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Technology Infusion Enabled Value Chain Flexibility: A Learning and Capability-Based Perspective

by

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Submitted as partial fulfillment of the requirements for the Doctor of Philosophy degree in Manufacturing Management

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An Abstract of

TECHNOLOGY INFUSION ENABLED VALUE-CHAIN FLEXIBILITY: A LEARNING AND CAPABILITY-BASED PERSPECTIVE

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Environmental uncertainties in customer requirements, competition, and technology create an urgent need for a firm to achieve flexibility across the value chain: (1) product development flexibility, (2) manufacturing flexibility, (3) logistics flexibility, and (4) spanning flexibility. Flexibility is the ability of a firm to meet a variety of customer needs without excessive cost, time, organizational disruption, or loss of performance. Infusion of technology (i.e., technology is fully understood, appreciated, and put to its best use) is a useful concept to explain the attainment of flexibility across the value chain. Value chain flexibility enables firms to respond quickly to specific customer expectation because resources can be rapidly shifted to develop, produce, and deliver various products.

Although manufacturing flexibility is widely studied, the concept and dimension of flexibility are unclear. Little is ever mentioned about flexibility at product development, logistics, or spanning activities. This research is to conceptualize value chain flexibility anchored in a comprehensive understanding of flexibility concept, develop a nomological network that explains the relationship among environmental uncertainty, use of technology, infusion of technology, value chain flexibility, and competitive advantage grounded on a learning and capability theory, and provide and validate instruments to support organizational and resource level research on flexibility. The new lenses of value chain flexibility bring a systematic, resource-based view of firms' competitive advantage.

The methodology used to define constructs and derive measures includes a literature review. interviews with four practitioners, Q-sort, and expert evaluation with ten professors. A pilot study is conducted with 33 firms to purify the items and evaluate unidimensionality, reliability, and validity. Where appropriate, items are deleted. modified, or added. An exploratory large-scale data analysis with 273 firms follows. The factor matrix exhibits an easily interpretable structure. All the scales show good convergent and discriminant validity and have Crobach's alpha greater than 0.82 except competition uncertainty with an alpha of 0.79.

The hypothesized structure (i.e., direct and indirect paths) is tested using LISREL. The results confirm that a strong causal chain exists from environmental uncertainty, through use of technology, infusion of technology, value chain flexibility, and competitive advantage, to customer satisfaction and financial performance. Contradictory to previous literature, environmental uncertainty is not significantly, positively related to value chain flexibility. A new finding is that use of technology and infusion of technology are two strong intervening variables of this relationship. Infusion of technology is a dominant determinant to attaining value chain flexibility. The directions for future research are discussed.

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LIST OF ABBREVIATIONS AND CODINGS

Abbreviations

AGFI	Adjusted-Goodness-of-Fit Index
AGVS	Automated Guided Vehicles Systems
AIS	Automated Inspection Systems
AMHS	Automated Material Handling Systems
AMT	Advanced Manufacturing Technology
AS/RS	Automated Search and Retrieval Systems
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAI	Computer Aided Intelligence
CAM	Computer Aided Manufacturing
CAPP	Computer Aided Process Planning
CEO	Chief Executive Officer
CFI	Comparative Fit Index
CIM	Computer Integrated Manufacturing
CITC	Corrected Item-to-Total Correlation
CM	Cellular Manufacturing
CNC	Computer Numerically Controlled Machines
CPM	Critical Path Method
CS	Customer Satisfaction
DNC	Direct Numeric Control
DSS	Decision Support Systems
EDI	Electronic Data Interchange
EFA	Exploratory Factor Analysis
EIS	Executive Information Systems
FMC	Flexible Manufacturing Cells
FMS	Flexible Manufacturing Systems
FP	Financial Performance
GFI	Goodness-of-Fit Index
GT	Group Technology
IPD	Integrated Product Development
IT	Information Technology
JIT	Just In Time
LAN	Local Area Networks
LISREL	LInear Structural RELations
MP	Managerial Practices
MRP	Material Requirements Planning
MRPII	Manufacturing Resource Planning
MTMM	Multiple Traits Multiple Methods
NC	Numeric Control
NFI	Normed Fit Index
OS	Office Systems
PD	Product Development
PPD	Phased Product Development

SEM	Structural Equation Modeling
SME	The Society of Manufacturing Engineers
TQM	Total Quality Management
WAN	Wide Area Networks

Codings

CA	Competitive Advantage
CA/DD	Delivery Dependability
CA/PC	Price/Cost
CA/PI	Product Innovation
CA/QU	Quality
CA/TM	Time-to-Market
EU	Environmental Uncertainty
EU/CO	Competitor Uncertainty
EU/CU	Customer Uncertainty
EU/SU	Supplier Uncertainty
EU/TE	Technology Uncertainty
IT	Infusion of Technology
IT/LK	Learning and Knowledge Accumulation
IT/QW	Quality of Work Life
IT/TE	Task Efficiency / Task Productivity
IT/TI	Task Innovation
LF	Logistics Flexibility
LF/DM	Demand Management Flexibility
LF/PD	Physical Distribution Flexibility
LF/PF	Purchasing Flexibility
LF/PS	Physical Supply Flexibility
MF	Manufacturing Flexibility
MF/MA	Machine Flexibility
MF/MH	Material Handling Flexibility
MF/MI	Mix Flexibility
MF/RO	Routing Flexibility
MF/VO	Volume Flexibility
MF/WO	Labor Flexibility / Worker Flexibility
MP/CE	Concurrent Engineering
MP/CI	Continuous Improvement / Improvement Practices
MP/IN	Integration Practice
PF	Product Development Flexibility
PF/MO	Product Modification Flexibility
PF/NP	New Product Flexibility
PF/PC	Product Concept Flexibility
PF/PP	Product Prototype Flexibility
SF	Spanning Flexibility
SF/ID	Information Dissemination Flexibility
SF/SD	Strategy Development Flexibility
UT	Use of Technology

CHAPTER 1: INTRODUCTION

Increasing global competition, accelerating technological change, and demanding customers are creating a more turbulent, complex, knowledge-intensive, and uncertain environment (Huber, 1984; Skinner, 1985; Doll & Vonderembse, 1991). In response, manufacturers are seeking to increase flexibility as they strive to compete in the 21st century. Flexibility enables firms to design, produce, and deliver a wide variety of high-quality, low-cost products quickly and thus it is strategically important as an order-winning criterion (Gerwin, 1993; Upton, 1995; Hill, 1994; Jordan & Graves, 1995). Only as flexibility is added to total quality management capabilities and productivity improvement efforts, can manufacturers be successful in highly competitive global markets.

Global competitions, including Japanese companies, are competing for and winning orders based on their responsiveness to customer needs as well as better quality and low cost. To be competitive, manufacturers should add flexibility to their customer-valued competitive capabilities. Flexibility enables a firm to meet a variety of customer needs without excessive cost, time, organizational disruption, or loss of performance. Thus, flexibility is regarded as a source of competitive advantage (De Meyer, Nakane, Miller & Ferdows, 1989). Gunasekaran (1999) and Yusuf, Sarhadi & Gunasekaran (1999) advocate flexibility and agility as the paradigm for the 21st century manufacturing.

The concept of flexibility appears widely in manufacturing literature (Gerwin, 1987; Hayes & Wheelwright, 1979; Hill, 1994). The past two-decade's emphasis on the strategic role of manufacturing sets a big stage for research on manufacturing flexibility. From a strategic perspective, Skinner (1969) claims that manufacturing is the missing link in corporate strategy and that firms integrating manufacturing strategy with corporate strategy can achieve a competitive advantage. He promotes building a flexible and learning organization by using flexible technology and management techniques (Skinner, 1985). Hayes & Wheelwright (1979) incorporate flexibility in discussing the product-process matrix as a tool to coordinate the interfaces of marketing and manufacturing to achieve unified corporate goals. Wheelwright & Hayes (1985) define a hierarchy of manufacturing strategies (i.e., internal neutral, internal support, external neutral, and external support) along the reactive-proactive use of flexible technology. Hill (1994) states a manufacturing strategy model including flexibility as an order-winner or order qualifier.

Besides the studies on the strategic nature of flexibility, the multiple dimensions of flexibility have been offered in the literature. Slack (1983, 1987) defines the differences between resource flexibility (e.g., machine flexibility) and systems flexibility (e.g., mix flexibility). Correa & Slack (1996) distinguish between the dimensions of systems flexibility (i.e., range and response) and types of systems flexibility (e.g., new product flexibility and volume flexibility). Upton (1994, 1995) defines flexibility as increasing the range of products available, increasing a firm's ability to respond quickly, and achieving good performance over the range of products produced. Although these authors have made great efforts to define and measure flexibility, there is no unified concept that is widely accepted, and many questions about flexibility remain unanswered.

First, the concepts and dimensions of flexibility are vague and ambiguous. Many researchers point out that flexibility is a hard-to-capture concept (Sethi & Sethi, 1990; Upton, 1995). Some writings capture partial dimensions of flexibility; some writings mingle the dimensions of flexibility with the types of flexibility (Barad, 1992; Gupta, 1993; Benjaafar, 1994). This imprecise language makes it difficult to measure this concept and further impede empirical research efforts.

Second, there is a lack of theoretical explanation on the association of flexibility with a sustainable competitive advantage. Some researchers emphasize flexibility as internal resource and competence (Carter, 1986; Das & Nagendra, 1993). They highlight task sequencing or dispatching disciplines (e.g., routine flexibility) to embrace many possibilities and even to make one system (e.g., FMS) with totally automated functions to deal with a variety of situations. But such flexible system may not have external capability to enable competitive advantage. Thus, the internal and external roles of flexibility need to be clarified and connected.

Third, most studies exclusively focus on manufacturing flexibility; little is ever mentioned about flexibility at product development, logistics (acquisition, distribution/storage), or spanning activities. This is partially due to the past twenty years' emphasis on the strategic importance of manufacturing for a firm to compete in the global market. Since Skinner's landmark paper (1969), many researchers have emphasized that manufacturing should interact directly with customers; it should not be insulated from customers by buffers such as marketing tactics and finished goods inventory (Thompson, 1967; Nemetz & Fry, 1988; Parthasarty & Sethi, 1992). These studies contribute to substantial progress in research on the strategic benefits of manufacturing flexibility, however, manufacturing flexibility alone is not sufficient to win competition.

In reality, fast and dramatic changes in customer requirements, competition, and technology create an urgent need for flexibility across the whole value chain. By looking at the order fulfillment as a process, the shop floor is only part of the entire flow from customer request to customer receipt. It is apparent that no single function could significantly reduce lead-time experienced by customer. Only a companywide effort to increase flexibility and eliminate bottlenecks could make the kind of difference needed to compete (Day, 1994; Blackburn, 1991; Hamad & Prahalad, 1989; Yusuf, Sarhadi & Gunasekran, 1999). Therefore, value chain flexibility must be broadly defined, and it includes (1) product development flexibility, (2) manufacturing flexibility, (3) logistics flexibility, and (4) spanning flexibility. That is, the organization should be able to deal with the internal and external uncertainty along the value chain to meet the desired demands.

Value chain flexibility enables a firm to introduce new products more quickly, support product customization, shorten manufacturing lead times, and reduce inventory levels. Product development flexibility enables a firm to respond quickly to the changing environment and customer expectations with product modifications and new product commercialization (Sobek, Ward & Liker, 1999;

Srinivasan, Lovejoy, & Beach, 1997). Such flexible design and development capabilities can increase the manufacturability of products by simplifying the structure of the product and standardizing component parts (Clark & Fujimoto, 1991; Gerwin, 1987; Sethi & Sethi, 1990; Griffin, 1993). This, in turn, makes manufacturing easier and fast.

Manufacturing flexibility enables firms to produce the needed quantity of high-quality products quickly and efficiently through setup time reduction, cellular manufacturing layouts, preventive maintenance, quality improvement efforts, and dependable suppliers. These are predicated on machining, material handling, labor, and routing flexibility (Boyer & Leong, 1996; Chen, Calantone & Chung, 1992; Koufteros, Vonderembse & Doll, 1998; Hyun & Ahn, 1992; Gupta, 1993; Ramasesh & Jayakumar, 1991; Sethi & Sethi, 1990).

Logistics flexibility enables the smooth flow of materials, which facilitates the production and deliveries of high-quality, value-added product (Porter & Millar, 1985; Day, 1994). Flexibility in physical supply, purchasing, physical distribution, and demand management are key components of logistics flexibility (Lambert & Stock, 1993; Porter, 1985). Spanning flexibility insures that different departments or groups (inside and outside of the organization) can coordinate product design, production, and delivery in ways that add value to customers (Hayes & Pisano, 1994; Day, 1994; Cooper & Zmud, 1990; Wheelwright & Hayes, 1985).

The next logical research question is how value chain flexibility can be achieved? In literature, it is widely written that the effective use of advanced manufacturing technology and information technology in design (CAD, CAE, CAPP, etc.), manufacturing (CAM, FMS, GT, etc.), logistics (EDI, Bar code, etc.), and administration (MRP, JIT, etc.) makes value chain flexibility more likely (Boyer, Ward, & Leong, 1996; Small & Chen, 1995; Lei & Goldhar, 1991). However, not all the firms who use technology fully gained the potential benefits. The studies show that U.S. firms do not achieve enough flexibility compared with Japanese firms although they use many flexible technologies (De Meyer, Nakane, Miller & Ferdows, 1989).

The literatures on organizational learning (Leonard-Barton, 1992; Cohen & Levinthal, 1990), innovation diffusion (Cooper & Zmud, 1990; Kendall, 1997), and capability-based strategies (Day, 1994; Prahalad & Hamel, 1990; Barney, 1991) suggest that technology has to be used in a human way. It means that technology has to be infused to organization so that the potential of technology can be exploited. Therefore, infusion of technology, defined as technology that is fully understood, appreciated, and put to its best uses, is a useful concept to explain the value-chain flexibility of an organization. It is a critical determinant of the attainment of value chain flexibility together with successful implementation and management of AMT and IT (i.e., routine use of technology).

The purpose of this research is to conceptualize value chain flexibility, conjecture a nomological network of constructs that explain the causal relationship between environmental uncertainty, infusion of technology, value chain flexibility, and competitive advantage, and develop reliable and valid instruments to support organizational and resource level research on flexibility. This research examines the following questions: (1) What is flexibility / value chain flexibility, including the dimensions and types of value chain flexibility? (2) How can each component of value chain flexibility be consistently measured? (3) What makes the difference for a manufacturer to be more or less flexible? (4) How does flexibility as an order-winning criterion help achieve competitive advantage, customer satisfaction, and financial performance? The analysis of these substantial problems depends on the conceptualization and measurement of the concept of value chain flexibility. Research in value chain flexibility is at the critical cross road today with increased emphasis in developing theoretical concepts and testing empirical relationships based on such concepts.

Specifically, the primary work of this study is (1) to develop flexibility-based manufacturing theory including identification, definitions, and interrelationships of key constructs for value chain flexibility in manufacturing firms; (2) to develop and validate the measurement instruments of key constructs: environment uncertainty, use of technology, infusion of technology, product development flexibility, manufacturing flexibility, logistics flexibility, and spanning flexibility; (3) to test the relationships among key constructs based on a large-scale survey of national manufacturing firms in various industries.

A framework for examining value chain flexibility and its theoretical bases are presented in Chapter 2. The research methodology and results for items generation and pilot study appear in Chapter 3. Large-scale survey methods and results including model and hypotheses testing using LISREL are reported in Chapter 4. Chapter 5 provides a discussion, recommendation for future research, and conclusion.

CHAPTER 2: THEORY DEVELOPMENT

In order to cope with environmental uncertainty and win competition based on flexibility, organizations have to be proficient across the whole value chain: product development flexibility, manufacturing flexibility, logistics flexibility, and spanning flexibility (Buzacott, 1998; Day, 1994; Aggarwal, 1997).

Each component of value chain flexibility falls into two categories: primary flexibility and secondary flexibility. Primary flexibility is directly related to customers' purchase decision criteria such as product variety, product design, volume, product mix, physical distribution, service and firm's strategic response. Therefore, primary flexibility is a linkage between the corporate, marketing, or competitive strategy, and the manufacturing strategy (Watts, Hahn & Sohn, 1993). Secondary flexibility is related to organizational competencies in terms of processes and infrastructure to provide the desired level of primary flexibility. These two categories assist managers in identifying what types of primary flexibility are most critical to their relationship with their customers and what secondary flexibility support the customer valued primary flexibility.

High flexible competence and capability along the value chain results from the use of technology, integrated practices, employees' involvement, and accumulation of knowledge. Thus, they have attributes of imperfect imitability and substitutability, which lead to sustained competitive advantage for the firm such as providing innovative products with low cost, high quality, dependable delivery, and high speed. Such competitive advantages, in turn, create customer satisfaction and superior financial performance.

As illustrated in Figure 1, the framework provides a nomological network that describes the causal relationships among environmental uncertainty, use of technology, infusion of technology, value chain flexibility, competitive advantage, and performance. It can be used to study flexible and agile manufacturing on an organizational or resource level and test the hypotheses and structural relationships of the constructs.

Before developing and testing the relationships, it is theoretically and conceptually sound to identify, define, and discuss the key constructs in the framework through a review of the major literature and a discussion of the theoretical logic or rationale.

2.1 ENVIRONMENTAL UNCERTAINTY

Environmental uncertainty is a main driver for a firm to seek flexibility (Swamidass & Newell, 1987; Gerwin, 1986; Slack, 1989). Although environmental uncertainty is widely studied, many arguments about the definition of uncertainty and how to assess uncertainty exist: objective or perceptual.

The multiple definitions of uncertainty are offered in the literature (Matthews & Scott, 1995): lack of knowledge for decision-making (Duncan, 1972; Thompson, 1967); choice (Child, 1972); complexity (Galbraith, 1973); unpredictability (Cyert & March, 1963); and turbulence (Emery & Trist, 1965). Gifford, Bobbitt & Slocum (1979) find two general notions of uncertainty that characterize various approaches - information load (related to the complexity of

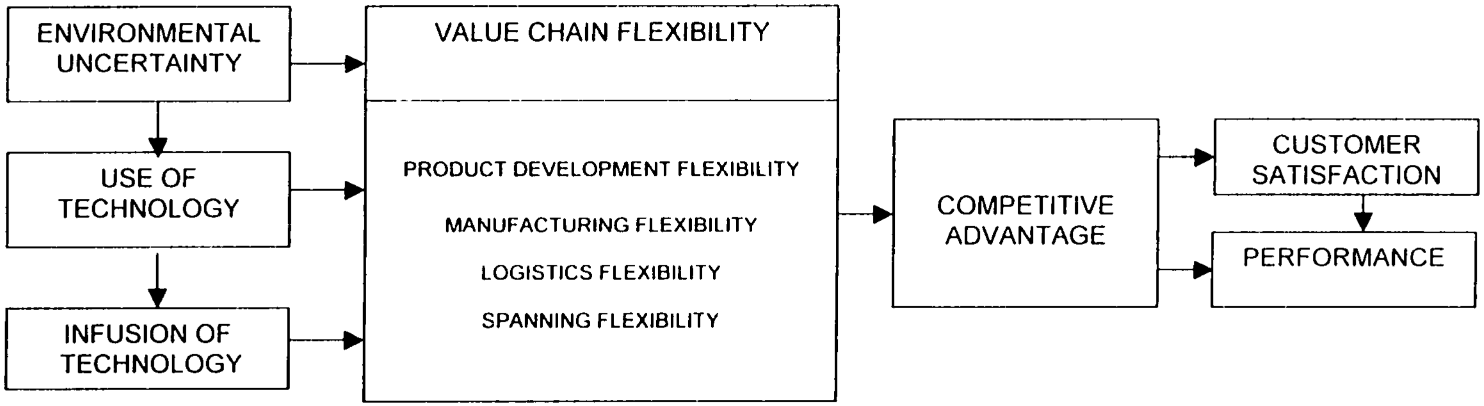


Figure 1: Technology Infusion Enabled Value Chain Flexibility: A Research Framework

decision situation) and pattern/randomness (distinguishing between patterns and randomness of events). The classical definition of uncertainty as the inability to assign probabilities to outcomes and of risk as the ability to assign these probabilities is based on the differing perceptions of the existence of the orderly relationships or patterns. They imply low uncertainty if data are available at the time needed and if the decision-maker discerns a pattern of regularity among the cues of the data. Lawrence & Lorsch (1969) develop a nine-item questionnaire designed to measure uncertainty in the three sub-environments of marketing, manufacturing, and research within organizations about the following characteristics: (1) lack of clarity of information, (2) general uncertainty of causal relations, and (3) long time span for feedback of results.

Thompson (1967) views organizations as open systems faced by ambiguity and uncertainty, but requiring clarity and certainty in order to function in a rational manner. In Thompson's theory, management's role is to reduce existing uncertainties so that the organization can operate as efficiently as possible. Uncertainty is defined as lack of information on goals, alternatives, and consequences. A good deal of human behavior can be analyzed in terms of efforts to deal with these problems by developing coping strategies which either avoid, adjust to, reduce, or take advantage of the uncertainties (Gerwin & Tarondeau, 1982).

However, the existence or nonexistence of information itself is not the only factor that influences the uncertainty level under which an organization operates. Such stimuli lack meaning until an individual or an organization perceives them.

Some authors suggest objective measures of uncertainty base on physical attributes of the environment such as the number of product changes, the number of competitors, technological factors, and the like. But the same environmental changes can foster different levels of perceived uncertainty in different individuals or organizations (Perrow, 1967). Downey & Slocum (1975) propose that perceived uncertainty in the physical environment can be expected to vary with (1) perceived characteristics of the environment (2) individual differences in cognitive processes and behavioral response, and (3) social expectations.

Jauch & Kraft (1986) review and summarize three different approaches to environmental uncertainty: classical view, transition view, and process view. The classical view emphasizes the belief that the reality of the objective external environment influences decision, structure, and performance (March & Simon, 1958; Chandler, 1962; Cyert & March, 1963; Emery & Trist, 1965). The transition view claims that the source of uncertainty is both external and internal and decision-makers have choices and influence rather than an uncertainty imperative (Thompson, 1967; Perrow, 1970; Galbraith, 1973). The process view argues that decision-maker's perceptions, not objective properties of the environment, mediate the link between uncertainty and system characteristics (Lawrence & Lorsch, 1967; Duncan, 1972, 1973; Downey, Hellriegel & Slocum, 1977). It seems that research work on environmental uncertainty has shifted away from "objective" to "perceived" environmental uncertainty (Jauch & Kraft, 1986). This does not mean, however, that the objective environment is not an important factor for organizational design or decisions. Just as Tinker (1976) emphasizes that perceived uncertainty alone would reduce the study of organizations to a "problem of psychoanalysis of actors".

Facing such problems, some authors have suggested that it is necessary to objectively measure environmental uncertainty as a means to validate the perceptual measures (Starbuck, 1976), but such efforts result in inconsistent findings (Snyder & Glueck, 1982). Therefore, either objective or perceived environmental uncertainty construct needs to be considered carefully based on the conducted research.

Duncan (1972) establishes relationships between the managers' perceptions of uncertainty and some characteristics of the environment. He originally identifies 15 sources of uncertainty (including government, labor, and suppliers) in an organizational environment that involves two dimensions – dynamism and complexity. His "dynamism" means the relevant factors for decision-making are in a constant state of change, and complexity is the number of interactive relationships relevant for decision making require a high degree of abstraction. Duncan finds that the static/dynamic dimension of the environmental uncertainty is a more important contributor to uncertainty than the simple/complex dimension. But, as several authors (Child, 1972; Ettlie & Reza, 1992) have noted or found empirically, organizations typically concentrate attention on just a few of these uncertainty elements – usually customers, competitors, suppliers, and technologies in manufacturing industries. Managers generally attempt, during the interviews, to translate the abstract term "uncertainty" into the concept of change that is more meaningful and closer to their activities such as unexpected changes in the availability of materials from suppliers or changes in the set of tasks to be performed. Therefore, uncertainty is regarded as attributes of unplanned change. Here, environmental uncertainty is conceptualized as unexpected changes in terms of customers, suppliers, competitors, and technology based on managers' perceptions. The perceptual uncertainty is used due to a lack of publicly available objective indicators and substantial relatedness and usefulness of managers' perceptions of environmental uncertainty to their efforts in flexible capability building.

Specifically, Gupta & Wilemon (1990) think that such perceived uncertainties come from the following factors: (1) increased global competition, (2) continuous development of new technologies that quickly obsolete existing products, (3) changing customer needs and requirements which truncate product life cycles, and (4) increasing need for involvement of external organizations such as suppliers, customers, and vendors. Bacon et al. (1994) argue that successful firms understand their business unit's strategic directions, customer and user needs, competitive product offerings, as well as currently available and prospective technologies. Gerwin (1986) analyzes and lists different types of uncertainty that a firm faces, for example, volume changes, customer preference changes, and product mix changes. Consistent with these perspectives, we adopt Ettlie & Reza's (1992) view on the important sub-constructs for perceived environmental uncertainty and define environmental uncertainty as unexpected changes of customers, suppliers, technology, and competitors (Table 2.1).

Table 2.1 The Definition of Sub-constructs of Environmental Uncertainty

Construct	Definition	Literature
1. Environmental uncertainty	The extent of changes of customer, supplier, technology, and competition.	Loch, Stein & Terwisch (1996); Skinner (1985); Doll & Vonderembse (1991); Cyert & March (1963)
1.1 Customer uncertainty	The extent of changes of customer needs, preferences, and purchasing pattern	Gerwin (1987); Bacon, Beckman, Mowery & Wilson (1994); Khurana & Rosenthal (1997)
1.2 Supplier uncertainty	The extent of changes of suppliers' supply, design, and manufacturing capacity	Gerwin (1987); Khurana & Rosenthal (1997)
1.3 Technology uncertainty	The extent of changes of technology in the industry that firm belongs to	Gerwin & Tarondeau (1982); Gupta & Mileson (1990)
1.4 Competition uncertainty	The extent of changes of primary competitors' nature and actions about product development and technology adoption	Gupta & Mileson (1990); Khurana & Rosenthal (1997)

2.2 USE OF TECHNOLOGY

All variables about environmental uncertainty are beyond the control of firm managers. None of these environmental requirements are compatible with mass production. Thus, economies of scale seems the thing of the past and flexibility management becomes de facto the new frontier.

With the new microelectronics and information technologies incorporated into the process technologies, a new paradigm, economies of scope, is established to challenge the concept of economies of scale since new technologies make changeover time negligible. Such new technologies make it possible to produce different products at the same rate as a single or a few products. Specifically, the following three sub-constructs (Table 2.2) will be discussed in the next section: (1) use of advanced manufacturing technology (AMT) (2) use of information technology (IT) (3) managerial practices of technology.

Table 2.2 The Definitions of Sub-constructs of Use of Technology

Construct	Definition	Literature
2. Use of Technology	The extent to which firms use and integrate AMT and IT in design, manufacturing, and logistics, and the ways the technology is used in management and work practices.	Chiantalla (1982); Kotha & Orne (1989); Small & Chen (1995); Zmud & Jacobs (1994);
2.1 Use of AMT	The extent to which a firm uses advanced manufacturing technology in design, manufacturing, logistics, and administration.	Boyer, Ward & Leong, 1996; Small & Chen (1995); Cooper & Zmud (1990); Tracey, Vonderembse & Lim (1999)
2.2 Use of IT	The extent to which a firm uses information technology in strategic planning, operational decision, and internal and external integration.	Boynton, Zmud & Jacobs (1994); Sethi & King (1994)
2.3 Managerial practices of technology	The work practices reflecting people, policies and systems that make design, manufacturing, and distribution work, including concurrent engineering, improvement practices, and integration practices.	Skinner (1969, 1974); Hayes & Wheelwright (1984); Leong (1990); Koufteros, Vonderembse & Doll (1998)

2.2.1 Use of Advanced Manufacturing Technology

The role of production technology in modern firm's operations has been an important theme of managerial research (Gerwin & Kolodny, 1992). In particular, for discrete parts manufacturing, as the predictable world of assembly line collapses, research is gradually concentrating on AMT such as cellular manufacturing (CM) to achieve strategic benefits of flexibility. Lei, Hitt & Goldhar (1996) explain that investments of AMT that provide significant economies of scope produce strategic options that allow a firm to enter related markets that it may potentially want to. In addition, CAD/CAM networks enable the firm to work selectively with external designers, suppliers, customers, and other firms to rapidly compress the product development and commercialization process. Then, what types of AMT are utilized in modern firms? And how?

Since the late 1960s, group technology was brought up to improve manufacturing – in particular for the cellular flow line (i.e., manufacturers who have to make a variety of different but similar parts). In the early 1970s, flexible manufacturing systems (FMS) and robotics began to attract interest. These offered solutions to the problems of job shops by reducing batch sizes for a variety of parts through short changeover, setup, and tool-changing time at machines. By the 1980s, however, the success of Japanese manufacturing techniques – in particular Just-In-Time (JIT) and total quality management (TQM) shocked the manufacturing fields. Accordingly, many manufacturing organizations tried to apply these ideas to their operations.

In literature, many AMT categories can be found. Small & Chen (1995) provide the following categories based on different justification techniques of AMT investment: stand-alone systems (CAD, CAPP, NC, CNC, DNC, etc.), intermediate systems (AS/RS, AMHS, AIS, etc), and integrated systems (FMC, FMS, CIM, JIT, MRP, etc). Boyer, Ward, & Leong (1996) identify three types of AMTs based on an empirical analysis of the patterns in which companies invest in advanced manufacturing technologies: design (CAD, CAE, CAPP), manufacturing (CNC, CAM, FMS, GT, CM, AMHS), and administration (MRP, JIT, MRPII). Similar classification can be found in the work of Rosenthal (1984), Meredith (1987), Adler (1988), Lei & Goldhar (1991), and Saraph & Sebastian (1992). In summary, AMT is used primarily in the activities of product and process design (CAD, CAE, CAPP, GT, & CM), manufacturing planning and control (MRP, JIT, MRPII, CPM), the production process (NC, CNC, FMS, FMC, AS/RS, AGVS, CAI), and in their integration (LAN, WAN, CAD/CAM, CIM) (Gunn, 1987). Such AMT automation can be adapted to a variety of uses through computer programming, while AMT integration creates links among these elements. Therefore, the use of AMT makes possible the partial flexibility through programmable automation and the system flexibility through integration of technology.

If integrated manufacturing only focuses on automating manufacturing activities as far as possible (e.g., firms use robots, NC, and AMHS and integrate individual fabrication, inspection, assembly, and material handling into flexible manufacturing or assembly systems) to maximize the speed and reliability of information transmission, then all uncertainties have to be anticipated in advance so that appropriate response and design can be implemented. Thus, such automation and integration are the most appropriate in an environment that all changes can be anticipated and recognized sufficiently in advance. But environment is perceived as inherently unstable. It is difficult and expensive to anticipate disturbances and prepare corresponding programmed responses. Therefore, the organization needs to provide flexible facilities and ensure that people are inherently flexible and able to respond to new situation through experiences, education, and training. Furthermore, they can work as a team to maximize the effectiveness. These problems will be detailed in 2.2.3.

2.2.2 Use of Information Technology

As environments change dramatically, organizations are increasingly concerned with making more effective use of information technology (IT). Information technology is used in an organization to perform certain functions (e.g., facilitate problem solving / decision making, strategic planning, and coordinate work activities horizontally and vertically). How extensively IT is used to perform these functions determines the degree of flexibility that organization can achieve.

Hirschhorn & Farduhar (1985) identify three functions: (1) decision support, (2) work integration, and (3) customer service. Doll & Torkzadeh (1998) conceptualize and measure IT use as multidimensional construct (1) problem solving, (2) decision rationalization, (3) horizontal integration, (4) vertical integration, and (5) customer service. Ives & Jarvenpaa (1991) and Boynton, Zmud, & Jacobs (1994) define IT use as the application of IT within an organization's operational and strategic activities. Specifically, IT use involves the extent to which IT takes the form of cost reduction, management support, strategic planning, and competitive thrust applications. Based on the above conceptualizations, the following three sub-constructs of IT usage are to be discussed in detail: strategic planning, operations decisions, and internal & external integration.

On the strategic use of IT, Ramasech & Jayakumar (1993) argue that a strategic analysis should involve the strategic fit and competitive advantage of IT. Many writers hold that IT needs to be used as a strategic weapon (McFarlan, 1984; Parson, 1983; Henderson & Venkatraman, 1993). Sabherwal & King (1991) and Sethi & King (1994) conceptualize and measure the strategic use of IT as functionality (i.e., resource management and resource acquisition), cost efficiency of IT use, synergy (i.e., integration with business goals), preemptiveness, and threats (i.e., impact of IT use on the bargaining power of customers and suppliers). Segars & Grover (1998) define and measure IS planning success using four dimensions of alignment, analysis, cooperation, and planning capability. These literatures provide a solid foundation for conceptualizing and measuring use of IT in the strategic planning. The strategic use of IT refers to the extent to which IT is used to support managers' effort to formulate business strategies.

On the operational use of IT, empirical studies are characterized by a narrow and quantitative concept of usage such as hour of use (Ettama, 1985), frequency of use (Benbasat, Dexter & Masulis, 1981), the number of features used (Green & Hughes, 1986), the number of messages sent or received on an average day (Straub, Limaryem & Karahanna-Evaristo, 1995), and the extent of IS use to support production activities (Baroudi, Olson & Ives, 1986). But such definitions and measures only consider the amount of use. The concept needs to be extended as the extent to which IT is used to monitor, control, and design business activities, and thus reduce cost of business operational activities.

Work integration includes both vertical and horizontal integration of job tasks. IT shapes the extent of the division of labor within the flow of work (horizontal) and between the managers and the managed (vertical). IT facilitates the communication and sharing experiences among the members of a work group. Likewise, IT can be used to provide more differentiated and customized service to external clients. Therefore, work integration can be expressed as two concepts: internal integration (i.e., the extent that IT is used to communicate among internal work group members) and external integration (i.e., the extent that IT is used to connect with external customers). Such integrated use of IT can increase the organizational flexible response capability.

2.2.3 Managerial Practices of Technology

Influenced by the development of the new process technologies such as CNC, FMS, and the like, many authors (Gupta & Goyal, 1989) associate the flexibility with technology resources only, ignoring other resources in manufacturing system: people and infrastructure. Blackburn & Millen (1986) and Schonberger (1986) argue that systems can achieve flexibility with simple and cheap machines as long as they are utilized with the reduction of setup time. Whether the benefits of technology use can be realized or technology can be routinized depends not only on what technology is used, how often it is used but also on how it is used. Jakumar (1986) reports that most American firms who adopt FMS are inflexible because of the lack of the supportive managerial systems. Therefore, flexible automation is not sufficient to ensure the attainment of flexibility and flexible technology can be used in a non-flexible way. Accordingly, technology, people, and systems need to be integrated to achieve the flexibility benefits. From a macro perspective, it depends on managerial practices of technology; From a micro perspective, it depends on the human side of technology (employees' sensemaking). The latter part will be discussed in the section of infusion of technology. Here the following three management practices will be discussed: (1) concurrent engineering practice, (2) improvement practice, and (3) integration practice.

Concurrent engineering practice. Concurrent engineering is the extent to which product and process design are done simultaneously. An important concept related to managerial practices of technology is time-based competition, which emphasizes time as a competitive weapon. Time and inventory are related by Little's Law -- time-in-process equals work-in-process multiplied by the mean time between successive releases. The same logic can be applied to the speed of response to orders and speed of developing a new product. The development of a new product is concerned not with the processing and movement of materials, but with the communication of ideas. Therefore, serial structures for processes are not as appropriate as parallel structures that promote collaborative activities.

Product development (PD) literatures roughly classify PD schemes into two categories: phased product development (PPD) and integrated product development (IPD). An activity orientation stimulates the phase review, which underwrites an activity completion check by senior management. Implicit in the review process is a lack of trust. Phase reviews during development have been attacked because they do not add value. The development team needs time to prepare for them, frequently giving pre-review presentations to functional managers. It must also deal with the lack of detailed knowledge on the part of reviewers, many of who cannot ask good questions because of a lack of firsthand understanding.

IPD approach establishes its development path using concurrent and overlapping development practices that accent early planning and decision making. The focus is on intense communication and information gathering among team members. This allows development to move swiftly using partial information, thus blurring structured phases of development. The advantages are as follows: (1) A balance of power is achieved between project teams and senior management; (2) Empowering teams are responsible for project concept, resources, and delivery; (3) Focusing on the early stage of development and including all stakeholders can coordinate product and process design; (4) Time-to-market is enhanced by the team's decision control, funding control, and commitment to results that they own.

While PPD comes from a more traditional, hierarchical, and functionally segmented organization, IPD stems from an independent, innovative, team-oriented, and informal development company. The core difference between the two approaches is that PPD is activity oriented whereas IPD is information and decision oriented. PPD leads to viewing new product development as a structured activity chain – breaking activities into a predetermined, step-by-step flow chart. The mindset is: How do we control this complex process and delineate it into progressive, rational steps and activities as a product's development matures? IPD starts from a different focal point, perceiving development as an invisible information and decision-making process rather than a tangible compartmentalization of building block activities along a product maturity curve. The mindset is: What information is needed for development decisions, and how efficiently can information be gathered to make critical decisions in the development process as early as possible? The entailed concurrence becomes the platform for systematizing the product development process and guides the way people interact and exchange information within it.

Even though various models for managing a new product development process are suggested, the basic progression of activities over the course of the process is similar. In addition to stage-gate process, processes such as cycle-time excellence (facilitator-implemented stage-gate system), concurrent engineering approaches (activities undertaken in parallel) are widely used. Quality function deployment (incremental improvements and information structure) and value proposition process (continuous learning and continuous cycling) have been employed in order to improve development outcomes (Griffin & Hauser, 1996; Wheelwright & Clark, 1992). Accordingly, concurrent engineering is a good indicator of the overlapping nature of various phases, and it is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support (Shina, 1991; Bicknell & Bicknell, 1995).

Improvement practice. Improvement practice is the extent to which a firm commits to continuous improvement. Toward the end of the 1970s, Japanese companies began to assault world markets with increasing ferocity. Japan's success is the triumph of sheer manufacturing virtuosity. From the outside view, the attractiveness of their products lies in both their low cost and high quality; From the inside view, their success lies in their flexible competence with speed. Their emphasis on "repetitive manufacturing", "Just-in-time" production scheduling, and smooth work flows cause them to be obsessive in their pursuit of the long runs of limited product lines. And their emphasis on "continuous improvement" appears to mirror improving learning curve. Many Japanese companies achieve lower cost, higher quality, faster product introduction, and greater flexibility – all at the same time, which is termed "lean manufacturing". This refutes the necessity of "focus" and "trade-off" that Skinner advocated. Lean producers employ teams of multi-skilled workers at all levels of the organization and use highly flexible, increasingly automated machines to produce volumes of products in enormous variety (White, 1996).

The "Japanese" and "lean" approach to manufacturing became the dogma of manufacturing management during the 1980s and 1990s. It is characterized by an emphasis on quality, flexibility, and speed over volume and cost. People should broadly be trained rather than specialized. No amount of rejection and variation is accepted: the organization should work tirelessly to reduce them. Communication should take place informally and horizontally, among line workers rather than via prescribed hierarchical paths. Equipment should be general-purpose (preferably using programmable automation) and organized in cells designed to produce a group of products, rather than specialized by process stage. Throughput time is more important than labor or equipment utilization rates. Inventory is considered "waste" like rejects. Supplier relationship should be managed on the basis of trust with cooperative problem solving.

The main ideas for JIT are reducing inventory (i.e., lowering the water to reveal the rocks), eliminating any non-value-added processing steps, identifying all sources of variability, uncertainty, or disturbances and then eliminating, if possible, or reducing their magnitude. Therefore, the systems will respond. Typical practices include setup time reduction, preventive maintenance, cellular manufacturing, and pull production.

TQM begins with a focus on the customer (external and internal) and meeting the customer needs. This results in an emphasis on links between work groups, in particular on the impact that variability originating from one group has on that group's customers and suppliers. Thus improved communication and feedback between work groups can benefit the whole systems. The activities associated with TQM are continuous improvement of processes. The search for improvement opportunities has to involve all group members, thus employees need to be trained in team skills and problem-solving skills.

The best place to provide response competence is as close to the source of the problem as possible. We should respond immediately, not wait until information about the need is transmitted up the organizational hierarchy and down to the staff expert. People have to be trained and motivated to deal with problems as they occur, and the closest person who has the competence should deal with the problems. Competence has to be widely diffused, down to the level of the individual worker. Also, different people have different skills, thus small teams are more effective than individuals for problem solving. Typical practices include employee involvement and quality improvement efforts.

Such time-based manufacturing practices (Koufteros, Vonderembse & Doll, 1998) reduce WIP and lead time, thus increase response speed and improve the flexible capability. Naylor, Naim & Berry (1999) provided theoretical support that lean (time-based) practices can be integrated with agile (flexible) manufacturing along the value chain because both have key characteristics: use of market knowledge and response to market, virtual corporation/value stream, lead time compression, eliminate waste, and rapid reconfiguration.

Integration practice. Integration practice is the extent to which a firm integrates decisions and operations. The concept of integration corresponds to Weick's (1976) concept of loose coupling. Orton & Weick (1990) define and interpret the loose coupling mechanism in two dimensions: responsiveness (independence – dependence) and distinctiveness (determinate – indeterminate). If a system does not have distinctive quality, it is not really a system and is non-coupled. A system that is responsive but not distinct is defined as tightly coupled. If it is distinct and not responsive, it is decoupled. If a system is distinctive and responsive, it is loosely coupled and thus integrated.

Ettlie & Reza (1992) summarize the literature of organizational integration and find four broad areas: (1) contingency model of integration (Lawrence & Lorsch, 1967), (2) interdependency of subunits in the organizations (Nemetz & Fry, 1988; Collins, Hage & Hull, 1988), (3) interfirm and interindustry connections (Clelland & Finkelstein, 1990), and (4) technology as an occasion for structuring (Orton & Weick, 1990; Markus & Robey, 1988). They propose four integration mechanisms associated with process innovation based on Porter's (1985) value chain model: (1) customer integration (market-directed integration), (2) design-manufacturing integration, (3) hierarchical integration, and (4) supplier integration. Because these integration practices are related to managerial practices of technology along the value chain, their conceptualizations of integration practices are adapted in this research to study the relationships of integration practices and value chain flexibility. The integration practices included in this research are (1) hierarchical integration, (2) work team integration, (3) customer integration, and (4) supplier integration.

The first type of value-added integration is hierarchical integration. A hierarchical system will operate effectively with a high degree of power sharing between levels (Walton, 1985) and coordinated decentralization (Collins, Hage & Hull, 1988; Dewar & Dutton, 1986). Lei, Hitt & Goldhar (1996) thought that integration results in a combination of both organizational distinctiveness and responsiveness that help firms achieve a careful balance of centralization and decentralization. From the bottom up, the centralization of hierarchies increases responsiveness while, from the top down, the decentralization of hierarchies supports the autonomy and distinctiveness. Therefore, hierarchical integration is necessary to achieve responsiveness and flexibility.

The second type of value-added integration is teamwork integration. Some authors suggest that design-manufacturing integration will be paramount to the capture of the value via process innovation (Collins & Colleagues, 1988; Gerwin, 1988; Souder & Padmanabhan, 1989). For product innovation, studies have suggested that close integration of marketing and R&D is important (Mansfield & Wagner, 1975; Griffin & Hauser, 1996). Here, the concept of integration of design and manufacturing or marketing and R&D are extended as cross-functional work team integration, which includes all teamwork across functions, departments, or other boundaries.

The third type of value-added integration is supplier integration, which is defined here as the suppliers of the components and raw materials participate in the firm's activities. Handfield & Pannesi (1995) provide the convincing evidence that supplier involvement is one of the preconditions of time-based competition and thus flexibility.

The fourth and final type of value-added integration is customer integration, which is called market-directed integration (Teece, 1988; Ettlie & Reza, 1992). Lengnick-Hall (1996) thought that customers can not only receive what an organization produces and delivers, but they also can directly and indirectly influence the operations and outcomes of an enterprise. From an input – transformation – output systems perspective, two customer roles are at the input/upstream side of organizational activity: the customer as resource and the customer as co-producer. Three roles cluster at the output/downstream side of the system: the customer as buyer, the customer as user, and the customer as product (Lengnick-Hall, 1996). Therefore customer involvement can reduce uncertainty from the input and output side of product development and manufacturing, and thus increase the organizational capability of timely and accurate response.

The three major managerial practices are important to the routine use of technology to achieve value chain flexibility, but whether or not the flexible potential of technology can be exploited ultimately depends on the potential and the feeling (sensemaking) of human (or workers) who use technology. This will be detailed in the next section.

2.3 INFUSION OF TECHNOLOGY

Customers have demanded an increasing variety of products with shorter life-cycles; competitors have been more and more competent; the rate of technology development may have outstripped the ability to use it to its full advantage or even understand its potential (Voss, 1986). These conditions demand an increasing capability to respond well to changing circumstances or develop flexibility in other words. Just due to technological rapid changes, does the firm under-use (at best routine use) the new technologies. An organization has to be managed to transform technological potential flexibility into actual flexibility. Great efforts have been put in trying to work out how to do it effectively but results are unsatisfactory.

In industrial engineering literature, research on flexibility focuses on the equipment involved in the production process, generally labeled flexible manufacturing systems (FMS), with a quite technical approach which emphasizes task sequencing or dispatching disciplines. They try to make one flexible system with totally automated functions to deal with a variety of situations such as flexible machining tools and hardware-based simulator using processors to capture real-time data and process those data based on stored algorithms in processors. This is a technical-orientation research paradigm. The organizational behavior researchers are primarily concerned with the flexibility of the human resources and they use tools such as behavior theory, psychology and sociology of work, while industrial organization researchers focus on flexible organizational structure. Both organizational behavior researchers and organizational theory researcher are using social-oriented paradigm. We follow the social-technical research paradigm with emphasizing the infusion of technology in organization, which in turn provides the flexible competence and capability.

In innovation literature, Cooper & Zmud (1990) study MRP use and provide the six steps of technological implementation: initiation, adoption, adaptation, routinization, and infusion. They argue that most cases end up with the routinization stages, then engineers leave. Therefore, the potential of technology cannot be exploited. Kendall (1997) provides the similar steps: technological invention and discovery, technological emergence, technological acceptance, technological sublime, and technological surplus. Here, Technological sublime (infusion) means, "technology is fully understood, appreciated, and put to its best uses". Zuboff (1988) holds that AMT and IT provide the potential of automating and informating work, but most people use technology only as automation and never attempt to exploit the informating capability of technology, thus feel frustrated when new problems happened. Therefore, in order to realize the potential of technology, the human side of technology has to be explored.

Robotics, CAM, FMS, and so on make possible the flexible process, but new process technologies have not proved to be so flexible and influential in America. Hayes, Wheelwright & Clark (1988) provided the results of multiyear research projects on manufacturing performance of plants in Japan, America, and Europe, covering a wide range of industries, including automobiles, semiconductor, electronics, steel, textiles, consumer packaged good, pharmaceuticals, medical products, advanced ceramics, and chemicals. They argue that "there is one common denominator in high-performance plants: an ability to learn – to achieve sustained improvement in performance over a long period of time. When assessing a manufacturing organization, learning is the bottom line."

Hayes, Wheelwright & Clark's analysis confirms that capital investment in new equipment and technology is essential to sustained growth in performance over long periods of time but simply investing money in new facilities does not guarantee improvement. Long-term growth in productivity and quality is not primarily attributable to advances in raw technical competence embedded in new machinery. Of greater importance is the impact that capital investment plays in driving continual improvement throughout the production organization.

The importance of learning indicates the need for a much closer look at the human side of the factory. Especially, in order to achieve sustained improvement in performance, the people in the organization and the way they are linked to other elements of manufacturing should become the focus of attention besides technology investment, the systems, and procedures, which dominate our thinking and analysis when we are studying manufacturing. The learning literature is briefly reviewed as follows.

It is widely agreed that learning consists of the two kinds of activity: "Learning I" and "Learning II" (Bateson, 1973) or "Single-loop learning" and "Double-loop learning" (Argyris & Schon, 1978). Learning I or single-loop learning is obtaining know-how in order to solve specific problems based on existing premises. Learning II or double-loop learning is establishing new premises (i.e., paradigms, mental models, or perspectives) to override the existing ones. The creation of knowledge certainly involves interaction between these two kinds of learning, which forms a kind of dynamic spiral. Besides single-loop learning and double-loop learning, Mckee (1992) suggests meta-learning. Meta-learning involves institutionalizing the ability to learn (Bateson 1972). Senge (1990) argues that the learning organization has the capacity for both generative learning (i.e., active) and adaptive learning (i.e., passive) as the sustainable sources of competitive advantage. He advocates the following five disciplines: (1) systems thinking (2) personal mastery (3) mental model (4) shared vision (5) team Learning. He emphasizes the importance of systems thinking as the discipline that fuses all five disciplines into a coherent body of theory and practices.

Nonaka & Takeuchi (1995) argue "knowledge development constitutes learning". Organizational learning is an adaptive change process that is influenced by past experience, focused on developing or modifying routine, and supported by organizational memory. Especially, double-loop learning or unlearning is related to organizational development, which implicitly or explicitly assumes that someone inside or outside an organization objectively knows the right time and method for putting organizational development program (double-loop learning) into practices. Seen from the viewpoint of organizational knowledge creation, double-loop learning is not a special, difficult task but a daily activity for the organization. Organization continuously creates new knowledge (tacit and explicit) by reconstructing existing perspectives, frameworks, or premises on a daily basis through four conversion activities: socialization, internalization, combination, and externalization.

Kim (1993) develops a model that links individual learning (observe-assess-design-implement) and organizational learning through mental models and that explains how individual learning can be transferred to the organization. While individuals are the agents through which organizations learn, individual learning must be communicable, shared publicly, and integrated for it to become "organizational" (Duncan 1974; Nonaka & Takeuchi, 1995). Communication, knowledge sharing, and information distribution processes are instrumental for making individual insights and know-how accessible to others since the information from highly differentiated individuals is facilitated, validated, and accepted by interactive and relational learning processes that enable debate, clarification, and varied interpretations (Daft & Lengel 1986). This view suggests that knowledge such as new formulas, specifications, theories, procedures, or typologies is the outcome of organizational learning processes. It is through the social interaction and exchange that knowledge about action-outcome relationships and the effect of the environment on these relationships is developed (Duncan & Weiss 1979). Changes in states of knowledge as an outcome suggests that organizational learning processes are simultaneously interactive and interpretive, social, and cognitive.

Weick (1990) state that AMT and IT are simultaneously the source of stochastic, continuous, and abstract events, and thus require ongoing structuring and sensemaking if they are to be managed. This is consistent with Leonard-Barton's (1988) view that technology and organizations adapt to each other in cycles. Tyre & Orlikowski (1994) find that these windows of sensemaking are rare unless an unusual event provides a trigger that connect technology features and sensemaking, thus such improvement has to be managed periodically as Japanese firm does.

Although AMT includes the hardware, software (codified procedures), and human components, AMT puts more emphasis on software (computer programming) for control purposes. Computer-based technology and automation is self-regulating and machines control the whole process. But this kind of control creates the new source of errors and such new errors require workers to take care of. That is, machines control the first-order errors and workers control the second-order errors. Therefore, the workers' skills are required to change from the ability to execute to the ability to solve problems and the ability to learn. Therefore, planning and problem solving should be pushed down to the floor worker's level because of the intellectual nature and intensive information of work itself (Hirschchorn 1981; Zuboff, 1988; Shaiken, 1986). Furthermore, there are more needs for training (Weick, 1990). Instead of working individually, workers form self-directed teams. Learning and accumulation of knowledge are more important than control.

Zmud & Apple (1992) conceptualize and measure the infusion of electronic scanner in supermarket chains with specific environment. Motiwalla & Fairfield-Sonn (1998) measure the impact of expert systems using efficient, effectiveness, innovation, and quality of work life. Torkzadeh & Doll (1999) provide instruments of infusion (impact) of IT: (1) task productivity, (2) task innovation, (3) customer service, and (4) management control. Here, the above conceptualization is extended with general terms and includes the following four dimensions (Table 2.3): (1) task efficiency, (2) task innovation, (3) quality of work life, and (4) learning and knowledge accumulation.

Table 2.3 The Definitions of Sub-constructs of Infusion of Technology

Construct	Definition	Literature
3. Infusion of Technology	The extent to which technology is fully understood, appreciated, exploited, and put to its best use	Cooper & Zmud (1990); Kendall (1997)
3.1 Task productivity	The extent to which technology is used to improve employee's productivity	Weick (1990); Zuboff (1988)
3.2 Task innovation	The extent to which technology is used to help employees create and try out new ideas in adapting products, services, and processes to meet internal and external customer needs	Hirschhorn (1981); Zuboff (1988); Boynton, Zmud & Jacobs (1994)
3.3 Quality of work life	The extent of employees' affective responses to working and living in the organization	Motiwalla & Fairfield-Sonn (1998); Zmud & Apple (1992)
3.4 Learning and knowledge accumulation	The extent of employees and managers' knowledge (tacit and explicit) about technology and the extent of learning & knowledge sharing	Nonaka & Takeuchi (1995); Kim (1993)

The first two dimensions emphasize the extent that employees create and try out new ideas in adapting product, services, and processes to meet internal and external customer needs, and further improve efficiency. The last two dimensions capture employees' feeling and learning. Employees fully use technology to informate and automate their work. Such practices of trial-and-error and experiment increase employees' tacit and explicit knowledge about technology, and thus workers can use technology in a flexible way based on their solid knowledge base and hand-on experiences. A good learning environment also increases employees' skills and motivates workers to learn continuously, and thus employees have strong feeling of belong to the organization. Learning and innovating in the organization become an inseparable part of employees' life. Therefore, the flexible potential of technology can be fully exploited.

2.4 VALUE CHAIN FLEXIBILITY

In order to deal with environmental uncertainty, the organization has two ways to balance the demand and supply: (1) inventory and (2) flexibility in value chain, which allows the company to alter the activity rate on the factory floor so as to satisfy the demand fluctuations without severe disruption. Because it is well accepted that large inventory hides all the problems and raise the cost, the firm seeks another way to cope with uncertainty: value chain flexibility, which is defined as the ability of the organization to deal with the internal and external uncertainty along the value chain so as to meet the desired demands quickly and performance-effectively.

Regarding the contents of manufacturing strategy, two main content areas are divided: competitive priority (Leong, Snyder & Ward, 1990) or order winning criteria (Hill, 1994) and decision areas. The literature points out six main manufacturing objectives: cost, quality, delivery speed, delivery dependability, service, and flexibility. In the history, cost efficiency appears to be key manufacturing competitive priority in the 1950s and 1960s. From the 1970s to

1980s, quality replaced it. From the1990s on to the next century, flexibility (including quick product introduction), delivery speed, and delivery dependability become primary order winning criteria together with cost and quality. Therefore, flexible or agile manufacturing has been advocated as the 21st century manufacturing paradigm (Gunasekaran, 1999; Yusuf, Sarhadi & Gunasekaran, 1999).

Stalk & Hout (1990) hold that time will be the next source of competitive advantage. Therefore, the companies that manage to reduce the time span of their processes will take the lead in the near future. Since flexible system responds quicker to the variety of customer needs without loss of cost, flexibility and time-based competitiveness are somehow linked as manufacturing priorities. Through the comparison of large manufacturing companies in Europe, Japan, and America, De Meyer (1986) argues that manufacturing companies realized that there is no tradeoff of quality and cost in the 1980s, while the 1990s has the potential to be an era without the tradeoff of flexibility and cost efficiency. De Mayer contends that Japanese companies achieve current leadership and advantage in term of quality over American and European competitors to concentrate on their efforts on the tradeoffs between flexibility and cost.

As a response to increasingly turbulent environment, flexibility can be seen as one of the most valuable features a company can possess. Based on Hayes & Wheelwright's (1984) four-phases model (internal neutral, external neutral, internal support, and external support), whatever role (reactive or proactive) manufacturing plays, flexibility, which provides quick reaction to environmental and internal unexpected changes without loss of cost efficiency, will be critical priority for the next decade's competitive battle. The literatures in capability-based strategies provided the strong theoretical support for value chain flexibility as competitive priority.

How does a business achieve and maintain a superior competitive position? The capabilities or resource-based theories provide a compelling explanation that two related sources of advantages are assets and capabilities (Day, 1994). The competitive forces approach (Porter, 1985), the dominant strategic paradigm, puts the emphasis on the intensity of competition in the industry and market segment that determines the profit potential. This approach is rooted in the structure – conduct – performance paradigm of industrial organization (Mason, 1949; Bain, 1959). How to achieve a defensible cost or differentiation position in an attractive market and keep their rivals off the balance through investment, pricing and signals is the main concern.

Despite the considerable insight the Porter framework provides for scholars and practitioners, the fascination with short–term barrier building will distract managers from seeking to build more enduring sources of competitive advantage. This approach unfortunately ignores competition as a process involving the development, accumulation, combination and protection of unique skills and capabilities (Teece, Pisano & Shuen, 1997). Building on foundations laid years before by Schumpter (1942) and Penrose (1959), Wernerfelt (1984) argues that strategic analysis should shift its attention from industry forces and product market positioning to developing and exploiting the unique set of resources (e.g., technical and organizational skills) upon which a firm's long-term profitability depended.

Prahalad & Hamel (1990) contend that firms should focus on building core competencies that could create competitive advantages in a variety of markets. Numerous subsequent articles supplement Hamel & Prahalad's initial work on competence and extend the initial concept to an abstraction identified as core capabilities. Teece, Pisano & Shuen (1997) provide an explicit statement of the dynamic aspects of the resource-based view that they labeled the "dynamic capabilities approach". They argue that firm should be viewed not just as a portfolio of assets and separable businesses, or even as a bundle of human resources and organizational capabilities, but also as a set of mechanisms by which new skills and capabilities are selected and built. Stalk, Evans & Shulman (1992) make the following distinction: "... whereas core competence emphasizes technological and production expertise at specific points along the value chain, capabilities are more broadly based encompassing the entire value chain. In this respect capabilities are visible to the consumer while core competencies rarely are". Therefore, a firm's capabilities are particularly useful in strategic-level analysis.

The capabilities approach locates the sources of competitive advantage in the distinctive capabilities along the value chain (Penrose, 1959; Learned et al., 1969). Day (1994) provides a framework to study capabilities along the value chain. He argues that capabilities could be sorted into three categories, depending on the orientation and focus of the defining processes. At one end of the spectrum are those that are deployed from the inside out and activated by market requirements, competitive challenges, and external opportunities (e.g., manufacturing, logistics, and transformation activities). At the other end of the spectrum are the outside in capabilities such as marketing sensing, customer linking, channel bounding, and technology monitoring. Finally, Spanning capabilities are needed to integrate the inside-out and outside-in capabilities such as strategy development and information dissemination. Therefore, flexibility along the value chain can at least be identified as the following four components: (1) product development flexibility, (2) manufacturing flexibility, (3) logistics flexibility, and (4) spanning flexibility. Each component includes two categories based on Stalk, Evans & Shulman (1990): (1) capability and (2) competence. Watts, Hahn & Sohn (1993) label these two categories as (1) primary flexibility and (2) secondary flexibility. Flexible capability is related to consumers' purchasing decisions while flexible competence plays supportive and auxiliary roles.

Before each component of value chain flexibility is discussed, the concept of flexibility needs to be clarified.

2.4.1The Dimensions of Flexibility

The improvement of flexibility has become increasingly important in achieving competitive advantage in manufacturing (Beckman, 1990; De Meyer et al., 1989). One of the main impediments to its improvement has been the vagueness of the term. The literatures show that flexibility is a complex, multidimensional, and hard-to-capture concept (Sethi & Sethi, 1990). The confusion and ambiguity about this concept seriously inhibits its effective management (Upton, 1995). Academic work on this subject has been carried out in a wide variety of fields. With regard to manufacturing, the relevant literature derives from three primary sources: economics, organizational sciences and manufacturing management.

Economic View. Stigler (1939) considers a plant to be flexible if it has a relatively flat average cost curve and notes that "flexibility will not be a free good: a plant certain to operate x units of output per week will surely have lower costs at that output than a plant designed to be efficient from fluctuating X/2 to 2x units per week." That is, a plant will be inflexible if it operates in the varying outputs with the corresponding varying average cost. Marschak & Nelson (1962) argue that minimum average costs (i.e., the slope of the marginal cost curve) vary inversely with flexibility.

Marschak & Nelson (1962) hold that the greater the flexibility in decision making the greater the value of information gathering, which corresponds with the notion that good current actions may be those that permit good later responses to later observations. Jones & Ostroy (1984) emphasize: "the way flexibility is used to exploit forthcoming information may be dictated by attitudes toward risk; but flexible positions are attractive not because they are safe stores of value, but because they are good stores of options."

Carlsson (1989) suggests two types of flexibilities. Type I flexibility is related to risk and refers to the firm's positioning itself to deal with foreseeable events. It is built into production processes so that the organization can produce dissimilar existing products on one production line. Aimed at rapid short-term response to changes in market conditions, it permits very significant shifts in the composition of output without the usual penalties involved in closing down entire production lines. Type II flexibility is related to uncertainty and is concerned with the ability to make good use of newly disclosed opportunities. To rapidly respond to uninsurable changes in market conditions and unprogrammable advances in technology, firms must be aware of feedback that suggests opportunities for new products and processes.

Organizational Science View. Organizational flexibility is the ability of an organization to suffer limited change without severe disorganization (Feibleman & Friend, 1945). March & Simon (1958) introduce the concept of organizational slack, which provides an organization with the excess resources to cope with internal as well as environmental uncertainties. Burns & Stalker's (1961) organic structure, Emery & Frist's (1962) sociotechnical system, Walton's (1980) high commitment system, and some forms of decentralized, divisionalized, project management, matrix structures (Child, 1982) and Daft (1978) and Mintzberg's (1979) concept of adhocracy refer to models of organization that have the flexibility to operate responsively in a rapidly changing environment.

In the context of flexible technologies, product-focused forms are the organizational arrangements capable of much faster response to changing environment than functional structures. They are organized around the output functions rather than around the input functions. They are named group technology cells, parallel assembly cells, flexible focused factories, plant-within-plants, and network organizations.

Manufacturing Management View. Diebold (1952) recognizes flexibility to be essential for manufacturing of discrete parts. Leaver & Brown (1946) propose a series of small, functionally oriented machines that can be plugged together.

Flexibility is viewed as a tradeoff against efficiency in production and dependability in the marketplace (Abernathy, 1978; Hayes & Wheelwright, 1984). Two extreme situations exist: job shop being flexible but inefficient and mass production being efficient but inflexible. How to extend flexibility to large-scale production without sacrificing efficiency begins with the development of FMSs in the early 1970s. Instead of economies of scale, the term "economies of scope" captures the efficiency in batch production (Talaysum et al., 1986). The efficiency of the midvolume, midvariety production is accomplished by a drastic reduction of setup costs and times required for switching from the production of one product to another.

Kickert (1985) believes that "flexibility can be considered as a form of metacontrol aimed at increasing control capacity by means of an increase in variety, speed, and amount of responses as a reaction to uncertain future environmental development." Sethi & Sethi (1990) considers manufacturing flexibility as the property of the system elements integrally designed and linked to each other in order to allow the adaptation of production equipment to various production tasks: that is, flexibility in manufacturing means being able to reconfigure manufacturing resources so as to efficiently produce different products of acceptable quality.

Flexibility should be planned, managed, and with learning expanded. For example, the speed and the cost of response, the amount of required reinvestment, and the extent of interruptions in the existing system must be considered in advance. Upton (1995) holds that "flexibility is the ability to change or react with little penalty in time, effort, cost or performance." He identifies potential flexibility and demonstrated flexibility; robustness (i.e., maintaining a status quo despite a change) and agility (i.e., instigating change rather than react to it); internal (i.e., what we can do) and external (i.e., what the customer sees).

Flexibility is about increasing range, increasing mobility, or achieving uniform performance across a specified range (Upton, 1995). Product range can mean different things. For example, a plant can have the ability to make a small number of products very different from one another, or it can have the ability to produce concurrently a large number of stock-keeping units that are only slightly different from one another. Mobility means a plant's ability to change nimbly from making one product to making another. It is this kind of flexibility that is associated with quick response times -- mobility minimizes the need for long runs and allows production to follow demand without excessive inventory; uniformity of performance means that when a plant moves away from its favored set of parameters, performance falls off. If it falls off dramatically, managers will label the plant inflexible.

In summary, flexibility includes three dimensions: range, mobility, and uniformity. These dimensions correspond to the Leeuw & Volberda's (1996) three dimensions of flexibility: variety, rapidity, and procedures, and Sethi & Sethi's variety and response.

2.4.2 The Measures of Flexibility

Two primary streams about measuring flexibility can be identified: objective measures (Gerwin, 1986) and perceptual measures (Slack, 1987; Swamidass, 1987). Gerwin advocates using the number of design changes during a period to measure modification flexibility. One difficulty in developing such objective measures is that flexibility is a potential ability to realize something rather than something measurable as performance. Furthermore, such objective measures are difficult considering the heterogeneity of design changes in terms of magnitude or complexity. Kumar (1987) proposes to assess flexibility using the concept of entropy. The bigger the number of possible choices and the more similar the preferences between them, the higher the flexibility indicator. It is useful to measure resource flexibility like machine flexibility, but it is hard to measure system as a whole such as new product flexibility and volume flexibility. Furthermore, it cannot capture responsiveness. In sum, objective measures are developed using mathematical variables or models, and such oversimplified indexes, in most cases, fail to hold to the modeled reality.

Perceptual measures are developed using the perception of experienced people involved in the process. This has its advantages over hard-data (quantified). Slack (1987) proposes a method based on managers' perception of the relative position of assessed systems among competitors (or compared with industry average). Then these measures are compared with the importance of these measures to competitiveness. Gaps guide a manager's decision making. An alternative is to compare the company's flexibility performance with customers' expected levels. Because we must measure flexibility of both system level and resource level, while flexibility of resource level is difficult to compare with customer expectations, we based our flexibility measures on the comparisons among a firm's primary competitors.

2.4.3 The Components of Value Chain Flexibility

Based on the above discussion of the dimensions of flexibility (i.e., range, mobility, and uniformity) and measurement methods, each component of value chain flexibility will be conceptualized and defined in the remaining sections.

2.4.3.1 Product Development Flexibility

As illustrated in Table 2.4, product flexibility is defined as the introduction of new products and the modification of existing products (Cox, 1989; Hyun & Ahn, 1992; Sethi & Sethi, 1990; Slack, 1987). Olson, Walker & Ruekert (1995) mention that the organizational skills and abilities required to introduce new products may be significantly different form these required to modify existing products.

Radically new products often require intensive technology development and protracted development times that may span 2 to 5 years. The market opportunities for these types of products are often unspecified and unclear. Conventional market research techniques may be of little help in the formulation and early development of these products because customers have nothing to compare the product to, nor do they necessarily have the ability to envision the potential of the radically innovative product. Therefore, it is necessary to address product flexibility via two dimensions: new product flexibility and modification flexibility. Besides these two capability-related dimensions, recent literature about product development raises at least two important competence issues: set-based product concept and quick prototype. Here, they are called "product concept flexibility" and "prototype flexibility" respectively.

Table 2.4 The Definitions of Sub-constructs of Product Development Flexibility

Construct	Definition	Literature
Product development flexibility	The ability of a firm to introduce and launch new product or respond to customer needs for design changes quickly and performance-effectively.	Dixon (1992); Suarez, Cusumano & Fine (1995, 1996); Gerwin (1987, 1993);
- Product concept flexibility	The ability to quickly produce and keep set-based product concepts and definitions.	Griffin & Hauser (1997); Rosenthal & March (1988)
- Prototype flexibility	The ability to build and modify the product prototypes quickly and cost-effectively	Clark & Fujimoto (1991); Cooper & Kleischmidt (1994)
- Modification flexibility	The ability to respond to customer needs for design changes quickly and performance-effectively	Sethi & Sethi (1990); Gupta (1993)
- New product flexibility	The ability to introduce and launch new product quickly and performance-effectively	Sethi & Sethi (1990); Gupta (1993)

Product concept flexibility. Product concept flexibility is the ability to quickly produce and keep set-based product concepts and definitions. Traditional design practice, whether concurrent or not, often converges on a solution quickly, and then modifies that solution until objectives are met (this is called point-based product development). If the initial choice is right, then it is effective. Once one picks a wrong starting point, then refining the solution will be time-consuming and money-consuming. Sobek, Ward & Liker (1999) provides the principles of set-based concurrent engineering based on Toyota's product development practices. Set based concept begins by broadly considering sets of possible solutions and gradually narrows it down to a final point. A set of wide possible options makes finding better solutions more likely. Thus, an organization may take more time early on to define the solutions, but it can move more quickly to refine or change the solution toward production.

Prototype flexibility. Prototype flexibility is the ability to build and modify the product prototype quickly and cost-efficiently. The traditional attribute-based approach to product design typically specifies the product characteristics based on the survey of customer preferences and then produces it, but such characteristics are not easily perceived or verified by customers. Thus the organization does not know whether a product will be accepted or rejected before appearing on the market. In order to reduce such uncertainty, customer-ready prototype can provide accurate reactions from customers since it is nearly the same as they are to an eventual commercial product. The physical artifact has nearly the same product attributes, aesthetics, usability, and quality of manufacture as the product eventually to be marketed (Srinivasan, Lovejoy, & Beach, 1997). Also, such a prototype provides a good opportunity for an organization to learn. Japanese firms produce prototype quickly and gain more experience by doing, thus it makes easier for them to provide a new product quickly.

Modification flexibility: Modification flexibility is the ability of an organization to respond to customer needs for design changes quickly and performance effectively. A product is considered modified if its functional characteristics are maintained, but other aspects of the product are changed to better satisfy a customer's needs (Dixon, 1992). Modification flexibility addresses those product changes less involved than the development of a totally new product. The number of modified products indicates the customer responsiveness achieved by an organization.

New Product flexibility. New product flexibility is the ability to introduce and launch new products quickly and performance effectively. A product is considered new if its functional characteristics differed from those of any other product made previously by the plant (Dixon, 1992). The range elements of new product flexibility are captured by the number and variety of new products introduced by an organization, which reflects an organization's strategic emphasis on product development. An organization that develops and introduces products very different from each other should be considered as more flexible than one that introduces products fairly similar to each other. Development time or costs incurred by the organization in creating a new product could represent the degree of flexibility in terms of mobility and performance uniformity.

2.4.3.2 Manufacturing Flexibility

Hayes & Wheelwright (1984) consider manufacturing flexibility (Table 2.5) as one of the dimensions of the competitive strategy of a business along with price (cost), quality, and dependability. Priorities assigned to each of these dimensions determine how the business positions itself relative to its competitors. According to Skinner (1985), it is not always easy to grasp the interrelationship between manufacturing operations and corporate strategy. What is required is the concept of manufacturing strategy, which consists of a sequence of decisions that, over time, enable a business to achieve a desired manufacturing structure (i.e., capacity, facilities, technology, and vertical integration), infrastructure (i.e., workforce, quality, production planning control, and organization), and asset of specific capabilities that enables it to pursue its chosen competitive strategy over the long term (Hayes & Wheelwright, 1984).

Table 2.5 The Definitions of Sub-constructs of Manufacturing Flexibility

Construct	Definition	Literature
Manufacturing flexibility	The ability of a firm to deal with the inherent manufacturing resource and management uncertainty so as to provide or support the desired demands.	Chen, Calantone & Chung (1992); Leong, Snyder & Ward (1990);
- Machine flexibility	The ability of a machine to perform different operations economically and performance-effectively.	Gupta (1993); Hyun & Ahn (1992); Chen, Calantone & Chung (1992); Sethi & Sethi (1990)
- Material Handling flexibility	The ability to performance-effectively transport different work pieces through work centers	Hutchinson (1991); Sethi & Sethi (1990); Coyle, Bardi & Novack (1992)
- Labor flexibility	The ability of the workforce to perform a broad range of manufacturing tasks performance-effectively	Upton (1994); Hyun & Ahn (1992); Ramasesh & Jayakumar (1991)
- Routing flexibility	The ability to process a given set of part types using multiple routes performance-effectively	Upton (1995); Gerwin (1993); Sethi & Sethi (1990)
- Volume flexibility	The ability of a production system to operate at various batch sizes and/or at different production output levels performance-effectively.	Carlsson (1989); Gerwin (1993); Sethi & Sethi (1990)
- Mix flexibility	The ability of a production system to produce different combinations of products performance-effectively given certain capacity	Boyer & Leong (1996); Sethi & Sethi (1990); Gupta & Somers (1992)

Flexible manufacturing capability can be addressed at least via two dimensions: mix flexibility and volume flexibility. Such flexible capability must be a permanent preoccupation and not just an improvisation (Behrbohm, 1985). It is much more than simply buying an FMS, and it must be planned and managed. Then what secondary manufacturing flexibility may provide such support? In literature, at least four dimensions need to be mentioned: machine flexibility, material handling flexibility, labor flexibility, and routing flexibility.

Machine flexibility. Machine flexibility is the ability of a machine to perform different operations economically and performance effectively. It is a key variable in shop floor scheduling and dual resource constrained job shop. The range element of machine flexibility can be assessed with the number of operations a machine can perform (Gupta, 1993; Hyun & Ahn, 1992, Ramasesh & Jayakumar, 1991). Mobility can be assessed using changeover time and setup cost while uniformity can be examined by quality and by efficiency of operations for different switches.

Material handling flexibility. Material handling flexibility is the ability to economically and performance-effectively transport different work pieces between processing centers with multiple existing paths. Hutchinson (1991) notes that insufficient consideration of the material handling subsystem can constrain the benefits of a flexible manufacturing system. The number of paths between processing centers and kinds of materials that the system can transport capture the range element of material handling flexibility. Mobility can be examined using time or cost associated with adding a path. Material transfer time and cost or the number of parts for different paths can assess uniformity.

Labor flexibility. Labor flexibility is the ability of the workforce to perform a broad range of manufacturing tasks economically and performance effectively. It is a major consideration in the dual resource constrained literature but the conceptual and empirical literature tends to focus on the equipment flexibility, neglecting the potential impact of labor force. The workforce, however, plays a vital role in most production processes. Japanese flexible workers can handle uncertainty in the production process such as absent workers or respond to changes in demand by shifting the workforce as needed. The number of tasks a worker can perform assesses the range element of labor flexibility. Effectiveness of work transfer can be used to address the mobility and uniformity elements of labor flexibility.

Routing flexibility. Routing flexibility is the ability to process a given set of part type using multiple routes effectively. It is widely studied in FMS scheduling literature. It essentially relates to the ability to use alternate processing centers in case of machine breakdowns or overloads. The number of alternative routes that exist and the extent to which a route can be varied can assess the range element of routing flexibility. Mobility and uniformity can be examined respectively by time and cost expended to a change, and by differences in processing time or in quality with the use of an alternative route.

Volume flexibility. Volume flexibility is the ability of a production system to operate at various batch sizes and/or at different production volumes/capacities economically and performance effectively, given certain product mix. It is widely discussed in economics literature and assessed by the cost curve (Carlsson, 1989). If a cost curve is more flat bottomed, it is more flexible. In manufacturing literature, it is a measure of capacity in terms of labor hours. The level of aggregate output over which the firm sustains profitability under normal conditions indicates the range element of volume flexibility. Economists express the range as the range of output over which the average cost curve is flat. Time required to change output level captures the mobility element while production costs and quality levels provide a measure of uniformity. Volume flexibility provides competitive potential; it either increases market share profitably under a rising market or decreases inventory under the low demand.

Mix flexibility. Mix flexibility is the ability of a production system to changeover to different product mix changes in the market quickly, economically, and performance effectively without large changes in capacity. Mix flexibility has to be evaluated within the current production system configuration without considering major setups or facility modifications (Dixon, 1992; Gupta & Somers, 1996; Sethi & Sethi, 1990). That means the production system can respond to the changes in kinds of product demanded, given the certain level of capacity. Without this condition, an organization can acquire additional equipment or other resources to produce the products needed (that belongs to the category of volume flexibility). The number of different products an organization produces captures the range element of mix flexibility. Time and cost incurred for changing product mix are a measure of mobility while quality and productivity are a measure of uniformity.

2.4.3.3 Logistics Flexibility

Supported by the value chain concept (Porter, 1985; Porter & Millar, 1985), both top managers and researchers view logistics as critically important to competitive advantage. A manufacturing firm managed as a value or supply chain is capable of concurrently lowering cost and increasing service to achieve differentiation (Davis, 1993). An important characteristic of successful logistics process is the ability to support a high level of operational flexibility (Perry, 1991). This implies effectively purchasing and disseminating materials to support organizational activities and meet the needs of the final customers (Langley & Holcomb, 1992). To support the flexible operations, according to Day (1994), at least four components along the value chain need to be considered: physical supply flexibility, purchasing flexibility, physical distribution flexibility, and demand management flexibility (Table 2.6). The first two components are important constituents of the organizational competences from the supply side while the last two components are related to customer's service and thus have more attributes of strategic capability.

Table 2.6 The Definitions of Sub-constructs of Logistics Flexibility

Construct	Definition	Literature
Logistics flexibility	The ability of a firm to quickly respond to customer needs in delivery, support and services	Day (1994); Davis (1993): Perry (1991)
- Physical supply flexibility	The ability of a firm to quickly and accurately provide inbound transportation and material inventory	Day (1994); Langley & Holcomb (1992)
- Purchasing flexibility	The ability of a firm to quickly provide the variety of materials and supplies through relationships with suppliers	Porter (1985); Ernst & Whinney (1987)
- Physical distribution flexibility	The ability of a firm to quickly adjust the inventory, packaging, warehousing, and transportation of physical products to meet customer needs	Day (1994); Langley & Holcomb (1992); Lambert & Stock (1993)
- Demand management flexibility	The ability of a firm to quickly respond to the variety of customer needs in terms of customer order taking, delivery time scheduling, installation, repair, training, and maintenance of products	Chase & Garvin (1989); Coyle, Bardi & Novack (1992); Lengnick-Hall (1996)

Physical supply flexibility. Physical supply flexibility is the ability of a firm to quickly and accurately provide the variety of requirements in inbound transportation, warehousing, and material inventory. Physical supply consists of those logistics processes that take place before or during the production process (Ernst & Whinney, 1987): inbound transportation, material warehousing, and inventory control. The quality of inbound transportation service (such as in-transit time, frequency of delivery, cost, and the occurrence of damage and/or lost freight) impacts a manufacturer's inventory levels, the frequency of stockouts and shutdowns, and the utilization of material handling equipment. Warehousing facilitates the supply mixing.

Purchasing flexibility. Purchasing flexibility is the ability of a firm to quickly and performance-effectively provides the variety of materials and supplies through cooperative relationships with suppliers. Traditional purchasing practice emphasizes arm's length adversarial bargaining with suppliers to achieve the lowest prices for each transaction. Therefore, the firm is not aware of a supplier's costs and capabilities. Now, the firm seeks cooperative relationships with suppliers based on a high level of coordination, participation, and close communication (Day, 1994). It achieves advantage through total quality improvement and reduced time to market, and thus increased flexibility.

Physical distribution flexibility. Physical distribution flexibility is the ability of a firm to quickly and performance-effectively adjust the inventory, packaging, warehousing, and transportation of physical products to meet customer needs. It is also called outbound logistics flexibility in Porter's term. It stipulates flexibility embodied in those activities in the latter portion of value chain such as packaging, warehousing, and outgoing transportation. These activities are important to strategic responses since they are visible to customers. It deals with range, mobility and performance uniformity of physical supply. The range element of physical distribution flexibility is captured by the kinds of packaging and the number of transportation modes. The mobility can be assessed by the difference of time and cost of different transportation modes and different packages. The uniformity can be examined by the quality and delivery dependability.

Demand management flexibility. Demand management flexibility is the ability of a firm to quickly and performance-effectively respond to a variety of customer needs such as customer order taking, delivery time scheduling, installation, repair, training, maintenance of products, and building a long-term customer relationship. It is a market sensing and customer-linking capability -- meeting a variety of customer needs timely by creating and managing close customer relationships (Day, 1994). To flexibly act on events and trends of present and prospective markets/customers, the firms need to sense and timely gather customer requirements. The organization has to commit itself to customers so customers and firms share interdependence, values, and strategies over the long term. To achieve this, firms foster direct customer contact, collect information from customers about their needs, and use customer-supplied information to design and deliver products and services (Schneider & Bowen, 1995). Customer sophistication and knowledge are increasing. As expectations rise, customers' attention to detail and ability to articulate gaps between expectations and experiences increases. Therefore, customers are viewed as important potential co-designers and co-producers since they can make effective contributions to production activities (Chase & Garvin, 1989; Lengnick-Hall, 1996). Because customers are the final stakeholder and arbiter of a product, involving them in product design and production can reduce their uncertainty. Otherwise, the firm can produce perfect product but can not guarantee selling. Also, other services including installation, repair part, and training have to be considered, and the firm should be prepared to deal with all kinds of customer requirements.

2.4.3.4 Spanning Flexibility

Spanning capabilities include many activities or actions, which need to cross several organizational boundaries (or outside) and make horizontal connections to satisfy the customer needs. In coordinating the activities of a complex process, information availability and corresponding strategies acting on such information are two important elements to manage.

Information, unfiltered by a hierarchy, is readily available to all team members so that everybody knows what results or effects a question or action has on the whole process. Therefore, the speed of problem solving and timeliness of strategy development can be improved based on accurate and timely information. At least these two important components for spanning flexibility need to be detailed (Table 2.7): information dissemination flexibility and strategy development flexibility.

Table 2.7 The Definitions of Sub-constructs of Spanning Flexibility

Construct	Definition	Literature
Boundary Spanning flexibility	The ability of a firm to provide horizontal information connections across supply chain to meet customer needs	Day (1994)
- Information dissemination flexibility	The ability of a firm to quickly collect and disseminate the variety of data along a supply chain to respond resourcefully to the customer needs	Mintzberg (1989); Cooper & Zmud (1990)
- Strategy development flexibility	The ability of a firm to continuously develop strategy based on internal competence and external customer needs	Wheelwright & Hayes (1985)

Information dissemination flexibility. Information dissemination flexibility means the ability of a firm to quickly collect and disseminate the variety of data along a supply chain to meet the variety of customer needs. A firm may collect the information, but the information is stored separately or the firm cannot assemble / distribute all the needed pieces. Day (1994) provides a vivid example about competitor information, which is stored in different nodes along the value chain. Manufacturing may be aware of certain activities through common equipment suppliers; sales may hear about initiatives from distributors and collect rumors from customers; and engineering department may have hired recently from a competitor. If such information-qua-knowledge is kept in separate departments or information flow is restricted to vertical movement, the firm can never take timely unified action to compete in the market. Instead, information is widely distributed and its value appreciated. For example, suppliers continuously exchange information about their problems and emerging requirements and actively participate in the firm's development processes before product specifications are established. Such joint product design and production planning /scheduling make each know the other's requirements and status, thus orders can be communicated electronically so that the firms can share logistics and product movement information and joint planning for product changes. Therefore, the firm can coordinate all the functions, anticipate needs, demonstrate responsiveness, and build trust.

Strategy development flexibility. Strategy development flexibility means a firm's ability to develop strategy based on internal competence and external customer needs continuously and effectively. It is a concept developed based on capability-based strategy literature (Hayes & Pisano, 1994; Pisano, 1994; McGrath, MacMillan & Venkataraman, 1995). Here, strategy development is a type of capability that emphasizes the key role of strategic management in appropriate adapting, integrating, and reconfiguring internal and external organizational skills, resources, and functional competences to match the requirements of a changing environment (Teece, Pisano & Shuen, 1997). Flexibility refers to certain timely and innovative responses when time-to-market and timing are critical.

It is expected that the improvement of the capability in value chain flexibility would be an advantage to win competition. Such advantages can be assessed via price/cost, product innovation, delivery dependability, value to customer /quality, and time-to-market.

2.5 COMPETITIVE ADVANTADGE, CUSTOMER SATISFACTION, AND FINANCIAL PERFORMANCE

Recently, many researchers and practitioners have provided support for cumulative models of competitive priorities rather than tradeoff models (Corbett & Wassenhove 1993, Ferdows & De Meyer, 1990, Flynn & Flynn 1996, Garvin 1988, Noble 1995). Especially, Japanese firms have exhibited a capability to pursue multiple strategies and objectives simultaneously. Many empirical studies attests to this fact (Roth & Miller, 1992; Nemetz, 1990).

White (1996) provides a meta-analysis of manufacturing performance, which includes quality, delivery speed, delivery dependability, cost, flexibility, and innovation. Schroeder, Anderson & Cleveland (1986) report a similar measure of performance. Specifically, Koufeteros (1995) provide measurements of the following dimensions of competitive capabilities compared with competitors: cost, competitive pricing, premium pricing, value to customer quality, product mix flexibility, product innovation, and customer service. Tracey, Vonderembse & Lim (1999) provide similar measurements of competitive capability: price offered, quality of products, product line breadth, order fill rate, and frequency of delivery. Although these authors have provided measures of competitive capability, they need refinement and adaptation for this study. Specifically, cost and competitive pricing are so closed that they will be one dimension. Time-to-market, delivery dependability, and product innovation are three important dimensions to be added. In summary, the dimensions for this study are price/cost, product innovation, delivery dependability, value to customer quality, and time-to-market.

Price/Cost. Cost is a traditional measure of success and a determinant factor of the ability of the organization to profit. Most measures have been objective (accounting data) while recently some authors (Nemez, 1990) used subjective cost measures.

Product innovation. Product innovation refers to the capability of the organization to introduce new products and new features as needed by customers. Due to shorter life cycles, a firm innovates frequently and in small increments (Clark & Fujimoto, 1991).

Delivery dependability. Delivery dependability means the extent to which product is delivered to customers on time with accurate quantities and kinds of products needed (White, 1996). This is an important factor of competitive advantage.

Value to customer quality. Value to customer quality refers to the extent to which the firm is capable of offering product quality and performance that creates high value to customers (Doll & Vonderembse, 1991). Garvin (1988) has proposed eight dimensions of quality: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality, which are comprehensive but measures for each is difficult to establish.

Time to market. Time to market refers to the extent to which the firm can deliver product to market quickly. It is an important index for time-based competition (Vessey, 1991; Kessler & Chakrabarti, 1996; Griffin, 1993; Meyer & Utterback, 1995). It is a direct result of organizational flexible capability.

It is expected that companies that score high in these competitive advantages will achieve customer satisfaction and improve organizational performance. Firms that can respond fast to customer needs with high quality product and innovative design, and excellent after-sales service allegedly build customer loyalty, increase market share and ultimately gain high profits.

Customer satisfaction. One of the primary goals of an organization is to satisfy customers since a satisfied customer is more likely to repurchase (Innis &

LaLonde, 1994). Customer satisfaction is the result of clients perceiving that they receive products and services commensurate with the price they pay (Tracey, 1996). Firms with high customer satisfaction will build a reputation for providing high value to customers. High value results in loyal customers and thus promotes long-term prosperity through the creation of a base of steady clients, which in turn account for high profit growth of firms.

Financial performance. Financial outcome is widely used because profitability, market share, sale revenues, ROI, and cash flow are main yardsticks for most stakeholders (Loch, Stein & Terwisch, 1996; Cooper & Kleischmeidt, 1994).

2.6 THEORETICAL MODEL AND HYPOTHESES

Swamidass (1991) proposes empirical research as a new frontier in operations management, and he discusses empirical approaches to theory building. He suggests basing studies on mature theory and starting empirical studies in three areas: (1) conjecture, (2) searching for the law of interaction, and (3) falsification of theory. Conjecture means that researchers should throw off the limitations of anecdotal knowledge, boldly imagine the possible explanations for relationships, and develop and test hypotheses. Searching for the law of the interaction is used in the early stage of research to find significant correlation between variables rather than seeking pure causal relationships. Falsification of theory means that hypotheses can be strengthened or weakened through empirical investigation.

This research focuses on the relationships between environmental uncertainty, use of technology, infusion of technology, value chain flexibility and competitive advantage. The hypothesized relationships (all are positive) and their directions are depicted in Figure 2. Form right to left, this model suggests that value chain flexibility is a predictor of competitive advantages (including customer satisfaction and financial performance). It further shows that environmental uncertainty, use of technology, and infusion of technology are the co-determinants of value chain flexibility. This systemic framework presented here tries to use learning and capability-based theories to conjecture probable truth. The analysis of the relationships in this nomological network can be used to assess construct validity by relating it to the other constructs (Churchill, 1979).

Hypothesis 1: Environmental uncertainty has a significant positive relationship with use of technology

In terms of flexibility adoption, it is developed to cope effectively with uncertain changes, whether they are internal or environmental, or related to the inputs, the outputs, or to the manufacturing process. De Meyer (1986) holds that American and European firms mainly adopt automated flexible manufacturing systems not to change their product design quickly or adapt their product mix to customers' requirements, but in order to accommodate the variability of their inputs. Therefore, from the customers' view, American firms lack flexibility compared with Japanese, since Japanese companies seek to neutralize the effects of demand uncertainties from customers with flexibility while reducing supply (input) uncertainty through developing long-term relationship and effective technological cooperation with suppliers.

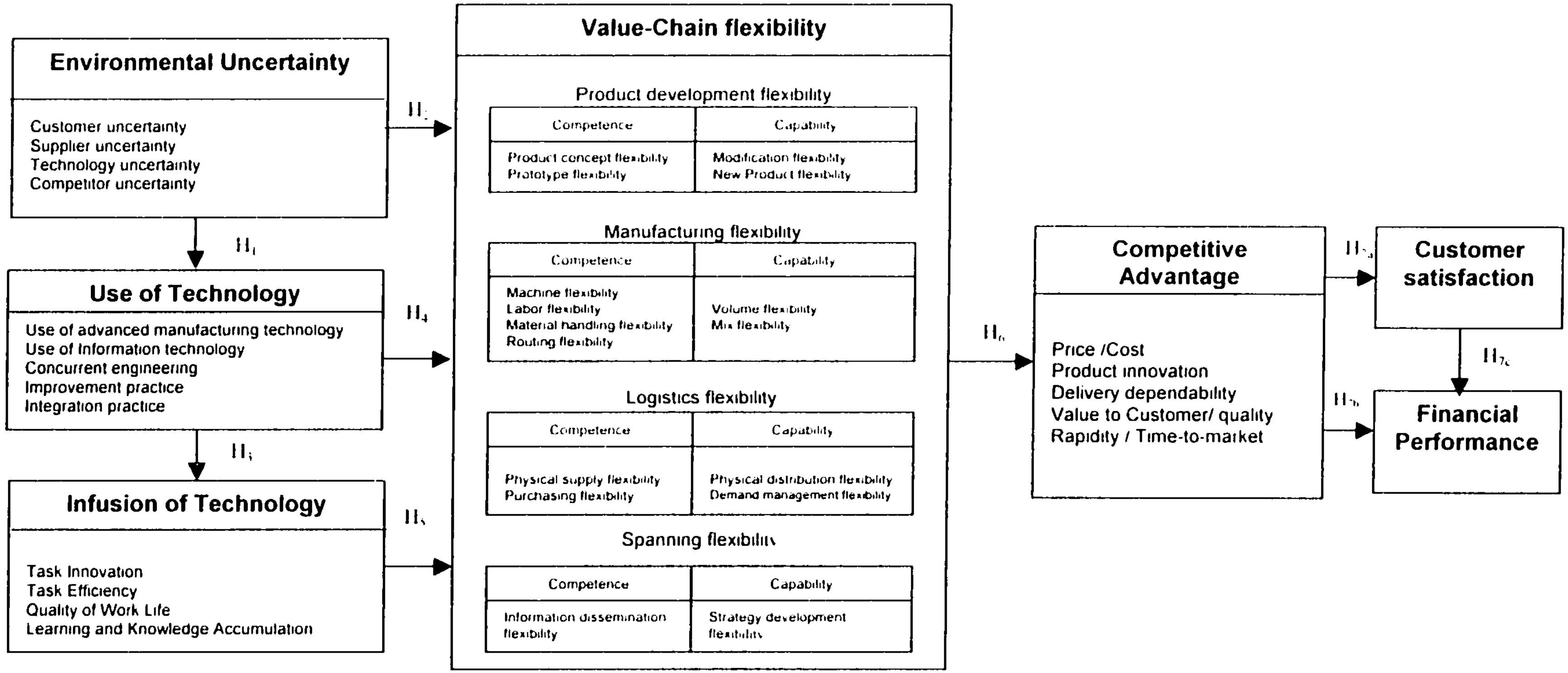


Figure 2: Technology Infusion Enabled Value Chain Flexibility: A Learning and Capability Perspective

Although the AMT is used in different ways, they use technology to serve the same purpose of coping with uncertainty. Facing environmental uncertainty, firms use advanced technology to automate the work to reduce the possible mistakes of human being and to speed up the work process (Gerwin & Kolodny, 1992). Typical AMT such as CAD, CAM, CNC, FMS, CM, ASRS, and EDI is widely used in design, manufacturing, and logistics to increase responses to customer changes, catch up with rapid technological changes (if firm does not adopt AMT, it will falls far behind and can never catch up), and compete with competitors. Especially, IT is adopted to speed daily work and decision process to deal with environmental changes. Also, corresponding managerial practices such as concurrent engineering, improvement (setup reduction, and quality improvement), and work team integration are taken to strengthen management of technology to cope with environmental uncertainty.

Hypothesis 2: Environmental uncertainty has a significant positive relationship with value chain flexibility

With regard to environment uncertainties, it should be understood that value chain flexibility is required in order for a firm to cope with both internal changes and external forces. Such environmental uncertainties such as demanding customer needs, rapid technological changes, and intensive competition requires firms to have high flexibility so as to act in a rational and manageable way (Thompson, 1967). Specifically, uncertainty may exist for level of demand, product prices, product mix, and availability of resources. Uncertainty may arise out of actions of competitors, changing consumer preferences, and technological innovations. Therefore, the organization has to have high product development flexibility to deal with rapid change of customer preferences, have high manufacturing flexibility to respond to mix and volume changes, have high logistics flexibility to deal with requirements of short lead time and a variety of services, and have high spanning flexibility to provide timely and accurate strategic response.

Hypothesis 3: Use of Technology has a significant positive relationship with infusion of technology

From the traditional technology adoption (diffusion) model, the cause-and-effect chain [i.e., beliefs (usefulness and ease of use) - attitude (user satisfaction) - behavior (system-use) - infusion and impact] provides the direct support that only organizations often (routinely) use technology and accumulate experience and knowledge of technology, can the technological potential be exploited and put to best use (Cooper & Zmud, 1990; Kendall, 1997). Furthermore, some improvement practices such as set up reduction and quality improvement cycle elevate employees' motivation to innovate their work with technology, further improve productivity, improve learning ability and increase the level of technological knowledge. Employees' involvement makes them feel that work is an inseparable part of their life and thus employees have strong feeling of belonging to the organization.

Hypothesis 4: Use of Technology has a significant positive relationship with value chain flexibility

Use of AMT in design such as CAD and CAE increase the agility of product development including shortened time, reduced cost, and increased range of trials. CAM, FMS, and CNC are used in manufacturing to reduce time and improve responsiveness; EDI and Bar Code are used in distribution of products to reduce human-made mistakes, reduce lead-time, and thus increase flexibility. Likewise, IT usage in daily operations, decision-making, and internal and external integration greatly improve the speed and quality of the organizational response. Furthermore, managerial practices cannot be neglected. Hyun & Ahn (1992) think that equipment manufacturers establish machine flexibility a priori. This implies machine flexibility is at a set level and cannot be altered by an organization. Although process choice plays an important role in the determination of the level of machine flexibility, it is influenced by the organization's policy and systems such as setup time reduction and continuous improvement efforts. Therefore, the actual level of machine flexibility achieved reflects the impact of technology and management

Hypothesis 5: Infusion of Technology has a significant positive relationship with value chain flexibility

The development of new process technologies has increased the availability of machinery with flexible automation. But it is important to be aware that although flexible automation plays an important role, it is not sufficient to ensure that the manufacturing systems will achieve flexibility. The potential of human side has to be exploited. As long as employees really use technology to innovate their work and are willing to learn and accumulate knowledge about technology, then gradually they will love to exploit technology to informate their work, and thus get involved in technological improvement. Continuously innovating their work can make employees feel that they are really the owner of the process and they collectively have complete autonomy on their teamwork; therefore, they look forward to being with the members of their work group in technology implementation. Such feeling of belonging to the organization can greatly increase organization agility in product design, labor deployment in manufacturing, and logistics management; further, it is the real source of organizational flexible capability.

Hypothesis 6: Value chain flexibility has a significant positive relationship with competitive advantage

As the quality and cost become necessary for the firm to stay in the competition, flexibility capability becomes more important in gaining a competitive advantage. Of course, flexibility capability comes not from the functional flexibility such as manufacturing flexibility alone, but from the flexible integration capability along the whole value chain. Increased flexibility can influence the level of the system in terms of quality, cost, delivery speed, delivery dependability, product innovation, and service.

With flexible product development, the firm can quickly respond to changes of environments with product modification and new product commercialization. Such flexible design and development capability can increase the manufacturability of products by simplifying the structure of products, reducing the number of parts, and standardizing parts. This, in turn, makes manufacturing easier and faster; therefore, the quality of the product is easier to control. With a flexible system, the changeover operations are quicker and easier, making it also faster and easier to bring production back to tolerances when a new production run starts. Therefore, quality can be improved with manufacturing flexibility under uncertain environment. With flexible logistics capability, the high-quality materials provide the possibility of a high-quality product. With flexible information spanning, different departments or groups (inside and outside) can coordinate easily about product design and production, thus, assuring the quality of products.

Cost efficiency is improved with flexibility since a flexible design makes the structure of product reasonable and a flexible logistics provides high quality materials that reduce cost of failure. A flexible distribution reduces transportation cost of products, and a flexible manufacturing utilizes resource more efficiently with shorter setup or non-value adding times. With shorter setup time, it is also possible to work with smaller lot size, which reduces the levels and costs of work-in-process inventory. Smaller lot size assures the smooth production flow, thus allowing for better utilization of equipment and people. All these aspects can positively influence resource productivity and cost efficiency.

Flexibility enhances dependability because a flexible system is more apt to cope with unplanned and unexpected events affecting both process (such as machine breakdown and labor absenteeism) and supplies (such as faulty deliveries). Machine breakdown can be dealt with using flexible routing, and labor flexibility can compensate for labor shortages since workers can perform a variety of tasks and can be transferred between work centers. Flexible purchasing and distribution can accommodate unexpected (or faulty) supplies in materials and finished goods.

Time-to-market comes from fast development of new products or fast customizing of products and flexible operation and distribution. Flexible changeovers give small size, low WIP, smooth production flow, and therefore, fast throughput. Furthermore, processes with wide range of capabilities can accommodate new products without costly and time-consuming new investments. Flexible distribution can increase delivery speed with multiple transportation modes.

Product innovation capability can be improved as flexibility is increased. As flexible design and manufacturing increase trial-and-error and learning opportunities, small increments are enabled and multiple innovative products are generated. From flexible capability itself, product variety is a side-product of actual flexible product design and manufacturing. Likewise, flexible response to customer needs in terms of order taking, repair, and training improves the level of service, which satisfies the customers and elevates organizational reputation.

Hypothesis 7-a: Competitive advantage has a significant positive relationship with customer satisfaction
Hypothesis 7-b: Competitive advantage has a significant positive relationship with financial performance
Hypothesis 7-c: Customer satisfaction has a significant positive relationship with financial performance

Competitive advantages include price/cost, quality, product innovation, delivery dependability, time-to-market, and service. These competitive advantages provide high value to customers. Value can be expressed as follows.

Value to customer = (quality * product innovation * service* delivery dependability) / (cost * time-to-market)

This means, if firms can on-time deliver high-quality, low-cost innovative products with speed, then the firms are creating high value to customers; further firms will gain high reputation for satisfying customers. Satisfied customers are willing to pay their money to repurchase. They also like to disseminate messages to their friends and neighbors; therefore, firms keep and create steady source of customers, increase market share, further gain high profitability, and win competition.

CHAPTER 3: ITEM GENERATION AND PILOT STUDY

In order to test the hypothesized relationships between the constructs proposed in Figure 2, a reliable, valid measure for each construct has to be first developed. Thus, we will develop measures for these constructs covered in the theoretical model: (1) environmental uncertainty, (2) use of technology, (3) infusion of technology, (4) product development flexibility, (5) manufacturing flexibility, (6) logistics flexibility, and (7) spanning flexibility.

Based on the empirical methods that Churchill (1979) and Segar (1998) advocate, four steps are taken to develop and clarify the items at this stage of instrument development. First, an extensive literature review facilitates theory development, construct definition, and items generation, and further insures the content validity of construct. Second, structured interview and Q-sort clarify definitions and items. Third, pretest refines the definitions and items of constructs. Finally, a pilot test provides a preliminary assessment of reliability and validity of the instruments.

3.1 ITEM GENERATIONS

To generate items for each construct, previous research is extensively reviewed and an initial list of potential items is compiled. Our strategy is to use as a few items as possible to measure each construct based on our definitions. Then, the items are carefully compared, added, and devised.

To achieve the content validity for environmental uncertainty, previous literature in environmental uncertainty is reviewed (e.g., Lawrence & Losch, 1969; Duncan, 1972; Galbraith, 1973; Cyert & March, 1963; Gifford, Bobbitt & Slocum, 1979; Jauch & Kraft, 1986; Child, 1972; Skinner, 1985; Gerwin, 1986; Gupta & Mileson, 1990; Doll & Vonderembse, 1991; Ettlie & Reza, 1992). This literature is a rich source of measurement items for environmental uncertainty although most measures are broad. There are many sources of environmental uncertainty (Duncan, 1972), however, most firms only focus on just a few elements. Based on the definition that was presented in Table 2.1, 21 items are generated to measure environmental uncertainty as the managers' perception of unexpected changes in customers, suppliers, technology, and competitors. A five-point Likert scale is used to indicate the extent to which managers agree or disagree with each uncertainty statement where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. These initial items are created with four groups (scales) in mind.

To generate items for use of technology, previous research is reviewed (e.g., Kotha & Orne, 1989; Small & Chen, 1995; Zmud & Jacobs, 1994; Boyer, Ward & Leong, 1996; Tracey, Vonderembse & Lim, 1999; Boynton, Zmud & Jacobs, 1994; Koufteros, Vonderembse & Doll, 1998; Ettlie & Reza, 1992). This literature is a rich pool of illustrations, examples, and items for the usage of technology. Based on the definition in the research (see Table 2.2), 34 items are created or drawn from previous literature to present usage of advanced manufacturing technology and information technology in design, manufacturing, and logistics. These sample items from the pool also include the ways technology is used in management and work practices. A five-point Likert scale is used to seek the managers' perception of the extent to which the AMT and IT are used in the their firm and their management practices of technology. Items are created in five groups corresponding to five sub-dimensions proposed in Section 2.2.

Items for infusion of technology are generated by reviewing the relevant technological innovation and diffusion and organizational learning literature (e.g., Cooper & Zmud, 1990; Kendall, 1997; Weick, 1990; Zuboff, 1988; Motiwalla & Fairfield-Sonn, 1998; Nonaka & Takeuchi, 1995, Torkzadeh & Doll, 1999). This literature covers the whole domain of this construct. Based on the definition proposed in Table 2.3, 21 items are generated to measure the different aspects of technology Infusion. These items concentrate on the human side of the factory such as quality of work life, learning and knowledge accumulation, task innovation, and task productivity. A five-point Likert scale is used in reference to the managers' perception of the exploitation of technological potential in their firm where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. Following the proposed sub-dimensions in section 2.3, items are grouped into four scales.

For value chain flexibility, the literature on flexibility (Sethi & Sethi, 1990; Upton, 1995; Ettlie, 1997; Griffin & Hauser, 1997; Clark & Fujimoto, 1991; Gupta, 1995; Hyun & Ahn, 1992; Gerwin, 1993; Gupta & Somers, 1992; Day, 1994; Porter, 1985; Chase, 1989; Coyle, Bardi & Novack, 1992) is thoroughly reviewed.

Most of them are about manufacturing flexibility (see appendix A). Upton (1995, 1997) provided a measure of process range based on a small sample survey (54 plants). Some authors derive operational flexibility from mathematical models (Kumar, 1986; Gupta, 1993; Jordan & Graves, 1995; Byrne & Chutima, 1997). Suarez, Cusumano & Fine (1995, 1996) offer a measure of flexibility on the printed circuit board industry. Gupta & Somers (1992) measure manufacturing flexibility founded on a large-sample survey, but they do not clearly state the dimensions underlying each type of manufacturing flexibility and most constructs have only two or three items. After clarifying the concept of flexibility, out of the huge flexibility literature, items are created for flexibility across the value chain: 24 items for product development flexibility, 36 items for manufacturing flexibility, 24 items for logistics flexibility, and 12 items for spanning flexibility. The three dimensions of flexibility (i.e., range, mobility, and uniformity) underlie these items. Items are grouped corresponding to the dimensions proposed in section 2.4. Items for the constructs of competitive advantage, customer satisfaction, and financial performance were adapted from Koufteros, Vonderembse & Doll (1998) and Tracey, Vonderembse & Lim (1999).

3.2 STRUCTURED INTERVIEW AND Q-SORT

After we create items pool, the structured interviews are conducted with practitioners from four different manufacturing firms. The focus is to check the relevance and clarity of each sub-construct's definition. Then we ask each interviewee to sort out our question items into corresponding sub-construct. The objective is to pre-assess the convergent and discriminant validity of the scales.

The basic procedure is to show interviewees the conceptual model and definitions of each construct, and to see whether the model and construct make sense to practitioners. Then practitioners act as judges and sort the items in the pool into separate sub-constructs. Items are subjected to two sorting rounds by two independent judges per round. The judges are: (1) a purchasing manager of a medical facility firm, (2) an operations manager of an electronic firm, (3) a vice president of a small part supplier, and (4) a director of IT applications in a mechanical firm.

Each item is printed in a 3 × 5-inch index card. The cards are shuffled into random order for presentation to the judges. Then judges put each card to categories based on his/her judgment. A "not available" category is included to ensure that the judges do not force any items into a particular category. Judges are allowed to ask any questions related to model, definition, and procedures to ensure that they understand the procedures correctly.

To assess the reliability of items, three different measures are made. First, the inter-judge raw agreement scores are calculated. This is calculated by counting the number of items that both judges agree to place into certain category although the category into which items are sorted by both judges may not be the intended one.

Second, item placement ratios are calculated by counting all the items that are correctly sorted into the intended theoretical category by each of the judges, and divide them by twice the total number of items.

Third, Cohen's Kappa is calculated to measure the level of agreement between the two judges in categorizing the items. A description of the Cohen's Kappa concept and methodology is included in the Appendix B.

We have two groups of items. The first group consists of 13 sub-constructs in the construct of environmental uncertainty, use of technology, and infusion of technology. The second group consists of 16 sub-constructs in the construct of value chain flexibility.

In the first round, for the first group, the inter-judge raw scores averaged 78% (Table 3.1), the overall placement ratio of items is 83% (Table 3.2), and Kappa scores averaged 0.75 (Table 3.5). Based on the guidelines of Landis & Koch (1977) for interpreting the Kappa coefficient, the value of 0.75 indicates a moderate level of agreement. For the second group, the inter-judge raw scores averaged 82% (Table 3.3), the overall placement ratio of items is 88% (Table 3.4), and Kappa scores averaged 0.79 (Table 3.5). Based on the guidelines of Landis & Koch (1997), the value of 0.79 indicates an excellent level.

In order to improve the Cohen's Kappa measure of agreement, an examination of the off-diagonal entries in the placement matrix (Table 3.2 and 3.4) is conducted. Any ambiguous items (fitting in more than one category) or too indeterminate items (fitting in no category) are reworded, or even eliminated. For the first group, one item is deleted and 17 items are reworded. For the second group, 13 items are reworded.

Table 3.1 Inter-Judge Raw Agreement Scores: The First Sorting Round

Judge 2 \ Judge 1	1	2	3	4	5	6	7	8	9	10	11	12	13	NA	T	%
1	4															80%
2		5														100%
3			4													80%
4				5												100%
5					6											100%
6						9										150%
7							5									83%
8								2								25%
9									2							40%
10										3						75%
11											5					125%
12												5				100%
13													5			83%

Total Items Placement: 77 | Number of Agreement: 60 | Agreement Ratio: 78%

1. Customer uncertainty
2. Supplier uncertainty
3. Technology uncertainty
4. Competitor uncertainty
5. Use of AMT
6. Use of IT
7. Concurrent engineering
8. Improvement practice
9. Integration practice
10. Task innovation
11. Task productivity
12. Quality of work life
13. Learning and knowledge accumulation

Table 3.2 Items Placement Ratios: The First Sorting Round

Theoretical Categories \ Actual Categories	1	2	3	4	5	6	7	8	9	10	11	12	13	NA	T	%
1	9	1														90%
2		10														100%
3	1	1	9	1												75%
4				10												100%
5					8	1		1								80%
6					1	19										95%
7					1	1	13		1							81%
8					2	1		7	2							58%
9					5			1	6							50%
10										7	2	1				70%
11											8					100%
12										1		11				92%
13										1			11			92%

Total Items Placement: 154 | Number of Hits: 128 | Overall Hit Ratio: 83%

1. Customer uncertainty
2. Supplier uncertainty
3. Technology uncertainty
4. Competitor uncertainty
5. Use of AMT
6. Use of IT
7. Concurrent engineering
8. Improvement practice
9. Integration
10. Task innovation
11. Task productivity
12. Quality of work life
13. Learning and knowledge accumulation

Table 3.3 Inter-Judge Raw Agreement Scores: The First Sorting Round

		Judge 1																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NA	T	%
Judge 2	1	3																		50%
	2		3																	50%
	3			4																67%
	4				5															83%
	5					7														112%
	6						6													100%
	7							6												100%
	8								5											83%
	9									5										83%
	10										3									50%
	11											5								83%
	12												5							83%
	13													5						83%
	14														6					100%
	15															6				100%
	16																5			83%

Total Items Placement: 96 | Number of Agreement: 79 | Agreement Ratio: 82%

1. Product concept flexibility
2. Product prototype flexibility
3. Modification flexibility
4. New Product flexibility
5. Machine flexibility
6. Labor flexibility
7. Material handling flexibility
8. Routing flexibility
9. Volume flexibility
10. Mix flexibility
11. Physical supply flexibility
12. Purchasing flexibility
13. Physical distribution flexibility
14. Demand management flexibility
15. Information dissemination flexibility
16. Strategy development flexibility

Table 3.4 Items Placement Ratios: The First Sorting Round

		Actual Categories																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NA	T	%
Theoretical Categories	1	8		2	2															64%
	2		9	2	1															75%
	3	1		10	1															83%
	4	1	1		10															83%
	5					12														100%
	6						12													100%
	7							12												100%
	8					1			11											92%
	9									11	1									92%
	10					3			2		7									58%
	11											11			1					92%
	12												11	1						92%
	13												1	11						92%
	14												1		11					92%
	15															12				100%
	16															2	10			83%

Total Items Placement: 192 | Number of Hits: 168 | Overall Hit Ratio: 88%

1. Product concept flexibility
2. Product prototype flexibility
3. Modification flexibility
4. New Product flexibility
5. Machine flexibility
6. Labor flexibility
7. Material handling flexibility
8. Routing flexibility
9. Volume flexibility
10. Mix flexibility
11. Physical supply flexibility
12. Purchasing flexibility
13. Physical distribution flexibility
14. Demand management flexibility
15. Information dissemination flexibility
16. Strategy development flexibility

Table 3.5 Inter-Judge Agreements

Agreement Measure	**Round 1**	**Round 2**
Raw Agreement	78%	83%
Cohen's Kappa	75%	79%
Placement Ratio Summary		
Customer uncertainty	90%	90%
Supplier uncertainty	100%	100%
Technology uncertainty	75%	83%
Competitor uncertainty	100%	100%
Use of AMT	80%	81%
Use of IT	95%	100%
Concurrent engineering	81%	92%
Improvement practice	58%	83%
Integration practice	50%	79%
Task innovation	70%	100%
Task productivity	100%	100%
Quality of work life	92%	92%
Learning and knowledge accumulation	92%	92%
Average	**83%**	**91%**
Raw Agreement	82%	83%
Cohen's Kappa	79%	80%
Placement Ratio Summary		
Product concept flexibility	64%	75%
Product prototype flexibility	75%	83%
Modification flexibility	83%	92%
New product flexibility	83%	92%
Machine flexibility	100%	100%
Labor flexibility	100%	100%
Material handling flexibility	100%	100%
Routing flexibility	92%	92%
Volume flexibility	92%	92%
Mix flexibility	58%	83%
Physical supply flexibility	92%	83%
Purchasing flexibility	92%	83%
Physical distribution flexibility	92%	92%
Demand management flexibility	92%	83%
Information dissemination flexibility	100%	100%
Strategy development flexibility	83%	83%
Average	**87%**	**89%**

Table 3.6 Inter-Judge Raw Agreement Scores: The Second Sorting Round

	Judge 3															
Judge 4		1	2	3	4	5	6	7	8	9	10	11	12	13	NA	T	%
	1	4															80%
	2		5														100%
	3			4													80%
	4				5												100%
	5					6											100%
	6						8										133%
	7							5									100%
	8								4								67%
	9									4							80%
	10										4						100%
	11											4					100%
	12												5				100%
	13													5			83%
Total Items Placement: 76								Number of Agreement: 63					Agreement Ratio: 83%				

1. Customer uncertainty
2. Supplier uncertainty
3. Technology uncertainty
4. Competitor uncertainty
5. Use of AMT
6. Use of IT
7. Concurrent engineering
8. Improvement practice
9. Integration practice
10. Task innovation
11. Task productivity
12. Quality of work life
13. Learning and knowledge accumulation

Table 3.7 Items Placement Ratios: The Second Sorting Round

	Actual Categories															
Theoretical Categories		1	2	3	4	5	6	7	8	9	10	11	12	13	NA	T	%
	1	9			1												90%
	2		10														100%
	3	1		10	1												83%
	4				10												100%
	5					13	1	1	1								81%
	6					1	15										100%
	7							11		1							92%
	8					1			10	1							83%
	9							1	2	11							79%
	10										8						100%
	11											8					100%
	12										1		11				92%
	13											1		11			92%
Total Items Placement: 152								Number of Hits: 136					Overall Hit Ratio: 89%				

1. Customer uncertainty
2. Supplier uncertainty
3. Technology uncertainty
4. Competitor uncertainty
5. Use of AMT
6. Use of IT
7. Concurrent engineering
8. Improvement practice
9. Integration practice
10. Task innovation
11. Task productivity
12. Quality of work life
13. Learning and knowledge accumulation

Table 3.8 Inter-Judge Raw Agreement Scores: The Second Sorting Round

Judge 4 \ Judge 3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NA	T	%
1	3																		50%
2		4																	67%
3			5																83%
4				5															83%
5					6														100%
6						6													100%
7							6												100%
8								5											83%
9									5										83%
10										4									67%
11											5								83%
12												5							83%
13													5						83%
14														5					67%
15															6				100%
16																5			83%

Total Items Placement: 96 | Number of Agreement: 80 | Agreement Ratio: 83%

1. Product concept flexibility
2. Product prototype flexibility
3. Modification flexibility
4. New Product flexibility
5. Machine flexibility
6. Labor flexibility
7. Material handling flexibility
8. Routing flexibility
9. Volume flexibility
10. Mix flexibility
11. Physical supply flexibility
12. Purchasing flexibility
13. Physical distribution flexibility
14. Demand management flexibility
15. Information dissemination flexibility
16. Strategy development flexibility

Table 3.9 Items Placement Ratios: The Second Sorting Round

Theoretical Categories \ Actual Categories	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	NA	T	%
1	9		1	2															75%
2		10	1	1															83%
3	1		11																92%
4	1			11															92%
5					12														100%
6						12													100%
7							12												100%
8					1			11											92%
9									11	1									92%
10					1			1		10									83%
11											10	1	1						83%
12											1	10		1					83%
13													11	1					92%
14												1	1	10					83%
15															12				100%
16															2	10			83%

Total Items Placement: 192 | Number of Hits: 172 | Overall Hit Ratio: 90%

1. Product concept flexibility
2. Product prototype flexibility
3. Modification flexibility
4. New Product flexibility
5. Machine flexibility
6. Labor flexibility
7. Material handling flexibility
8. Routing flexibility
9. Volume flexibility
10. Mix flexibility
11. Physical supply flexibility
12. Purchasing flexibility
13. Physical distribution flexibility
14. Demand management flexibility
15. Information dissemination flexibility
16. Strategy development flexibility

After rewording items from the first round, a second sorting round is conducted with two new judges. The results are shown in Table 3.6, 3.7, 3.8, and 3.9. For the first group, the inter-judge raw scores averaged 83% (Table 3.6), the overall placement ratio of items is 89% (Table 3.7), and Kappa scores averaged 0.79 (Table 3.5). For the second group, the inter-judge raw scores averaged 83% (Table 3.8), the overall placement ratio of items is 90% (Table 3.9), and Kappa scores averaged 0.80 (Table 3.5). Based on the guidelines of Landis & Koch (1977), the value of 0.79 and 0.80 in the two groups respectively indicate an excellent level.

3.3 PRETEST

After the two-round Q-sort, 172 questionnaire items are refined and kept. Then, these items are distributed to ten reviewers (professors) including two practitioners, who review each item and indicate to keep, drop, modify, or add new items to some constructs. The focus of this step is to further refine the items and to assess whether the items are measuring the proposed sub-constructs based on the definitions provided, or any additional items are needed to cover the domain.

Based on the feedback from these ten reviewers, some items are further modified. Overall, 204 (172 + 32) questionnaire items, including 32 items adapted from Koufteros (1995) and Tracey, Vonderemse & Lim (1999) for the constructs of competitive advantage, customer satisfaction, and financial performance, are ready to be sent out for pilot survey. The pilot survey questionnaire items are provided in Appendix C.

3.4 PILOT STUDY

The objective of pilot study is to purify the items and assess unidimensionality, reliability, convergent, discriminant, and predictive validity. The main analysis tool will be corrected-item to total correlation (CITC), exploratory factor analysis, Cronbach's alpha, and correlation analysis.

A pilot study is conducted using respondents similar to the target respondents. Questionnaires are sent to 500 various managers in manufacturing firms including presidents, vice presidents, operations managers, facility and plant managers, material and purchasing managers. 500 target subjects for pilot study are systematically drawn from a mailing list of 3000 potential respondents purchased from American Business List. The sample respondents cover the five SIC codes:

SIC 34: Fabricated Metal Products Manufacturers
SIC 35: Industrial Machinery and Equipment Manufacturers
SIC 36: Electronic and Other Electric Equipment Manufacturers
SIC 37: Transportation Equipment Manufacturers
SIC 38: Measuring and Analyzing Instruments Manufacturers

33 usable response questionnaires are collected after sending out the same questionnaire three times, 500 each. This data set is used for the pilot analysis.

3.4.1 Methods for Pilot Study

Churchill (1979) suggests the following steps for pilot study. First, the researchers need to purify the items before the factor analysis, or there is a tendency for factor analysis to produce more confounding dimensions than can be conceptually identified. Items with CITC of less than or equal to 0.4 are eliminated one by one.

Second, after purifying the items, an exploratory factor analysis of the remaining items for each construct is conducted to assess the unidimensionality of each sub-construct and to eliminate the cross-loading items. Items with loadings on more than one factor at 0.45 or above are considered as candidates for elimination. If a certain sub-dimension has two factors or more, the items for this sub-dimension will be closely examined to see whether it can be separated as two factors, if not, choose the one that represents the initial intention most.

Third, once dimensionality is determined, the reliability (internal consistency) of the remaining items for each sub-dimension is examined using Crobach's α. At this stage, Crobach's α is at least 0.60 and 0.80 is aimed for by deleting some items with small CITC.

Finally, convergent and discriminant validity are assessed via correlation matrix. Convergent validity tests that the correlations between items of the same construct are significantly different from zero; discriminant validity is tested by counting the number of times it correlates more highly with an item of another variable than items of its own theoretical variable. The count is satisfactory if it is less than one-half the potential comparisons (Kerlinger, 1986; Davis, 1989; Campbell & Fiske, 1959). The procedure is similar to MTMM approach, but here it is inappropriate to use MTMM since we do not use multiple methods.

In addition, most sub-constructs have 5 to 6 items, so we do not have luxury to delete all of items that have either low CITC (<0.4) or cross loadings. For these items, based on the remaining core items for the sub-construct and items' cross loading, we reword these items or add new items in some way to closely relate them to the remaining sub-construct items and discriminate them with the items that they cross loads to.

3.4.2 Results of Pilot Study

In the following section, the results of pilot analysis for each construct will be reported and discussed. The pilot results include CITC calculation, factor analysis, convergent, and discriminant analysis. The coding for each item is shown in the following result tables; the items that need to be modified or deleted are in a bold face and the modified or added new items are in an italic font style.

3.4.2.1 Environmental Uncertainty

The analysis begins with CITC calculations eliminating the items with CITC of less than or equal to 0.4. Then factor analysis is run with the remaining items. Since the ratio of respondents to the number of items for the scale is low, the results shown are only used to roughly see whether the number of factors are as expected, how many items have cross loading of greater than 0.45, and what factors these items cross load to. The different rounds are run and results are shown in Table 3.10.

Five items for the sub-construct of customer uncertainty work well: the CITCs are greater than 0.4, Crobach's alpha is 0.84, and the factor loading is clean. For the sub-construct of technology uncertainty, three items remain high CITCs and an alpha of 0.91 after deleting two low-CITC items. Then these two items are reworded as shown in Table 3.10 for large-scale survey. Four out of five items for supplier uncertainty have satisfactory CITCs of greater than 0.4 and load together with an alpha of 0.73. The other item is reworded.

Table 3.10 Purification and Factor Loadings for Environmental Uncertainty (Pilot)

Sub-construct	Items	Coding	CITC_1	CITC_2	CITC_3	α	Factor Loadings			
							F1	F2	F3	F4
Customer Uncertainty	Customers' tastes are unpredictable	EU/CU1	0.69			0.84	0.849			
	Customers' requirements regarding product features are difficult to forecast	EU/CU2	0.67				0.851			
	Customers order different product combinations over the year	EU/CU3	0.60				0.648			
	Customers' product preferences change over the year	EU/CU4	0.64				0.790			
	Product demand from customers fluctuates over the year	EU/CU5	0.64				0.703			
Technology Uncertainty	Technology often changes in our industry	EU/TE1	0.56	0.67	0.85	0.91		0.922		
	The technology in our industry is changing significantly	EU/TE2	0.72	0.79	0.81			0.888		
	Technological changes provide large opportunities in our industry	EU/TE3	0.65	0.76	0.79			0.894		
	Many new product ideas come from technological breakthroughs in our industry *Technological breakthroughs in our industry lead new product ideas*	EU/TE4	0.46	0.27						
	New products substitute for old products frequently due to improving technology *Improving technology generates new products frequently*	EU/TE5	0.36							
Competition Uncertainty	Actions of competitors are unpredictable	EU/CO1	0.42	0.45	0.50	0.79			0.683	
	Competition threatens the survival of our firm *Competition is intensified in our industry*	EU/CO2	0.15							
	We have many foreign competitors *Competitors come from different countries*	EU/CO3	0.23	0.29						
	Competitors come from different industries	EU/CO4	0.60	0.60	0.64				0.837	
	Competitors often introduce new products unexpectedly	EU/CO5	0.72	0.74	0.79				0.922	
Supplier Uncertainty	The properties of materials delivered by suppliers can vary greatly within the same batch	EU/SU1	0.50	0.44		0.73				0.631
	The quantity of materials from suppliers can easily go wrong	EU/SU2	0.56	0.62						0.855
	Suppliers' engineering level is unpredictable	EU/SU3	0.56	0.55						0.782
	Suppliers' product quality is unpredictable	EU/SU4	0.42	0.47						0.666
	The timing of materials from suppliers can easily go wrong *Suppliers' delivery time is unpredictable*	EU/SU5	0.28							

Three out of five items for competitor uncertainty have satisfactory CITCs and load together with an alpha of 0.79. The other two items are reworded.

The correlation matrix (Table 3.11) of the remaining 15 items for all the sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: customer uncertainty = 0.35, supplier uncertainty = 0.38, technology uncertainty = 0.73, and competitor uncertainty = 0.35. All are significantly different from zero ($p<0.05$). Therefore, the items have good convergent validity.

An examination of the correlation matrix to assess discriminant validity reveals a total of 8 violations out of 166 comparisons. None of the counts for each item exceeds half the potential comparisons. Therefore, they exhibit good discriminant validity.

3.4.2.2 Use of Technology

The same analysis steps as those for previous construct are followed. The results are respectively reported in Table 3.12 and 3.13. Five out of six items comprising the sub-construct of use of AMT have good CITCs and load together with an alpha of 0.93. UT/AMT4 has cross loading with use of IT and thus it is reworded as shown in Table 3.12. The six items for the sub-construct of use of IT work very well: all CITCs are greater than 0.4, Crobach's alpha is 0.92, and factor loading is clean. For the managerial practices of technology, four out of five items for the sub-construct of concurrent engineering have CITCs of greater than 0.4, and only three out of these four load together with an alpha of 0.77. MP/CE3 has low CITC and MP/CE4 has significant cross loading with integration

Table 3.11 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Environmental Uncertainty (Pilot)

	EU/CU1	EU/CU2	EU/CU3	EU/CU4	EU/CU5	EU/SU1	EU/SU2	EU/SU3	EU/SU4	EU/TE1	EU/TE2	EU/TE3	EU/CO1	EU/CO4	EU/CO5
EU/CU1	1.00														
EU/CU2	0.92	1.00													
EU/CU3	0.35	0.35	1.00												
EU/CU4	0.49	0.50	0.49	1.00											
EU/CU5	0.37	0.35	0.77	0.59	1.00										
EU/SU1	0.19	0.07	-0.18	0.11	0.09	1.00									
EU/SU2	-0.12	-0.13	0.03	0.03	0.18	0.42	1.00								
EU/SU3	0.23	0.28	-0.06	0.24	0.24	0.38	0.50	1.00							
EU/SU4	-0.12	-0.09	-0.32	-0.23	-0.18	0.24	0.49	0.38	1.00						
EU/TE1	-0.32	-0.36	0.30	0.18	0.36	-0.09	0.26	-0.23	-0.02	1.00					
EU/TE2	-0.13	-0.11	0.41	0.42	0.46	-0.07	0.06	-0.22	-0.23	0.80	1.00				
EU/TE3	-0.26	-0.32	0.17	0.24	0.16	0.01	0.12	-0.33	-0.01	0.77	0.73	1.00			
EU/CO1	-0.16	-0.11	-0.26	-0.16	-0.32	0.18	0.01	-0.14	0.23	-0.08	-0.23	0.10	1.00		
EU/CO4	0.06	0.13	-0.28	0.13	-0.11	0.19	-0.04	0.20	0.45	-0.13	-0.01	0.21	0.35	1.00	
EU/CO5	0.20	0.22	-0.19	0.25	-0.15	0.20	-0.14	0.01	0.33	-0.19	-0.14	0.12	0.56	0.73	1.00

	EU/CU1	EU/CU2	EU/CU3	EU/CU4	EU/CU5	EU/SU1	EU/SU2	EU/SU3	EU/SU4	EU/TE1	EU/TE2	EU/TE3	EU/CO1	EU/CO4	EU/CO5
Mean	2.67	2.82	3.70	3.58	3.85	2.61	2.91	2.82	2.24	3.67	3.55	3.64	2.76	2.91	2.70
SD	1.08	1.13	1.05	0.97	1.03	1.00	0.95	0.88	0.79	0.78	0.90	0.78	0.87	0.95	1.13
# of Violations	0	1	1	1	2	0	0	0	3	0	0	0	0	0	0

Table 3.12 Purification and Factor Loadings for Use of Technology (Pilot)

Sub-construct	Items	Coding	CITC_1	CITC_2	CITC_3	α	Factor Loadings				
							F1	F2	F3	F4	F5
Use of AMT	We use AMT to aid product and process design	UT/AMT1	0.84			0.93		0.846			
	We use AMT to improve manufacturing	UT/AMT2	0.83					0.752			
	We use AMT to integrate manufacturing systems	UT/AMT3	0.89					0.819			
	We use AMT to plan and control material requirements *We use AMT to plan and control manufacturing requirements*	UT/AMT4	0.88								
	We use AMT to control production systems such as Just-In-Time	UT/AMT5	0.75					0.856			
	We use AMT to manage the interfaces of manufacturing and marketing	UT/AMT6	0.66					0.804			
Use of IT	We use IT to provide timely information	UT/IT1	0.84			0.92	0.823				
	We use IT to monitor operations	UT/IT2	0.82				0.806				
	We use IT to analyze problems in daily operations	UT/IT3	0.75				0.840				
	We use IT as a strategic weapon to gain competitive advantage	UT/IT4	0.81				0.860				
	We use IT to exchange and share information in work group	UT/IT5	0.87				0.836				
	We use IT to keep connection with key customers and suppliers	UT/IT6	0.61				0.670				
Concurrent Engineering	We do product and process design concurrently	MP/CE1	0.65	0.67		0.77				0.880	
	We involve process engineers early in product development	MP/CE2	0.74	0.74						0.912	
	We involve customers early in product development	MP/CE3	0.52	0.48						0.613	
	We involve suppliers in the design of components *We involve suppliers early in product development*	MP/CE4	0.37								
	We practice job rotation between design and manufacturing *We involve manufacturing early in product development*	MP/CE5	0.42	0.43							
Improvement Practice	**We improve our operations with setup time reductions** *We redesign setups for continuous improvement*	MP/CI1	0.07			0.79					
	We improve our operations with preventive maintenance *We use preventive maintenance for continuous improvement*	MP/CI2	0.65	0.65					0.909		
	We improve our operations with quality at the source *We improve quality at the source*	MP/CI3	0.67	0.62					0.886		
	We improve our operations with cells layout *We use cells layout for continuous improvement*	MP/CI4	0.70	0.79					0.870		
	We improve our operations with Just-in-time principles *We use just-in-time principles for continuous improvement*	MP/CI5	0.55	0.55							
	We improve our operations with pull production *We use pull production for continuous improvement*	MP/CI6	0.40	0.43							
Integration Practice	We involve multiple functions in adopting technology	MP/IN1	0.56	0.59		0.72					0.607
	We involve shop floor employees in decision making	MP/IN2	0.59	0.48							0.790
	We integrate problem-solving efforts by cross-disciplinary teams	MP/IN3	0.44	0.56							0.876
	We integrate suppliers' operations with Just-in-time delivery *We use teams in resolving problems that arise*	MP/IN4	0.37	0.43							
	We integrate customers' ideas in product development *We encourage team work in shop-floor operations*	MP/IN5	0.02								

Table 3.13 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Use of Technology (Pilot)

	UT/AMT1	UT/AMT2	UT/AMT3	UT/AMT5	UT/AMT6	UT/IT1	UT/IT2	UT/IT3	UT/IT4	UT/IT5	UT/IT6	MP/CE1	MP/CE2	MP/CE3	MP/CI2	MP/CI3	MP/CI4	MP/IN1	MP/IN2	MP/IN3
UT/AMT1	1.00																			
UT/AMT2	0.77	1.00																		
UT/AMT3	0.89	0.79	1.00																	
UT/AMT5	0.63	0.59	0.65	1.00																
UT/AMT6	0.53	0.52	0.54	0.88	1.00															
UT/IT1	0.54	0.59	0.59	0.38	0.42	1.00														
UT/IT2	0.50	0.58	0.58	0.42	0.50	0.80	1.00													
UT/IT3	0.33	0.47	0.43	0.34	0.23	0.62	0.73	1.00												
UT/IT4	0.31	0.40	0.47	0.40	0.36	0.64	0.70	0.78	1.00											
UT/IT5	0.56	0.61	0.64	0.44	0.45	0.83	0.77	0.69	0.80	1.00										
UT/IT6	0.36	0.39	0.31	0.36	0.31	0.72	0.51	0.40	0.52	0.59	1.00									
MP/CE1	0.21	0.23	-0.30	-0.06	0.16	-0.30	-0.06	0.16	0.24	0.25	0.27	1.00								
MP/CE2	0.25	0.06	-0.11	0.03	0.27	-0.11	0.03	0.27	0.14	0.16	0.19	0.66	1.00							
MP/CE3	0.03	0.29	0.00	0.23	-0.01	0.00	0.23	-0.01	0.18	0.17	0.05	0.54	0.46	1.00						
MP/CI2	0.05	0.14	0.05	0.15	0.23	0.15	0.17	0.18	-0.30	-0.06	0.16	-0.30	-0.06	0.16	1.00					
MP/CI3	0.08	0.14	0.16	0.07	0.19	-0.30	-0.06	0.16	-0.11	0.03	0.27	-0.11	0.03	0.27	0.78	1.00				
MP/CI4	0.00	0.23	0.16	0.18	0.08	-0.11	0.03	0.27	0.00	0.23	-0.01	0.00	0.23	-0.01	0.67	0.66	1.00			
MP/IN1	0.41	0.27	-0.30	-0.06	0.16	0.00	0.23	-0.01	-0.30	-0.06	0.16	0.41	0.27	0.10	0.09	0.12	0.28	1.00		
MP/IN2	0.14	0.01	-0.11	0.03	0.27	0.29	0.23	0.25	-0.11	0.03	0.27	0.14	0.01	0.35	0.35	0.26	0.08	0.39	1.00	
MP/IN3	0.27	-0.01	0.00	0.23	-0.01	0.18	0.18	0.16	0.00	0.23	-0.01	0.27	-0.01	0.33	0.07	0.15	-0.11	0.51	0.47	1.00
	UT/AMT1	UT/AMT2	UT/AMT3	UT/AMT5	UT/AMT6	UT/IT1	UT/IT2	UT/IT3	UT/IT4	UT/IT5	UT/IT6	MP/CE1	MP/CE2	MP/CE3	MP/CI2	MP/CI3	MP/CI4	MP/IN1	MP/IN2	MP/IN3
Mean	3.06	3.39	3.06	3.36	3.30	3.52	3.48	3.39	3.18	3.30	3.12	3.36	3.37	3.70	4.15	4.30	3.58	3.33	3.73	3.61
SD	1.09	1.09	1.06	0.70	0.73	0.80	0.87	0.97	0.98	0.85	0.93	0.90	0.82	0.88	0.57	0.53	1.00	0.85	0.84	0.75
# of Violations	2	3	3	0	0	4	5	2	3	5	3	0	0	0	0	0	0	1	0	0

practice. Therefore, both items are reworded. For the sub-construct of improvement practice, five out of six items remain high CITC and an alpha of 0.79 after deleting one low-CITC item. Three out of these five items load together and the other two has significant cross loading with integration practice. Since three out of the six items does not work well, all the six items are restated to make them simple and clear (see Table 3.12). Four out of five items for integration practice have satisfactory CITCs of greater than 0.4 and an alpha of 0.72 after deleting MP/IN5. Only three of these four load together, and the other has significant cross loading with concurrent engineering. Both unsatisfactory items are deleted. Two new items are added emphasizing teamwork integration.

The correlation matrix (Table 3.13) of the remaining 20 items for these two sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are use of AMT = 0.52, use of IT = 0.40, concurrent engineering = 0.46, improvement practice = 0.66, and integration practice = 0.39. All are significantly different from zero ($p<0.05$). Therefore, the items have good convergent validity.

An examination of the correlation matrix to assess discriminant validity reveals a total of 31 violations out of 312 comparisons. For the construct of use of technology, the number of violations is 22, which is almost half the number of potential comparisons (48). They exhibit moderate discriminant validity. This is understandable since use of AMT (e.g., CAD, CAM, CAPP, FMS, MRP, and JIT) and use of IT (e.g., office systems, group decision support systems, and executive information systems) are closely related. The manufacturing firms with more experience on use of either AMT or IT are likely to use the other. Although both constructs are closely related, the use of word AMT and IT in each question item makes these two factors load separately. All the other items have good discriminant validity.

3.4.2.3 Infusion of Technology

The analysis begins with purification eliminating the items with CITC of less than or equal to 0.4. Then factor analysis is run with the remaining items. The different rounds are run and results are shown in Table 3.14.

The four items for the sub-construct of customer uncertainty work well: all CITCs are greater than 0.4, Crobach's alpha is 0.84, and factor loading is clean. For the sub-construct of task productivity, the four items have high CITC and an alpha of 0.86. Only two out of these four items load together and the other two have significant cross loading. Cross-loading items are reworded as shown in Table 3.14 for large-scale survey. Four out of the five items for quality of work life have satisfactory CITCs and load together with an alpha of 0.79. The other item is reworded due to low CITC. The six items comprising the sub-construct of learning and knowledge accumulation have satisfactory CITCs and load together with an alpha of 0.93.

The correlation matrix (Table 3.15) of the remaining 16 items for all the sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: task innovation = 0.44, task productivity = 72, quality of work life = 0.31, learning and knowledge accumulation = 0.60. All are significantly different from zero ($p<0.05$). Therefore,

Table 3.14 Purification and Factor Loadings for Infusion of Technology (Pilot)

Sub-construct	Items	Coding	CITC_1	CITC_2	CITC_3	α	Factor Loadings			
							F1	F2	F3	F4
Task Innovation	Our employees perceive that technology helps them to create new ideas	IT/TI1	0.70			0.84		0.679		
	Our employees perceive that technology helps them to try out new ideas	IT/TI2	0.83					0.795		
	Our employees perceive that technology help them to solve problems creatively	IT/TI3	0.64					0.817		
	Our employees perceive that technology help them to innovate their work	IT/TI4	0.56					0.697		
Task Productivity	Our employees perceive that technology saves them time *Technology saves our employees' time*	IT/TE1	0.66			0.86				0.914
	Our employees perceive that technology increases their productivity *Technology increases our employees' productivity*	IT/TE2	0.66							0.927
	Our employees perceive that technology allows them to accomplish more work *Technology enables our employees to do work faster*	IT/TE3	0.76							
	Our employees perceive that technology makes work more efficient Technology makes work easier for our employees	IT/TE4	0.79							
Quality of Work Life	**Employees feel their tasks are significant** *Employees feel that their work is significant*	IT/QW1	0.07			0.79				
	Employees have autonomy in their work *Employees feel that they have autonomy in their work*	IT/QW2	0.23	0.72					0.829	
	Employees are responsible for outcome of their work	IT/QW3	0.09	0.42					0.707	
	Employees look forward to being with their work group	IT/QW4	0.21	0.66					0.811	
	Employees have strong feeling of belonging to our organization	IT/QW5	0.18	0.67					0.769	
Learning and Knowledge Accumulation	Our employees learn from each other by using technology	IT/LK1	0.78			0.93	0.856			
	Our employees learn by doing to gain valuable technical know-how	IT/LK2	0.83				0.877			
	Our employees learns from documents and manuals to enrich their knowledge base about technology	IT/LK3	0.77				0.800			
	Our employees exchange and combine knowledge of technology through documents and meetings	IT/LK4	0.81				0.803			
	We often summarize successful and unsuccessful approaches to technology implementation	IT/LK5	0.80				0.836			
	Management representatives from different departments have periodic debriefings about technology implementation	IT/LK6	0.86				0.873			

Table 3.15 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Infusion of Technology (Pilot)

	IT/TI1	IT/TI2	IT/TI3	IT/TI4	IT/TE1	IT/TE2	IT/QW2	IT/QW3	IT/QW4	IT/QW5	IT/LK1	IT/LK2	IT/LK3	IT/LK4	IT/LK5	IT/LK6
IT/TI1	1.00															
IT/TI2	0.78	1.00														
IT/TI3	0.50	0.68	1.00													
IT/TI4	0.49	0.54	0.44	1.00												
IT/TE1	0.03	-0.08	-0.08	0.06	1.00											
IT/TE2	-0.05	-0.02	-0.02	-0.02	0.72	1.00										
IT/QW2	0.47	0.32	0.14	0.39	0.15	0.09	1.00									
IT/QW3	0.13	-0.03	-0.16	-0.04	0.04	-0.04	0.47	1.00								
IT/QW4	0.32	0.29	0.12	0.45	0.12	-0.16	0.67	0.31	1.00							
IT/QW5	0.42	0.35	0.14	0.29	-0.31	-0.37	0.61	0.35	0.71	1.00						
IT/LK1	0.44	0.40	0.31	0.26	-0.12	-0.05	0.05	-0.03	0.12	0.29	1.00					
IT/LK2	0.33	0.50	0.40	0.26	-0.12	0.19	-0.05	-0.27	-0.08	0.17	0.78	1.00				
IT/LK3	0.33	0.48	0.48	0.29	-0.09	0.14	0.07	-0.28	0.02	0.16	0.62	0.71	1.00			
IT/LK4	0.54	0.62	0.43	0.37	-0.05	0.03	0.15	-0.15	0.17	0.22	0.69	0.76	0.60	1.00		
IT/LK5	0.46	0.49	0.34	0.31	-0.10	0.06	0.22	-0.09	0.10	0.24	0.65	0.65	0.75	0.70	1.00	
IT/LK6	0.43	0.56	0.31	0.37	-0.16	-0.09	0.11	-0.16	0.25	0.37	0.72	0.72	0.72	0.79	0.76	1.00
	IT/TI1	IT/TI2	IT/TI3	IT/TI4	IT/TE1	IT/TE2	IT/QW2	IT/QW3	IT/QW4	IT/QW5	IT/LK1	IT/LK2	IT/LK3	IT/LK4	IT/LK5	IT/LK6
Mean	3.70	3.73	3.73	3.73	3.82	3.76	3.85	4.06	3.82	4.03	3.70	3.70	3.55	3.42	3.70	3.64
SD	0.53	0.63	0.63	0.52	0.39	0.50	0.57	0.75	0.58	0.47	0.53	0.53	0.62	0.79	0.64	0.60
# of Violations	3	5	1	1	0	0	3	0	2	4	0	0	0	0	0	0

the items have good convergent validity.

An examination of the correlation matrix to assess discriminant validity reveals a total of 19 violations out of 184 comparisons. None of the counts for each item exceeds half the potential comparisons. Therefore, they exhibit good discriminant validity.

3.4.2.4 Product Development Flexibility

The analysis begins with CITC calculations. The items with CITC of less than or equal to 0.4 are eliminated one by one. Then factor analysis is run with the remaining items. The different rounds are run and results are shown in Table 3.16.

The items for the sub-construct of product concept flexibility, product prototype flexibility, and new product flexibility work very well: 6 items for each sub-construct; all CITCs are greater than 0.4; Crobach's alpha is respectively 0.90, 0.85, and 0.89; and factor loadings are clean for each factor. For the sub-construct of modification flexibility, five out of the six items have high CITC and load together with an alpha of 0.93. The other item has low CITC and is reworded for the large-scale survey.

The correlation matrix (Table 3.17) of the remaining 23 items for all the sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: product concept flexibility = 0.44, product prototype flexibility = 0.20, modification flexibility = 0.63, new product flexibility = 0.44. All are significantly different from zero ($p<0.05$) except product prototype flexibility. On a closer look at the correlation matrix, all the correlation

Table 3.16 Purification and Factor Loadings for Product Development Flexibility (Pilot)

Sub-construct	Items	Coding	CITC_1	CITC_2	CITC_3	α	Factor Loadings			
							F1	F2	F3	F4
Product Concept Flexibility	We can develop multiple product concepts for the same customer requirements	PF/PC1	0.67			0.90		0.796		
	We can develop multiple product concepts along the different stages of product development	PF/PC2	0.74					0.843		
	We evaluate multiple alternatives over time in product development decision (use set-based approach)	PF/PC3	0.78					0.810		
	We can quickly capture trends for customer requirements	PF/PC4	0.71					0.753		
	We can quickly transform customer requirements to product concepts	PF/PC5	0.68					0.770		
	We can quickly convert product ideas to product concepts	PF/PC6	0.79					0.826		
Product Prototype Flexibility	We can keep multiple product prototypes for the same customer requirements	PF/PP1	0.71			0.85			0.795	
	We can easily develop a product prototype for each product concept	PF/PP2	0.49						0.650	
	We can easily modify existing product prototype for new product requirements	PF/PP3	0.46						0.808	
	We can build product prototype quickly	PF/PP4	0.80						0.829	
	We can quickly transform product concepts to product prototypes	PF/PP5	0.78						0.777	
	We can develop multiple product prototypes cost-efficiently	PF/PP6	0.64						0.650	
Modification Flexibility	**We can quickly respond to customer requests for design changes** *We can quickly modify product design in response to customer requests*	PF/MO1	0.01			0.93				
	We can easily modify products to a specific customer need	PF/MO2	0.78	0.78			0.858			
	We can better meet customer needs by quickly modifying existing products	PF/MO3	0.75	0.80			0.867			
	We can modify products by adding new parts or substituting old parts easily	PF/MO4	0.85	0.83			0.887			
	We can modify existing products quickly	PF/MO5	0.88	0.88			0.940			
	We can modify existing products inexpensively	PF/MO6	0.68	0.75			0.798			
New Product Flexibility	We can quickly introduce a new product into the market	PF/NP1	0.78			0.89				0.730
	We take the lead in new product introduction	PF/NP2	0.71							0.707
	We can quickly substitute new products for those currently being produced	PF/NP3	0.68							0.820
	We can launch new product easily	PF/NP4	0.82							0.856
	We can launch new product inexpensively	PF/NP5	0.66							0.723
	We can quickly introduce a new product into the market	PF/NP1	0.78							0.730

Table 3.17 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Product Development Flexibility (Pilot)

	PF/PC1	PF/PC2	PF/PC3	PF/PC4	PF/PC5	PF/PC6	PF/PP1	PF/PP2	PF/PP3	PF/PP4	PF/PP5	PF/PP6	PF/MO2	PF/MO3	PF/MO4	PF/MO5	PF/MO6	PF/NP1	PF/NP2	PF/NP3	PF/NP4	PF/NP5
PF/PC1	1.00																					
PF/PC2	0.62	1.00																				
PF/PC3	0.56	0.62	1.00																			
PF/PC4	0.44	0.73	0.69	1.00																		
PF/PC5	0.60	0.49	0.61	0.48	1.00																	
PF/PC6	0.62	0.61	0.72	0.59	0.67	1.00																
PF/PP1	-0.11	-0.03	0.08	0.22	0.27	0.16	1.00															
PF/PP2	-0.22	0.18	-0.16	0.20	-0.06	-0.11	0.52	1.00														
PF/PP3	0.17	0.09	0.32	0.10	0.66	0.28	0.51	0.20	1.00													
PF/PP4	0.12	0.00	0.25	0.30	0.18	0.20	0.61	0.47	0.45	1.00												
PF/PP5	0.13	-0.09	0.09	0.08	0.11	0.14	0.61	0.43	0.38	0.83	1.00											
PF/PP6	0.03	-0.15	-0.03	0.07	0.20	0.15	0.47	0.30	0.34	0.69	0.71	1.00										
PF/MO2	0.12	-0.16	0.20	-0.15	-0.10	0.18	-0.16	-0.42	-0.05	0.15	0.03	0.13	1.00									
PF/MO3	0.31	-0.27	0.22	-0.18	0.14	0.14	0.03	-0.50	0.17	0.14	0.20	0.16	0.63	1.00								
PF/MO4	0.20	-0.31	0.12	-0.29	0.12	0.19	0.04	-0.44	0.24	0.25	0.18	0.23	0.80	0.74	1.00							
PF/MO5	0.37	-0.17	0.22	-0.24	0.13	0.27	-0.17	-0.51	0.14	0.02	0.11	0.14	0.73	0.82	0.79	1.00						
PF/MO6	0.33	-0.05	0.36	0.09	0.25	0.33	-0.02	-0.42	0.26	0.24	0.20	0.32	0.65	0.68	0.65	0.76	1.00					
PF/NP1	0.13	0.32	0.42	0.51	0.40	0.34	0.55	0.37	0.46	0.57	0.41	0.26	-0.10	-0.04	0.07	-0.10	0.18	1.00				
PF/NP2	0.25	0.18	0.22	0.39	0.27	0.15	0.31	0.22	0.23	0.53	0.42	0.25	-0.10	0.09	0.13	0.02	0.18	0.79	1.00			
PF/NP3	0.22	0.29	0.40	0.37	0.27	0.39	0.10	-0.12	0.03	0.24	0.24	0.19	0.18	0.05	0.04	0.12	0.29	0.55	0.56	1.00		
PF/NP4	0.11	0.13	0.38	0.22	0.42	0.34	0.32	0.01	0.47	0.45	0.35	0.25	0.24	0.03	0.25	0.13	0.33	0.66	0.56	0.77	1.00	
PF/NP5	-0.01	-0.06	0.27	0.12	0.25	0.18	0.37	0.01	0.46	0.46	0.41	0.22	0.27	0.17	0.33	0.15	0.33	0.58	0.47	0.44	0.77	1.00

	PF/PC1	PF/PC2	PF/PC3	PF/PC4	PF/PC5	PF/PC6	PF/PP1	PF/PP2	PF/PP3	PF/PP4	PF/PP5	PF/PP6	PF/MO2	PF/MO3	PF/MO4	PF/MO5	PF/MO6	PF/NP1	PF/NP2	PF/NP3	PF/NP4	PF/NP5
Mean	3.70	3.61	3.64	3.64	3.67	3.73	3.67	3.45	3.76	3.85	3.76	3.73	4.06	3.97	3.97	4.06	3.79	3.39	3.36	3.67	3.45	3.39
SD	0.59	0.61	0.60	0.65	0.60	0.63	0.65	0.83	0.50	0.67	0.66	0.52	0.70	0.64	0.73	0.66	0.78	0.83	0.78	0.65	0.75	0.70
# of Violations	0	0	0	1	1	0	1	5	5	4	4	1	0	0	0	0	0	3	1	1	2	2

coefficients within the sub-construct of product prototype flexibility, except the correlation coefficient between PF/PP2 and PF/PP3 (0.20) and between PF/PP3 and PF/PP6 (0.34), are significantly different from zero ($p<0.05$, critical value =0.35). Basically, the items have good convergent validity.

An examination of the correlation matrix to assess discriminant validity reveals a total of 31 violations out of 396 comparisons. None of the counts for each item exceeds half the potential comparisons. Therefore, they exhibit good discriminant validity.

3.4.2.5 Manufacturing Flexibility

The analysis begins with purification eliminating the items with CITC of less than or equal to 0.4. Then factor analysis is run with the remaining items. The different rounds are run and results are shown in Table 3.18.

All the items for each sub-construct have good CITC except MF/MI1. Crobach's alpha is respectively 0.89, 0.92, 0.86, 0.93, 0.88, and 0.89. Some items have significant cross loadings. The number of responses is less than the number of items analyzed, and thus the results are too sensitive, not stable. Cross-loading items are reworded with the idea in mind that these items should be closely related to the sub-construct that they are supposed to load and should be distinguished with the sub-construct that they are cross loaded. Reworded items are shown in Table 3.18.

The correlation matrix (Table 3.19) of the 33 items (except MF/MI1) for all the sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: machine flexibility =

0.32, labor flexibility = 0.54, material handling flexibility = 0.26, route flexibility = 0.30, volume flexibility = 0.50, and mix flexibility = 0.31. All are significantly different from zero ($p<0.10$).

An examination of the correlation matrix to assess discriminant validity reveals a total of 267 violations out of 895 comparisons. The violation counts for the items of MF/MA2, MF/MA5, MF/MH4, MF/MH5, and MF/VO1 exceed half the potential comparisons. After rewording items improve the correlations within factor, the number of violations will be greatly reduced. Basically, items exhibit overall discriminant validity.

3.4.2.6 Logistics Flexibility

The analysis begins with purification eliminating the items with CITC of less than or equal to 0.4. Then factor analysis is run with the remaining items. The different rounds are run and results are shown in Table 3.20.

The items for the sub-constructs of physical supply flexibility, physical distribution flexibility, and demand management flexibility work well: all CITCs are greater than 0.4, factor loadings are clean, and Crobach's alpha is respectively 0.93, 0.90, and 0.85. For the sub-construct of purchasing flexibility, five out of the six items have high CITCs and load together with an alpha of 0.92 after deleting low-CITC item. The unsatisfactory item is reworded as shown in Table 3.20 for large-scale survey.

The correlation matrix (Table 3.21) of the remaining 23 items for all the sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: physical supply flexibility = 0.49,

Table 3.18 Purification and Factor Loadings for Manufacturing Flexibility (Pilot)

Sub-construct	Items	Coding	CITC_1	CITC_2	CITC_3	α	Factor Loadings					
							F1	F2	F3	F4	F5	F6
Machine Flexibility	Machine setup can be replaced quickly	MF/MA1	0.54			0.89						0.609
	A typical machine can perform many types of operations economically *A typical machine can perform many types of operations*	MF/MA2	0.74					0.516				
	A typical machine can use many different tools effectively *A typical machine can effectively use many different tools*	MF/MA3	0.72				0.599					
	Machines often become obsolete when new operations are required	MF/MA4	0.65									0.734
	Machine tools can be changed quickly	MF/MA5	0.84									0.720
	Machine changeovers are easy *Machine setup changeovers are easy*	MF/MA6	0.82						0.518			0.639
Labor Flexibility	Workers can perform many types of operations effectively	MF/WO1	0.85			0.92		0.799				
	A typical worker can use many different tools effectively	MF/WO2	0.86					0.842				
	Cross-trained workers can perform a broad range of manufacturing tasks effectively in the organization	MF/WO3	0.76					0.744				
	Workers can operate various types of machines	MF/WO4	0.81					0.849				
	Workers can be transferred easily between organizational units	MF/WO5	0.69					0.778				
Material Handling Flexibility	**A typical material handling system can handle different parts** *A typical material handling system can handle different part types*	MF/MH1	0.43			0.86		0.493		0.548		
	A typical material handling system can link different processing centers	MF/MH2	0.78							0.811		
	Material handling system can move different part types through manufacturing facilities	MF/MH3	0.69							0.851		
	Material handling changeovers between parts are quick	MF/MH4	0.85							0.857		
	Material handling tools can be changed or replaced quickly	MF/MH5	0.68							0.728		
Route Flexibility	A typical part operation can be routed to different machines	MF/RO1	0.87			0.93	0.856					
	A typical part can use many different routes	MF/RO2	0.79				0.833					
	The system can operate with back-up routes in case machines break down *The system has alternative routes in case machines break down*	MF/RO3	0.57				0.587		0.453			
	The operating sequence through which the parts flow can be changed	MF/RO4	0.89				0.913					
	Machine visitation sequence can be changed or replaced quickly	MF/RO5	0.78				0.834					
	Route changeovers are easy	MF/RO6	0.89				0.889					
Volume Flexibility	We can operate efficiently at different levels of output	MF/VO1	0.70			0.88			0.474			
	We can operate profitably at different production volumes	MF/VO2	0.80						0.804			
	We can operate at various batch sizes economically *We can economically run various batch sizes*	MF/VO3	0.54					0.467	0.664			
	We can quickly change the quantities for our products produced	MF/VO4	0.67						0.748			
	We can vary aggregate output from one period to the next	MF/VO5	0.70						0.859			
	We can change the aggregate volumes of a manufacturing process easily *We can easily change the production volume of a manufacturing process*	MF/VO6	0.70									
Mix Flexibility	**We can produce a wide variety of products** *We can produce a wide variety of products in our plants*	MF/MI1	0.23			0.89						
	We can produce different product types without major changeover	MF/MI2	0.64	0.61							0.573	
	We can build different products in the same plants at the same time	MF/MI3	0.79	0.90							0.839	
	We can produce, simultaneously or periodically, multiple products in a steady-state operating mode	MF/MI4	0.58	0.49							0.766	
	We can vary product combinations from one period to the next	MF/MI5	0.80	0.88							0.913	
	We can changeover quickly from one product to another	MF/MI6	0.66	0.78				0.524			0.714	

Table 3.19 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Manufacturing Flexibility (Pilot)

	MA1	MA2	MA3	MA4	MA5	MA6	WO1	WO2	WO3	WO4	WO5	MH1	MH2	MH3	MH4	MH5	VO1	VO2	VO3	VO4	VO5	VO6	RO1	RO2	RO3	RO4	RO5	RO6	MI2	MI3	MI4	MI5	MI6
MA1	1.00																																
MA2	0.32	1.00																															
MA3	0.46	0.80	1.00																														
MA4	0.53	0.42	0.45	1.00																													
MA5	0.47	0.77	0.59	0.68	1.00																												
MA6	0.51	0.71	0.66	0.57	0.82	1.00																											
WO1	-0.22	0.56	0.32	-0.01	0.36	0.41	1.00																										
WO2	-0.17	0.57	0.29	0.04	0.47	0.51	0.85	1.00																									
WO3	-0.33	0.30	0.14	-0.09	0.20	0.26	0.72	0.74	1.00																								
WO4	-0.19	0.54	0.37	-0.01	0.39	0.37	0.75	0.74	0.68	1.00																							
WO5	-0.25	0.38	0.36	0.09	0.38	0.38	0.63	0.64	0.54	0.66	1.00																						
MH1	0.13	0.19	0.25	0.16	0.39	0.35	0.28	0.40	0.20	0.28	0.60	1.00																					
MH2	0.37	0.24	0.32	0.37	0.40	0.33	0.17	0.04	-0.11	-0.01	0.21	0.48	1.00																				
MH3	0.13	0.18	0.18	0.06	0.16	0.04	0.27	0.08	-0.05	-0.10	0.07	0.26	0.70	1.00																			
MH4	0.35	0.37	0.48	0.36	0.39	0.29	0.20	0.07	0.02	-0.04	0.21	0.45	0.73	0.70	1.00																		
MH5	0.38	0.28	0.32	0.31	0.40	0.35	0.12	0.00	-0.12	-0.13	0.10	0.31	0.57	0.57	0.78	1.00																	
VO1	0.37	0.61	0.65	0.34	0.65	0.56	0.30	0.40	0.18	0.22	0.35	0.39	0.33	0.33	0.51	0.45	1.00																
VO2	0.30	0.35	0.31	0.31	0.51	0.56	0.36	0.41	0.32	0.16	0.22	0.12	0.25	0.30	0.29	0.54	0.57	1.00															
VO3	0.38	0.35	0.36	0.24	0.36	0.28	0.17	0.19	0.11	0.04	-0.05	0.04	0.49	0.50	0.43	0.38	0.61	0.68	1.00														
VO4	0.17	0.53	0.51	0.25	0.48	0.66	0.52	0.60	0.48	0.29	0.41	0.31	0.04	0.14	0.31	0.30	0.56	0.58	0.33	1.00													
VO5	0.12	0.50	0.50	0.17	0.52	0.62	0.41	0.52	0.50	0.29	0.42	0.21	0.07	0.13	0.12	0.03	0.57	0.52	0.30	0.67	1.00												
VO6	0.33	0.38	0.26	0.36	0.65	0.66	0.27	0.40	0.27	0.18	0.21	0.16	0.05	0.10	0.10	0.30	0.49	0.75	0.32	0.56	0.72	1.00											
RO1	0.58	0.28	0.46	0.37	0.29	0.24	-0.11	-0.11	-0.24	-0.13	-0.27	-0.05	0.35	0.26	0.37	0.29	0.43	0.37	0.61	0.09	0.08	0.10	1.00										
RO2	0.52	0.29	0.52	0.32	0.18	0.19	0.00	-0.17	-0.23	-0.08	-0.21	-0.12	0.35	0.35	0.55	0.44	0.35	0.29	0.49	0.19	-0.02	0.02	0.83	1.00									
RO3	0.18	0.37	0.49	0.28	0.38	0.37	0.27	0.22	0.12	0.05	0.30	0.07	0.23	0.16	0.27	0.19	0.59	0.48	0.43	0.43	0.54	0.37	0.50	0.46	1.00								
RO4	0.53	0.42	0.55	0.41	0.41	0.32	-0.01	-0.04	-0.17	0.06	-0.05	-0.06	0.29	0.08	0.31	0.33	0.40	0.35	0.46	0.06	0.08	0.13	0.86	0.71	0.51	1.00							
RO5	0.52	0.55	0.61	0.40	0.45	0.38	0.05	0.03	-0.18	0.05	-0.06	-0.14	0.13	0.11	0.26	0.39	0.48	0.39	0.39	0.24	0.21	0.30	0.69	0.63	0.51	0.83	1.00						
RO6	0.52	0.41	0.54	0.38	0.36	0.30	0.06	0.06	-0.09	0.08	-0.02	0.06	0.33	0.14	0.38	0.25	0.43	0.28	0.52	0.23	0.12	0.09	0.81	0.78	0.59	0.87	0.73	1.00					
MI2	0.10	0.29	0.11	0.37	0.40	0.14	0.34	0.31	0.13	0.19	0.38	0.44	0.34	0.21	0.46	0.30	0.20	0.01	0.06	0.11	-0.04	0.12	-0.11	-0.02	0.02	0.05	0.07	0.15	1.00				
MI3	-0.32	0.27	0.03	0.08	0.20	0.03	0.58	0.38	0.48	0.39	0.57	0.14	0.11	0.20	0.20	0.15	0.04	0.11	-0.01	0.19	0.15	0.16	-0.48	-0.28	0.04	-0.24	-0.11	-0.19	0.66	1.00			
MI4	-0.11	0.04	-0.07	0.06	-0.07	-0.15	0.20	-0.06	0.01	0.20	0.12	-0.12	0.19	0.04	0.04	0.14	-0.13	-0.04	0.04	-0.37	-0.26	-0.13	-0.16	-0.09	-0.05	0.08	0.03	-0.02	0.31	0.51	1.00		
MI5	-0.22	0.33	0.11	0.16	0.26	0.10	0.45	0.28	0.43	0.37	0.47	-0.04	0.03	-0.01	0.16	0.13	0.05	0.14	-0.01	0.14	0.20	0.22	-0.41	-0.23	0.13	-0.10	0.02	-0.12	0.56	0.89	0.59	1.00	
MI6	-0.26	0.35	0.24	0.04	0.18	0.14	0.59	0.44	0.58	0.46	0.66	0.24	0.04	-0.02	0.19	0.11	0.08	0.14	-0.04	0.30	0.28	0.11	-0.34	-0.19	0.21	-0.06	0.03	-0.01	0.54	0.82	0.36	0.82	1.00
	MA1	MA2	MA3	MA4	MA5	MA6	WO1	WO2	WO3	WO4	WO5	MH1	MH2	MH3	MH4	MH5	VO1	VO2	VO3	VO4	VO5	VO6	RO1	RO2	RO3	RO4	RO5	RO6	MI2	MI3	MI4	MI5	MI6
Mean	2.91	3.73	3.45	2.97	3.61	3.39	3.73	3.79	3.97	3.85	3.91	3.64	3.36	3.3	3.27	3.15	3.76	3.73	3.73	3.85	3.91	3.91	3.24	3.21	3.76	3.3	3.24	3.18	3.79	4.09	4.06	4.21	4.03
SD	1.04	0.94	0.87	1.07	1.14	1.2	0.8	0.65	0.64	0.71	0.63	0.65	0.74	0.68	0.67	0.76	0.75	0.72	0.8	0.8	0.68	0.88	97	1.02	0.71	1.07	1.03	1.01	0.7	0.72	0.5	0.6	0.68
# of Violations	12	17	13	8	19	14	3	1	1	0	1	7	13	5	18	15	19	13	14	13	10	7	3	4	4	2	4	2	7	7	0	5	6

Note: In order to save spaces, all the item labels in this table have no prefix (MF/). For example, MF/MA1 is presented as MA1.

Table 3.20 Purification and Factor Loadings for Logistics Flexibility (Pilot)

Sub-construct	Items	Coding	CITC_1	CITC_2	CITC_3	α	Factor Loadings			
							F1	F2	F3	F4
Physical Supply Flexibility	We can deliver multiple kinds of materials in responding to mixed-model operations	LF/PS1	0.83			0.93	0.876			
	Our inbound transportation can deliver the variety of shipments on time	LF/PS2	0.87				0.863			
	We pick and assemble multiple production orders accurately and quickly at the material warehouse	LF/PS3	0.80				0.801			
	We have accurate records of inventory quantities and locations at the material warehouse	LF/PS4	0.80				0.854			
	We can quickly move materials to the correct production location	LF/PS5	0.87				0.926			
	Our inbound supply systems is effective for all shipments	LF/PS6	0.67				0.758			
Purchasing Flexibility	We can quickly obtain multiple kinds of materials that meet specification	LF/PF1	0.64	0.73		0.92			0.717	
	We can obtain multiple batch sizes of materials from suppliers quickly	LF/PF2	0.72	0.77					0.809	
	Purchasing can fill multiple requests quickly	LF/PF3	0.80	0.84					0.856	
	Purchasing keeps close communication with suppliers	LF/PF4	0.84	0.85					0.895	
	Suppliers cooperatively work on product and process specifications with us	LF/PF5	0.84	0.81					0.845	
	We streamline purchasing ordering, receiving and other paperwork easily and effectively *We streamline purchasing ordering, receiving, and other paperwork easily*	LF/PF6	0.00							
Physical Distribution Flexibility	We pick and assemble multiple customer orders accurately and quickly at the finished goods warehouse	LF/PD1	0.70			0.90		0.722		
	We can provide multiple kinds of product packaging effectively at the finished goods warehouse	LF/PD2	0.71					0.739		
	We can use multiple transportation modes to meet schedule for deliveries	LF/PD3	0.69					0.821		
	We can quickly and accurately label finished products	LF/PD4	0.82					0.871		
	We have accurate records of quantities and locations of finished goods	LF/PD5	0.82					0.891		
	We can take different customer orders with accurate available-to-promise	LF/PD6	0.67					0.736		
Demand Management Flexibility	We can quickly respond to multiple customers' delivery time requirements	LF/DM1	0.73			0.85				0.769
	We can effectively respond to multiple customers' requirements in terms of repair, installation and maintenance of products	LF/DM2	0.56							0.818
	We can negotiate with customers in terms of prices and delivery time effectively through long term relationships	LF/DM3	0.70							0.718
	We involve customers to improve our services effectively	LF/DM4	0.77							0.741
	We quickly respond to feedback from retailers and consumers effectively	LF/DM5	0.61							0.602

purchasing flexibility = 0.55, distribution flexibility = 0.73, competitor uncertainty = 0.50. All are significantly different from zero ($p<0.01$). Therefore, the items have good convergent validity.

An examination of the correlation matrix to assess discriminant validity reveals a total of 18 violations out of 396 comparisons. None of the counts for each item exceeds half the potential comparisons. Therefore, they exhibit very good discriminant validity.

3.4.2.7 Spanning Flexibility

The analysis begins with purification eliminating the items with CITC of less than or equal to 0.4. Then factor analysis is run with the remaining items. The different rounds are run and results are shown in Table 3.22.

Three out of the six items for the sub-construct of information dissemination work well: all CITCs are greater than 0.4, Crobach's alpha is 0.82, and factor loading is clean. The other three have low CITCs, and thus SF/ID1 and SF/ID5 are reworded; SF/ID6 is deleted since it is already captured by SF/ID5. For the sub-construct of strategy development flexibility, all the six items have high CITC and load together with an alpha of 0.88.

The correlation matrix (Table 3.23) of the remaining 9 items for all the sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: information dissemination flexibility = 0.39 and strategy development flexibility = 0.26. All are significantly different from zero ($p<0.10$). Therefore, the items have moderate convergent validity. An examination of the correlation matrix to assess discriminant validity

Table 3.21 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Logistics Flexibility (Pilot)

	LF/PS1	LF/PS2	LF/PS3	LF/PS4	LF/PS5	LF/PS6	LF/PF1	LF/PF2	LF/PF3	LF/PF4	LF/PF5	LF/PD1	LF/PD2	LF/PD3	LF/PD4	LF/PD5	LF/PD6	LF/DM1	LF/DM2	LF/DM3	LF/DM4	LF/DM5
LF/PS1	1.00																					
LF/PS2	0.76	1.00																				
LF/PS3	0.75	0.72	1.00																			
LF/PS4	0.70	0.69	0.77	1.00																		
LF/PS5	0.78	0.78	0.77	0.84	1.00																	
LF/PS6	0.63	0.81	0.49	0.51	0.60	1.00																
LF/PF1	-0.09	-0.21	-0.21	-0.26	-0.22	-0.02	1.00															
LF/PF2	-0.19	-0.17	-0.31	-0.23	-0.19	0.03	0.79	1.00														
LF/PF3	-0.30	-0.35	-0.40	-0.26	-0.30	-0.13	0.66	0.67	1.00													
LF/PF4	-0.32	-0.30	-0.40	-0.18	-0.22	-0.14	0.60	0.64	0.84	1.00												
LF/PF5	-0.32	-0.30	-0.35	-0.22	-0.27	-0.19	0.55	0.64	0.79	0.90	1.00											
LF/PD1	-0.37	-0.40	-0.31	-0.23	-0.13	-0.34	0.20	0.27	0.39	0.39	0.39	1.00										
LF/PD2	-0.30	-0.38	-0.33	-0.31	-0.16	-0.34	0.22	0.24	0.13	0.11	0.28	0.63	1.00									
LF/PD3	-0.06	-0.36	-0.16	-0.12	-0.07	-0.25	0.21	0.03	0.29	0.16	0.11	0.56	0.53	1.00								
LF/PD4	-0.22	-0.38	-0.30	-0.22	-0.09	-0.19	0.15	0.14	0.15	0.29	0.29	0.59	0.60	0.69	1.00							
LF/PD5	-0.06	-0.33	-0.25	-0.12	-0.05	-0.25	0.23	0.15	0.17	0.29	0.36	0.65	0.65	0.65	0.80	1.00						
LF/PD6	-0.27	-0.36	-0.30	-0.27	-0.11	-0.23	0.22	0.27	0.18	0.12	0.18	0.53	0.54	0.50	0.68	0.61	1.00					
LF/DM1	-0.18	-0.37	-0.11	-0.12	-0.23	-0.31	0.54	0.36	0.45	0.38	0.31	0.33	0.33	0.49	0.25	0.33	0.45	1.00				
LF/DM2	0.22	0.16	0.29	0.20	0.16	0.20	0.19	0.16	0.11	0.15	0.25	-0.07	0.07	-0.17	-0.18	-0.08	0.00	0.42	1.00			
LF/DM3	-0.14	-0.16	-0.08	0.00	-0.07	0.08	0.37	0.43	0.47	0.47	0.40	0.26	0.00	0.00	0.11	0.00	0.19	0.50	0.63	1.00		
LF/DM4	-0.10	-0.32	-0.11	-0.05	-0.14	-0.15	0.58	0.53	0.52	0.47	0.47	0.41	0.30	0.39	0.30	0.46	0.57	0.86	0.47	0.58	1.00	
LF/DM5	-0.28	-0.33	-0.18	-0.33	-0.33	-0.10	0.65	0.43	0.37	0.43	0.48	0.34	0.36	0.19	0.35	0.36	0.29	0.55	0.41	0.53	0.55	1.00
	LF/PS1	LF/PS2	LF/PS3	LF/PS4	LF/PS5	LF/PS6	LF/PF1	LF/PF2	LF/PF3	LF/PF4	LF/PF5	LF/PD1	LF/PD2	LF/PD3	LF/PD4	LF/PD5	LF/PD6	LF/DM1	LF/DM2	LF/DM3	LF/DM4	LF/DM5
Mean	3.73	3.64	3.61	3.70	3.70	3.39	3.88	3.94	3.91	4.00	4.00	3.73	3.79	3.85	4.06	4.12	4.00	4.09	3.76	4.00	4.00	3.94
SD	0.88	0.78	0.79	0.88	0.86	0.83	0.86	0.86	0.80	0.79	0.78	0.72	0.70	0.76	0.56	0.55	0.66	0.63	0.79	0.50	0.75	0.83
# of violations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	3	7	4

Table 3.22 Purification and Factor Loadings for Spanning Flexibility (Pilot)

Sub-construct	Items	Coding	CITC_1	CITC_2	CITC_3	α	Factor Loadings	
							F1	F2
Information Dissemination Flexibility	**We timely collect and disseminate the information along the supply chain** *We timely disseminate the information along the supply chain*	SF/ID1	0.11			0.82		
	We have joint production planning and scheduling among suppliers, manufacturing, marketing, distributors	SF/ID2	0.59	0.58	0.53			0.711
	We link information systems so that each member of a supply chain knows the other's requirements and status	SF/ID3	0.47	0.68	0.86			0.952
	Information flows quickly along the value chain	SF/ID4	0.35	0.51	0.69			0.880
	Accurate information is usually available *Accurate information is usually available for decision making*	SF/ID5	0.32	0.21				
	We provide the information that we need to make effective decisions (delete)	SF/ID6	0.13	0.09				
Strategy Development Flexibility	We continuously renew our competence to meet changing customer needs	SF/SD1	0.50			0.88	0.621	
	We take some actions quickly based on all the information continuously collected along the value chain	SF/SD2	0.68				0.776	
	We continuously develop strategy based on maintaining a good relationship with our major suppliers	SF/SD3	0.69				0.819	
	We continuously experiment, learn, and improve our practices to improve productivity	SF/SD4	0.70				0.803	
	We quickly develop strategy based on the coordination and integration of information along the value chain	SF/SD5	0.83				0.893	
	We continuously experiment, learn, and improve our practices to improve customer satisfaction	SF/SD6	0.77				0.832	

Table 3.23 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Spanning Flexibility (Pilot)

	SF/ID2	SF/ID3	SF/ID4	SF/SD1	SF/SD2	SF/SD3	SF/SD4	SF/SD5	SF/SD6
SF/ID2	1.00	0.62	0.39	0.34	0.33	0.27	0.32	0.25	0.28
SF/ID3	0.62	1.00	0.79	0.06	0.14	-0.07	0.03	-0.01	0.15
SF/ID4	0.39	0.79	1.00	-0.10	-0.08	-0.18	0.06	-0.02	0.11
SF/SD1	0.34	0.06	-0.10	1.00	0.57	0.26	0.31	0.49	0.45
SF/SD2	0.33	0.14	-0.08	0.57	1.00	0.51	0.44	0.61	0.63
SF/SD3	0.27	-0.07	-0.18	0.26	0.51	1.00	0.70	0.71	0.61
SF/SD4	0.32	0.03	0.06	0.31	0.44	0.70	1.00	0.72	0.64
SF/SD5	0.25	-0.01	-0.02	0.49	0.61	0.71	0.72	1.00	0.71
SF/SD6	0.28	0.15	0.11	0.45	0.63	0.61	0.64	0.71	1.00
	SF/ID2	SF/ID3	SF/ID4	SF/SD1	SF/SD2	SF/SD3	SF/SD4	SF/SD5	SF/SD6
Mean	3.27	3.09	3.21	3.97	3.91	4.06	4.15	4.06	3.88
SD	0.57	0.80	0.86	0.68	0.63	0.70	0.62	0.75	0.60
# of violations	0	0	0	1	1	1	1	0	1

reveals a total of 5 violations out of 36 comparisons. None of the counts for each item exceeds half the potential comparisons. Therefore, they exhibit good discriminant validity.

3.4.2.8 Competitive Advantage

The analysis begins with purification eliminating the items with CITC of less than or equal to 0.4. Then factor analysis is run with the remaining items. The different rounds are run and results are shown in Table 3.24.

All the items have good CITCs for each construct, and Crobach's alpha is respectively 0.88, 0.92, 0.93, 0.90, and 0.83. Factor loadings for the sub-construct of product variety, delivery dependability, and quality are clean. For the other two sub-constructs of price and time-to-market, one item each has cross loading, and thus they are reworded shown in Table 3.24 for the large-scale study.

The correlation matrix (Table 3.25) of the remaining 18 items for all the sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: price/cost = 0.77, product variety = 0.65, delivery dependability = 0.67, quality = 0.56, time-to-market = 0.57. All are significantly different from zero ($p<0.01$). Therefore, the items have good convergent validity.

An examination of the correlation matrix to assess discriminant validity reveals a total of 2 violations out of 258 comparisons. None of the counts for each item exceeds half the potential comparisons. Therefore, they exhibit good discriminant validity.

Table 3.24 Purification and Factor Loadings for Competitive Advantage (Pilot)

Sub-construct	Items	Coding	CITC_1	CITC_2	CITC_3	α	Factor Loadings				
							F1	F2	F3	F4	F5
Price/Cost	We offer competitive prices	CA/PC1	0.72			0.88				0.862	
	We are able to compete based on our prices	CA/PC2	0.88							0.916	
	We are able to offer prices as low or lower than our competitors	CA/PC3	0.87							0.941	
	We produce products efficiently / *We are able to produce products efficiently*	CA/PC4	0.50								
Product Innovation	We provide customized products	CA/PI1	0.72			0.92	0.862				
	We alter our product offerings to meet client needs	CA/PI2	0.86				0.895				
	We respond well to customer demand for "new" features	CA/PI3	0.89				0.908				
	We provide many new products to markets	CA/PI4	0.81				0.809				
Delivery Dependability	We deliver accurate quantity of products needed	CA/DD1	0.85			0.93		0.847			
	We deliver the kind of products needed	CA/DD2	0.86					0.853			
	We deliver customer order on time	CA/DD3	0.76					0.872			
	We provide dependable delivery	CA/DD4	0.90					0.863			
Quality	We are able to compete based on quality	CA/QU1	0.72			0.90			0.868		
	We offer products that are highly reliable	CA/QU2	0.89						0.912		
	We offer products that are very durable	CA/QU3	0.71						0.692		
	We offer high quality products to our customer	CA/QU4	0.82						0.854		
Time-to-Market	We deliver product to market quickly	CA/TM1	0.63			0.83					0.851
	We are first in the market / *We introduce product first in the market*	CA/TM2	0.48								
	We have time-to-market lower than industry average	CA/TM3	0.70								0.771
	We have fast product development	CA/TM4	0.83								0.821

Table 3.25 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Competitive Advantage (Pilot)

	CA/PC1	CA/PC2	CA/PC3	CA/PI1	CA/PI2	CA/PI3	CA/PI4	CA/DD1	CA/DD2	CA/DD3	CA/DD4	CA/QU1	CA/QU2	CA/QU3	CA/QU4	CA/TM1	CA/TM3	CA/TM4
CA/PC1	1.00																	
CA/PC2	0.80	1.00																
CA/PC3	0.77	0.85	1.00															
CA/PI1	0.12	0.08	0.05	1.00														
CA/PI2	0.21	0.15	-0.02	0.67	1.00													
CA/PI3	0.39	0.25	0.15	0.70	0.87	1.00												
CA/PI4	0.30	0.33	0.19	0.65	0.77	0.79	1.00											
CA/DD1	0.18	0.02	0.07	0.40	0.35	0.38	0.45	1.00										
CA/DD2	0.28	0.12	0.13	0.38	0.33	0.36	0.32	0.84	1.00									
CA/DD3	0.07	0.08	0.24	0.06	-0.08	-0.05	0.12	0.70	0.67	1.00								
CA/DD4	0.30	0.16	0.20	0.22	0.25	0.29	0.30	0.81	0.85	0.79	1.00							
CA/QU1	0.01	-0.25	-0.25	-0.04	0.19	0.12	0.16	0.29	0.26	0.25	0.34	1.00						
CA/QU2	0.18	-0.06	-0.01	0.14	0.29	0.26	0.33	0.41	0.37	0.39	0.48	0.75	1.00					
CA/QU3	0.39	0.13	0.07	0.17	0.39	0.39	0.31	0.62	0.59	0.36	0.65	0.56	0.73	1.00				
CA/QU4	0.21	0.05	0.03	0.11	0.27	0.26	0.31	0.38	0.42	0.45	0.52	0.68	0.87	0.66	1.00			
CA/TM1	0.34	0.22	0.09	0.04	0.22	0.18	0.26	0.44	0.42	0.13	0.27	0.18	0.21	0.35	0.26	1.00		
CA/TM3	0.43	0.41	0.26	0.26	0.46	0.40	0.56	0.29	0.30	0.15	0.27	0.16	0.36	0.33	0.33	0.57	1.00	
CA/TM4	0.43	0.50	0.35	0.14	0.36	0.34	0.51	0.35	0.40	0.27	0.32	0.01	0.13	0.32	0.23	0.63	0.79	1.00
	CA/PC1	CA/PC2	CA/PC3	CA/PI1	CA/PI2	CA/PI3	CA/PI4	CA/DD1	CA/DD2	CA/DD3	CA/DD4	CA/QU1	CA/QU2	CA/QU3	CA/QU4	CA/TM1	CA/TM3	CA/TM4
Mean	4.15	3.94	3.58	4.21	4.18	4.27	4.21	4.18	4.21	4.18	4.12	4.36	4.48	4.33	4.39	4.21	3.79	3.82
SD	0.80	0.90	1.03	0.65	0.77	0.76	0.78	0.68	0.70	0.58	0.70	0.60	0.57	0.74	0.56	0.70	0.82	0.81
# of violations	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

The calculation and factor analysis for customer satisfaction are reported in table 3.26. Except the item CS1, all the items have good loadings. Item CS1 is reworded as italic statement in Table 3.26.

Table 3.26 Purification and Factor Loadings for Customer Satisfaction (Pilot)

Sub-construct	Items	Coding	CITC_1	CITC_2	CITC_3	α	Factor Loading
Customer Satisfaction	**We have high customer retention rate** *Customers keep doing business with us*	CS1	0.18			0.80	
	Customers are satisfied with ratio of price and functions of our products	CS2	0.63	0.59			0.763
	Customers perceive they receive their money's worth when they purchase our products	CS3	0.71	0.74			0.862
	Our customers are satisfied with the quality of our products	CS4	0.58	0.63			0.787
	Our firm have good reputation for our products	CS5	0.43	0.44			0.626
	Our customers are loyal to our products	CS6	0.50	0.55			0.710

Overall, the scales do not pose any conceptual or interpretation problems. Before moving to the administration of the instrument to a large sample the scales are reassessed based on the results from the pilot study (see italic statements from Table 3.10 to Table 3.26). Where appropriate, some items are deleted, some items are modified, and some scales are augmented with additional items. This modified set of items (see appendix D) is managed for the large-scale survey with a total of 190 items, 158 developed and 32 adapted.

CHAPTER 4: LARGE-SCALE EXPLORATORY CONSTRUCT AND STRUCTURAL ANALYSIS

To further explore the measurements for the constructs and assess the reliability and factorial structures, a national executive survey is conducted. The survey uses the mailing list of 3000 firms provided by The Society of Manufacturing Engineers (SME). Firms with more than 100 employees are chosen because firms with less than 100 employees are unlikely to be engaged in flexible product development. Five SIC codes are covered in the survey: 34 "Fabricated metal products"; 35 "Industrial & commercial machinery"; 36 "Electronic & electrical equipment and components"; 37 "Transportation equipment"; 38 "Instruments and measurements equipment". Respondents are manufacturing executives including president, CEO, vice president, manager, and director. The second-wave mailing is conducted two weeks after the first mailing. Out of 314 responses received (21 undeliverables, 11 blank returns, and 9 incomplete), 273 are usable resulting in a response rate of 9.2%[1]

Sample characteristics appear on Table 4.1 based on SIC code, firm size, and respondents' position. The respondents come from manufacturing industries, namely, SIC 34, 35, 36, 37 and 38. The highest three respondent categories by SIC code are 34, 35, and 36 (i.e., 75% of respondents). Almost half of firms have between 100 and 250 employees. 42% of the respondents are presidents/CEO & vice presidents; half are managers.

1 The formulas for response rate = 273/(3000 – 21).

A chi-square test is conducted to check non-response bias; the results (see Table 4.1) show that there is no significant difference between the sample and respondents by all three categories (i.e., SIC code, employee size, and job title) at the level of 0.02. It exhibits that received questionnaires (respondents) represent an unbiased sample.

Table 4.1 Comparisons of Sample and Respondents

Variables	Sample	Respondents (expected f_e)	Respondents (observed f_o)
SIC			
34	760 (26)	70	83
35	680 (23)	62	65
36	599 (20)	55	58
37	490 (16)	45	38
38	450 (15)	41	29
Chi-square test		(χ^2 = 7.6, df=4, p > 0.10)	
Employment size			
100-249	1280 (43)	117	135
250-499	650 (22)	60	63
500-999	419 (15)	38	35
1000+	630 (20)	58	40
Chi-square test		(χ^2 = 8.6, df=3, p > 0.02)	
Job Title			
CEO/President	680 (23)	62	70
Vice President	459 (15)	42	43
Manager	1610 (54)	148	131
Director	230 (8)	21	29
Chi-square test		(χ^2 =5.3, df=3, p > 0.10)	
Total	2979* (100)	273	273

Note: 1. * 2979 = 3000-21, where 3000 is the sample size and 21 is the number of undeliverables.

2. Figures in parentheses are percentage; the calculation formula $\chi^2 = \sum (f_e - f_o)^2 / f_e$

3. The sample (SME) list is cleaned up by eliminating some names from the same company

4.1 RESEARCH METHODS

Responses from 273 firms are analyzed here with some objectives in mind: items purification, factor structure, reliability, convergent and discriminant validity. Following Churchill's (1979) guidance, purification is performed using CITC analysis. Items are eliminated if their CITC was less than 0.50. All instruments are then factor analyzed. Since the anticipated item groupings are identified prior to factoring, a common factor solution that is consistent with these groupings provides some evidence of factorial validity (Comrey, 1988).

To achieve a stable factor structure, it is suggested that the ratio of respondents to items should be at least between 5 and 10 (Tinsley & Tinsley, 1987). Comrey (1988) also states that a sample size of 200 is adequate for factor analysis that involves no more than 40 items. Items with factor loading below 0.50 and/or cross-loadings of 0.40 or above are deleted.

The reliability of all the scales is examined using Crobach's alpha. In general, alpha of 0.8 indicates that scale performs well (Nunnally, 1978). Next, convergent and discriminant validity is assessed using correlation matrix (Davis, 1989; Campbell & Fiske, 1959), as explained in chapter 3.

Finally, using LISREL the hypothesized structural model is examined. This allows the assessment of construct validity in a nomological network of constructs. It also gives an evidence of testing substantive hypotheses. The methods and results will be detailed in the section 4.3.

4.2 LARGE SCALE MEASUREMENT RESULTS

In the following section, the results of large scale analysis for each construct will be reported and discussed, which include CITC calculation, factor analysis, convergent and discriminant analysis.

4.2.1 Environmental Uncertainty

The purification and factor analysis are conducted on the 20 items proposed. The ratio of respondents to items is 14 and, thus, meets the general guidelines. The factor results are shown in Table 4.2. Crobach's alpha's for four sub-constructs are respectively 0.85, 0.92, 0.79, and 0.88. The cumulative variance explained by the four factors is 65.9%. For simplicity, Table 4.2 shows only loadings above 0.40. All items load on their respective factors and there are no items with cross-loadings greater than 0.40.

Table 4.2 Purification and Factor Loadings for Environmental Uncertainty (Large Scale)

Sub-construct	Coding	CITC_1	CITC_2	α	Factor Loadings			
					F1	F2	F3	F4
Customer Uncertainty	EU/CU1	.643		.85			.798	
	EU/CU2	.671					.816	
	EU/CU3	.694					.791	
	EU/CU4	.678					.768	
	EU/CU5	.633					.725	
Technology Uncertainty	EU/TE1	.786		.92	.865			
	EU/TE2	.827			.892			
	EU/TE3	.814			.884			
	EU/TE4	.813			.860			
	EU/TE5	.702			.760			
Competition Uncertainty	EU/CO1	.586		.79				.691
	EU/CO2	.523						.634
	EU/CO3	.581						.735
	EU/CO4	.533						.708
	EU/CO5	.642						.802
Supplier Uncertainty	EU/SU1	.698		.88		.795		
	EU/SU2	.702				.814		
	EU/SU3	.729				.809		
	EU/SU4	.738				.798		
	EU/SU5	.682				.785		
Eigenvalue					3.84	3.39	3.16	2.80
% of Variance					19.2	16.9	15.8	14.0
Cumulative % of Variance					19.2	36.1	51.9	65.9

The correlation matrix (Table 4.3) of all 20 items for the four sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: customer uncertainty = 0.39, supplier uncertainty = 0.52, technology uncertainty = 0.58, competitor uncertainty = 0.29. All items are significantly different from zero ($p<0.01$). Therefore, the items have good convergent validity.

Table 4.3 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Environmental Uncertainty (Large Scale)

	EU/CU1	EU/CU2	EU/CU3	EU/CU4	EU/CU5	EU/SU1	EU/SU2	EU/SU3	EU/SU4	EU/SU5	EU/TE1	EU/TE2	EU/TE3	EU/TE4	EU/TE5	EU/CO1	EU/CO2	EU/CO3	EU/CO4	EU/CO5
EU/CU1	1.00																			
EU/CU2	0.81	1.00																		
EU/CU3	0.44	0.46	1.00																	
EU/CU4	0.44	0.44	0.70	1.00																
EU/CU5	0.39	0.44	0.64	0.61	1.00															
EU/SU1	0.07	0.04	-0.05	-0.03	0.03	1.00														
EU/SU2	0.00	0.01	0.00	-0.06	0.09	0.68	1.00													
EU/SU3	0.06	0.10	-0.07	0.00	0.02	0.55	0.58	1.00												
EU/SU4	0.05	0.04	-0.16	-0.12	-0.10	0.57	0.56	0.69	1.00											
EU/SU5	0.00	-0.02	-0.01	-0.01	0.05	0.53	0.52	0.60	0.64	1.00										
EU/TE1	0.10	0.08	0.26	0.21	0.29	0.02	0.10	0.03	0.01	0.09	1.00									
EU/TE2	0.10	0.10	0.27	0.27	0.31	-0.02	0.05	0.03	-0.03	0.07	0.82	1.00								
EU/TE3	0.11	0.07	0.30	0.26	0.31	0.04	0.04	-0.02	0.04	0.11	0.70	0.76	1.00							
EU/TE4	0.18	0.20	0.15	0.20	0.25	0.05	-0.02	-0.01	-0.02	0.06	0.65	0.72	0.74	1.00						
EU/TE5	0.20	0.23	0.23	0.30	0.26	0.08	-0.03	0.00	-0.01	0.03	0.58	0.58	0.63	0.72	1.00					
EU/CO1	0.19	0.14	0.04	0.08	0.04	0.30	0.34	0.31	0.31	0.30	0.09	0.06	0.08	0.10	0.06	1.00				
EU/CO2	0.02	0.07	0.06	0.17	0.18	0.23	0.23	0.32	0.30	0.26	0.11	0.09	0.19	0.19	0.10	0.43	1.00			
EU/CO3	0.01	0.08	0.05	0.09	0.14	0.19	0.21	0.22	0.29	0.14	0.10	0.11	0.13	0.21	0.17	0.41	0.52	1.00		
EU/CO4	0.09	0.08	0.00	0.13	0.03	0.20	0.21	0.29	0.31	0.26	0.04	0.06	0.01	0.04	0.05	0.40	0.29	0.39	1.00	
EU/CO5	0.14	0.11	0.02	0.14	0.04	0.26	0.19	0.24	0.29	0.24	0.09	0.05	0.08	0.17	0.24	0.55	0.37	0.44	0.57	1.00
	EU/CU1	EU/CU2	EU/CU3	EU/CU4	EU/CU5	EU/SU1	EU/SU2	EU/SU3	EU/SU4	EU/SU5	EU/TE1	EU/TE2	EU/TE3	EU/TE4	EU/TE5	EU/CO1	EU/CO2	EU/CO3	EU/CO4	EU/CO5
Mean	2.78	2.97	3.49	3.38	3.69	2.74	2.89	2.84	2.55	2.80	3.55	3.50	3.64	3.48	3.36	3.03	3.47	3.39	2.74	2.91
SD	1.08	1.08	1.05	1.03	1.05	1.03	1.04	0.97	0.98	0.97	1.09	1.05	0.98	1.05	1.06	0.98	1.09	1.15	1.09	1.01
# of Violations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0	1	0

An examination of the correlation matrix to assess discriminant validity reveals a total of 8 violations out of 300 comparisons. None of the counts for each item exceeds half of the potential comparisons. Therefore, they exhibit good discriminant validity.

4.2.2 Use of Technology

Following the same analysis steps for previous construct, the results are reported in Table 4.4 and Table 4.5. The purification and factor analysis are conducted on the 28 items proposed. The ratio of respondents to items is 15 and thus meets the general guidelines. The factor results are shown in Table 4.4.

Table 4.4 Purification and Factor Loadings for Use of Technology (Large Scale)

Sub-construct	Coding	CITC_1	CITC_2	α	Factor Loadings				
					F1	F2	F3	F4	F5
Use of AMT	UT/AMT1	.774		0.92	.834				
	UT/AMT2	.832			.862				
	UT/AMT3	.841			.871				
	UT/AMT4	.830			.862				
	UT/AMT5	.738			.799				
	UT/AMT6	.600			.689				
Use of IT	UT/IT1	.749		0.91		.803			
	UT/IT2	.802				.838			
	UT/IT3	.790				.823			
	UT/IT4	.743				.790			
	UT/IT5	.818				.863			
	UT/IT6	.729				.819			
Concurrent Engineering	MP/CE1	.736		0.89					.771
	MP/CE2	.816							839
	MP/CE3	.673							.768
	MP/CE4	.748							.827
	MP/CE5	.702							.808
Improvement Practice	MP/CI1	.632		0.88			.714		
	MP/CI2	.644					.750		
	MP/CI3	.721					.807		
	MP/CI4	.705					.797		
	MP/CI5	.735					.832		
	MP/CI6	.700					.813		
Integration Practice	MP/IN1	.720		0.91				.757	
	MP/IN2	.782						.844	
	MP/IN3	.830						.876	
	MP/IN4	.809						.863	
	MP/IN5	.755						.841	
Eigenvalue					4.30	4.29	3.81	3.77	3.52
% of Variance					17.9	17.9	11.9	11.8	11.0
Cumulative % of Variance					17.9	35.8	47.7	59.5	70.5

Table 4.5 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Use of Technology (Large Scale)

	UT/AMT1	UT/AMT2	UT/AMT3	UT/AMT4	UT/AMT5	UT/AMT6	UT/IT1	UT/IT2	UT/IT3	UT/IT4	UT/IT5	UT/IT6	MP/CE1	MP/CE2	MP/CE3	MP/CE4	MP/CE5	MP/CI1	MP/CI2	MP/CI3	MP/CI4	MP/CI5	MP/CI6	MP/IN1	MP/IN2	MP/IN3	MP/IN4	MP/IN5
UT/AMT1	1.00																											
UT/AMT2	0.80	1.00																										
UT/AMT3	0.84	0.84	1.00																									
UT/AMT4	0.67	0.75	0.76	1.00																								
UT/AMT5	0.54	0.60	0.59	0.74	1.00																							
UT/AMT6	0.42	0.48	0.47	0.58	0.70	1.00																						
UT/IT1	0.37	0.37	0.39	0.39	0.26	0.22	1.00																					
UT/IT2	0.34	0.39	0.38	0.37	0.30	0.25	0.70	1.00																				
UT/IT3	0.30	0.38	0.33	0.37	0.39	0.31	0.60	0.74	1.00																			
UT/IT4	0.26	0.34	0.32	0.38	0.36	0.33	0.57	0.68	0.70	1.00																		
UT/IT5	0.32	0.37	0.37	0.37	0.30	0.21	0.73	0.69	0.68	0.65	1.00																	
UT/IT6	0.23	0.29	0.28	0.24	0.21	0.23	0.63	0.59	0.63	0.58	0.72	1.00																
MP/CE1	0.31	0.29	0.20	0.21	0.22	0.31	0.29	0.20	0.21	0.22	0.23	0.15	1.00															
MP/CE2	0.12	0.13	0.13	0.14	0.08	0.12	0.13	0.13	0.14	0.08	0.06	0.16	0.78	1.00														
MP/CE3	0.09	0.13	0.19	0.18	0.18	0.09	0.13	0.19	0.18	0.18	0.29	0.27	0.56	0.61	1.00													
MP/CE4	0.22	0.19	0.08	0.15	0.29	0.22	0.19	0.08	0.15	0.29	0.14	0.01	0.61	0.65	0.61	1.00												
MP/CE5	0.10	0.11	0.09	0.10	0.13	0.10	0.11	0.09	0.10	0.13	0.14	0.23	0.54	0.67	0.53	0.65	1.00											
MP/CI1	0.12	0.08	0.04	0.03	0.15	0.12	0.08	0.04	0.03	0.15	0.23	0.19	0.31	0.29	0.20	0.21	0.22	1.00										
MP/CI2	0.21	0.23	0.30	0.06	0.16	-0.30	-0.06	0.16	0.24	0.25	0.27	0.08	0.12	0.13	0.13	0.14	0.08	0.57	1.00									
MP/CI3	0.25	0.06	-0.11	0.03	0.27	-0.11	0.03	0.27	0.14	0.16	0.19	0.16	0.09	0.13	0.19	0.18	0.18	0.53	0.64	1.00								
MP/CI4	0.03	0.29	0.00	0.23	-0.01	0.00	0.23	0.01	0.18	0.17	0.05	0.27	0.22	0.19	0.08	0.15	0.29	0.49	0.45	0.59	1.00							
MP/CI5	0.05	0.14	0.05	0.15	0.23	0.15	0.17	0.18	0.30	0.06	0.16	0.01	0.10	0.11	0.09	0.10	0.13	0.48	0.52	0.58	0.64	1.00						
MP/CI6	0.08	0.14	0.16	0.07	0.19	0.30	-0.06	0.16	0.11	0.03	0.27	0.22	0.12	0.08	0.04	0.03	0.15	0.49	0.45	0.53	0.64	0.68	1.00					
MP/IN1	0.00	0.23	0.16	0.18	0.08	-0.11	0.03	0.27	0.00	0.23	0.01	0.10	0.48	0.47	0.28	0.36	0.33	0.21	0.12	0.12	0.20	0.15	0.22	1.00				
MP/IN2	0.41	0.27	-0.30	-0.06	0.16	0.00	0.23	-0.01	0.30	0.06	0.16	0.12	0.40	0.38	0.29	0.32	0.25	0.13	0.21	0.13	0.11	0.09	0.09	0.66	1.00			
MP/IN3	0.14	0.01	0.11	0.03	0.27	0.29	0.23	0.25	0.11	0.03	0.27	0.33	0.40	0.40	0.31	0.33	0.24	0.12	0.10	0.04	0.02	0.01	0.01	0.67	0.70	1.00		
MP/IN4	0.27	-0.01	0.00	0.23	0.01	0.18	0.18	0.16	0.00	0.23	0.01	0.21	0.42	0.44	0.29	0.30	0.26	0.08	0.07	0.00	0.02	0.11	-0.03	0.64	0.67	0.80	1.00	
MP/IN5	0.23	-0.30	0.06	0.16	-0.30	-0.06	0.23	0.29	0.28	0.24	0.21	0.23	0.34	0.34	0.26	0.26	0.21	0.03	0.08	0.04	0.01	-0.09	-0.06	0.57	0.70	0.68	0.70	1.00
	UT/AMT1	UT/AMT2	UT/AMT3	UT/AMT4	UT/AMT5	UT/AMT6	UT/IT1	UT/IT2	UT/IT3	UT/IT4	UT/IT5	UT/IT6	MP/CE1	MP/CE2	MP/CE3	MP/CE4	MP/CE5	MP/CI1	MP/CI2	MP/CI3	MP/CI4	MP/CI5	MP/CI6	MP/IN1	MP/IN2	MP/IN3	MP/IN4	MP/IN5
Mean	3.33	3.40	3.25	3.28	3.23	3.09	3.70	3.66	3.51	3.34	3.64	3.52	3.49	3.51	3.64	3.45	3.41	3.77	3.80	3.97	3.72	3.67	3.62	3.51	3.56	3.62	3.62	3.81
SD	0.99	0.99	0.97	0.89	0.88	0.91	0.80	0.89	0.93	1.02	0.84	0.89	0.97	0.99	0.92	0.98	0.96	0.86	0.91	0.80	0.94	0.94	0.94	0.87	0.93	0.87	0.91	0.80
# of Violations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

For simplicity, Table 4.4 only shows loadings above 0.40. All items load on their respective factors and there are no items with cross-loadings greater than 0.40. Crobach's alpha's for the five sub-constructs are respectively, 0.92, 0.91, 0.89, 0.88, and 0.91. The cumulative variance explained by the five factors is 70.5%.

The correlation matrix (Table 4.5) of the 28 items for these five sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: use of AMT = 0.42, use of IT = 0.57, concurrent engineering = 0.53, improvement practice = 0.45, integration practice = 0.57. All are significantly different from zero ($p<0.01$). Therefore, the items have good convergent validity. An examination of the correlation matrix to assess discriminant validity reveals no violations out of 312 comparisons. They exhibit excellent discriminant validity.

4.2.3 Infusion of Technology

The purification is conducted on the 19 items proposed. All the items, except IT/QW1, have good CITCs. IT/QW1 (employees feel their work is significant) is too general compared to the rest of the items (e.g., employees are responsible for outcome of their work). Although this item captures the employees' feeling, it does not directly address employees' love of their work and thus, this item is deleted. After deleting the item of IT/QW1, factor analysis is conducted on the remaining 18 items. The ratio of respondents to items is 14, thus it meets the general guidelines. The factor results are shown in Table 4.6. Crobach's alpha for four sub-constructs is respectively 0.93, 0.89, 0.88, and 0.90.

The cumulative variance explained by the four factors is 75.0%. For simplicity, Table 4.6 shows only loadings above 0.40. All items loaded on their respective factors and there were no items with cross-loadings greater than 0.40.

Table 4.6 Purification and Factor Loadings for Infusion of Technology (Large Scale)

Sub-construct	Coding	CITC_1	CITC_2	α	Factor Loadings			
					F1	F2	F3	F4
Task Innovation	IT/TI1	.830		.93		.857		
	IT/TI2	.870				.875		
	IT/TI3	.831				.867		
	IT/TI4	.825				.886		
Task Productivity	IT/TE1	.793		.89			.882	
	IT/TE2	.794					.899	
	IT/TE3	.775					.829	
	IT/TE4	.703					.819	
Quality of Work Life	IT/QW1	.223		.88				
	IT/QW2	.574	.771					.832
	IT/QW3	.504	.664					.823
	IT/QW4	.568	.765					.809
	IT/QW5	.563	.760					.807
Learning and Knowledge Accumulation	IT/LK1	.736		.90	.769			
	IT/LK2	.611			.710			
	IT/LK3	.771			.807			
	IT/LK4	.804			.847			
	IT/LK5	.751			.768			
	IT/LK6	.742			.803			
Eigenvalue					4.06	3.39	3.07	2.99
% of Variance					22.6	18.8	17.1	16.6
Cumulative % of Variance					22.6	41.4	58.4	75.0

The correlation matrix (Table 4.7) of the remaining 18 items for all the sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: task innovation = 0.73, task productivity = 0.62, quality of work life = 0.59, learning and knowledge accumulation = 0.43. All are significantly different from zero ($p<0.01$). Therefore, the items have good convergent validity.

An examination of the correlation matrix to assess discriminant validity reveals a total of 2 violations out of 240 comparisons. None of the counts for

Table 4.7 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Infusion of Technology (Large Scale)

	IT/TI1	IT/TI2	IT/TI3	IT/TI4	IT/TE1	IT/TE2	IT/TE3	IT/TE4	IT/QW2	IT/QW3	IT/QW4	IT/QW5	IT/LK1	IT/LK2	IT/LK3	IT/LK4	IT/LK5	IT/LK6
IT/TI1	1.00																	
IT/TI2	0.80	1.00																
IT/TI3	0.73	0.82	1.00															
IT/TI4	0.77	0.77	0.76	1.00														
IT/TE1	0.18	0.19	0.20	0.18	1.00													
IT/TE2	0.11	0.15	0.15	0.12	0.78	1.00												
IT/TE3	0.25	0.25	0.27	0.28	0.71	0.70	1.00											
IT/TE4	0.19	0.13	0.14	0.12	0.62	0.63	0.66	1.00										
IT/QW2	0.39	0.35	0.31	0.26	-0.03	-0.06	0.00	0.03	1.00									
IT/QW3	0.25	0.23	0.15	0.19	-0.03	0.00	-0.08	0.04	0.59	1.00								
IT/QW4	0.34	0.35	0.32	0.30	0.00	-0.09	-0.05	-0.02	0.73	0.58	1.00							
IT/QW5	0.34	0.33	0.24	0.29	-0.06	-0.12	-0.03	-0.02	0.69	0.61	0.68	1.00						
IT/LK1	0.27	0.32	0.28	0.21	0.16	0.11	0.20	0.20	0.39	0.29	0.45	0.46	1.00					
IT/LK2	0.20	0.26	0.23	0.16	0.17	0.30	0.20	0.21	0.17	0.23	0.18	0.22	0.59	1.00				
IT/LK3	0.35	0.35	0.37	0.29	0.16	0.14	0.29	0.20	0.32	0.21	0.34	0.38	0.63	0.50	1.00			
IT/LK4	0.34	0.35	0.39	0.30	0.15	0.15	0.26	0.18	0.30	0.17	0.37	0.30	0.66	0.64	0.72	1.00		
IT/LK5	0.42	0.40	0.39	0.41	0.14	0.09	0.25	0.16	0.32	0.24	0.35	0.39	0.58	0.47	0.66	0.65	1.00	
IT/LK6	0.24	0.30	0.33	0.25	0.12	0.08	0.19	0.21	0.30	0.20	0.31	0.36	0.61	0.43	0.65	0.64	0.72	1.00
	IT/TI1	IT/TI2	IT/TI3	IT/TI4	IT/TE1	IT/TE2	IT/TE3	IT/TE4	IT/QW2	IT/QW3	IT/QW4	IT/QW5	IT/LK1	IT/LK2	IT/LK3	IT/LK4	IT/LK5	IT/LK6
Mean	3.68	3.75	3.73	3.69	3.85	3.88	3.76	3.80	3.74	4.01	3.79	3.88	3.60	3.74	3.35	3.43	3.29	3.38
SD	0.71	0.70	0.70	0.68	0.60	0.62	0.68	0.67	0.80	0.71	0.75	0.78	0.83	0.73	0.87	0.82	0.94	0.98
# of Violations	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0

each item exceeds half the potential comparisons. Therefore, they exhibit excellent discriminant validity.

4.2.4 Product Development Flexibility

The purification is conducted on the 23 items proposed. All the items, except PF/MO1, have good CITCs. PF/MO1 (we can quickly modify product design in response to customer requests) addresses the quick response to customer requests instead of needs. Usually the customer request is more demanding and specific than general needs, therefore, it does not load well with the rest of the items and is deleted. Then, factor analysis is conducted on the remaining 22 items. The ratio of respondents to items is 12 and meets the general guidelines. The factor results are shown in Table 4.8. For simplicity, Table 4.8 shows only loadings above 0.40. All items, except PF/PP6, loaded on their respective factors. PF/PP6 has cross-loading of 0.404 with new product flexibility. After deleting PF/PP6, a factor analysis is rerun with the remaining 21 items and the results are shown in Table 4.8.1. Crobach's alpha for four sub-constructs is respectively 0.88, 0.93, 0.92, and 0.92. The cumulative variance explained by the four factors is 74.6%.

The correlation matrix (Table 4.9) of the remaining 21 items for the four sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: product concept flexibility = 0.42, product prototype flexibility = 0.61, modification flexibility = 0.63, new product flexibility = 0.55. All are significantly different from zero ($p<0.01$). Therefore, the

Table 4.8 Purification and Factor Loadings for Product Development Flexibility (Large Scale)

Sub-construct	Coding	CITC_1	CITC_2	α	Factor Loadings			
					F1	F2	F3	F4
Product Concept Flexibility	PF/PC1	.639		.88				.811
	PF/PC2	.687						.829
	PF/PC3	.665						.769
	PF/PC4	.724						.774
	PF/PC5	.732						.729
	PF/PC6	692						.688
Product Prototype Flexibility	PF/PP1	.764		.94	.804			
	PF/PP2	.828			.851			
	PF/PP3	.726			.791			
	PF/PP4	.848			.851			
	PF/PP5	.850			.833			
	PF/PP6	.759			722		*.404*	
Modification Flexibility	PF/MO1	.215		.92				
	PF/MO2	.705	.802			.861		
	PF/MO3	.658	.784			.858		
	PF/MO4	.692	.824			.876		
	PF/MO5	.752	.865			.898		
	PF/MO6	.638	.747			.795		
New Product Flexibility	PF/NP1	.835		.92			.750	
	PF/NP2	.685					.784	
	PF/NP3	.825					.782	
	PF/NP4	.875					.841	
	PF/NP5	.803					.806	
Eigenvalue					4.69	4.19	3.83	3.76
% of Variance					20.4	18.2	16.6	16.4
Cumulative % of Variance					20.4	38.6	55.2	71.6

Table 4.8.1 Final Factor Results for Product Development Flexibility (Large Scale)

Sub-construct	Coding	CITC	α	Factor Loadings			
				F1	F2	F3	F4
Product Concept Flexibility	PF/PC1	.639	.88				.810
	PF/PC2	.687					.829
	PF/PC3	.665					.771
	PF/PC4	.724					.772
	PF/PC5	.732					.729
	PF/PC6	.692					.686
Product Prototype Flexibility	PF/PP1	.780	.93		.800		
	PF/PP2	.836			.844		
	PF/PP3	.758			.811		
	PF/PP4	.860			.847		
	PF/PP5	.865			.821		
Modification Flexibility	PF/MO2	.802	.92	.862			
	PF/MO3	.784		.864			
	PF/MO4	.824		.881			
	PF/MO5	.865		.900			
	PF/MO6	.747		.796			
New Product Flexibility	PF/NP1	.835	.92			.767	
	PF/NP2	.685				.801	
	PF/NP3	.825				.796	
	PF/NP4	.875				.858	
	PF/NP5	.803				.821	
Eigenvalue				4.11	4.02	3.81	3.73
% of Variance				19.6	19.1	18.2	17.8
Cumulative % of Variance				19.6	38.7	56.9	74.6

Table 4.9 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Product Development Flexibility (Large Scale)

	PF/PC1	PF/PC2	PF/PC3	PF/PC4	PF/PC5	PF/PC6	PF/PP1	PF/PP2	PF/PP3	PF/PP4	PF/PP5	PF/MO2	PF/MO3	PF/MO4	PF/MO5	PF/MO6	PF/NP1	PF/NP2	PF/NP3	PF/NP4	PF/NP5
PF/PC1	1.00																				
PF/PC2	0.75	1.00																			
PF/PC3	0.50	0.55	1.00																		
PF/PC4	0.51	0.54	0.58	1.00																	
PF/PC5	0.44	0.49	0.54	0.65	1.00																
PF/PC6	0.42	0.46	0.51	0.59	0.77	1.00															
PF/PP1	0.11	0.17	0.23	0.28	0.30	0.27	1.00														
PF/PP2	0.06	0.18	0.13	0.31	0.29	0.29	0.75	1.00													
PF/PP3	0.07	0.19	0.14	0.22	0.35	0.35	0.61	0.66	1.00												
PF/PP4	0.09	0.14	0.19	0.26	0.32	0.35	0.69	0.74	0.68	1.00											
PF/PP5	0.07	0.15	0.22	0.35	0.42	0.44	0.66	0.73	0.66	0.85	1.00										
PF/MO2	0.04	0.08	0.10	0.18	0.30	0.32	0.07	0.17	0.18	0.20	0.26	1.00									
PF/MO3	0.05	0.07	0.02	0.12	0.28	0.22	0.00	0.06	0.15	0.10	0.18	0.73	1.00								
PF/MO4	-0.01	0.07	0.07	0.16	0.29	0.33	0.04	0.10	0.21	0.15	0.22	0.71	0.72	1.00							
PF/MO5	0.04	0.10	0.07	0.18	0.34	0.31	0.09	0.15	0.27	0.22	0.25	0.78	0.73	0.79	1.00						
PF/MO6	-0.03	0.03	0.10	0.17	0.28	0.32	0.13	0.17	0.18	0.21	0.22	0.64	0.63	0.69	0.73	1.00					
PF/NP1	0.13	0.22	0.19	0.33	0.39	0.47	0.47	0.54	0.46	0.54	0.58	0.27	0.21	0.34	0.34	0.41	1.00				
PF/NP2	0.15	0.12	0.21	0.24	0.18	0.21	0.32	0.35	0.22	0.38	0.38	0.08	0.02	0.10	0.09	0.12	0.65	1.00			
PF/NP3	0.15	0.15	0.23	0.27	0.31	0.38	0.43	0.44	0.44	0.48	0.55	0.29	0.24	0.30	0.32	0.45	0.76	0.62	1.00		
PF/NP4	0.20	0.15	0.27	0.31	0.31	0.37	0.48	0.47	0.38	0.50	0.52	0.20	0.17	0.20	0.23	0.38	0.77	0.67	0.79	1.00	
PF/NP5	0.08	0.07	0.16	0.23	0.30	0.37	0.41	0.48	0.35	0.47	0.49	0.22	0.20	0.28	0.24	0.53	0.75	0.55	0.73	0.81	1.00

	PF/PC1	PF/PC2	PF/PC3	PF/PC4	PF/PC5	PF/PC6	PF/PP1	PF/PP2	PF/PP3	PF/PP4	PF/PP5	PF/MO2	PF/MO3	PF/MO4	PF/MO5	PF/MO6	PF/NP1	PF/NP2	PF/NP3	PF/NP4	PF/NP5
Mean	3.70	3.63	3.56	3.43	3.52	3.54	3.41	3.43	3.63	3.59	3.53	3.79	3.82	3.63	3.72	3.39	3.22	3.43	3.23	3.20	3.11
SD	0.75	0.79	0.76	0.85	0.86	0.89	0.95	1.03	0.87	0.94	0.96	0.94	0.89	0.96	0.93	1.06	1.03	0.98	1.01	0.98	1.05
# of Violations	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

items have good convergent validity. With only 3 violations out of 330 comparisons, the items exhibit excellent discriminant validity (Table 4.9).

4.2.5 Manufacturing Flexibility

The purification is conducted on the 34 items proposed. All the items, except MF/MA3 and MF/MH5, have good CITCs. MF/MA3 (a typical machine can use many different tools effectively) is a little bit vague. Also, another item (MF/MA5: machine tools can be changed quickly) is more meaningful to the respondents, and thus, MF/MA3 is deleted. MF/MH5 (material handling tools can be changed or replaced quickly) is too specific compared with the rest items (e.g., material handling changeovers between parts are quick) and thus it is deleted. Then, factor analysis is conducted on the remaining 32 items. The ratio of respondents to items is 9 and meets the general guidelines. The factor results are shown in Table 4.10. For simplicity, Table 4.10 shows only loadings above 0.40. All items load on their respective factors. Crobach's alpha for six sub-constructs is respectively 0.83, 0.91, 0.92, 0.92, 0.90, and 0.92. The cumulative variance explained by the four factors is 69.4%.

The correlation matrix (Table 4.11) of the remaining 32 items for the six sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: machine flexibility = 0.34, labor flexibility = 0.54, material handling flexibility = 0.66, routing flexibility = 0.60, volume flexibility =0.22, and mix flexibility = 0.51. All sub-constructs are significantly different from zero ($p<0.01$). Therefore, the items have good convergent validity.

An examination of the correlation matrix to assess discriminant validity reveals a total of 11 violations out of 850 comparisons. None of the counts for each item exceeds half the potential comparisons. Therefore, the items exhibit good overall discriminant validity.

Table 4.10 Purification and Factor Loadings for Manufacturing Flexibility (Large Scale)

Sub-construct	Coding	CITC_1	CITC_2	α	Factor Loadings					
					F1	F2	F3	F4	F5	F6
Machine Flexibility	MF/MA1	.555	.640	.83						.733
	MF/MA2	.547	.535							.590
	MF/MA3	.285								
	MF/MA4	.438	.515							.725
	MF/MA5	.579	.693							.757
	MF/MA6	.622	.785							806
Labor Flexibility	MF/WO1	.785		.91			.844			
	MF/WO2	.851					.896			
	MF/WO3	.806					.877			
	MF/WO4	.824					.890			
	MF/WO5	.642					.726			
Material Handling Flexibility	MF/MH1	.626	.777	.92				.843		
	MF/MH2	.613	.857					.861		
	MF/MH3	.684	.828					.855		
	MF/MH4	.618	.781					.790		
	MF/MH5	.273								
Route Flexibility	MF/RO1	.759		.92	.815					
	MF/RO2	.791			.832					
	MF/RO3	.762			.816					
	MF/RO4	.793			.852					
	MF/RO5	.812			.861					
	MF/RO6	.777			.815					
Volume Flexibility	MF/VO1	.750		.90					755	
	MF/VO2	.793							.790	
	MF/VO3	.684							.679	
	MF/VO4	.770							.683	
	MF/VO5	.714							.663	
	MF/VO6	.719							.674	
Mix Flexibility	MF/MI1	.669		.92		.755				
	MF/MI2	.754				.802				
	MF/MI3	.830				.874				
	MF/MI4	.797				.860				
	MF/MI5	.783				.845				
	MF/MI6	.774				.808				
Eigenvalue					4.52	4.32	3.86	3.22	3.20	3.09
% of Variance					41.1	13.5	12.1	10.1	10.0	9.6
Cumulative % of Variance					41.1	27.7	39.7	49.8	59.8	69.4

4.2.6 Logistics Flexibility

The purification is conducted on the 23 items proposed. All the items, except LF/DM1, have good CITCs. LF/DM1 (we can quickly respond to multiple customers' delivery time requirements) is not well worded. Sometimes, customers do not require quick delivery and thus "effectively" is better wording than "quickly". So this item is deleted. Then, factor analysis is conducted on the remaining 22 items. The ratio of respondents to items is 12 and meets the general guidelines. The factor results are shown in Table 4.12. For simplicity, Table 4.12 shows only loadings above 0.40. All items, except LF/PF2, load on their respective factors. LF/PF2 loads on demand management flexibility with the coefficient of 0.692. Although LF/PF2 (we can obtain multiple batch sizes of materials from suppliers quickly) is relevant to quickly respond to customer needs, but it is a different issue from demand management and thus it is deleted. After deleting LF/PF2, a factor analysis is rerun with the remaining 21 items and the results are shown in Table 4.12.1. Crobach's alpha for six sub-constructs is respectively 0.85, 0.89, 0.90 and 0.82. The cumulative variance explained by the four factors is 64.7%.

The correlation matrix (Table 4.13) of the remaining 21 items for the four sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: physical supply flexibility = 0.32, purchasing flexibility = 0.46, physical distribution flexibility = 0.42, demand management flexibility = 0.47. All are significantly different from zero ($p<0.01$). Therefore, the items have good convergent validity.

An examination of the correlation matrix to assess discriminant validity reveals a total of 5 violations out of 328 comparisons. None of the counts for

Table 4.11 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Manufacturing Flexibility (Large Scale)

	MA1	MA2	MA4	MA5	MA6	WO1	WO2	WO3	WO4	WO5	MH1	MH2	MH3	MH4	RO1	RO2	RO3	RO4	RO5	RO6	VO1	VO2	VO3	VO4	VO5	VO6	MI1	MI2	MI3	MI4	MI5	MI6
MA1	1.00																															
MA2	0.41	1.00																														
MA4	0.42	0.34	1.00																													
MA5	0.54	0.46	0.45	1.00																												
MA6	0.64	0.51	0.46	0.70	1.00																											
WO1	0.11	0.16	0.04	0.16	0.23	1.00																										
WO2	0.11	0.18	0.03	0.19	0.24	0.80	1.00																									
WO3	0.05	0.13	-0.01	0.12	0.12	0.69	0.75	1.00																								
WO4	0.04	0.18	0.03	0.10	0.16	0.71	0.78	0.77	1.00																							
WO5	0.06	0.17	0.07	0.10	0.21	0.54	0.60	0.59	0.59	1.00																						
MH1	0.21	0.22	0.03	0.28	0.24	0.03	0.02	0.05	-0.01	0.14	1.00																					
MH2	0.25	0.22	0.14	0.31	0.22	0.03	-0.01	-0.04	-0.05	0.06	0.77	1.00																				
MH3	0.30	0.22	0.06	0.25	0.21	0.01	-0.05	-0.03	-0.07	0.07	0.70	0.79	1.00																			
MH4	0.34	0.25	0.13	0.28	0.32	0.04	-0.05	-0.07	-0.10	0.09	0.66	0.74	0.75	1.00																		
RO1	0.12	0.31	0.03	0.19	0.14	-0.13	-0.05	-0.11	-0.11	-0.04	0.32	0.32	0.29	0.33	1.00																	
RO2	0.07	0.27	0.15	0.15	0.17	-0.06	-0.02	-0.05	-0.02	0.06	0.33	0.39	0.29	0.34	0.78	1.00																
RO3	0.21	0.32	0.04	0.15	0.19	0.02	0.09	0.00	-0.01	0.10	0.26	0.26	0.28	0.34	0.68	0.65	1.00															
RO4	0.11	0.29	0.05	0.22	0.18	0.03	0.10	0.06	0.05	0.05	0.25	0.27	0.26	0.24	0.60	0.63	0.67	1.00														
RO5	0.06	0.26	0.04	0.21	0.15	0.02	0.10	0.06	0.05	0.08	0.32	0.32	0.28	0.25	0.61	0.66	0.65	0.81	1.00													
RO6	0.15	0.31	0.06	0.26	0.31	0.01	0.08	0.00	0.00	0.15	0.33	0.30	0.31	0.35	0.61	0.67	0.63	0.69	0.75	1.00												
VO1	0.22	0.15	0.18	0.14	0.16	0.28	0.29	0.19	0.22	0.19	0.00	0.10	0.06	0.09	-0.03	0.05	0.09	0.04	0.05	0.10	1.00											
VO2	0.28	0.15	0.20	0.10	0.18	0.24	0.20	0.14	0.13	0.20	-0.04	0.07	0.08	0.20	-0.09	-0.01	0.01	-0.04	-0.04	0.06	0.79	1.00										
VO3	0.24	0.14	0.21	0.19	0.21	0.17	0.21	0.12	0.09	0.17	-0.01	0.06	0.08	0.14	0.06	0.01	0.01	0.05	0.05	0.13	0.59	0.69	1.00									
VO4	0.14	0.07	0.01	0.11	0.11	0.07	0.05	0.03	0.04	0.05	0.07	0.10	0.08	0.10	-0.03	-0.01	0.05	-0.03	0.00	0.00	0.24	0.24	0.53	1.00								
VO5	0.26	0.22	0.19	0.16	0.14	0.15	0.16	0.12	0.13	0.04	0.02	0.12	0.11	0.16	0.05	0.03	0.07	0.06	0.00	-0.01	0.55	0.55	0.53	0.71	1.00							
VO6	0.16	0.10	0.01	0.10	0.15	0.07	0.07	0.05	0.05	0.08	0.06	0.09	0.11	0.12	-0.03	0.00	0.08	-0.02	-0.01	0.00	0.22	0.25	0.52	0.97	0.66	1.00						
MI1	0.12	0.08	0.03	0.02	0.00	0.12	0.15	0.13	0.15	0.18	0.07	0.16	0.11	0.18	0.14	0.17	0.17	0.15	0.12	0.12	0.18	0.15	0.12	0.02	0.26	0.03	1.00					
MI2	0.17	0.14	0.16	0.11	0.18	0.22	0.20	0.17	0.15	0.30	0.05	0.06	0.10	0.21	0.09	0.12	0.18	0.19	0.15	0.22	0.20	0.22	0.26	0.06	0.12	0.10	0.58	1.00				
MI3	0.00	0.12	-0.02	0.08	0.05	0.22	0.20	0.17	0.15	0.24	0.08	0.07	0.10	0.17	0.23	0.19	0.23	0.25	0.23	0.23	0.05	0.03	0.15	0.03	0.16	0.04	0.67	0.67	1.00			
MI4	0.05	0.07	0.04	0.07	0.07	0.19	0.15	0.16	0.14	0.20	0.08	0.09	0.05	0.16	0.10	0.09	0.13	0.12	0.14	0.17	0.18	0.17	0.17	0.06	0.18	0.07	0.58	0.64	0.76	1.00		
MI5	0.02	0.05	0.07	0.10	0.04	0.29	0.24	0.25	0.23	0.13	0.10	0.09	0.08	0.12	0.04	0.08	0.11	0.14	0.18	0.12	0.09	0.05	0.11	0.04	0.19	0.04	0.56	0.59	0.73	0.71	1.00	
MI6	0.16	0.17	0.11	0.14	0.22	0.32	0.25	0.28	0.24	0.32	0.08	0.05	0.05	0.17	0.07	0.09	0.15	0.16	0.17	0.22	0.23	0.26	0.31	0.09	0.20	0.10	0.51	0.72	0.66	0.68	0.73	1.00
	MA1	MA2	MA4	MA5	MA6	WO1	WO2	WO3	WO4	WO5	MH1	MH2	MH3	MH4	RO1	RO2	RO3	RO4	RO5	RO6	VO1	VO2	VO3	VO4	VO5	VO6	MI1	MI2	MI3	MI4	MI5	MI6
Mean	3.25	3.39	2.89	3.44	3.32	3.75	3.76	3.90	3.84	3.65	3.40	3.28	3.34	3.25	3.34	3.20	3.21	3.23	3.19	3.16	3.44	3.39	3.56	3.86	3.71	3.71	3.90	3.73	4.05	3.95	4.08	3.85
SD	0.88	0.92	0.96	0.92	0.95	0.78	0.76	0.71	0.72	0.84	0.84	0.81	0.81	0.83	0.94	0.96	0.95	0.95	0.92	0.94	0.96	1.01	0.93	2.56	0.79	2.62	0.92	1.01	0.88	0.85	0.75	0.91
# of Violations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	2	2	1	1	0	0	0	0	0	0

Note: In order to save spaces, all the item labels in this table have no prefix (MF/). For example, MF/MA1 is presented as MA1

Table 4.12 Purification and Factor Loadings for Logistics Flexibility (Large Scale)

Sub-construct	Coding	CITC_1	CITC_2	α	Factor Loadings			
					F1	F2	F3	F4
Physical Supply Flexibility	LF/PS1	.708		.85		.795		
	LF/PS2	.623				.779		
	LF/PS3	.600				.651		
	LF/PS4	630				.712		
	LF/PS5	.719				.807		
	LF/PS6	.555				.690		
Purchasing Flexibility	LF/PF1	.721		.90			.754	
	LF/PF2	.762						.692
	LF/PF3	.830					.852	
	LF/PF4	.715					.822	
	LF/PF5	.687					.792	
	LF/PF6	.585					.682	
Physical Distribution Flexibility	LF/PD1	.754		.90	.820			
	LF/PD2	.752			.836			
	LF/PD3	.724			.835			
	LF/PD4	.775			.807			
	LF/PD5	.694			.732			
	LF/PD6	.634			654			
Demand Management Flexibility	LF/DM1	.354		.82				
	LF/DM2	.527	.575					.590
	LF/DM3	.510	.639					.636
	LF/DM4	.562	.707					.678
	LF/DM5	.533	.648					.643
Eigenvalue					4.10	3.58	3.40	3.00
% of Variance					17.9	15.5	14.8	13.0
Cumulative % of Variance					19.1	33.4	48.2	61.2

Table 4.12.1 Final Factor Results for Logistics Flexibility (Large Scale)

Sub-construct	Coding	CITC	α	Factor Loadings			
				F1	F2	F3	F4
Physical Supply Flexibility	LF/PS1	.708	.85		.795		
	LF/PS2	.623			.779		
	LF/PS3	.600			.650		
	LF/PS4	.630			.711		
	LF/PS5	.719			.807		
	LF/PS6	.555			.690		
Purchasing Flexibility	LF/PF1	.730	.89			.741	
	LF/PF3	.860				.855	
	LF/PF4	.740				.830	
	LF/PF5	.680				.805	
	LF/PF6	.650				.683	
Physical Distribution Flexibility	LF/PD1	.754	.90	.810			
	LF/PD2	.752		.832			
	LF/PD3	.724		.827			
	LF/PD4	.775		.824			
	LF/PD5	.694		.755			
	LF/PD6	.634		.658			
Demand Management Flexibility	LF/DM2	.575	.82				.660
	LF/DM3	.639					.789
	LF/DM4	.707					.820
	LF/DM5	.648					.779
Eigenvalue				4.01	3.56	3.40	2.61
% of Variance				19.1	17.0	16.2	12.4
Cumulative % of Variance				19.1	36.1	52.3	64.7

Table 4.13 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Logistics Flexibility (Large Scale)

	LF/PS1	LF/PS2	LF/PS3	LF/PS4	LF/PS5	LF/PS6	LF/PF1	LF/PF3	LF/PF4	LF/PF5	LF/PF6	LF/PD1	LF/PD2	LF/PD3	LF/PD4	LF/PD5	LF/PD6	LF/DM2	LF/DM3	LF/DM4	LF/DM5
LF/PS1	1.00																				
LF/PS2	0.61	1.00																			
LF/PS3	0.56	0.41	1.00																		
LF/PS4	0.49	0.35	0.55	1.00																	
LF/PS5	0.62	0.50	0.49	0.63	1.00																
LF/PS6	0.44	0.58	0.32	0.41	0.47	1.00															
LF/PF1	0.15	0.08	0.10	0.11	0.13	0.30	1.00														
LF/PF3	0.13	-0.04	0.11	0.16	0.14	0.18	0.71	1.00													
LF/PF4	0.06	0.04	0.06	0.13	0.15	0.09	0.57	0.68	1.00												
LF/PF5	0.04	-0.02	0.09	0.16	0.11	0.06	0.48	0.59	0.69	1.00											
LF/PF6	0.15	0.21	0.22	0.28	0.19	0.29	0.46	0.55	0.46	0.51	1.00										
LF/PD1	0.22	0.15	0.35	0.17	0.17	0.18	0.22	0.20	0.12	0.13	0.20	1.00									
LF/PD2	0.23	0.12	0.36	0.24	0.11	0.16	0.20	0.15	0.06	0.06	0.14	0.76	1.00								
LF/PD3	0.26	0.13	0.34	0.23	0.20	0.09	0.13	0.07	0.07	0.07	0.00	0.66	0.71	1.00							
LF/PD4	0.25	0.18	0.30	0.25	0.22	0.20	0.17	0.20	0.18	0.24	0.20	0.63	0.59	0.64	1.00						
LF/PD5	0.21	0.12	0.20	0.46	0.25	0.18	0.18	0.23	0.13	0.19	0.21	0.50	0.52	0.53	0.69	1.00					
LF/PD6	0.22	0.17	0.22	0.30	0.26	0.28	0.21	0.34	0.14	0.20	0.31	0.52	0.48	0.42	0.60	0.65	1.00				
LF/DM2	0.26	0.22	0.22	0.29	0.23	0.22	0.28	0.35	0.25	0.24	0.33	0.22	0.18	0.09	0.21	0.24	0.36	1.00			
LF/DM3	0.16	0.11	0.13	0.14	0.17	0.09	0.22	0.21	0.22	0.24	0.26	0.23	0.16	0.16	0.18	0.17	0.20	0.47	1.00		
LF/DM4	0.14	0.09	0.08	0.12	0.13	0.12	0.31	0.33	0.31	0.19	0.22	0.29	0.28	0.18	0.19	0.21	0.32	0.52	0.60	1.00	
LF/DM5	0.17	0.02	0.30	0.07	0.06	0.11	0.35	0.33	0.26	0.28	0.26	0.36	0.33	0.24	0.22	0.15	0.26	0.47	0.53	0.61	1.00
	LF/PS1	LF/PS2	LF/PS3	LF/PS4	LF/PS5	LF/PS6	LF/PF1	LF/PF3	LF/PF4	LF/PF5	LF/PF6	LF/PD1	LF/PD2	LF/PD3	LF/PD4	LF/PD5	LF/PD6	LF/DM2	LF/DM3	LF/DM4	LF/DM5
Mean	3.77	3.75	3.67	3.75	3.84	3.50	3.49	3.53	3.77	3.76	3.41	3.81	3.75	3.97	4.00	4.03	3.87	3.66	3.77	3.74	3.61
SD	0.71	0.64	0.76	0.87	0.71	0.75	0.40	0.86	0.75	0.80	0.87	0.88	0.91	0.84	0.79	0.85	0.84	0.81	0.78	0.78	0.79
# of violations	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

each item exceeds half the potential comparisons. Therefore, they exhibit very good discriminant validity.

4.2.7 Spanning Flexibility

The purification and factor analysis are conducted on the 11 items proposed. All the items have good CITCs. The ratio of respondents to items is 25 and meets the general guidelines. The factor results are shown in Table 4.14. Table 4.14 shows only loadings above 0.40. All items load on their respective factors. Crobach's alpha for the two sub-constructs is 0.85 and 0.89. The cumulative variance explained by the two factors is 64.0%.

Table 4.14 Purification and Factor Loadings for Spanning Flexibility (Large Scale)

Sub-construct	Coding	CITC_1	CITC_2	α	Factor Loadings	
					F1	F2
Information Dissemination Flexibility	SF/ID1	.595		.85		.655
	SF/ID2	.670				.737
	SF/ID3	.707				.791
	SF/ID4	.689				.818
	SF/ID5	.643				.765
Strategy Development Flexibility	SF/SD1	.655		.89	.676	
	SF/SD2	.723			.734	
	SF/SD3	.637			.746	
	SF/SD4	.756			.830	
	SF/SD5	.745			.783	
	SF/SD6	.720			.808	
Eigenvalue					3.79	3.25
% of Variance					34.5	29.5
Cumulative % of Variance					34.5	64.0

The correlation matrix (Table 4.15) of the 11 items for the two sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: information dissemination flexibility = 0.44 and strategy development flexibility = 0.41. All are significantly different from zero ($p<0.01$). Therefore, the items have good convergent validity.

An examination of the correlation matrix to assess discriminant validity reveals a total of 5 violations out of 60 comparisons. None of the counts for

Table 4.15 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Spanning Flexibility (Large Scale)

	SF/ID1	SF/ID2	SF/ID3	SF/ID4	SF/ID5	SF/SD1	SF/SD2	SF/SD3	SF/SD4	SF/SD5	SF/SD6
SF/ID1	1.00										
SF/ID2	0.49	1.00									
SF/ID3	0.44	0.71	1.00								
SF/ID4	0.46	0.49	0.64	1.00							
SF/ID5	0.58	0.46	0.44	0.62	1.00						
SF/SD1	0.36	0.36	0.41	0.39	0.41	1.00					
SF/SD2	0.39	0.44	0.44	0.42	0.37	0.58	1.00				
SF/SD3	0.37	0.31	0.26	0.23	0.32	0.41	0.59	1.00			
SF/SD4	0.39	0.39	0.36	0.31	0.30	0.58	0.58	0.54	1.00		
SF/SD5	0.42	0.37	0.41	0.42	0.32	0.56	0.62	0.57	0.65	1.00	
SF/SD6	0.36	0.40	0.38	0.28	0.25	0.56	0.55	0.52	0.70	0.59	1.00
	SF/ID1	SF/ID2	SF/ID3	SF/ID4	SF/ID5	SF/SD1	SF/SD2	SF/SD3	SF/SD4	SF/SD5	SF/SD6
Mean	3.35	3.07	2.93	3.11	3.38	3.68	3.68	3.79	3.86	3.59	3.81
SD	0.82	0.88	0.88	0.85	0.78	0.78	0.78	0.75	0.69	0.81	0.68
# of violations	0	0	0	0	0	1	3	0	0	1	0

each item exceeds half the potential comparisons. Therefore, they exhibit excellent discriminant validity.

4.2.8 Competitive Advantage

The purification is conducted on the 20 items proposed. All the items have good CITCs. Then, factor analysis is conducted on these 20 items. The ratio of respondents to items is 14 and meets the general guidelines. The factor results are shown in Table 4.16. For simplicity, Table 4.16 shows only loadings above 0.40. CA/PI4 (we provide many new products to markets) has a significant cross loading with time-to-market. This item is too close to item CA/TM1 (We deliver product to market quickly) and CA/TM2 (we introduce product first in the market). Since CA/PI4 does not load well with the rest of product innovation items and it is deleted. All other items load on their respective factors. After deleting the item CA/PI4, a factor analysis is rerun with the remaining 19 items and the results are shown in Table 4.16.1. Crobach's alpha for five sub-constructs is respectively 0.87, 0.85, 0.92, 0.93, and 0.92. The cumulative variance explained by the five factors is 80.3%.

The correlation matrix (Table 4.17) of the remaining 19 items for all the sub-constructs is examined for the evidence of convergent and discriminant validity. The smallest within-factor items correlation are: price/cost = 0.47, product variety = 0.69, delivery dependability = 0.64, quality = 0.74, time-to-market = 0.65. All are significantly different from zero ($p<0.01$). Therefore, the items have good convergent validity. With no violations out of 258 comparisons, the items exhibit excellent discriminant validity.

Table 4.16 Purification and Factor Loadings for Competitive Advantage (Large Scale)

Sub-construct	Coding	CITC_1	CITC_2	α	Factor Loadings				
					F1	F2	F3	F4	F5
Price/Cost	CA/PC1	.771		.87				.874	
	CA/PC2	.800						.903	
	CA/PC3	.777						.874	
	CA/PC4	.543						.632	
Product Innovation	CA/PI1	.699		.83					847
	CA/PI2	.797							.916
	CA/PI3	.787							866
	CA/PI4	.508			*0.450*				*570*
Delivery Dependability	CA/DD1	.828		.92			.905		
	CA/DD2	.776					856		
	CA/DD3	.798					.864		
	CA/DD4	.849					.890		
Quality	CA/QU1	.834		.93		.891			
	CA/QU2	.842				.885			
	CA/QU3	826				.877			
	CA/QU4	839				.888			
Time-to-Market	CA/TM1	749		.92	785				
	CA/TM2	.833			871				
	CA/TM3	.822			858				
	CA/TM4	.885			.902				
Eigenvalue					3.42	3.34	3.24	2.91	2.80
% of Variance					17.1	16.7	16.2	14.5	14.0
Cumulative % of Variance					17.1	33.8	50.0	64.5	78.5

Table 4.16.1 Final Factor Results for Competitive Advantage (Large Scale)

Sub-construct	Coding	CITC	α	Factor Loadings				
				F1	F2	F3	F4	F5
Price/Cost	CA/PC1	.771	.87				.872	
	CA/PC2	800					.905	
	CA/PC3	.777					.875	
	CA/PC4	543					.630	
Product Innovation	CA/PI1	.802	.85					871
	CA/PI2	.835						.917
	CA/PI3	.821						.863
Delivery Dependability	CA/DD1	.828	.92			.904		
	CA/DD2	.776				.856		
	CA/DD3	.798				.864		
	CA/DD4	.849				.891		
Quality	CA/QU1	.834	.93	.894				
	CA/QU2	.842		.885				
	CA/QU3	.826		.877				
	CA/QU4	.839		.888				
Time-to-Market	CA/TM1	.749	.92		.796			
	CA/TM2	.833			.880			
	CA/TM3	.822			.867			
	CA/TM4	.885			.904			
Eigenvalue				3.34	3.30	3.24	2.90	2.50
% of Variance				17.6	17.4	17.0	15.2	13.1
Cumulative % of Variance				17.6	34.9	52.0	67.2	80.3

Table 4.17 Item Correlation Matrix, Descriptive Statistics, and Discriminant Validity Tests for Competitive Advantage (Large Scale)

	CA/PC1	CA/PC2	CA/PC3	CA/PC4	CA/PI1	CA/PI2	CA/PI3	CA/DD1	CA/DD2	CA/DD3	CA/DD4	CA/QU1	CA/QU2	CA/QU3	CA/QU4	CA/TM1	CA/TM2	CA/TM3	CA/TM4
CA/PC1	1.00																		
CA/PC2	0.79	1.00																	
CA/PC3	0.69	0.74	1.00																
CA/PC4	0.47	0.48	0.53	1.00															
CA/PI1	0.08	0.05	0.02	0.16	1.00														
CA/PI2	0.08	0.02	-0.02	0.07	0.76	1.00													
CA/PI3	0.11	0.09	0.04	0.14	0.69	0.77	1.00												
CA/DD1	0.04	-0.03	0.01	0.11	0.10	0.05	0.11	1.00											
CA/DD2	0.07	-0.01	-0.01	0.07	0.08	0.06	0.13	0.80	1.00										
CA/DD3	0.10	0.05	0.11	0.22	0.02	-0.01	0.05	0.71	0.64	1.00									
CA/DD4	0.08	-0.01	0.07	0.20	0.00	-0.02	0.09	0.75	0.71	0.82	1.00								
CA/QU1	0.02	-0.05	-0.03	0.09	0.25	0.24	0.25	0.25	0.28	0.17	0.21	1.00							
CA/QU2	0.03	-0.04	0.02	0.06	0.34	0.27	0.29	0.25	0.34	0.18	0.24	0.76	1.00						
CA/QU3	0.01	-0.02	-0.01	0.06	0.32	0.30	0.31	0.24	0.32	0.11	0.25	0.74	0.80	1.00					
CA/QU4	0.05	-0.04	0.00	0.16	0.28	0.26	0.29	0.25	0.30	0.18	0.26	0.80	0.76	0.75	1.00				
CA/TM1	0.30	0.28	0.32	0.40	0.24	0.13	0.29	0.22	0.18	0.32	0.29	0.17	0.17	0.16	0.23	1.00			
CA/TM2	0.32	0.27	0.30	0.34	0.24	0.16	0.25	0.11	0.12	0.25	0.19	0.10	0.09	0.09	0.12	0.71	1.00		
CA/TM3	0.32	0.28	0.28	0.36	0.19	0.19	0.31	0.13	0.16	0.28	0.23	0.15	0.15	0.11	0.16	0.65	0.75	1.00	
CA/TM4	0.33	0.29	0.31	0.40	0.18	0.16	0.29	0.17	0.16	0.34	0.30	0.16	0.13	0.10	0.20	0.73	0.81	0.84	1.00
	CA/PC1	CA/PC2	CA/PC3	CA/PC4	CA/PI1	CA/PI2	CA/PI3	CA/DD1	CA/DD2	CA/DD3	CA/DD4	CA/QU1	CA/QU2	CA/QU3	CA/QU4	CA/TM1	CA/TM2	CA/TM3	CA/TM4
Mean	3.88	3.70	3.44	3.83	4.06	4.06	4.03	4.06	4.09	3.93	3.99	4.32	4.36	4.38	4.35	3.77	3.50	3.54	3.48
SD	0.80	0.96	1.02	0.80	0.83	0.82	0.81	0.74	0.71	0.85	0.81	0.64	0.62	0.62	0.62	0.90	1.03	0.98	1.03
# of violations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The purification and factor loadings for customer satisfaction are reported in Table 4.18. Crobach's alpha for this construct is 0.79 and one factor comes out with 49.8% of the variance explained.

Table 4.18 Purification and Factor Loadings for Customer Satisfaction (Large Scale)

Sub-construct	Coding	CITC_1	CITC_2	α	Factor Loading
Customer Satisfaction	CS1	.477		.79	.623
	CS2	.592			.754
	CS3	.621			.772
	CS4	.540			.698
	CS5	.562			.717
	CS6	.506			.659
Eigenvalue					2.99
% of variance					49.8
Cumulative % of variance					49.8

Overall, the measures for all the constructs have very good reliability, factorial validity, and excellent convergent and discriminant validity. The research instruments after the large-scale study are summarized in Appendix E. These instruments can be confidently used to test the relationships among the constructs.

4.3 STRUCTURAL ANALYSIS

Linear structural equation modeling (SEM) is a systematic, statistical methodology for the assessment of construct validity and structural relationships among the constructs. It takes a hypothesis testing approach to the multivariate analysis of a structural theory, in other words, the hypothesized model can be tested statistically in a simultaneous analysis of the entire systems of variables to determine the extent to which it is consistent with the data.

SEM has become a popular methodology for non-experimental research because of its highly desirable characteristics compared with exploratory factor analysis (EFA). Whereas EFA is incapable of either assessing or correcting for measurement error, SEM provides explicit estimates of these parameters. Whereas EFA is based on observed measurements only, SME can incorporate both unobserved and observed variables. Thus, by specifying the pattern of inter-variable relations a priori, SEM is an approach to the analysis of data for inferential rather than descriptive purposes.

Typically, a researcher postulates a research model (i.e., a statistical model including latent and observed variables) based on his/her knowledge of related theory. Then, the research tests its plausibility based on sample data that comprise all observed variables in the model (i.e., the researcher imposes the structure of the hypothesized model on the sample data and see how well the observed data fit this restricted structure). Because it is unlikely that a perfect fit will exist between the observed data and the hypothesized model, there will be a discrepancy (i.e., residual) between these two. If the residual is adequately small, the theory-driven model is statistically well fitting and, thus, substantially meaningful.

4.3.1 LISREL Model

LISREL is a specific, basic tool in this widely used research methodology (i.e., SEM). It consists of two parts: measurement model and structural model. In reality, the variables that are directly manipulated and observed typically not the ones of theoretical interest but are merely some convenient variables acting as proxies or indexes for theoretical construct. Thus, the measurement model defines relations between the observed and unobserved variables. In other words, it provides the link between scores on a measuring instrument (i.e., the observed indicator variables) and the underlying constructs they are designed to measure (i.e., the unobserved latent variables). The measurement model, therefore, specifies the pattern by which each measure loads on a particular factor. It also describes the measurement properties (reliability, validity) of the observed variables. It is to assess how good all the measurement items (i.e., indicators) represent the latent (i.e., unobserved) construct.

The structured model defines relations among the unobserved variables. Accordingly, it specifies which latent variables directly or indirectly influences (i.e., causes) changes in the values of other latent variables in the model. Structural model is to see how well a specific hypothesized structure accounts for the observed relationships in the data. If goodness-of-fit is adequate, the model argues for the plausibility of postulated relations among variables; if it is inadequate, the tenability of such relations is weakened.

To assess the suggested relationships shown in Figure 2, the correlation matrix that is entered into LISREL is presented and is used to preliminarily assess alleged relationships. The relationships are also explored via LISREL. The same data are used for both the measurement and structural model. First, the aggregate score of the items factorially loaded for each sub-construct is computed. Second, the sub-construct's aggregate score is used as indicators for the corresponding construct. Third, the structural relationships between constructs are specified as Figure 3.

To be congruent with the hypothesized model in Chapter 2, environmental uncertainty is treated as the exogenous variable (ξ_1). The endogenous variables include use of technology (η_1), infusion of technology (η_2), value chain flexibility (η_3), competitive advantage (η_4), customer satisfaction (η_5), and financial performance (η_6). Exogenous latent variables (i.e., independent variables, X-variables) cause fluctuations in the values of other latent variables in the model. Changes in the values of exogenous variables are not explained by the model. Endogenous latent variables (i.e., dependent variables, Y-variables) are affected by the exogenous variables in the model, either directly or indirectly. They are explained by the model because their causal antecedents are specified within the model under consideration. Taken together, the general LISREL model can be captured by the following three equations:

Measurement model for the X-variables:
$X = \Lambda_x \xi + \delta$ (1)

Measurement model for the Y-variables:
$Y = \Lambda_y \eta + \varepsilon$ (2)

Structural equation model:
$\eta = B\eta + \Gamma\xi + \zeta$ (3)

In the equation (1), X is a (4x1) vector of the observed measure of the exogenous latent variable. ξ is a (1x1) vector of the latent exogenous variable. This latent exogenous variable, environmental uncertainty, is a second order construct with the four first-order sub-constructs as indicators. Λ_x is a (4x1) vector of factor loading of X on ξ. δ is a (4x1) vector of measurement error in X. In the equation (2), Y is a (40x1) vector of the observed measures of latent endogenous variables. η is a (6x1) vector of latent endogenous variables. Λ_y is an (40x6) matrix of factor loading of Y on η. ε is a (40x1) vector of measurement error in Y. In the equation (3), Γ is a (6x1) vector of coefficients relating the exogenous variable to 6 endogenous variables. B is an (6x6) matrix of coefficients of relating the 6 endogenous variables to one another. ζ is a (6x1) vector of errors in the structural equations.

The structural equation model, as expressed by equation (1), (2), and (3), can be transformed into a path diagram shown in Figure 3. By convention, observed variables are shown in boxes and unobserved variables in circles. The one-way bold arrows represent the influences of one variable on another (i.e., causal relationships). For the completeness of presentation, both measurement and structural model are presented in Figure 3; it shows an overall fit between data and hypothesized measure and structure.

For the sake of clarity, the computed values rather than the symbols for these arrows (i.e. γ's and β's) are given. If the model fits the data adequately, the magnitudes and t-values of the gamma and beta coefficients will be evaluated to test the hypotheses. A γ-value greater than or equal to 0.70 indicates a good construct loading (Hair et al., 1995). Using two-tailed test, a t-value greater than 2.58 is significant at the level of 0.01; a t-value greater than 1.96 is significant at 0.05; a t-value of 1.65 is significant at the level of 0.10.

To assess the fit of the hypothesized model to the data, various fit indices can be used. These include chi-square, goodness-of-fit index (GFI), adjusted-goodness-of-fit index (AGFI), comparative-fit index (CFI), and normed-fit index

(NFI). The chi-square statistic is a good global test of a model's ability to reproduce the sample variance/covariance matrix. Nonsignificant chi-square values are desirable and provide evidence of good fit. GFI represents the overall degree of fit, but is not adjusted for the degrees of freedom. AGFI is an extension of GFI that is adjusted by the degrees of freedom. Two widely used incremental fit indices are CFI and NFI. NFI is a relative comparison of the proposed model to the null model. CFI avoids the underestimation of fit often noted in small samples for NFI (Bentler, 1990). Many researchers interpret these index scores in the range of 0.80 - 0.89 as representing reasonable fit; scores of 0.90 or higher are considered as evidence of good fit (Joreskog and Sorbom, 1986; Byrne, 1989).

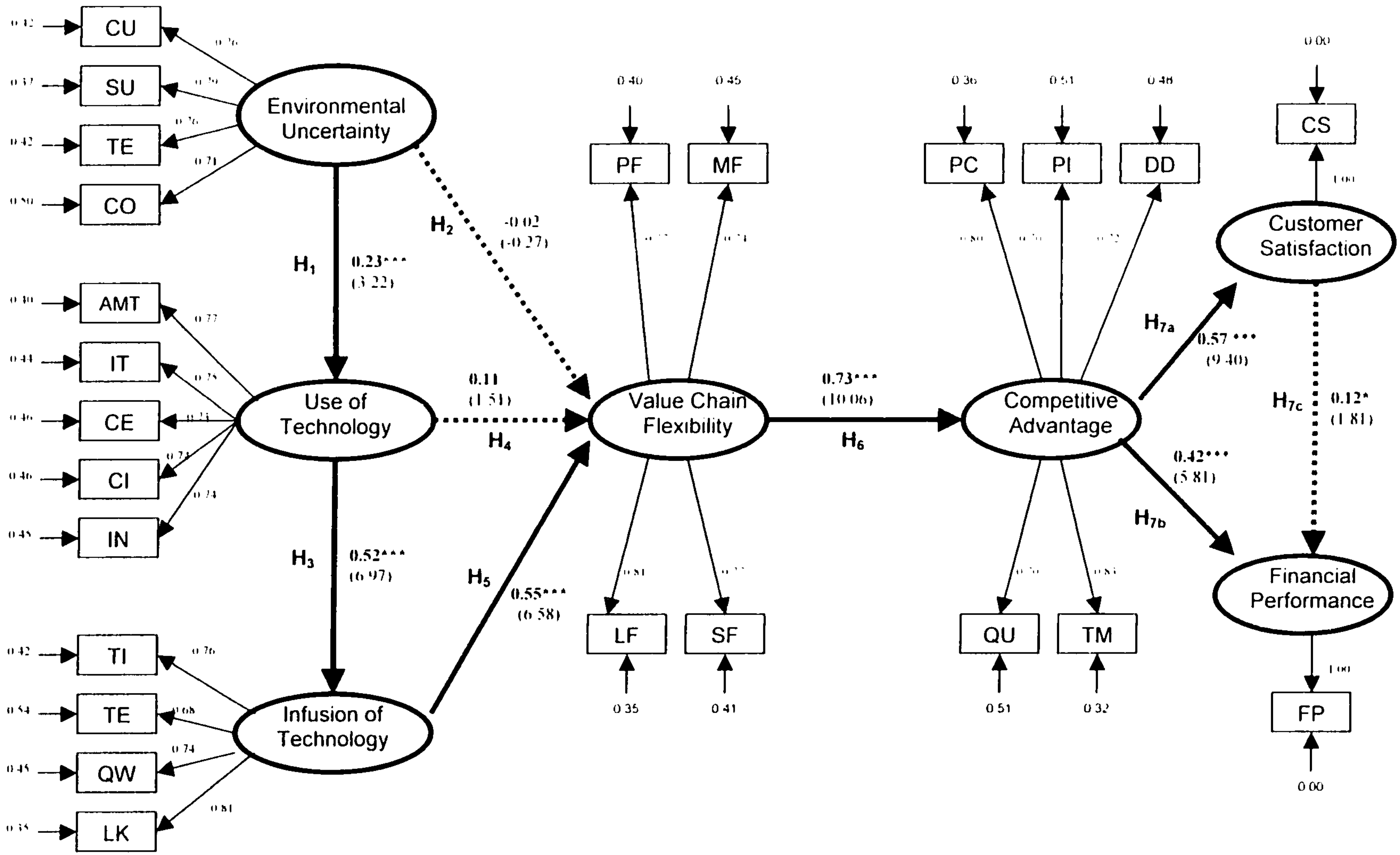
4.3.2 Results of Structural Analysis

Using the bivariate correlation (i.e., no causal relationships are specified), the correlation matrix (Table 4.19) shows that the relationships for H1, H3, H4, H5, H6, H7a, H7b, H7c are significant at the 0.01 level, while the relationship for H2 is significant at the 0.10 level. Specifically, environmental uncertainty is significantly related to use of technology (r = 0.23). Although its relationship with value chain flexibility is significant, it is relatively weak (r= 0.08). All the other relationships are positively, highly significant. The highest correlation coefficients are 0.73 (value chain flexibility to competitive advantage), 0.61 (Infusion of technology to value chain flexibility), 0.57 (competitive advantage to customer satisfaction), and 0.52 (use of technology to infusion of technology). All the other correlation coefficients are less than 0.50. From the correlation matrix, all the relationships are as expected and in the hypothesized direction.

To further examine the hypotheses, a closer look at the causal model is needed. The LISREL results (Figure 3) exhibit that all the measurements have significant loadings to their corresponding second-order construct (i.e., all the γ's have values greater than or equal to 0.70 except the sub-construct of technology efficiency (TE) with a γ of 0.68). Table 4.20 shows that all the constructs have good construct validity with both composite reliability (ρ_c) and average variance extracted (AVE) greater than 0.50 (Hair et al., 1995). Figure 3 indicates that the model has a reasonable fit (Chi-square =658.68, d.f. =245, p-value =0.000, RMSEA =0.079). The goodness-of-fit (GFI), adjusted-goodness-of-fit (AGFI), normed-fit-index (NFI), and comparative-fit-index (CFI) are respectively 0.83, 0.79, 0.81, and 0.87. Root-mean-square-residual (RMR) is 0.024.

The findings for the structural equation model are summarized in Table 4.21. According to Joreskog and Sorbem (1986), it is helpful to study relationships by breaking total effects into direct, indirect, and noncausal. To examine the total and component effects, all the coefficients are calculated. The hypotheses with merely direct effect are first examined. Then, the hypotheses with both direct and indirect effects are discussed.

From Table 4.21, most hypothesized relationships are strongly supported with the significant, direct positive effects at the 0.01 level. These hypotheses include H1 (environmental uncertainty to use of technology), H3 (use of technology to infusion of technology), H5 (infusion of technology to value chain flexibility), H6 (value chain flexibility to competitive advantage), H7a (competitive advantage to customer satisfaction). The coefficient β's (t-value) are respectively



Note: 1. Bold lines are for paths, dashed lines indicate insignificant paths; t-value is in parenthesis
2. Using two tailed test, *** path is significant at 0.01; ** significant at 0.05; * significant at 0.10
3. For the model testing, Chi-Square = 658.69, df = 245, P-value = 0.0000; RMSEA = 0.079

Figure 3: Hypotheses Test Using Structural Equation Model (Path & Measurement)

Table 4.19 Descriptive Statistics and Correlations for Variables in the Structural Model

Variables	Means	S. D.	1	2	3	4	5	6	7
1. Environmental Uncertainty	3.16	0.52	1.00						
2. Use of Technology	3.54	0.46	0.23***	1.00					
3. Infusion of Technology	3.71	0.44	0.12**	0.52***	1.00				
4. Value Chain Flexibility	3.55	0.39	0.08*	0.39***	0.61***	1.00			
5. Competitive Advantage	4.52	0.56	0.05	0.29***	0.44***	0.73***	1.00		
6. Customer Satisfaction	4.19	0.46	0.03	0.16***	0.25***	0.41***	0.57***	1.00	
7. Financial Performance	3.71	0.68	0.03	0.14***	0.22***	0.36***	0.49***	0.36***	1.00

Note: *** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.10 level

Table 4.20 Assessment of Composite Reliability of the Constructs

Variables	Number of indicators	Average Variance Extracted (AVE)	Composite reliability (ρ_c)
1. Environmental Uncertainty	4	0.57	0.84
2. Use of Technology	5	0.56	0.86
3. Infusion of Technology	4	0.56	0.84
4. Value Chain Flexibility	4	0.60	0.86
5. Competitive Advantage	5	0.56	0.87
6. Customer Satisfaction	1	1.00	1.00
7. Financial Performance	1	1.00	1.00

Table 4.21 Decomposition of Effects (Standardized Coefficients)

Relationship	Total Effects	Direct Effects	Indirect Effects	Noncausal Effects	Degree of Support
H1: Environmental Uncertainty to Use of Technology	0.23*** (3.22)	0.23*** (3.22)			strong
H2: Environmental Uncertainty to Value Chain Flexibility	0.08 (1.15)	-0.02 (-0.27)	0.09*** (2.83)	0.01	not
H3: Use of Technology to Infusion of Technology	0.52*** (6.97)	0.52*** (6.97)			strong
H4: Use of Technology to Value Chain Flexibility	0.40*** (5.45)	0.11 (1.51)	0.28*** (5.12)	0.01	not
H5: Infusion of Technology to Value Chain Flexibility	0.55*** (6.58)	0.55*** (6.58)			strong
H6: Value Chain Flexibility to Competitive Advantage	0.73*** (10.06)	0.73*** (10.06)			strong
H7a: Competitive Advantage to Customer Satisfaction	0.57*** (9.40)	0.57*** (9.40)			strong
H7b: Competitive Advantage to Financial Performance	0.49*** (8.04)	0.42*** (5.81)	0.07* (1.80)		strong
H7c: Customer Satisfaction to Financial Performance	0.12* (1.81)	0.12* (1.81)			weak

Note: For two-tailed test, *** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.10 level; t-values are in parentheses.

0.23 (3.22), 0.52 (6.97), 0.55 (6.58), 0.73 (10.06), and 0.57 (9.40). H7c (customer satisfaction to financial performance) is supported with the significant, direct positive effect (β = 0.12, t-value = 1.81) at the 0.10 level. Thus, the direct (i.e., total) effects confirm these hypotheses including H1, H3, H5, H6, H7a, and H7c.

The hypotheses with merely direct effect are already discussed. A closer look at the hypotheses with both direct and indirect effects in Table 4.20 is needed. It is hypothesized that environmental uncertainty has a significant positive relationship with value chain flexibility (H2). Although the direct effect of environmental uncertainty on value chain flexibility is not significant, the indirect effect (β = 0.09, t-value = 2.83) is significant at the 0.01 level. Therefore, environmental uncertainty has the impact on value chain flexibility, merely indirectly, through use of technology and infusion of technology. But the total effect (β = 0.08, t-value = 1.15) of environmental uncertainty on value chain flexibility is not significant. These two facts demonstrate that use of technology and infusion of technology are two strong mediating variables for this relationship. In other words, even a firm faces very uncertain environment, if the firm does not flexibly use technology, or the potential of technology is not full exploited, high value chain flexibility can not be achieved. Therefore, the perceived environmental uncertainty does not directly lead to the high value chain flexibility. To achieve high flexibility, the firm has to take some active actions to use technology and corresponding management practices, and further exploit the potential of technology with high employees' participation and learning.

It was postulated that use of technology has significant positive relationship with value chain flexibility (H4). From the results, H4 is not supported with the significant, direct positive effect (β = 0.11, t-value = 1.51) even at the 0.10 level. But the indirect effect of use of technology on value chain flexibility (β = 0.28, t-value = 5.12) is significant at the 0.01 level. This indirect effect is through infusion of technology. It further confirms that, in order to achieve high value chain flexibility, only using technology is not sufficient and technology has to be infused into the employees' learning and work life.

It is also hypothesized that competitive advantage has a significant positive relationship with financial performance (H7b). From the results, the direct effect of competitive advantage on financial performance (β = 0.42, t-value = 5.81) is significant at the 0.01 level. Competitive advantage also has significant indirect impact on financial performance through customer satisfaction (β = 0.07, t-value = 1.80) at the 0.10 level. Therefore, the direct effect plays a big role in this relationship, in other words, the competitive advantage can directly create superior financial performance.

Overall, the data indicates a strong causal relationship from environmental uncertainty, through use of technology (H1), infusion of technology (H3), and value chain flexibility (H5), to competitive advantage (H6). It also shows that the strong causal relationships exist from competitive advantage to customer satisfaction (H7a) and financial performance (H7b).

CHAPTER 5: DISCUSSION, RECOMMENDATION, AND CONCLUSION

5.1 SUMMARY IN DISCUSSION

Fast and dramatic changes in customer requirements, competition, and technology have created an uncertain environment, which necessitate an integrated approach to speculate and manage the whole value chain. Researchers suggest that flexibility be a new strategic imperative to cope with, manage, control, and reduce environmental uncertainty and yield sustainable competitive advantage. They further posit that manufacturing flexibility alone may not be sufficient to win competition and, thus, the flexibility across the whole value chain has to be adequately configured and managed.

The literature on this important subject is rapidly accumulating; however, much of the research evidence concerning flexibility is anecdotal, based primarily on case study (Maffei & Meredith, 1995), study on a specific industry (Suzrez, Cusumano, & Fine, 1996), mathematical model (Kumar, 1987; Benjaafar & Ramakrishnan, 1996), or survey research (Gupta & Somer, 1992). Although these studies have made important contributions, the literature about value chain flexibility and its organizational performance implications are still fragmentary. They are generally founded on a partial understanding of the concept of flexibility. The concept and dimension of flexibility are unclear and are usually imprecisely used. Furthermore, the flexibility at product development, logistics, and spanning activities are almost ignored in the literature.

It is argued that the environmental uncertainty is a main driver to pursue the flexibility (Swamidass & Newell, 1987; Gerwin, 1987); however, most empirical studies lack accurate measures. The hypotheses testing of the relationship is by and large based on the general, broad measures of environmental uncertainty and the incomplete capture of flexibility dimensions. The existing literature has several limitations. First, it offers many sources of uncertainty (Duncan, 1972; Lawrence & Losch, 1969). Typically, organizations concentrate on only a few of these uncertainty elements (e.g., customers, suppliers, competitors, and technology). Accordingly, measures based on the broad uncertainty sources rather than a parsimonious conception examine the relationship less sensitively. Second, the measures of flexibility, especially manufacturing flexibility, are anchored in a fractional dimension of flexibility (i.e., measures only cover one or two of the three dimensions of range, mobility, and uniformity). Third, no consistent underlying flexibility concept is applied across the whole value chain including product development, manufacturing, logistics, and spanning activities. Thus, the imprecise definition and biased measures have tendency to lower the reliability, and then distort the relationship between environmental uncertainty and value chain flexibility.

In order to achieve higher value chain flexibility, advanced technology and management practices are adopted in many firms. However, the results are not satisfactory. The implementation and management of technology can not catch up with the fast advancing of technology and changing environmental imperative. As a result, most firms under-use (at best routine use) new technologies and thus, technological potential flexibility can not be transformed into actual flexibility. What is missing here is that firms fail to focus attention on the human side besides technology investment, the systems, and the procedures. Although there exist many literatures on technology implementation, most of writings end up discussing routine use of technology (i.e., automation). A major determinant, infusion of technology, which contributes most to the attainment of value chain flexibility, is left unexplored. This ignorance leaves many variations of value chain flexibility unexplained.

Value chain flexibility as an order-winning criterion, in turn, enables a firm to achieve competitive advantage. To win competition, an organization usually adopts various marketing strategies to enhance its competitive capabilities. As computer and communication technologies rapidly advance, a firm's strategy can be easily emulated and thus, the first mover advantage becomes ephemeral. This phenomenon changes researchers' thinking from the analysis of the industrial structure and market attractiveness to the imperfectly imitable flexible competence and capability inside a firm. Although many literatures hold that flexibility can help attain the competitive advantage, the rationale for the attainment of sustainable competitive advantage from the flexibility view is ungrounded and empirical supports are trivial.

The purpose of this research is to study value chain flexibility grounded on a learning and capability theory. It has anchored in a comprehensive understanding of flexibility and its various flexibility components across the whole value chain. It has explored the relationship between environmental uncertainty and value chain flexibility based on a specific, narrow conception of uncertainty sources. It has also explored technology use and infusion as the antecedent variables of value chain flexibility from a learning angle. The study has further explored the value chain flexibility as an enabling factor of the sustainable competitive advantage from a competence and capability perspective. The new lenses of value chain flexibility bring a systematic, resource-based view of firms' competitive advantage. The new conceptualization of constructs has provided many opportunities to approach many important issues of firms' value chain flexibility, the antecedents to achieve it, and the intervening mechanisms.

By constructing a nomological network of value chain flexibility related constructs and conducting an analysis across a relatively large number of organizations with more accurate measurements, this study has represented an initial investigation of value chain flexibility rooted in a comprehensive understanding of the concept of flexibility. A set of reliable and valid instruments has been developed to measure these constructs including environmental uncertainty, use of technology, infusion of technology, value chain flexibility, competitive advantage, customer satisfaction, and financial performance. This study has contributed to the knowledge of value chain flexibility both in theory and in practices in many ways, which is shown in Table 5.1.

First, the concept and dimension of flexibility are clarified. In the existing literature, the vagueness of flexibility concept can be attributed to the following definitional problems. Some flexibility terms overlap considerably. For example, process flexibility intersects with operational flexibility. Using different names to refer to the similar types of flexibility causes some unnecessary confusion. Some terms are aggregates of others. For example, process flexibility includes routine flexibility, machine flexibility, and material handling flexibility. Even identical terms used by different writers are not necessarily meaning the same thing. What makes the concept of flexibility even more vague is that the dimensions of flexibility (i.e., range, mobility, and uniformity) and types of flexibility (e.g., machine flexibility, material handling flexibility, labor flexibility, volume flexibility) are mingled. As discussed in chapter 1, flexibility is the ability to meet a variety of customer needs (internal & external) without excessive cost, time, organizational disruption, or loss of performance. Implicitly, the concept of flexibility includes three dimensions: range, mobility, and uniformity. These three dimensions underlie each type of flexibility (e.g., machine flexibility, labor flexibility, volume flexibility, and mix flexibility). Also, these underlying dimensions of flexibility concept are consistently used to define and operationalize all the flexibility components across the whole value chain.

Table 5.1 Summary of Contributions, Findings, and Implications

Categories	Key Contributions
Concept	1. Clarified the concept & dimensions of flexibility
Framework	2. Developed a theoretical framework for research on value chain flexibility
Measurement	3. Developed & validated instruments for value chain flexibility (29 scales)
Hypotheses Confirmation	4. Confirmed that a strong casual chain exists in the model (including H1, H3, H5, H6, H7a & H7b)
New Findings	5. H2 is not supported; use of technology and infusion of technology are two strong mediating variables for this relationship
	6. H4 is not supported; infusion of technology is a dominant determinant for the attainment of value chain flexibility
Methodology	7. Provided a methodology guide for an empirical research
Practical Implications	8. Before deciding on buying newest technologies, managers will be better off exploiting the potential flexibility of the current organization and technology
	9. The instruments developed in the study can be used for a benchmark
	10. The dichotomy of flexible competence and capability can be used to focus managers' attention on advantage adding capability

Second, built on previous research, a theoretical value chain flexibility framework is provided that identifies environmental uncertainty, use of technology, infusion of technology, value chain flexibility, competitive advantage, customer satisfaction, and financial performance. The framework forms a foundation for research in value chain flexibility by identifying some of the most salient dimensions of value chain flexibility. Value chain flexibility includes four elements: product development flexibility, manufacturing flexibility, logistics flexibility, and spanning flexibility. Use of these constructs, related constructs, and their sub-dimensions permits researchers to formulate and test numerous propositions. Other constructs may be added to complement the nomological network of constructs in future research.

Third, the study provides a set of validated instruments of value chain flexibility related constructs. The instruments proposed in this study represent substantial progress towards the establishment of a standard instrument for measuring value chain flexibility and related constructs. Evidence of the reliability and validity of these measures has been demonstrated for use in future research. Such measurement instruments have been lacking in previous studies of value chain flexibility. It is hoped that this research has provided the groundwork for the future. Although it is the first attempt to create value chain flexibility based on the new conceptualization of flexibility, the scales have well met the criteria in terms of reliability, factorial validity, as well as discriminant and convergent validity. The establishment of these standardized instruments benefits academic community with more precision in answering research questions.

Fourth, the study provides supporting evidence of previously untested statements regarding value chain flexibility and related constructs. The results in the study strongly demonstrate that environmental uncertainty has a significant, positive impact on use of technology, which in turn has a significant positive relationship with infusion of technology. The data do not support that higher level of use of technology leads to higher level of value chain flexibility, but the data strongly confirm that higher level of infusion of technology leads to higher level of value chain flexibility. The data also support the notion that higher level of value chain flexibility creates higher level of competitive advantage. It strengthens the claim that higher level of competitive advantage creates the higher level of customer satisfaction and financial performance. The notion that higher levels of customer satisfaction lead to higher financial performance is weakly supported. From the structural model, the data indicate that a strong overall causal chain exists from environmental uncertainty, through use of technology (H1), infusion of technology (H3), value chain flexibility (H5), and competitive advantage (H6), to customer satisfaction (H7a) and financial performance (H7b).

Fifth, the data in the study do not support the hypothesis that environmental uncertainty has a significant positive relationship with value chain flexibility. This is contradictory with previous literatures. But the results lend support to the claim that use of technology and infusion of technology are two strong mediating variables of the relationship between environmental uncertainty and value chain flexibility. This is understandable because, even though managers perceive high environmental uncertainty, a firm may not achieve high value chain flexibility if it does not actively use technology and exploit the potential of technology.

Sixth, the infusion of technology is a dominant determinant to achieving value chain flexibility. The data do not support the relationship between use of technology and value chain flexibility (H4), but the results strongly support the relationship between infusion of technology and value chain flexibility (H5). It confirms that the potential of technology has to be infused into the employees' work life to attain value chain flexibility. The active participation and commitment of employees are the sources of organizational absorptive capability. The accumulation of knowledge and skill bases cultivates the customer-valued flexibility. This is consistent with Suerez, Cusumano, & Fine's (1995) findings that the plants with more programmable automation (i.e. use of technology) may end up being the less flexible plants if technology is not infused into employees' growth and work life.

Seventh, this research provides a methodological guide for manufacturing management researchers who are undertaking empirical research in the area. It offers a step-by-step procedure to conduct an empirical research that includes model building, measurement development (i.e., item generation, structured interview, Q-sort, pretest, pilot study, and large-scale survey), and structural testing.

Eighth, the contrast between use of technology and infusion of technology in their relationships with value chain flexibility has a significant practical meaning. Before making decision on buying the latest available technologies, managers would be better off concentrating on exploiting the potential flexibility in their current organization and technology. In the short term, managers squeeze much more flexibility from their existing equipment by exploring non-technology factors. In the long run, it creates the source of potential flexibility.

Ninth, the instruments developed in this study have several applications in practice. It can be utilized to evaluate value chain flexibility in an organization. In addition to an overall assessment, it can be used to identify which aspect of value chain flexibility constructs is more problematical. It can also be used to compare component flexibility between various divisions or compare value chain flexibility across organizations. The results can in turn be used in developing the strategy of an organization. In fact, over 200 respondents have indicated that they would like to receive results for their firms and benchmark results in their industry.

Tenth, this study implicitly provides a valuable tool for executives to assess their flexible competence and capability in technology use and management. For example, value chain flexibility scales can be used by managers to evaluate the extent of their competence and capability to achieve competitive advantage. If managers have a partial rather than a comprehensive view of flexibility, they are likely to focus on flexible competence rather than flexible capability, thus it will limit themselves to a particular type of resource. Flexible competence (e.g.. machine flexibility) alone would not be adequate to ensure a competitive edge. It can improve competitiveness only if the added flexibility advantage in the management of flexible capability is exhibited. It is thus essential to understand the relationships between various flexible competence and flexible capability and explore their association with performance in detail in the future research.

Although the results from the study are very encouraging, the moderate support or lack of confirmation for some of the alleged relationships between value chain flexibility and related constructs calls attention to its limitations. Several measurements as well as structural issues and problems will be pointed out that may contribute to the absence of some significant correlations. By addressing these issues, possible directions for future research are proposed.

5.2 DISCUSSION OF MEASUREMENT ISSUES

The generic nature of value chain flexibility and related constructs should allow for their broad usage. The scales were developed here with the objective that it can be used confidently across discrete manufacturing industries. Even certain continuous process industries such as chemical or oil refinery industries may be also feasible with the instruments developed in the study. Due to exploratory nature of this work, these scales should be revalidated in the same industries; they should also be validated in other industries.

From the view of the research cycle in developing standardized instruments, confirmatory factor analyses that test hypothesized measurement models against new data gathered from the same referent population are needed in the future. This will facilitate the general agreement on the standardization and use of instruments. Thus, confirmatory factor analyses warrants study in the near future so that the diffusion of a standardized instrument among the academic community can be speeded.

The generalizability of measurement instruments may be supported by factorial invariance test. Using the instruments developed in this research, a factorial invariance test can be conducted across different manufacturing industries (i.e., SIC codes), across different firm sizes (i.e., small versus large), or across different production types (i.e., engineering-to-order, assembly-to-order, make-to-order, versus make-to-order). The instruments are developed to be widely applicable and factor structure is expected to be similar across different groups. To conduct factorial invariance tests, it is necessary to collect sufficient data for each of the groups for comparison (Marsh and Hocevar, 1985). The factor structure of one group should essentially be compared with the factor structure of another group.

Other important variables that may affect the instrument are the firm's product characteristics and innovation strategy. There is a difference in flexible competence and capability between standardized products, incremental products, and breakthrough products. It is expected that incremental products need more flexible competence and capability than standardized and breakthrough products. It is also expected that different kinds of product be produced under the different levels of environmental uncertainty.

The use of single respondents to represent all the variables may have generated some inaccuracy. More than the typical amount of random error is likely because informants (i.e., president, VP, managers) are asked to make inferences about micro-level phenomena (e.g., employee's feeling). Over-reporting or under-reporting of certain phenomena may occur as a function of the informant's position, tenure time, job satisfaction, or other personal or role characteristics (Bagozzi & Phillips, 1982). It is also recognized that biases arising from a common method used to derive measures across independent variables and dependent variables can artificially increase observed association (Campbell & Fiske, 1959). In all these cases, it is suggested that multiple methods should be used to derive estimates of measures. It may be even appropriate to use both subjective and objective methods of measurement to verify each other.

5.3 DISCUSSION OF STRUCTURAL ISSUES

The level of flexibility is valued differently in various industries. As a consequence, structural relationships between variables might be different across industries. The different component flexibility (i.e., product development flexibility, manufacturing flexibility, logistics flexibility, and spanning flexibility) may be emphasized differently for different industries. Assuming an adequate sample in each industry, such analysis can be conducted to shed some light on different typologies or taxonomies for different industries.

This research only hypothesized relationships at the aggregate level (i.e., the second-order constructs). The use of the aggregate variables is useful for hypotheses testing in the overall framework. The detailed relationships can be studied at the sub-dimensional level; the sub-dimensional analysis will bring much rich and refined relationships among the constructs. Practitioners will also be interested in the specific construct and relationships that they can manipulate or manage. For example, concurrent engineering practice may affect product development flexibility, manufacturing flexibility, and logistics flexibility differently.

The precise definition and standard measure of flexibility have encouraged the use of the concept of flexibility in strategic and competitive analysis. In the future research, many basic questions can be answered with the measures of different types of flexibility. What are the different types of flexibility that are important? Under what conditions is each types of flexibility more desirable? What are the relationships or tradeoffs among the different flexibility types with regard to the different dimensions of competitive advantages such as cost, quality, dependability, and delivery? What are types of flexibility that affect a firm's competitive position? How can different types of flexibility be achieved?

The proposed structural relationships may also be affected by contextual variables. Such contextual variables include employee size, annual sales, production types (i.e., engineering-to-order, assembly-to-order, make-to-order, and make-to-stock), production process (i.e., project, batch/job shop, flow line/cells layout, and continuous line), and competitive strategies (i.e., cost leadership, broad differentiation, niche differentiation, and lean competitors). The incorporation of these contextual variables will provide much insight into the structural relationships among these constructs. It can also explore value chain flexibility taxonomy based on extensive data analysis rather than primarily based on informal observation as done in previous literature. For example, based on the fit of the environmental requirements for flexibility and the organizational capability of achieving flexibility, taxonomy can be done by clustering analysis among the sub-dimensions of environmental uncertainty and value chain flexibility. Such taxonomy analysis is more than seeking causal relationships among constructs. It configures all the firms into different groups, and further explores the characteristics of each group. Taxonomy analysis can also be used to study the dynamics of a firm's transformation among different groups as strategic group analysis does.

The research has explored one plausible model. Alternative structural models can be tested and their relative efficacy in explaining variation in endogenous variables can be evaluated in future research. For example, an important exogenous variable, environmental uncertainty can be modeled as a moderating variable instead of a direct cause of value chain flexibility. This may shed some light on the nature of the relationship between environmental uncertainty and value chain flexibility. A model generation technique using LISREL may also be applied to seek the fittest model specification but it has an unfavorable tendency of overfitting data.

A longitudinal study will demonstrate clearly the causal relationships among these constructs. A cross-sectional study is a better way to research on the interactive relationship among variables but may not confirm pure causal relationship. The causal direction can be studied by measuring the same set of constructs at different points of time. Therefore, a longitudinal study is necessary to confirm the reliability of measures and to strengthen the causal relationship proposed in the framework.

5.4. CONCLUSION

The environmental changes require a paradigm shift at manufacturing priority and management mind-set. Flexible and agile manufacturing have emerged as the manufacturing paradigm for the 21st century. Thus, value chain flexibility has become critically important for a firm to achieve a sustainable competitive advantage.

The research has clarified the concept of flexibility and its dimensions. Flexibility is the ability to meet a variety of customer needs without excessive cost, time, organizational disruption, or loss of performance. Implicitly, the concept includes three dimensions of flexibility: range, mobility, and uniformity. With these three elements as the underlying dimensions, the study has identified and defined four flexibility components across the whole value chain: product development flexibility, manufacturing flexibility, logistics flexibility, and spanning flexibility. The research has also defined a useful concept, infusion of technology, to explain the attainment of value chain flexibility. Infusion of technology means that technology is fully understood, appreciated, and put to its best use.

The study has developed standard measurement instruments to support empirical value chain flexibility research. 29 scales have been developed to measure value chain flexibility and its related constructs and the relationships between these constructs have been explored. These scales can be used individually or in combinations to answer some research questions with more precision. The addition of these scales improves the inventory of scales for organizational research in manufacturing.

Reliabilities for the scales are, in general, higher (i.e., all greater than 0.82 except the sub-construct of competition uncertainty with an alpha of 0.79) than those reported in other empirical researches in manufacturing. This can be attributed to the implementation of a systematic instrument development methodology to define and derive measures. A review of literature, interviews with four practitioners, Q-sort, expert evaluation with ten professors, and pilot study with 33 firms have helped to enhance the measurement attributes of scales and to gain a better understanding of the behavior of scales before a large-scale administration.

Grounded on a learning, competence, and capability theory, this research has provided a nomological network of constructs to research on the relationships among environmental uncertainty, use of technology, infusion of technology, value chain flexibility, competitive advantage, customer satisfaction, and financial performance. Using LISREL, the results have exhibited that most hypothesized relationships are supported at the significant level of 0.01. A new finding in the research is that the use of technology and infusion of technology are two strong mediating variables of the relationship between environmental uncertainty and value chain flexibility.

This research is only starting point for organizational level research on value chain flexibility and its related constructs. The agenda for future research have been provided. Discussions and recommendations for measurement as well as structural issues have also been offered.

Appendix A: The Literature Review of Manufacturing Flexibility

Table A1: Definitions and Operationalizations of Machine Flexibility

Literature	Definition	Note	Variety	response	perform.
Barad (1992)	Variety of tasks that the machine can perform	Setup time	•	•	
Benjaafar (1994)	Number of machines which can perform a given operation	Different processing cost and/or processing time on different work stations	•		•
Boyer & Leong (1996)	The various types of operations that the machine can perform without requiring a prohibitive effort in switching from one operation to another	Expected output for total flexibility vs. expected output at different flexibility levels, changeover cost	•	•	
Browne et al. (1984)	Ease of making the changes required to produce a given set of part types		•	•	
Carter (1986)	The ability of a machine to perform a variety of processing or assembly operations	Tasks that can be performed by the machine, the range of possible dimensions, the cost and time incurred in making the changeover	•	•	
Chandra & Tombak (1992)	Ease with which machine can make changes in order to produce a given set of part types	Maximum expected contribution of the system, setup time	•	•	
Chen et al. (1992)	Capability of a machine to perform different operations required by a given set of part types	Includes the ability to respond quickly and economically	•	•	
Das & Nagendra (1993)	Ability of a machine or workcenter to perform more than one type of processing operation efficiently	Efficiencies at which machine performs different opertions	•		•
Gupta (1993)	Sum total of a machine's ability to process a variety of different parts effectively	Number of products in the set, degree of component commonality, degree of processing commonality	•		•
Gupta & Somers (1992, 1996)	Variety of operations that the machine can perform without incurring high costs or expending prohibitive amounts of time in switching from one operation to another		•	•	
Hyun & Ahn (1992)	The ability to replace worn out or broken tools, change tools and assemble or mount the required fixture, without interference or long setup time, and the capability to process wider range of products		•	•	
Malhotra & Ritzman (1990)	Number of different items which can be processed by a group, averaged across all groups		•		
Mandelbaum & Brill (1989)	Weighted effectiveness over all the tasks in the set		•		•
Naguar (1992)	Ability of a machine to handle the operations of other machines	Extent to which the systen will be able to execute its intended functions or tasks	•		•
Nandkeolar & Christy (1992)	Number of different operations a machine can perform		•		
Ramasesh & Jayakumar (1991)	Capability to produce any or all of a set of products	Manufacturing system continues to function effectively in response to a wide range of changes	•		•
Sethi & Sethi (1990)	Various types of operations that the machine can perform without requiring a prohibitive effort in switching from one operation to another		•	•	

Table A2: Definitions and Operationalizations of Labor Flexibility

Literature	Definition	Note	Variety	response	perform.
Atkinson (1985)	Functional flexibility concerns the readiness with which the tasks performed by workers can be changed in response to varying business demands		•		
Bobrowski & Park (1993)	Worker efficiency at each work station	Labor efficiency matrix	•		•
Chen et al. (1992)	Ability of the workforce to perform a broad range of manufacturing tasks effectively	Includes the ability to respond quickly and economically	•	•	
Elvers & Trelevan (1985)		Transfer delay time, moderate levels of cross-training with loss of efficiency		•	•
Fryer (1974)	The relative ease with which workers can be transferred between organization units		•	•	
Hyun & Ahn (1992)	The ability of line workers to operate various types of machines, to alter working methods and standards		•		
Kher & malhotra (1994)		Cross-trained workers, worker transfer delays, worker learning effects	•	•	•
Malhotra, Fry, Kher, & Donohue (1993)	Cross-trained workers can perform a variety of tasks in the organization		•		
Malhotra & Kher (1994)	Efficiency of workers varies in performing different tasks in the shop	Transfer delays	•	•	•
Malhotra & Ritzman (1990)	Number of work stations or machines that a worker can operate, averaged across all workers		•		
Nelson (1967)		Labor efficiency matrix	•		•
Park & Bobrowski (1989)	Ability of workers to operate more than one type of machine without any loss in productivity	Labor efficiency matrix	•		•
Ramasesh & Jayakumar (1991)	Capability to use the two types of labor resource interchangeably in the production operations	Manufacturing system continues to function effectively (maximizes revenues net of costs and any assignable penalties) in response to a wide range of changes	•		•
Treleven & Elvers (1985)		Transfer delay time, moderate levels of cross-training with loss of efficiency	•	•	•

Table A3: Definitions and Operationalizations of Material Handling Flexibility

Literature	Definition	Note	Variety	response	perform.
Chatterjee et al. (1984)	Capabilities of the material handling system, linkages between processing centers		•		
Chen et al. (1992)	Capability to trnsport different workpieces from the loading area, through machining centers, to the unloading or storage areas	Includes the ability to respond quickly and economically	•	•	
Gupta & Somers (1992, 1996)	Ability of material handling systems to move different part types effectively through the manufacturing facility, including loading and unloading of parts, inter-machine transportation and storage of parts under various conditions of the manufacturing facility		•		
Sethi & Sethi (1990)	Ability to move different part types efficiently for proper positioning and processing through the manufacturing facility it serves		•		•

Table A4: Definitions and Operationalizations of Routing Flexibility

Literature	Definition	Note	Variety	Response	Perform.
Azzone & Bertele (1989)	Ability to operate with one or more machines out of order				
Benjaafar (1994)	Number of different machines to which a part can be routed		•		
Bernardo & Mohamed (1992)	Ability of the system to continue producing a given part mix despite internal and/or external disturbances				•
Browne et al. (1984)	Ability to ahndle breakdowns and to continue producing the given set of part types				•
Carter (1986)	The ability of the system to operate with one or more machines not working	Alternate routes, alternate sequences, or alternate resources	•		•
Chandra & Tombak (1992)	Capability to continue producing a given set of part types despite machine breakdowns	Maximum expected contribution of the system			•
Chen et al. (1992)	Capability to process a given set of part types using more than one route	Includes the ability to respond quickly and economically	•	•	
Das & Nagendra (1993)	Ability of the system to manufcture products via a variety of different routes	Number of routes, frequency of route usage, differences between routes	•		•
Gerwin (1987, 1993)	Degree to which the operating sequence through which the parts flow cn be changed	The vcariety of parts for which reroutig occurs and the extent to which a part can be rerouted and how long it takes to make the adjustment	•	•	
Gupta & Somers (1992, 1996)	Ability of a manufcturing system to produce a part by alternate routes through the system		•		
Hyun & Ahn (1992)	The ability to vary machine visitation sequences, and to continue producing the given set of part types		•		•
Sethi & Sethi (1990)	Ability of a manufacturing systen to produce a part by alternate routes through the system		•		

Table A5: Definitions and Operationalizations of Volume Flexibility

Literature	Definition	Note	Variety	response	perform.
Azzone & Bertele (1989)	Ability to operate with a low reduction of the operating margin during a decrease in market demand		•		•
Browne et al. (1984)	Ability to use an FMS profitably at different production volumes		•		•
Chen et al. (1992)	Capability of a production system to operate, in the short term, at various batch sizes and/or at different production volumes economically	The ability to respond quickly and economically	•	•	
Cox (1989)	The capacity to quickly expand the quantities of aa given product mix produced		•		
Dixon, Nanni, & Vollmann (1990)	Ability to vary aggregate output from one period to the next		•		
Gerwin (1987)	Ease with which changes in the aggregate amount of production of a manufacturing process can be achieved		•	•	
Gerwin (1993)	Permits increases or decreases in the aggregate production level	Amount of change and length of time to make a change	•	•	
Gupta & Somers (1992, 1996)	Ability of a manufacturing system to be operated profitably at different overall output levels		•		•
Hyun & Ahn (1992)	The ability to accelerate production very quickly and juggle the orders to meet demands for usually rapid delivery, and to operate profitably at different production volumes		•	•	•
Noble (1995)	Ability to ramp up or decrease output levels as needed		•		
Ramasesh & Jayakumar (1991)	Costs associated with the production level of the different items is the same over the full range of their production volume	Manufacturing system continues to function effectively (maximizes revenues net of costs and any assignable penalties) in response to a wide range of changes	•	•	•
Sethi & Sethi (1990)	Ability of a manufacturing system to be operated profitably at different overall output levels		•		•
Slack (1983)	Ability to change the volume of output	Includes the range of states a system can adopt, the cost of moving from one state to another, and the time which is necessary to move from one state to another	•	•	
Slack (1987)	The ability to change the level of aggregated output	Includes range of states and the ease with which it moves from one state to another, in terms of cost, time or organization disruption	•	•	
Suarez et al. (1995)	Ability to vary production with no detrimental effect on efficiency (cost) and quality		•		•
Suarez et al. (1996)	Ability to shrink and expand production volume widely and still keep costs low and quality level high		•		•

Table A6: Definitions and Operationalizations of Mix Flexibility

Literature	Definition	Note	Variety	response	perform.
Azzone & Bertele (1989)	Ability to operate product changes among a given mix with low setup times		•	•	
Boyer & leong (1996)	Relates to the set of part types the system can produce without major setups - the ability to build different products in the same plant at the same time	Expected output for total flexibility vs expected output at different flexibility levels	•		•
Browne et al. (1984)	Ability to produce a given set of part types, each possibly using different materials, in several ways		•		
Carter (1986)	The ability of the system to produce simultaneously or periodically, multiple products in a steady state operating mode	Number of different parts that can be produced in the system while maintaining efficient production, cost and time of making the changeovers	•	•	•
Das & Nagendra (1993)	The different products that the plant is able to manufacture, and their relative production volumes	Product differentiation	•		
Dixon (1992)	The ability to manufacture a variety of products within a short period of time and without major modification of existing facilities	The average number of different product characteristics made simultaneously, average number of changeovers, and the cost and time of changeovers	•	•	
Dixon, Nanni, & Vollmann (1990)	Ability to manufacture a variety of products in a shot time		•		
Ettlie & Pennerhahn (1994)	Ease of switching from one state to another in productive capacity for joint production of several products	Ratios that included number of part types or part families to changeover time	•	•	
Gerwin (1987)	Ability of a manufacturing process to produce a number of different products at the same point in time		•		
Gerwin (1993)	Able to handle a range of products or variants with fast setups	Extent of product variety and setup time	•	•	
Gupta & Somers (1992, 1996)	Ability of a manufacturing system to produce a set of part types without major setups		•		
Hyun & Ahn (1992)	The adaptability of a manufacturing system to changes in product mix (changes in relative volumes of products or production)		•		
Jordan & Graves (1995)	Being able to build different types of products in the same plant or production facility at the same time	Sales under total flexibility vs sales under different levels of flexibility	•		•
Noble (1995)	Ability to respond to frequent product mix changes		•		
Sethi & Sethi (1990)	Set of part types that the system can produce without major setups		•		
Slack (1983)	Ability to manufacture a particular mix of products within the minimum planning period used by the company	The range of states a system can adopt, the cost and time of moving from one state to another	•	•	
Slack (1987)	The ability to change the range of products made within a given time period	Includes range of states and the ease with which it moves from one state to another in terms of cost, time or organization disruption	•	•	
Suarez, et al. (1995, 1996)	Ability to produce a number of heterogeneous products at any point in time	The number and heterogeneity of products produced by the system	•		
Upton (1995)	Ability to change quickly among a group of known products	The breadth of paper grades a plant could produce and the changeover time, no relationship between mobility and range	•	•	•
Upton (1997)	Ability to produce large variation on key product characteristics	Metric of difference between products along one product characteristic	•		•

Table A7: Definitions and Operationalizations of Product Flexibility

Literature	Definition	Note	Variety	response	perform.
Azzone & Bertele (1989)	Ability to introduce new products into production with low costs		•	•	
Browne et al. (1984)	Ability to changeover to produce a new set of products very economically and quickly		•	•	
Chen et al. (1992)	Capability to changeover to introduce new product	The ability to respond quickly and economically	•	•	
Cox (1989)	The ability to quickly change the types of products produced in the plant by adding new ones		•	•	
Dixon (1992)	The ability to introduce new products	The number of samples and new product introductions and the average costs of introducing new products into full-scale production	•	•	
Dixon, Nanni, & Vollmann (1990)	The ability to introduce new products rapidly, and to do so at relatively low cost		•	•	
Ettlie & Pennerhahn (1994)	Changes in the parts planned for the system	Ratios that included number of part types or part families to changeover time	•		
Gerwin (1987)	Ability of a process to deal with additions to and subtractions from the mix over time		•		
Gerwin (1993)	Ability to quickly substitute new products for those currently being offered	The variety of major design changes which can be accommodated and the portion of new product introduction time which occurs in the manufacturing function	•	•	
Gupta & Somers (1992, 1996)	Ease with which new parts can be added or substituted for existing parts, i.e., the ease with which the current part mix can be changed at relatively low cost in a short period		•	•	
Hyun & Ahn (1992)	The ability to take the lead in new product introduction		•	•	
Noble (1995)	Ability to successfully develop and introduce new products	Rapidity and frequency of new product introduction	•	•	
Sethi & Sethi (1990)	Ease with which new parts can be added or substituted for existing parts		•	•	
Slack (1983)	Ability to make something novel	The range of states a system can adopt, the cost of moving from one state to another, and the time which is necessary to move from one state to another	•	•	
Slack (1987)	The ability to introduce novel products	Includes range of states and the ease with which it moves from one state to another, in terms of cost, time or organization disruption	•	•	
Suarez et al. (1995, 1996)	Ability to introduce new products quickly	The time-to-market from earliest stage of design to production of salable product	•	•	

Table A8: Definitions and Operationalizations of Modification Flexibility

Literature	Definition	Note	Variety	response	perform.
Chen et al. (1992)	Capability to respond to customer requests for design changes	The ability to respond quickly and economically	•	•	
Cox (1989)	The ability to quickly change the types of products produced in the plant by modifying existing products		•	•	
Dixon (1992)	Ability to better meet customer needs by modifying existing products	The number of products which were either new combinations of existing characteristics or had new processes applied to them and the average costs of introducing modified products into full-scale production	•	•	
Dixon, Nanni, & Vollmann (1990)	Ability to modifying existing products. Product is considered new when its basic functional characteristics differ from those of any product offered by the company. A modification is a product feature whose characteristics permit the basic function of the product to be accomplished in a better way		•		
Ettlie & Pennerhahn (1994)	Changes in the part families planned for the system		•		
Gerwin (1987)	Ability of a process to make functional changes in the product		•		
Gerwin (1993)	Ability to implement minor design changes in a given product	How many different kinds of minor changes are possible and the speed with which a given change is accomplished	•	•	
Hyun & Ahn (1992)	The ability to handle difficult, nonstandard order; it encompasses the ability to make functional or engineering design changes		•		
Noble (1995)	Ability to customize products		•		
Sethi & Sethi (1990)	Set of part types that the system can produce without major setups		•		
Slack (1987)	The ability to modify existing products	Includes range of states and the ease with which it moves from one state to another, in terms of cost, time or organization disruption	•	•	

Table A9: Potential Item Measures for Machine Flexibility

Type of flexibility	Dimension	Items	Literature
Machine flexibility	Variety (range)	MF1: A typical machine can perform a large percentage of the total number of operations in the shop MF2: A large number of operations can be performed by more than one machine MF3: Machines can perform many types of operations MF4: The number of different operations that a typical machine can perform is high MF5: A typical machine can use many different tools MF6: The number of operations that a machine can perform is high MF7: The Operations which machines perform are very similar to one another MF8: Machines often become obsolete when new operations are required MF9: Machines can perform a wide variety of operations MF10: Machines can perform operations which differ greatly from one another	Barad (1992) Benjaafar (1994) Carter (1986) Sethi & Sethi (1990) Gupta (1993)
	Response (mobility)	MF11: Machine set-ups between operations are quick MF12: Machine changeovers between operations use a lot of available capacity MF13: Machine changeovers between operations are not expensive MF14: Machine tools can be changed or replaced quickly MF15: Machine changeovers are easy	Chen et al (1992) Boyer & Leong (1996) Carter (1986)
	Performance (uniformity)	MF16: Machines are equally efficient for all processing operations MF17: Machines are equally effective, in terms of quality, for all processing operations MF18: Machines are equally effective, in terms of productivity, for all processing operations MF19: Machines are equally reliable for all processing operations MF20: All machines achieve similar performance when performing operations	Mandelbaum & Brill (1989) Ramasesh & Jayakumar (1991) Benjaafar (1994)

Table A10: Potential Item Measures for Labor Flexibility

Type of flexibility	Dimension	Items	Literature
Labor flexibility	Variety (range)	LF1: A typical worker can perform a large percentage of the total number of operations in the shop LF2: A large number of operations can be performed by more than one worker LF3: workers can perform many types of operations LF4: The number of different operations that a typical worker can perform is high LF5: A typical workers can use many different tools LF6: The number of operations that a worker can perform is high LF7: The Operations which workers perform are very similar to one another LF8: Cross-trained workers can perform a broad range of manufacturing tasks effectively in the organization LF9: Workers can operate various types of machines, to alter working methods and standards LF10: Workers can perform operations which differ greatly from one another	Hyun & Ahn (1992) Malhotra, Fry, Kher & Donohue (1993) Chen, et al (1992)
	Response (mobility)	LF11: The tasks performed by workers can be changed easily in response to varying business demands LF12: Workers' efficiency is similar at each station LF13: Workers can be transferred easily between organizational units LF14: the ability to use labor resource interchangeably in the production operations	Atkinson (1985) Bobrowski & Park (1993) Fryer (1974)
	Performance (uniformity)	LF15: Workers are equally efficient for all processing operations LF16: Workers are equally effective, in terms of quality, for all processing operations LF17: Workers are equally effective, in terms of productivity, for all processing operations LF18: All workers achieve similar performance when performing operations	Malhotras & Kher (1994); Malhotra & Ritzman (1990)

Table A11. Potential Item Measures for Material Handling Flexibility

Type of flexibility	Dimension	Items	Literature
Material Handling flexibility	Variety (range)	MH1: A typical material handling system can perform a large percentage of the total number of parts in the shop MH2: A large number of parts can be performed by more than one material handling path MH3: The number of different parts that a typical material handling system can perform is high MH4: A typical material system can link different processing centers MH5: A typical material handling systems can move different workpieces from the loading area, through machining centers, to the unloading or storage areas MH6: Material handling system can move different part types through the manufacturing facility MH7: The parts which material handling systems can transport are very similar to one another MH8: Material handling system can move different part types for proper positioning and processing through the manufacturing facility it serves MH9: Material handling system can move different part types under various conditions of the manufacturing facility MH10: Material handling system can transport parts which differ greatly from one another	Chen et al. (1992); Gupta & Somers (1996)
	Response (mobility)	MH11: Material handling changeovers between parts are quick MH12: Material handling changeovers between parts use a lot of available capacity MH13: Material handling changeovers between parts are not expensive MH14: Material handling tools can be changed or replaced quickly	Atkinson (1985) Bobrowski & Park (1993)
	Performance (uniformity)	MH15: Material handling are equally efficient for all parts transported MH16: Material handling are equally effective, in terms of quality, for all parts transported MH17: Material handling are equally effective, in terms of productivity, for all parts transported MH18: All material handling system achieve similar performance when performing transportation	Malhotras & Kher (1994);

Table A12: Potential Item Measures for Routing Flexibility

Type of flexibility	Dimension	Items	Literature
Routing flexibility	Variety (range)	RF1: A typical route can perform more than a part in the shop RF2: A large number of parts can be performed by more than one route RF3: The system can continue producing a given part mix despite internal and/or external disturbances RF4: The number of different machines that a typical part can routed is high RF5: A typical parts can use many different routes RF6: The system can operate with one or more machine breakdown RF7: The different routes are mainly due to the duplication of machines RF8: Degree to which the operating sequence through which the parts flow can be changed RF9: Ability to adjust the sequence of machines through which a part flows RF10: Routes that can perform the same parts differ greatly from one another	Chen et al. (1992); Gupta & Somers (1996)
	Response (mobility)	RF11: New route setups are quick RF12: New routes use a lot of available capacity RF13: New route setups are not expensive RF14: Machine visitation sequence can be changed or replaced quickly RF15: Route changeovers are easy	Bobrowski & Park (1993) Fryer (1974)
	Performance (uniformity)	RF16: Operations are equally efficient for all possible routes RF17: Operations are equally effective, in terms of quality, for all routes RF18: Operations are equally effective, in terms of productivity, for all routes RF19: Operations are equally reliable for all routes RF20: All routes achieve similar performance when performing operations	Malhotra & Ritzman (1990)

Appendix B: Cohen's Kappa and Moore and Benbasat Coefficients

The following example will to describe the Cohen's Kappa measure of agreement. Two judges independently classified a set of N components as either acceptable or rejectable. After the work was finished the following table was constructed:

		Judge 1		
		Acceptable	Rejectable	Totals
Judge 2	Acceptable	X_{11}	X_{12}	X_{1+}
	Rejectable	X_{21}	X_{22}	X_{2+}
	Totals	X_{+1}	X_{+2}	N

Xij = the number of components in the i[th] row and j[th] column, for i,j = 1,2.

The above table can also be constructed using percentages by dividing each numerical entry by N. For the population of components, the table will look like:

		Judge 1		
		Acceptable	Rejectable	Totals
Judge 2	Acceptable	P_{11}	P_{12}	P_{1+}
	Rejectable	P_{21}	P_{22}	P_{2+}
	Totals	P_{+1}	P_{+2}	N

$$k = \frac{\Sigma_i P_{ii} - \Sigma_i (P_{i\cdot}\, P_{\cdot i})}{1 - \Sigma_i (P_{i\cdot}\, P_{\cdot i})}$$

Pij = the percentage of components in the i[th] row and j[th] column.

We will use this table of percentages to describe the Cohen's Kappa coefficient of agreement. The simplest measure of agreement is the proportion of components that were classified the same by both judges, i.e., $\Sigma_i P_{ii} = P_{11} + P_{22}$. However, Cohen suggested comparing the actual agreement, $\Sigma_i P_{ii}$, with the chance of agreement that would occur if the row and columns are independent, i.e., $\Sigma_i P_{i+}P_{+i}$. The difference between the actual and chance agreements, $\Sigma_i P_{ii} - \Sigma_i P_{i+}P_{+i}$, is the percent agreement above that which is due to chance. This difference can be standardized by dividing it by its maximum possible value, i.e., $100\% - \Sigma_i P_i + P_{+i} = 1 - \Sigma_i P_i + P_{+i}$. The ratio of these is denoted by the Greek letter kappa and is referred to as Cohen's kappa.

Thus, Cohen's Kappa is a measure of agreement that can be interpreted as the proportion of joint judgement in which there is agreement after chance agreement is excluded. The three basic assumptions for this agreement coefficient are: 1) the units are independent, 2) the categories of the nominal scale are independents, mutually exclusive, and 3) the judges operate independently. For any problem in nominal scale agreement between two judges, there are only two relevant quantities:

p_o= the proportion of units in which the judges agreed
p_c= the proportion of units for which agreement is expected by chance

Like a correlation coefficient, *k*=1 for complete agreement between the two judges. If the observed agreement is greater than or equal to chance K <= 0. The minimum value of k occurs when $\Sigma P_{ii} = 0$, i.e.,

$$\min(k) = \frac{-\Sigma_i (P_{i\cdot} P_{\cdot i})}{1 - \Sigma_i (P_{i\cdot} P_{\cdot i})}$$

When sampling from a population where only the total N is fixed, the maximum likelihood estimate of *k* is achieved by substituting the sample proportions for those of the population. The formula for calculating the sample kappa (*k*) is:

$$k = \frac{N_i Xii - \Sigma_i (X_{i\cdot} X_{\cdot i})}{N^2 - \Sigma_i (X_{i\cdot} X_{\cdot i})}$$

For kappa, no general agreement exists with respect to required scores. However, recent studies have considered scores greater than 0.65 to be acceptable (e.g. Vessey & Webber, 1984; Jarvenpaa 1989; Todd & Benbasat, 1991). Landis and Koch (1977) have provided a more detailed guideline to interpret kappa by associating different values of this index to the degree of agreement beyond chance. The following guideline is suggested:

Value of Kappa	Degree of Agreement Beyond Chance
.76 - 1.00	Excellent
.40 - .75	Fair to Good (Moderate)
.39 or less	Poor

A second overall measure of both the reliability of the classification scheme and the validity of the items was developed by Moore and Benbasat (1991). The method required analysis of how many items were placed by the panel of judges for each round within the target construct. In other words, because each item was included in the pool explicitly to measure a particular underlying construct, a measurement was taken of the overall frequency with which the judges placed items within the intended theoretical construct. The higher the percentage of items placed in the target construct, the higher the degree of inter-judge agreement across the panel that must have occurred.

Moreover, scales based on categories that have a high degree of correct placement of items within them can be considered to have a high degree of construct validity, with a high potential for good reliability scores. It must be emphasized that this procedure is more a qualitative analysis than a rigorous quantitative procedure. There are no established guidelines for determining good levels of placement, but the matrix can be used to highlight any potential problem areas. The following exemplifies how this measure works.

Item Placement Scores

CONSTRUCTS		ACTUAL						
		A	B	C	D	N/A	Total	% Hits
THEORETICAL	A	26	2	1	0	1	30	87
	B	8	18	4	0	0	30	60
	C	0	0	30	0	0	30	100
	D	0	1	0	28	1	30	93

Item Placements: 120 Hits: 102 Overall "Hit Ratio": 85%

The item placement ratio is an indicator of how many items were placed in the intended, or target, category by the judges. As an example of how this measure could be used, consider the simple case of four theoretical constructs with ten items developed for each construct. With a panel of three judges, a theoretical total of 30 placements could be made within each construct. Thereby, a theoretical versus actual matrix of item placements could be created as shown in the figure below (including an ACTUAL "N/A: Not Applicable" column where judges could place items which they felt fit none of the categories).

Examination of the diagonal of the matrix shows that with a theoretical maximum of 120 target placements (four constructs at 30 placements per construct), a total of 102 "hits" were achieved, for an overall "hit ratio" of 85%. More important, an examination of each row shows how the items created to tap the particular constructs are actually being classified. For example, row C shows that all 30-item placements were within the target construct, but that in row B, only 60% (18/30) were within the target. In the latter case, 8 of the placements were made in construct A, which might indicate the items underlying these placements are not differentiated enough from the items created for construct A. This finding would lead one to have confidence in scale based on row C, but be hesitant about accepting any scale based on row B. In an examination of off-diagonal entries indicate how complex any construct might be. Actual constructs based on columns with a high number of entries in the off diagonal might be considered too ambiguous, so any consistent pattern of item misclassification should be examined.

Appendix C: Questionnaire for Pilot Study

A NATIONAL SURVEY OF MANUFACTURING EXECUTIVES ON VALUE CHAIN FLEXIBILITY

... About the Environments of Your Firm

With regard to the perceived environmental uncertainty of your firm, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1 Strongly disagree, 2 Disagree, 3 Neutral, 4 Agree, 5 Strongly agree

Customers' tastes are unpredictable	1	2	3	4	5
Customers' requirements regarding product features are difficult to forecast	1	2	3	4	5
Customers order different product combinations over the year	1	2	3	4	5
Customers' product preferences change over the year	1	2	3	4	5
Product demand from customers fluctuates over the year	1	2	3	4	5
The properties of materials delivered by suppliers can vary greatly within the same batch	1	2	3	4	5
The quantity of materials from suppliers can easily go wrong	1	2	3	4	5
Suppliers' engineering level is unpredictable	1	2	3	4	5
Suppliers' product quality is unpredictable	1	2	3	4	5
The timing of materials from suppliers can easily go wrong	1	2	3	4	5
Technology often changes in our industry	1	2	3	4	5
The technology in our industry is changing significantly	1	2	3	4	5
Technological changes provide large opportunities in our industry	1	2	3	4	5
Many new product ideas come from technological breakthroughs in our industry	1	2	3	4	5
New products substitute for old products frequently due to improving technology	1	2	3	4	5
Actions of competitors are unpredictable	1	2	3	4	5
Competition threatens the survival of our firm	1	2	3	4	5
We have many foreign competitors	1	2	3	4	5
Competitors come from different industries	1	2	3	4	5
Competitors often introduce new products unexpectedly	1	2	3	4	5

... About Use of Technology in Your Firm

With regard to the typical use of Advanced Manufacturing Technologies (AMT) and Information Technologies (IT) in your firm, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1 Strongly disagree, 2 Disagree, 3 Neutral, 4 Agree, 5 Strongly agree

We use AMT to aid product and process design	1	2	3	4	5
We use AMT to improve manufacturing	1	2	3	4	5
We use AMT to integrate manufacturing systems	1	2	3	4	5
We use AMT to plan and control material requirements	1	2	3	4	5
We use AMT to control production systems such as Just-In-Time	1	2	3	4	5
We use AMT to manage the interfaces of manufacturing and marketing	1	2	3	4	5
We use IT to provide timely information	1	2	3	4	5
We use IT to monitor operations	1	2	3	4	5
We use IT to analyze problems in daily operations	1	2	3	4	5
We use IT as a strategic weapon to gain competitive advantage	1	2	3	4	5
We use IT to exchange and share information in work group	1	2	3	4	5
We use IT to keep connection with key customers and suppliers	1	2	3	4	5

... About Managerial Practices of Technology in Your Firm

With regard to your firm's typical managerial practices of technology, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1 Strongly disagree, 2 Disagree, 3 Neutral, 4 Agree, 5 Strongly agree

We do product and process design concurrently	1	2	3	4	5
We involve process engineers early in product development	1	2	3	4	5
We involve customers early in product development	1	2	3	4	5
We involve suppliers in the design of components	1	2	3	4	5
We practice job rotation between design and manufacturing	1	2	3	4	5
We improve our operations with setup time reductions	1	2	3	4	5
We improve our operations with preventive maintenance	1	2	3	4	5
We improve our operations with quality at the source	1	2	3	4	5
We improve our operations with cells layout	1	2	3	4	5
We improve our operations with Just-In-Time principles	1	2	3	4	5
We improve our operations with pull production	1	2	3	4	5
We involve multiple functions in adopting technology	1	2	3	4	5
We involve shop floor employees in decision making	1	2	3	4	5
We integrate problem-solving efforts by cross-disciplinary teams	1	2	3	4	5
We integrate suppliers' operations with Just-In-Time delivery	1	2	3	4	5
We integrate customers' ideas in product development	1	2	3	4	5

... About Infusion of Technology in Your Firm

With regard to the infusion/incorporation of technology in your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree

Our employees perceive that technology helps them to create new ideas	1	2	3	4	5
Our employees perceive that technology helps them to try out new ideas	1	2	3	4	5
Our employees perceive that technology help them to solve problem creatively	1	2	3	4	5
Our employees perceive that technology help them to innovate their work	1	2	3	4	5
Our employees perceive that technology saves them time	1	2	3	4	5
Our employees perceive that technology increases their productivity	1	2	3	4	5
Our employees perceive that technology allows them to accomplish more work	1	2	3	4	5
Our employees perceive that technology makes work more efficient	1	2	3	4	5
Employees feel their tasks are significant	1	2	3	4	5
Employees have autonomy in their work	1	2	3	4	5
Employees are responsible for outcome of their work	1	2	3	4	5
Employees look forward to being with their work group	1	2	3	4	5
Employees have strong feeling of belonging to our organization	1	2	3	4	5
Our employees learn from each other by using technology	1	2	3	4	5
Our employees learn by doing to gain valuable technical know-how	1	2	3	4	5
Our employees learns from documents and manuals to enrich their knowledge base about technology	1	2	3	4	5
Our employees exchange and combine knowledge of technology through documents and meetings	1	2	3	4	5
We often summarize successful and unsuccessful approaches to technology implementation	1	2	3	4	5
Management representatives from different departments have periodic debriefings about technology implementation	1	2	3	4	5

... About Product Development Flexibility of Your Firm

With regard to the flexible product development capability in your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement compared with competitors.

1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree

We can develop multiple product concepts for the same customer requirements	1	2	3	4	5
We can develop multiple product concepts along the different stages of product development	1	2	3	4	5
We evaluate multiple alternatives over time in product development decision (use set-based approach)	1	2	3	4	5
We can quickly capture trends for customer requirements	1	2	3	4	5
We can quickly transform customer requirements to product concepts	1	2	3	4	5
We can quickly convert product ideas to product concepts	1	2	3	4	5
We can keep multiple product prototypes for the same customer requirements	1	2	3	4	5
We can develop a prototype for each product concept	1	2	3	4	5
We can easily modify existing product prototype for new product requirements	1	2	3	4	5
We can build product prototype quickly	1	2	3	4	5
We can quickly transform product concepts to product prototypes	1	2	3	4	5
We can develop multiple product prototypes cost-effectively	1	2	3	4	5
We can quickly respond to customer requests for design changes	1	2	3	4	5
We can easily modify products to a specific customer need	1	2	3	4	5
We can better meet customer needs by quickly modifying existing products	1	2	3	4	5
We can modify products by adding new parts or substituting old parts easily	1	2	3	4	5
We can modify existing products quickly	1	2	3	4	5
We can modify existing products inexpensively	1	2	3	4	5
We can quickly introduce a new product into the market	1	2	3	4	5
We take the lead in new product introduction	1	2	3	4	5
We can quickly substitute new products for those currently being produced	1	2	3	4	5
We can launch new product easily	1	2	3	4	5
We can launch new product inexpensively	1	2	3	4	5

... About Manufacturing Flexibility of Your Firm

With regard to the flexible manufacturing capability in your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement compared with competitors.

1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree

Machine can be replaced quickly	1	2	3	4	5
A typical machine can perform many types of operations economically	1	2	3	4	5
A typical machine can use many different tools effectively	1	2	3	4	5
Machines often become obsolete when new operations are required	1	2	3	4	5
Machine tools can be changed or replaced quickly	1	2	3	4	5
Machine changeovers are easy	1	2	3	4	5
Workers can perform many types of operations effectively	1	2	3	4	5
A typical worker can use many different tools effectively	1	2	3	4	5

Cross-trained workers can perform a broad range of manufacturing tasks effectively in the organization	1	2	3	4	5
Workers can operate various types of machines	1	2	3	4	5
Workers can be transferred easily between organizational units	1	2	3	4	5
A typical material handling system can handle different parts	1	2	3	4	5
A typical material handling system can link different processing centers	1	2	3	4	5
Material handling system can move different part types through manufacturing facilities	1	2	3	4	5
Material handling changeovers between parts are quick	1	2	3	4	5
Material handling tools can be changed or replaced quickly	1	2	3	4	5
A typical part operation can be routed to different machines	1	2	3	4	5
A typical part can use many different routes	1	2	3	4	5
The system can operate with back-up routes in case machines break down	1	2	3	4	5
The operating sequence through which the parts flow can be changed	1	2	3	4	5
Machine visitation sequence can be changed or replaced quickly	1	2	3	4	5
Route changeovers are easy	1	2	3	4	5
We can operate efficiently at different levels of output	1	2	3	4	5
We can operate profitably at different production volumes	1	2	3	4	5
We can operate at various batch sizes economically	1	2	3	4	5
We can quickly change the quantities for our products produced	1	2	3	4	5
We can vary aggregate output from one period to the next	1	2	3	4	5
We can change the aggregate volumes of a manufacturing process easily	1	2	3	4	5
We can produce a wide variety of products	1	2	3	4	5
We can produce different part types without major changeover	1	2	3	4	5
We can build different products in the same plants at the same time	1	2	3	4	5
We can produce, simultaneously or periodically, multiple products in a steady-state operating mode	1	2	3	4	5
We can vary product combinations from one period to the next	1	2	3	4	5
We can changeover quickly from one product to another	1	2	3	4	5

... About Logistics Flexibility of Your Firm

With regard to the flexible logistics capability in your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement compared with competitors.

1	2	3	4	5
Strongly disagree	Disagree	Neutral	Agree	Strongly agree

We can deliver multiple kinds of materials in responding to mixed-model operations	1	2	3	4	5
Our inbound transportation can deliver the variety of shipments on time	1	2	3	4	5
We pick and assemble multiple production orders accurately and quickly at the material warehouse	1	2	3	4	5
We have accurate records of inventory quantities and locations at the material warehouse	1	2	3	4	5
We can quickly move materials to the correct production location	1	2	3	4	5
Our inbound supply systems is effective for all shipments	1	2	3	4	5
We can quickly obtain multiple kinds of materials that meet specification	1	2	3	4	5
We can obtain multiple batch sizes of materials from suppliers quickly	1	2	3	4	5
Purchasing can fill multiple requests quickly	1	2	3	4	5
Purchasing keeps close communication with suppliers	1	2	3	4	5
Suppliers cooperatively work on product and process specifications with us	1	2	3	4	5
We streamline purchasing ordering, receiving and other paperwork easily and effectively	1	2	3	4	5
We pick and assemble multiple customer orders accurately and quickly at the finished goods warehouse	1	2	3	4	5
We can provide multiple kinds of product packaging effectively at the finished goods warehouse	1	2	3	4	5
We can use multiple transportation modes to meet schedule for deliveries	1	2	3	4	5
We can quickly and accurately label finished products	1	2	3	4	5
We have accurate records of quantities and locations of finished goods	1	2	3	4	5
We can take different customer orders with accurate available-to-promise	1	2	3	4	5
We can quickly respond to multiple customers' delivery time requirements	1	2	3	4	5
We can effectively respond to multiple customers' requirements in terms of repair, installation and maintenance of products	1	2	3	4	5
We can negotiate with customers in terms of prices and delivery time effectively through long term relationships	1	2	3	4	5
We involve customers to improve our services effectively	1	2	3	4	5
We quickly respond to feedback from retailers and consumers effectively	1	2	3	4	5

... About Spanning Flexibility of Your Firm

With regard to the boundary spanning flexibility in your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement compared with competitors.

1	2	3	4	5
Strongly disagree	Disagree	Neutral	Agree	Strongly agree

We timely collect and disseminate the information along the supply chain	1	2	3	4	5
We have joint production planning and scheduling among suppliers, manufacturing, marketing, distributors	1	2	3	4	5

We link information systems so that each member of a supply chain knows the other's requirements and status	1	2	3	4	5
Information flows quickly along value chain	1	2	3	4	5
Accurate information is usually available	1	2	3	4	5
We provide the information that we need to make effective decisions	1	2	3	4	5
We continuously renew our competence to meet changing customer needs	1	2	3	4	5
We take some actions quickly based on all the information continuously collected along the value chain	1	2	3	4	5
We continuously develop strategy based on maintaining a good relationship with our major suppliers	1	2	3	4	5
We continuously experiment, learn, and improve our practices to improve productivity	1	2	3	4	5
We quickly develop strategy based on the coordination and integration of information along the value chain	1	2	3	4	5
We continuously experiment, learn, and improve our practices to improve customer satisfaction	1	2	3	4	5

... About Competitive Advantage of Your Firm

With regard to the advantages of your organization compared with primary competitors, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1 Strongly disagree — 2 Disagree — 3 Neutral — 4 Agree — 5 Strongly agree

We offer competitive prices	1	2	3	4	5
We are able to compete based on our prices	1	2	3	4	5
We are able to offer prices as low or lower than our competitors	1	2	3	4	5
We produce products efficiently	1	2	3	4	5
We provide customized products	1	2	3	4	5
We alter our product offerings to meet client needs	1	2	3	4	5
We respond well to customer demand for "new" features	1	2	3	4	5
We provide many new products to markets	1	2	3	4	5
We deliver accurate quantity of products needed	1	2	3	4	5
We deliver the kind of products needed	1	2	3	4	5
We deliver customer order on time	1	2	3	4	5
We provide dependable delivery	1	2	3	4	5
We are able to compete based on quality	1	2	3	4	5
We offer products that are highly reliable	1	2	3	4	5
We offer products that are very durable	1	2	3	4	5
We offer high quality products to our customer	1	2	3	4	5
We deliver product to market quickly	1	2	3	4	5
We are first in the market	1	2	3	4	5
We have time-to-market lower than industry average	1	2	3	4	5
We have fast product development	1	2	3	4	5

... About Customer Satisfaction to Your Firm

With regard to the customer satisfaction to your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1 Strongly disagree — 2 Disagree — 3 Neutral — 4 Agree — 5 Strongly agree

We have high customer retention rate	1	2	3	4	5
Customers are satisfied with ratio of price and function of our products	1	2	3	4	5
Customers perceive they receive their money's worth when they purchase our products	1	2	3	4	5
Our customers are satisfied with the quality of our products	1	2	3	4	5
Our firm have good reputation for our products	1	2	3	4	5
Our customers are loyal to our products	1	2	3	4	5

... About Performance of Your Firm

With regard to the overall performance of your organization compared with primary competitors, please circle the appropriate numbers which best indicate your perception of the level of performance.

1 Unacceptable — 2 Below satisfactory — 3 Satisfactory — 4 Above satisfactory — 5 Superior

Sales growth position relative to competition	1	2	3	4	5
Market share gains relative to competition	1	2	3	4	5
Return on investment relative to competition	1	2	3	4	5
Financial liquidity position relative to competition	1	2	3	4	5
Profit margin relative to competition	1	2	3	4	5
Overall competitive position	1	2	3	4	5

... General Information about Your Firm

The following questions are about general information of your firm. Please circle the appropriate one that best indicates your firm's situation.

Please indicate which SIC group your firm is in.
_Measuring/analyzing instruments _Fabricated metal products
_Industrial/commercial machinery _Transportation equipment
_Electronic/electrical equipment _Chemicals/allied products

The number of employees working in your plant(s).
_ 1-99 _ 100-249 _ 250-499 _ 500-999 _1000 +

The average annual sales $ (in Millions) for your plant(s).
__ 0.5-5 __5-50 __ 50-100 __100-500 __ 500 +

What's your primary production type?
___Engineering-to-order ____ Make-to-order
___Assembly-to-order ____ Make-to-stock

What's your primary production process?
___ Project ____ Batch /job shop
___ Flow line /cells layout ____ Continuous line

What's your present job title?
____CEO/ president _____Vice President
____ Manager _____Director

What are your primary product characteristics?
____One of a kind _____ Multiple products
____Few major products _____ Standardized products

What's your primary competitive strategy?
____ Cost leadership _____ Broad differentiation
____Niche differentiation _____ Lean Competitors

Would you like to receive the summary results of this research?
___ Yes ____ No (if yes, please include your business card in the return envelope)

Appendix D: Questionnaire for large Scale Survey

A NATIONAL SURVEY OF MANUFACTURING EXECUTIVES ON VALUE CHAIN FLEXIBILITY

... About the Environments of Your Firm

With regard to the perceived environmental uncertainty of your firm, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree

Customers' tastes are unpredictable	1	2	3	4	5
Customers' requirements regarding product features are difficult to forecast	1	2	3	4	5
Customers order different product combinations over the year	1	2	3	4	5
Customers' product preferences change over the year	1	2	3	4	5
Product demand from customers fluctuates over the year	1	2	3	4	5
The properties of materials delivered by suppliers can vary greatly within the same batch	1	2	3	4	5
The quantity of materials from suppliers can easily go wrong	1	2	3	4	5
Suppliers' engineering level is unpredictable	1	2	3	4	5
Suppliers' product quality is unpredictable	1	2	3	4	5
Suppliers' delivery time is unpredictable	1	2	3	4	5
Technology often changes in our industry	1	2	3	4	5
The technology in our industry is changing significantly	1	2	3	4	5
Technological changes provide large opportunities in our industry	1	2	3	4	5
Technological breakthroughs in our industry lead new product ideas	1	2	3	4	5
Improving technology generates new products frequently	1	2	3	4	5
Actions of competitors are unpredictable	1	2	3	4	5
Competition is intensified in our industry	1	2	3	4	5
Competitors come from different countries	1	2	3	4	5
Competitors come from different industries	1	2	3	4	5
Competitors often introduce new products unexpectedly	1	2	3	4	5

... About Use of Technology in Your Firm

With regard to the typical use of Advanced Manufacturing Technologies (AMT) and Information Technologies (IT) in your firm, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree

We use AMT to aid product and process design	1	2	3	4	5
We use AMT to improve manufacturing	1	2	3	4	5
We use AMT to integrate manufacturing systems	1	2	3	4	5
We use AMT to plan and control manufacturing requirements	1	2	3	4	5
We use AMT to control production systems such as Just-In-Time	1	2	3	4	5
We use AMT to manage the interfaces of manufacturing and marketing	1	2	3	4	5
We use IT to provide timely information	1	2	3	4	5
We use IT to monitor operations	1	2	3	4	5
We use IT to analyze problems in daily operations	1	2	3	4	5
We use IT as a strategic weapon to gain competitive advantage	1	2	3	4	5
We use IT to exchange and share information in work group	1	2	3	4	5
We use IT to keep connection with key customers and suppliers	1	2	3	4	5

... About Managerial Practices of Technology in Your Firm

With regard to your firm's typical managerial practices of technology, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree

We do product and process design concurrently	1	2	3	4	5
We involve process engineers early in product development	1	2	3	4	5
We involve customers early in product development	1	2	3	4	5
We involve suppliers early in product development	1	2	3	4	5
We involve manufacturing early in product development	1	2	3	4	5
We redesign setups for continuous improvement	1	2	3	4	5
We do oreventive maintenance for continuous improvement	1	2	3	4	5
We improve quality at the source	1	2	3	4	5
We use cells layout for continuous improvement	1	2	3	4	5
We use just-in-time principles for continuous improvement	1	2	3	4	5
We use pull production for continuous improvement	1	2	3	4	5
We involve multiple functions in adopting technology	1	2	3	4	5
We involve shop floor employees in decision making	1	2	3	4	5
We integrate problem-solving efforts by cross-disciplinary teams	1	2	3	4	5
We use teams in resolving problems that arise	1	2	3	4	5
We encourage teamwork in shop-floor operations	1	2	3	4	5

... About Infusion of Technology in Your Firm

With regard to the infusion/incorporation of technology in your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree

Statement					
Our employees perceive that technology helps them to create new ideas	1	2	3	4	5
Our employees perceive that technology helps them to try out new ideas	1	2	3	4	5
Our employees perceive that technology help them to solve problem creatively	1	2	3	4	5
Our employees perceive that technology help them to innovate their work	1	2	3	4	5
Technology save our employees' time	1	2	3	4	5
Technology increases our employees' productivity	1	2	3	4	5
Technology enables our employees to do work faster	1	2	3	4	5
Technology makes work easier for our employees	1	2	3	4	5
Employees feel their work is significant	1	2	3	4	5
Employees have autonomy in their work	1	2	3	4	5
Employees are responsible for outcome of their work	1	2	3	4	5
Employees look forward to being with their work group	1	2	3	4	5
Employees have strong feeling of belonging to our organization	1	2	3	4	5
Our employees learn from each other by using technology	1	2	3	4	5
Our employees learn by doing to gain valuable technical know-how	1	2	3	4	5
Our employees learns from documents and manuals to enrich their knowledge base about technology	1	2	3	4	5
Our employees exchange and combine knowledge of technology through documents and meetings	1	2	3	4	5
We often summarize successful and unsuccessful approaches to technology implementation	1	2	3	4	5
Management representatives from different departments have periodic debriefings about technology implementation	1	2	3	4	5

... About Product Development Flexibility of Your Firm

With regard to the flexible product development capability in your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement compared with competitors.

1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree

Statement					
We can develop multiple product concepts for the same customer requirements	1	2	3	4	5
We can develop multiple product concepts along the different stages of product development	1	2	3	4	5
We evaluate multiple alternatives over time in product development decision (use set-based approach)	1	2	3	4	5
We can quickly capture trends for customer requirements	1	2	3	4	5
We can quickly transform customer requirements to product concepts	1	2	3	4	5
We can quickly convert product ideas to product concepts	1	2	3	4	5
We can keep multiple product prototypes for the same customer requirements	1	2	3	4	5
We can easily develop a prototype for each product concept	1	2	3	4	5
We can easily modify existing product prototype for new product requirements	1	2	3	4	5
We can build product prototype quickly	1	2	3	4	5
We can quickly transform product concepts to product prototypes	1	2	3	4	5
We can develop multiple product prototypes cost-effectively	1	2	3	4	5
We can quickly modify product design in response to customer requests	1	2	3	4	5
We can easily modify products to a specific customer need	1	2	3	4	5
We can better meet customer needs by quickly modifying existing products	1	2	3	4	5
We can modify products by adding new parts or substituting old parts easily	1	2	3	4	5
We can modify existing products quickly	1	2	3	4	5
We can modify existing products inexpensively	1	2	3	4	5
We can quickly introduce a new product into the market	1	2	3	4	5
We take the lead in new product introduction	1	2	3	4	5
We can quickly substitute new products for those currently being produced	1	2	3	4	5
We can launch new product easily	1	2	3	4	5
We can launch new product inexpensively	1	2	3	4	5

... About Manufacturing Flexibility of Your Firm

With regard to the flexible manufacturing capability in your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement compared with competitors.

1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree

Statement					
Machine setup can be replaced quickly	1	2	3	4	5
A typical machine can perform many types of operations	1	2	3	4	5
A typical machine can effectively use many different tools	1	2	3	4	5
Machines often become obsolete when new operations are required	1	2	3	4	5
Machine tools can be changed quickly	1	2	3	4	5
Machine setups are easy	1	2	3	4	5
Workers can perform many types of operations effectively	1	2	3	4	5
A typical worker can use many different tools effectively	1	2	3	4	5
Cross-trained workers can perform a broad range of manufacturing tasks effectively in the organization	1	2	3	4	5

Workers can operate various types of machines	1	2	3	4	5
Workers can be transferred easily between organizational units	1	2	3	4	5
A typical material handling system can handle different part types	1	2	3	4	5
A typical material handling system can link different processing centers	1	2	3	4	5
Material handling system can move different part types through manufacturing facilities	1	2	3	4	5
Material handling changeovers between parts are quick	1	2	3	4	5
Material handling tools can be changed or replaced quickly	1	2	3	4	5
A typical part operation can be routed to different machines	1	2	3	4	5
A typical part can use many different routes	1	2	3	4	5
The system has alternative routes in case machines break down	1	2	3	4	5
The operating sequence through which the parts flow can be changed	1	2	3	4	5
Machine visitation sequence can be changed or replaced quickly	1	2	3	4	5
Route changeovers are easy	1	2	3	4	5
We can operate efficiently at different levels of output	1	2	3	4	5
We can operate profitably at different production volumes	1	2	3	4	5
We can run various batch sizes economically	1	2	3	4	5
We can quickly change the quantities for our products produced	1	2	3	4	5
We can vary aggregate output from one period to the next	1	2	3	4	5
We can easily change the production volume of a manufacturing process	1	2	3	4	5
We can produce a wide variety of products	1	2	3	4	5
We can produce different part types without major changeover	1	2	3	4	5
We can build different products in the same plants at the same time	1	2	3	4	5
We can produce, simultaneously or periodically, multiple products in a steady-state operating mode	1	2	3	4	5
We can vary product combinations from one period to the next	1	2	3	4	5
We can changeover quickly from one product to another	1	2	3	4	5

... About Logistics Flexibility of Your Firm

With regard to the flexible logistics capability in your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement compared with competitors.

1	2	3	4	5
Strongly disagree	Disagree	Neutral	Agree	Strongly agree

We can deliver multiple kinds of materials in responding to mixed-model operations	1	2	3	4	5
Our inbound transportation can deliver the variety of shipments on time	1	2	3	4	5
We pick and assemble multiple production orders accurately and quickly at the material warehouse	1	2	3	4	5
We have accurate records of inventory quantities and locations at the material warehouse	1	2	3	4	5
We can quickly move materials to the correct production location	1	2	3	4	5
Our inbound supply systems is effective for all shipments	1	2	3	4	5
We can quickly obtain multiple kinds of materials that meet specification	1	2	3	4	5
We can obtain multiple batch sizes of materials from suppliers quickly	1	2	3	4	5
Purchasing can fill multiple requests quickly	1	2	3	4	5
Purchasing keeps close communication with suppliers	1	2	3	4	5
Suppliers cooperatively work on product and process specifications with us	1	2	3	4	5
We streamline purchasing ordering, receiving and other paperwork easily	1	2	3	4	5
We pick and assemble multiple customer orders accurately and quickly at the finished goods warehouse	1	2	3	4	5
We can provide multiple kinds of product packaging effectively at the finished goods warehouse	1	2	3	4	5
We can use multiple transportation modes to meet schedule for deliveries	1	2	3	4	5
We can quickly and accurately label finished products	1	2	3	4	5
We have accurate records of quantities and locations of finished goods	1	2	3	4	5
We can take different customer orders with accurate available-to-promise	1	2	3	4	5
We can quickly respond to multiple customers' delivery time requirements	1	2	3	4	5
We can effectively respond to multiple customers' requirements in terms of repair, installation and maintenance of products	1	2	3	4	5
We can negotiate with customers in terms of prices and delivery time effectively through long term relationships	1	2	3	4	5
We involve customers to improve our services effectively	1	2	3	4	5
We quickly respond to feedback from retailers and consumers effectively	1	2	3	4	5

... About Spanning Flexibility of Your Firm

With regard to the boundary spanning flexibility in your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement compared with competitors.

1	2	3	4	5
Strongly disagree	Disagree	Neutral	Agree	Strongly agree

We timely disseminate the information along the supply chain	1	2	3	4	5
We have joint production planning and scheduling among suppliers, manufacturing, marketing, distributors	1	2	3	4	5
We link information systems so that each member of a supply chain knows the other's requirements and status	1	2	3	4	5

Information flows quickly along value chain	1	2	3	4	5
Accurate information is usually available for decision making	1	2	3	4	5
We continuously renew our competence to meet changing customer needs	1	2	3	4	5
We take some actions quickly based on all the information continuously collected along the value chain	1	2	3	4	5
We continuously develop strategy based on maintaining a good relationship with our major suppliers	1	2	3	4	5
We continuously experiment, learn, and improve our practices to improve productivity	1	2	3	4	5
We quickly develop strategy based on the coordination and integration of information along the value chain	1	2	3	4	5
We continuously experiment, learn, and improve our practices to improve customer satisfaction	1	2	3	4	5

... About Customer Satisfaction to Your Firm

With regard to the customer satisfaction to your organization, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1	2	3	4	5
Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Customers keep doing business with us	1	2	3	4	5
Customers are satisfied with ratio of price and function of our products	1	2	3	4	5
Customers perceive they receive their money's worth when they purchase our products	1	2	3	4	5
Our customers are satisfied with the quality of our products	1	2	3	4	5
Our firm have good reputation for our products	1	2	3	4	5
Our customers are loyal to our products	1	2	3	4	5

... About Competitive Advantage of Your Firm

With regard to the advantages of your organization compared with primary competitors, please circle the appropriate number to indicate the extent to which you agree or disagree with each statement.

1	2	3	4	5
Strongly disagree	Disagree	Neutral	Agree	Strongly agree

We offer competitive prices	1	2	3	4	5
We are able to compete based on our price	1	2	3	4	5
We are able to offer prices as low or lower than our competitors	1	2	3	4	5
We are able to produce products efficiently	1	2	3	4	5
We provide customized products	1	2	3	4	5
We alter our product offerings to meet client needs	1	2	3	4	5
We respond well to customer demand for new features	1	2	3	4	5
We provide many new products to markets	1	2	3	4	5
We deliver accurate quantity of products needed	1	2	3	4	5
We deliver the kind of products needed	1	2	3	4	5
We deliver customer order on time	1	2	3	4	5
We provide dependable delivery	1	2	3	4	5
We are able to compete based on quality	1	2	3	4	5
We offer products that are highly reliable	1	2	3	4	5
We offer products that are very durable	1	2	3	4	5
We offer high quality products to our customer	1	2	3	4	5
We deliver product to market quickly	1	2	3	4	5
We have a short product development cycle tine	1	2	3	4	5
We have time-to-market lower than industry average	1	2	3	4	5
We have fast product development	1	2	3	4	5

... About Performance of Your Firm

With regard to the overall performance of your organization compared with primary competitors, please circle the appropriate numbers which best indicate your perception of the level of performance.

1	2	3	4	5
Unacceptable	Below satisfactory	Satisfactory	Above satisfactory	Superior

Sales growth position relative to competition	1	2	3	4	5
Market share gains relative to competition	1	2	3	4	5
Return on investment relative to competition	1	2	3	4	5
Financial liquidity position relative to competition	1	2	3	4	5
Profit margin relative to competition	1	2	3	4	5
Overall competitive position	1	2	3	4	5

... General Information about Your Firm

The following questions are about general information of your firm. Please circle the appropriate one that best indicates your firm's situation.

Please indicate which SIC group your firm is in.
_Fabricated metal products _Industrial/commercial machinery
_Electronic/electrical equipment _Transportation equipment
_Instruments and related products

The number of employees working in your plant(s).
_Under 100 _ 100-249 _ 250-499 _ 500-999 _1000+

The average annual sales $ (in Millions) for your plant(s).
__Under 5 __5-9.9 __10-49.9 __ 50-99.9
__100-499.9 __ 500+

What's your primary production type?
___Engineering-to-order ____ Make-to-order
___Assembly-to-order ____ Make-to-stock

What's your primary production process?
____ Project ____ Batch /Job shop
____ Flow line /Cells layout ____ Continuous line

What's your present job title?
_____CEO/ president _____ Vice President
_____Manager _____ Director

What are your primary product characteristics?
_____One of a kind _____ Multiple products
_____Few major products _____ Standardized products

What's your primary competitive strategy?
_____Cost leadership _____ Broad differentiation
_____Niche differentiation _____ Lean Competitors

Would you like to receive the summary results of this research?
____ Yes _____ No (if yes, please include your business card in the return envelope).

Appendix E: Research Instruments after the Large Scale Study

ENVIRONMENTAL UNCERTAINTY

Note: These items measured the perceived environmental uncertainty using 5-point scale to indicate the extent to which the respondents agree or disagree to each statement: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree.

CUSTOMER UNCERTAINTY

EU/CU1 Customers' tastes are unpredictable
EU/CU2 Customers' requirements regarding product features are difficult to forecast
EU/CU3 Customers order different product combinations over the year
EU/CU4 Customers' product preferences change over the year
EU/CU5 Product demand from customers fluctuates over the year

TECHNOLOGY UNCERTAINTY

EU/TE1 Technology often changes in our industry
EU/TE2 The technology in our industry is changing significantly
EU/TE3 Technological changes provide large opportunities in our industry
EU/TE4 Technological breakthroughs in our industry lead new product ideas
EU/TE5 Improving technology generates new products frequently

COMPETITION UNCERTAINTY

EU/CO1 Actions of competitors are unpredictable
EU/CO2 Competition is intensified in our industry
EU/CO3 Competitors come from different countries
EU/CO4 Competitors come from different industries
EU/CO5 Competitors often introduce new products unexpectedly

SUPPLIER UNCERTAINTY

EU/SU1 The properties of materials from suppliers can vary greatly within the same batch
EU/SU2 The quantity of materials from suppliers can easily go wrong
EU/SU3 Suppliers' engineering level is unpredictable
EU/SU4 Suppliers' product quality is unpredictable
EU/SU5 Suppliers' delivery time is unpredictable

USE OF TECHNOLOGY

Note: These items measured the use of technology and managerial practices of technology using 5-point scale to indicate the extent to which the respondents agree or disagree to each statement: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree.

USE OF AMT

UT/AMT1 We use AMT to aid product and process design
UT/AMT2 We use AMT to improve manufacturing
UT/AMT3 We use AMT to integrate manufacturing systems
UT/AMT4 We use AMT to plan and control manufacturing requirements
UT/AMT5 We use AMT to control production systems such as Just-In-Time
UT/AMT6 We use AMT to manage the interfaces of manufacturing and marketing

USE OF IT

UT/IT1 We use IT to provide timely information
UT/IT2 We use IT to monitor operations
UT/IT3 We use IT to analyze problems in daily operations
UT/IT4 We use IT as a strategic weapon to gain competitive advantage
UT/IT5 We use IT to exchange and share information in work group
UT/IT6 We use IT to keep connection with key customers and suppliers

CONCURRENT ENGINEERING

MP/CE1 We do product and process design concurrently
MP/CE2 We involve process engineers early in product development
MP/CE3 We involve customers early in product development
MP/CE4 We involve suppliers early in product development
MP/CE5 We involve manufacturing early in product development

IMPROVEMENT PRACTICES

MP/CI1 We redesign setups for continuous improvement
MP/CI2 We use preventive maintenance for continuous improvement
MP/CI3 We improve quality at the source
MP/CI4 We use cells layout for continuous improvement
MP/CI5 We use just-in-time principles for continuous improvement
MP/CI6 We use pull production for continuous improvement

INTEGRATION PRACTICES

MP/IN1 We involve multiple functions in adopting technology
MP/IN2 We involve shop floor employees in decision making
MP/IN3 We integrate problem-solving efforts by cross-disciplinary teams
MP/IN4 We use teams in resolving problems that arise
MP/IN5 We encourage team work in shop-floor operations

INFUSION OF TECHNOLOGY

Note: These items measured the infusion of technology using 5-point scale to indicate the extent to which the respondents agree or disagree to each statement: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree.

TASK INNOVATION

IT/TI1 Our employees perceive that technology helps them to create new ideas
IT/TI2 Our employees perceive that technology helps them to try out new ideas
IT/TI3 Our employees perceive that technology help them to solve problems creatively
IT/TI4 Our employees perceive that technology help them to innovate their work

TASK EFFICIENCY

IT/TE1 Technology saves our employees' time
IT/TE2 Technology increases our employees' productivity
IT/TE3 Technology enables our employees to do work faster
IT/TE4 Technology makes work easier for our employees

QUALITY OF WORK LIFE

IT/QW2 Employees feel that they have autonomy in their work
IT/QW3 Employees are responsible for outcome of their work
IT/QW4 Employees look forward to being with their work group
IT/QW5 Employees have strong feeling of belonging to our organization

LEARNING AND KNOWLEDGE ACCUMULATION

IT/LK1 Our employees learn from each other by using technology
IT/LK2 Our employees learn by doing to gain valuable technical know-how
IT/LK3 Our employees learns from documents and manuals to enrich their knowledge base about technology
IT/LK4 Our employees exchange and combine knowledge of technology through documents and meetings
IT/LK5 We often summarize successful and unsuccessful approaches to technology implementation
IT/LK6 Management representatives from different departments have periodic debriefings about technology implementation

PRODUCT DEVELOPMENT FLEXIBILITY

Note: These items measured the product development flexibility compared with competitors using 5-point scale to indicate the extent to which the respondents agree or disagree to each statement: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree.

PRODUCT CONCEPT FLEXIBILITY

PF/PC1 We can develop multiple product concepts for the same customer requirements
PF/PC2 We can develop multiple product concepts along the different stages of product development
PF/PC3 We evaluate multiple alternatives over time in product development decision (use set-based approach)
PF/PC4 We can quickly capture trends for customer requirements
PF/PC5 We can quickly transform customer requirements to product concepts
PF/PC6 We can quickly convert product ideas to product concepts

PRODUCT PROTOTYPE FLEXIBILITY

PF/PP1 We can keep multiple product prototypes for the same customer requirements
PF/PP2 We can easily develop a product prototype for each product concept
PF/PP3 We can easily modify existing product prototype for new product requirements
PF/PP4 We can build product prototype quickly
PF/PP5 We can quickly transform product concepts to product prototypes

PRODUCT MODIFICATION FLEXIBILITY

PF/MO2 We can easily modify products to a specific customer need
PF/MO3 We can better meet customer needs by quickly modifying existing products
PF/MO4 We can modify products by adding new parts or substituting old parts easily
PF/MO5 We can modify existing products quickly
PF/MO6 We can modify existing products inexpensively

NEW PRODUCT FLEXIBILITY

PF/NP1 We can quickly introduce a new product into the market
PF/NP2 We take the lead in new product introduction
PF/NP3 We can quickly substitute new products for those currently being produced
PF/NP4 We can launch new product easily
PF/NP5 We can launch new product inexpensively

MANUFACTURING FLEXIBILITY

Note: These items measured the manufacturing flexibility compared with competitors using 5-point scale to indicate the extent to which the respondents agree or disagree to each statement: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree.

MACHINE FLEXIBILITY

MF/MA1 Machine setup can be replaced quickly
MF/MA2 A typical machine can perform many types of operations
MF/MA4 Machines often become obsolete when new operations are required
MF/MA5 Machine tools can be changed quickly
MF/MA6 Machine setups are easy

LABOR FLEXIBILITY

MF/WO1 Workers can perform many types of operations effectively
MF/WO2 A typical worker can use many different tools effectively
MF/WO3 Cross-trained workers can perform a broad range of manufacturing tasks effectively in the organization
MF/WO4 Workers can operate various types of machines
MF/WO5 Workers can be transferred easily between organizational units

MATERIAL HANDLING FLEXIBILITY

MF/MH1 A typical material handling system can handle different part types
MF/MH2 A typical material handling system can link different processing centers
MF/MH3 Material handling system can move different part types through manufacturing facilities
MF/MH4 Material handling changeovers between parts are quick

ROUTING FLEXIBILITY

MF/RO1 A typical part operation can be routed to different machines
MF/RO2 A typical part can use many different routes
MF/RO3 The system has alternative routes in case machines break down
MF/RO4 The operating sequence through which the parts flow can be changed
MF/RO5 Machine visitation sequence can be changed or replaced quickly
MF/RO6 Route changeovers are easy

VOLUME FLEXIBILITY

MF/VO1 We can operate efficiently at different levels of output
MF/VO2 We can operate profitably at different production volumes
MF/VO3 We can economically run various batch sizes
MF/VO4 We can quickly change the quantities for our products produced
MF/VO5 We can vary aggregate output from one period to the next
MF/VO6 We can easily change the production volume of a manufacturing process

MIX FLEXIBILITY

MF/MI1 We can produce a wide variety of products in our plants
MF/MI2 We can produce different product types without major changeover
MF/MI3 We can build different products in the same plants at the same time
MF/MI4 We can produce, simultaneously or periodically, multiple products in a steady-state operating mode
MF/MI5 We can vary product combinations from one period to the next
MF/MI6 We can changeover quickly from one product to another

LOGISTICS FLEXIBILITY

Note: These items measured the logistics flexibility compared with competitors using 5-point scale to indicate the extent to which the respondents agree or disagree to each statement: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree.

PHYSICAL SUPPLY FLEXIBILITY

LF/PS1 We can deliver multiple kinds of materials in responding to mixed-model operations
LF/PS2 Our inbound transportation can deliver the variety of shipments on time
LF/PS3 We pick and assemble multiple production orders accurately and quickly at the material warehouse
LF/PS4 We have accurate records of inventory quantities and locations at the material warehouse
LF/PS5 We can quickly move materials to the correct production location
LF/PS6 Our inbound supply systems is effective for all shipments

PURCHASING FLEXIBILITY

LF/PF1 We can quickly obtain multiple kinds of materials that meet specification
LF/PF3 Purchasing can fill multiple requests quickly
LF/PF4 Purchasing keeps close communication with suppliers
LF/PF5 Suppliers cooperatively work on product and process specifications with us
LF/PF6 We streamline purchasing ordering, receiving, and other paperwork easily

PHYSICAL DISTRIBUTION FLEXIBILITY

LF/PD1 We pick and assemble multiple customer orders accurately and quickly at the finished goods warehouse
LF/PD2 We can provide multiple kinds of product packaging effectively at the finished goods warehouse
LF/PD3 We can use multiple transportation modes to meet schedule for deliveries
LF/PD4 We can quickly and accurately label finished products
LF/PD5 We have accurate records of quantities and locations of finished goods
LF/PD6 We can take different customer orders with accurate available-to-promise

DEMAND MANAGEMENT FLEXIBILITY

LF/DM2 We can effectively respond to multiple customers' requirements in terms of repair, installation and maintenance of products
LF/DM3 We can negotiate with customers in terms of prices and delivery time effectively through long term relationships
LF/DM4 We involve customers to improve our services effectively
LF/DM5 We quickly respond to feedback from retailers and consumers effectively

SPANNING FLEXIBILITY

Note: These items measured the spanning flexibility compared with competitors using 5-point scale to indicate the extent to which the respondents agree or disagree to each statement: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree.

INFORMATION DISSEMINATION FLEXIBILITY

SF/ID1 We timely disseminate the information along the supply chain

SF/ID2 We have joint production planning and scheduling among suppliers, manufacturing, marketing, distributors

SF/ID3 We link information systems so that each member of a supply chain knows the other's requirements and status

SF/ID4 Information flows quickly along the value chain

SF/ID5 Accurate information is usually available for decision making

STRATEGY DEVELOPMENT FLEXIBILITY

SF/SD1 We continuously renew our competence to meet changing customer needs

SF/SD2 We take some actions quickly based on all the information continuously collected along the value chain

SF/SD3 We continuously develop strategy based on maintaining a good relationship with our major suppliers

SF/SD4 We continuously experiment, learn, and improve our practices to improve productivity

SF/SD5 We quickly develop strategy based on the coordination and integration of information along the value chain

SF/SD6 We continuously experiment, learn, and improve our practices to improve customer satisfaction

COMPETITIVE ADVANTAGE

Note: These items measured the competitive advantage compared with primary competitors using 5-point scale to indicate the extent to which the respondents agree or disagree to each statement: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree.

PRICE/COST

CA/PC1 We offer competitive prices
CA/PC2 We are able to compete based on our prices
CA/PC3 We are able to offer prices as low or lower than our competitors
CA/PC4 We are able to produce products efficiently

PRODUCT INNOVATION

CA/PI1 We provide customized products
CA/PI2 We alter our product offerings to meet client needs
CA/PI3 We respond well to customer demand for "new" features

DELIVERY DEPENDABILITY

CA/DD1 We deliver accurate quantity of products needed
CA/DD2 We deliver the kind of products needed
CA/DD3 We deliver customer order on time
CA/DD4 We provide dependable delivery

QUALITY

CA/QU1 We are able to compete based on quality
CA/QU2 We offer products that are highly reliable
CA/QU3 We offer products that are very durable
CA/QU4 We offer high quality products to our customer

TIME-TO-MARKET

CA/TM1 We deliver product to market quickly
CA/TM2 We introduce product first in the market
CA/TM3 We have time-to-market lower than industry average
CA/TM4 We have fast product development

CUSTOMER SATISFACTION

Note: These items measured the customer satisfaction using 5-point scale to indicate the extent to which the respondents agree or disagree to each statement: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree.

CUSTOMER SATISFACTION

CS1 Customers keep doing business with us
CS2 Customers are satisfied with ratio of price and functions of our products
CS3 Customers perceive they receive their money's worth when they purchase our products
CS4 Our customers are satisfied with the quality of our products
CS5 Our firm have good reputation for our products
CS6 Our customers are loyal to our products

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