fornell and Larker, 1981). Composite reliability (CR) and average variance extracted (AVE) were used in this study to assess convergent validity. All measures are acceptable since 0.7 for composite reliability suggest good internal consistency (Hulland, 1999). Additionally, AVE, representing proportion of average variance between constructs and indicator variables needs to be greater than 0.5 to suggest good convergent validity (Chin, 1998).For evaluating discriminant validity, this study followed the suggestion of Fornell and Larker (1981): the square root of AVE should be greater than correlations of variables to prove discriminant validity. Accordingly, the value of diagonal elements should be greater than those of off-diagonal elements (Fornell and Larker, 1981, Hulland, 1999). Table 2 and 3 describes measurement models.

**Table 2. Measurement Model**

| Main Constructs and Indicators | Factor Loadings | Cronbach's α | Composite Reliability (CR) | Avg. Variance Extracted |
|---|---|---|---|---|
| **Labor Flexibility** | | 0.734 | 0.729 | 0.605 |
| a. Frequent job rotation | 0.704 | | | |
| b. Non-union | 0.846 | | | |
| c. Team workforce | 0.795 | | | |
| **Machine Flexibility** | | 0.781 | 0.799 | 0.548 |
| a. High number of operations | 0.716 | | | |
| b. Changes in machining process | 0.785 | | | |
| c. Quick machine setup times | 0.858 | | | |
| **New Product Flexibility** | | 0.787 | 0.876 | 0.702 |
| a. Short time for introduction | 0.857 | | | |
| b. Low cost for introduction | 0.863 | | | |
| c. Low cost for design changes | 0.792 | | | |
| **Market Flexibility** | | 0.792 | 0.878 | 0.709 |
| a. Low cost on change in product mix | 0.904 | | | |
| b. Short time to change product mix | 0.916 | | | |
| c. Low cost to increase system capacity | 0.786 | | | |
| **E-Procurement** | | 0.803 | 0.884 | 0.718 |
| a. Information sharing | 0.856 | | | |
| b. Product design information sharing | 0.884 | | | |
| c. Product quality | 0.800 | | | |
| **AMT** | | 0.766 | 0.814 | 0.595 |
| a. Computer information network | 0.764 | | | |
| b. MRP Systems | 0.864 | | | |
| c. ERP Systems | 0.773 | | | |
| **Supply Chain Responsiveness** | | 0.730 | 0.845 | 0.646 |
| a. Responsiveness to customer | 0.762 | | | |
| b. Customer satisfaction | 0.759 | | | |
| c. Responsiveness for satisfaction | 0.883 | | | |

**Table 3. Correlation between Latent Variables and Square Root of AVE**

| | AMT | E-Pro | Labor | Machine | Market | NPD | SCR |
|---|---|---|---|---|---|---|---|
| **AMT** | **0.771*** | | | | | | |
| **E-Pro** | 0.120 | **0.847*** | | | | | |
| **Labor** | 0.013 | 0.038 | **0.778*** | | | | |
| **Machine** | 0.064 | 0.061 | 0.136 | **0.740*** | | | |
| **Market** | 0.102 | 0.000 | 0.191 | 0.049 | **0.842*** | | |
| **NPD** | 0.032 | 0.023 | 0.102 | 0.189 | 0.508 | **0.838*** | |
| **SCR** | 0.156 | 0.299 | 0.074 | 0.147 | 0.099 | 0.182 | **0.804*** |

*Square Root of AVE

***Main and Moderating Effects***

This research examined hypothesis 1, that machine flexibility has a positive impact on new product flexibility. The result indicated a statistical significance on this positive relationship, with a path coefficient of 0.184 and t-score of 1.892 at 0.05 level of significance. The research result also supported hypothesis 2, that labor flexibility makes a positive impact on new product flexibility with a path coefficient of 0.176 and t-score of 1.783 at 0.05 level of significance. Hypothesis 3 that new product flexibility positively affects on market flexibility was strongly supported by our research result. Path coefficient was 0.506 and t-score was 6.138 at 0.01 level of significance. Hypothesis 4 was also supported that market flexibility positively influences supply chain responsiveness. Path coefficient was 0.133 and t-score was 2.001 at 0.01 level of significance.

Regarding e-procurement, hypothesis 5 and 6 were not supported by our research result. However, hypothesis 7, e-procurement positively affects on supply chain responsiveness was supported. Path coefficient was 0.282 and t-score was 2.776 at 0.01 level of significance. Regarding AMT, the research result turned out to be very similar with that of e-procurement. Hypothesis 8 and 9 were not supported as our empirical research result represented that AMT does not have a significant relationship with new product and market flexibility. However, AMT has a positive and significant relationship with supply chain responsiveness, which supported hypothesis 10. The path coefficient was 0.134 and t-score was 1.711 at 0.05 level of significance. Figure 2 represents the result of main effects.

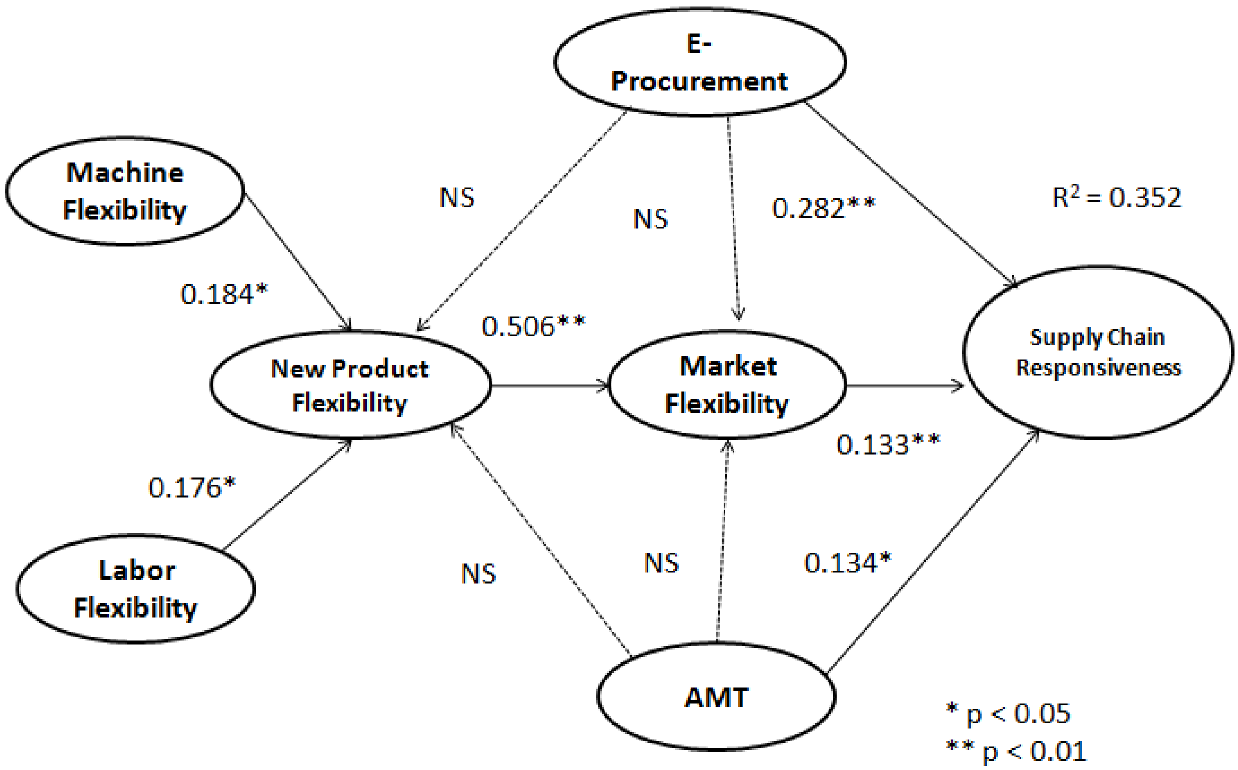


**Figure2. The research result of main effects**

Finally, this research examines the moderating effect of business environment on the relationship between market flexibility and supply chain responsiveness. Interaction effects can be evaluated with PLS by comparing $R^2$ between the main model, and the full model including both main model and interaction model *(*Chin *et al.*, *2003)*. Accordingly, the moderating effects of business environment such ascompetitionand market turbulence were analyzed along the lines of Carte and Russell, 2003. The difference in variance was tested between moderating and main effects using the following F-statistics: F ($df_{\text{interaction}}$ - $df_{\text{main}}$, $N$ - $df_{\text{interaction}}$ - 1) = ($\Delta R^2$ / ($df_{\text{interaction}}$ – $df$

$_{main}$)) / ((1-$R^2$ $_{interaction}$) / ($N$-$df$ $_{interaction}$-1)). Following Chin *et al.* (2003), moderating effects are also validated by comparing $R^2$ between main and moderating effects using Cohen's $f$ = ($R^2$ (interaction model – $R^2$ (main effects model)) / (1-$R^2$ (main effect model)) (Cohen, 1998). The research results show that the business environment has significant moderating effects on the relationship between market flexibility and supply chain responsiveness. The effect size of interaction between market flexibility and supply chain responsiveness indicated $f$ statistics of 2.83, significant at 0.1 level, and Cohen's $f$ of 0.02, which is a small effect size. Therefore, our research result supported hypothesis 11: Business environment has a moderating effect on the relationship between market flexibility and supply chain responsiveness.

By finding the moderating effects of business environments on the relationship between market flexibility and supply chain responsiveness, this research provided empirical evidences that if the market becomes more dynamic and competitive, market flexibility becomes more effective to improve supply chain responsiveness. However, according to our $f$ score, the size of the moderating effect is small which means that although dynamism and competition in market increases, the effectiveness of market flexibility on supply chain responsiveness is increased by a small amount.

## 6. Conclusion and Discussion

In this paper, an empirical investigation of the joint effects of manufacturing flexibility and manufacturing strategy was conducted in supply chain management. Many firms are currently improving their manufacturing flexibility as well as technological dimensions of manufacturing strategy such as e-procurement and AMT. In this research, implementing manufacturing flexibility and technical dimensions of manufacturing strategy simultaneously can create positive effects for improving supply chain responsiveness in order to mitigate and response toward supply chain disruptions. In order to improve supply chain responsiveness, applying various manufacturing flexibility and technological dimensions of manufacturing strategies such as AMT and e-procurement together can generate synergy effects. More importantly, this study investigates how technical dimensions of manufacturing strategy improve supply chain responsiveness in the supply chain management. Moreover, this study focuses on supply chain responsiveness with the perspective of customer satisfactions because an ability of reacting quickly toward disruptions leads to increasing customer satisfactions. Therefore, improving supply chain responsiveness can be considered as one of risk mitigating strategies in the supply chain.

There is a notable weakness among past studies has been the relative neglect of business characteristics, environmental factors and other contextual variables on how the various initiatives affect supply chain management (Van der Vaart and Van Donk, 2008). Thus, in line with the suggestions of Van der Vaart and Van Donk (2008), this empirical research also analyzed moderating effects of two business environment variables on the relationship between manufacturing flexibility and supply chain responsiveness.

Although past studies introduce various dimensions of manufacturing flexibility, there are few empirical researches to establish a hierarchy of dimensions of manufacturing flexibility. However, this paper empirically establishes the relationship among many types of manufacturing flexibility such as machine, labor, new product and market flexibility. Particularly, we found the strong positive relationship between new product flexibility and machine flexibility. According to the study of Larso *et al.,*2009, new product flexibility is positively associated with volume, operation and routing flexibility. These factors are antecedents for improving market flexibility.

In addition, this study provides some empirical evidences that that e-procurement, AMT and market flexibility play a crucial role on improving supply chain responsiveness so that supply chain members can develop their effective response plan against supply chain disruptions. On the other hand, this research found that AMT and e-procurement do not have a direct impact on both new product flexibility and market flexibility. Because this research measures the impact of both AMT and e-procurement, their impact may be limited to only routine operations on the production line so that this research could not find a statistically significant relationship among AMT, e-procurement, new product flexibility and market flexibility.

Regarding the moderating effects of the business environment variables, both degree of competition and market turbulence appeared to have a significant moderating effect on the relationship between market flexibility and supply chain responsiveness. As market turbulence and competition levels increase, market flexibility plays an enhanced role in improving supply chain responsiveness. Therefore, flexibility can be one of the answers for responding to dynamic changes in the business environment. In the previous research, moderating effects of business environments have been found in the relationship among organizational structure, supply chain process variability and firm's performance (Germain et al., 2008). Moderating effects of business environments are also found in the relationship between supply chain flexibility and firm's performance (Merschmann and Thonemann, 2011). This research filled a gap in the literature by contributing that business environments make a moderating effect on the relationship between market flexibility and supply chain responsiveness.

The research results clearly have many practical implications. It is clear that by implementing both manufacturing flexibility and manufacturing strategy, a firm can expect to improve supply chain responsiveness. When supply chain and operations managers make a decision on improving supply chain responsiveness, they need to consider an option of implementing manufacturing flexibility as well as technological dimensions of manufacturing strategy. Among various dimensions of manufacturing flexibility, market flexibility is the one which directly affects supply chain responsiveness. This study also gives managers useful insights that other dimensions of manufacturing flexibility such as machine, labor and new product flexibility also can positively influence supply chain responsiveness. Therefore, supply chain and operations managers should consider choosing one of various manufacturing flexibility as an option for improving supply chain responsiveness in dynamic and competitive business environments depending upon organizations' resource condition.

In addition, although technological dimensions of manufacturing strategy such as AMT and e-procurement do not show a significant relationship with manufacturing flexibility, AMT and e-procurement positively affect supply chain responsiveness. Thus, our research provide useful implications for supply chain and operations managers that implementing e-procurement and AMT play a significant role in making a quick response in the supply chain, leading to increased customer satisfactions. When establishing operation strategy for improving supply chain responsiveness, managers should make investments on implementing AMT or e-procurement.

Finally, our research results found the moderating effect of business environments on the relationship between market flexibility and supply chain responsiveness. It gives a helpful way to supply chain and operations managers to overcome dynamic and competitive business environments by implementing market flexibility. If business environments become more dynamic and competitive, the role of market flexibility has been amplified to improve the supply chain responsiveness. In other words, impact of market flexibility becomes greater as a solution toward improving supply chain responsiveness. Therefore, supply chain and operations managers utilize this solution in order to satisfy their customers in dynamic and competitive markets. This research serves to reinforce the utility of these initiatives in addition to highlighting the specific conditions under which they may yield significant benefits.

This study does have many of the same limitations as past studies, especially when considering that the information is elicited from single respondents within the firms. In addition, the research relied on data from a single andfocal firm in the supply chain like previous studies. The respondents were key executives in manufacturing industry who are sufficiently high in the organization, with an overall view of the firm internally and externally. Though this is accepted practice in empirical research, a broader respondent base may enable researchers to observe and analyze the interactions and interdependencies between firms in the supply chain context. Another point is that although this paper uses the context of supply chain risk management, this study  does not have any construct regarding supply chain risk which directly influenced by manufacturing flexibility and manufacturing strategy.

As future research extension, it would be also good to investigate the direct impact of manufacturing flexibility and manufacturing strategy on mitigating supply chain risk. Future study can also examine the risk management at procurement issues in service sectors and public sectors. Much work remains to be done in manufacturing flexibility and manufacturing strategy in the context of supply chain management and this study may be viewed as a first study exploring their joint impact of manufacturing flexibility and manufacturing strategy in the context of supply chain risk management.

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Appendix I. Survey Instruments

| Questions | Scale | Reference |
|---|---|---|
| Labor Flexibility relative to industry average | Strongly agree | Slack (1983), |
| a. We frequently utilize job rotation for workers | Strongly disagree<br>1 2 3 4 5 | Brown et al (1984), |

| | | |
|---|---|---|
| b. A large proportion of our labor is non-union | | Gerwin (1987),<br>Slack (1987),<br>Swamidass and Newell (1987),<br>Gupta and Goyal (1989)<br>Sethi and Sethi (1990),<br>Koste and Malhotra (1999),<br>Vokurka and O'Leary-Kelley (2000),<br>D'Souza and Williams (2000),<br>Papke-Shield and Malhotra (2001) |
| c. Much of our workforce is organized as teams | | |
| Machine Flexibility relative to industry average | Strongly agree<br>Strongly disagree<br>1 2 3 4 5 | |
| a. Number of operations a typical machine in our plant can perform is high | | |
| b. Changes in machining processes can be handled by existing machines | | |
| c. Machine setup times between operations are relatively quick | | |
| New Product Flexibility relative to industry average | Strongly agree<br>Strongly disagree<br>1 2 3 4 5 | |
| a. It takes us a short time for us to introduce new products | | |
| b. It is not costly for us to introduce new products | | |
| c. It is not costly for us to accommodate design changes | | |
| Market Flexibility relative to industry average | Strongly agree<br>Strongly disagree<br>1 2 3 4 5 | |
| a. It is not costly for us to change our product mix | | |
| b. It takes a short time for us to change our product mix | | |
| c. It is not costly to increase our system capacity | | |
| Impact of E-procurement on your firms after e-procurement | Strongly agree<br>Strongly disagree<br>1 2 3 4 5 | Croom (2000)<br>Van Weele (2000) |
| a. Improved information sharing with our suppliers | | |
| b. Improved sharing of product design information with suppliers | | |
| c. Increased product quality | | |
| Extent use of following AMT | Not used<br>Extensively used<br>1 2 3 4 5 | Boyer et al (1986)<br>Boyer and Pagell (2000)<br>Kotha and Swamidass (2000) |
| a. Computer information network | | |
| b. MRP systems | | |
| c. ERP systems | | |
| How Supply Chain Responsiveness changed after implementing manufacturing flexibility (labor, machine, new product, market flexibility), AMT and e-procurement? | Decreased significantly<br>Remained constant<br>Increased significantly<br>1 2 3 4 5 | Tracey and Tan (2000) |
| a. responsiveness to customer | | |
| b. customer satisfaction | | |
| c. responsiveness for satisfactions | | |