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AN INVESTIGATION OF INFORMATION TECHNOLOGY INVESTMENTS ON BUYER-SUPPLIER RELATIONSHIP AND SUPPLY CHAIN DYNAMICS

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ABSTRACT

AN INVESTIGATION OF INFORMATION TECHNOLOGY INVESTMENTS ON BUYER-SUPPLIER RELATIONSHIP AND SUPPLY CHAIN DYNAMICS

By

Soo Wook Kim

This research posits that information technology investment and deployment for efficient supply chain management should be implemented taking into consideration the interactive, feedback relationships among IT level, product customization level, buyer-supplier relationship, and supply chain structure.

Three kinds of feedback relationships are derived from prior literature. First is the mutual, positive feedback relationship among IT level, the number of suppliers, and buyer's bargaining power from the perspective of transaction cost theory. In other words, the continuous deployment of advanced IT ultimately can lead to perfect competition in an electronic market among a firm's suppliers by reducing transaction costs. As a result, such electronic market structure can enable further deployment of more advanced IT by the buyer. Second is a negative feedback relationship among IT level, the number of suppliers, and buyer's bargaining power from the perspective of "incomplete contract theory," which leads to a different and divergent view. Succinctly, the continuous deployment of advanced IT cannot lead to persistent increase in the number of suppliers due to the increased burden for non-contractible investment by the buyer. Consequently, this perspective suggests that the continuous improvement of IT level stemming from declining transaction costs is not possible. Third is a negative feedback relationship among information sharing by advanced IT, product customization level, and supply

chain dynamics. Such negative feedback relationship suggests that information sharing by the utilization of advanced IT may not guarantee persistent cost reduction or profit increase throughout the supply chain, and that the effect of information-sharing can be different depending on the detailed characteristics of SCM system including product customization level. The effect of IT investment in supply chain management can be different depending on the interaction among the above three feedback relationships representing IT effect on buyer-supplier relationship and reflecting IT effect on supply chain dynamics. In other words, depending on how the described feedback relationships affect each other or which feedback relationship mostly dominates, the effect of IT investment can be different.

The objective of this dissertation is to identify the nature of these interactive feedback relationships among IT deployment, buyer-supplier relationship, and supply chain structure, and also to ascertain whether or not there exists a significant effect from product customization level on such interactive feedback relationships. Based on this identification through the utilization of the system dynamics methodology, one of the dynamic simulation methods, we can attempt to suggest a set of advisable SCM strategies for effective IT investment and deployment. Investigating the responses of IT level according to the dynamic changes of product customization level, buyer-supplier relationship, and supply chain structural issues is a requisite first step. This would be helpful in suggesting a dynamic E-technology investment and adoption model appropriate for integrated supply chain management. The insights developed in this dissertation should provide theoretical foundations and practical guidelines as to the role and function of B-to-B electronic commerce for efficient supply chain integration.

DEDICATED TO MY PARENTS, MOON HO KIM AND YOUNG HEE DO

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CHAPTER 1. INTRODUCTION

1.1 Motivation

The cutting edge for business today is electronic commerce. In the face of strong market forces created by electronic commerce and mounting competition, firms can no longer plod along historical tracks or seek the preservation of the status quo (Kalakota and Whinston 1997). Commonly defined, electronic commerce is associated with the buying and selling of information, products and services via computer networks or via any one of the myriad of networks that make up the information superhighway (Kalakota and Whinston 1996). The Automotive Industry Action Group in North America defines it as the enablement of a business vision supported by advanced information technology to increase the effectiveness of the business relationships between trading partners (Kim 1999).

Electronic commerce is becoming critical in three interrelated dimensions: Customer-to-Business interactions; Intra-business interactions; and Business-to-Business interactions. In particular, from the Business-to-Business or inter-organizational perspective, electronic commerce facilitates changes in many business applications such as supplier management, channel management, payment management and so on (Kalakota and Whinston 1997). In the face of these changes, and in order to survive and be successful, management has to cope with the changes taking place in the various market spaces (Kim 1999).

The expansion of business-to-business electronic commerce changes the existing shape of transaction relationship between companies. This is because the introduction of B-to-B EC enables the construction of new business model, which was unavailable under the existing private network or customer-to-business electronic commerce. In other words, the rapid expansion of electronic commerce has huge potential for enabling companies, large and small, to gain new marketplaces globally at low cost, or to be disintermediated by others doing so. A totally new competitive environment opening up new opportunities is upon us. As a result, the electronic commerce is growing quickly and the importance of electronic marketplace is emphasized.

During the last decade, buying companies have increasingly emphasized the importance of strategic cooperation and supply-network construction with suppliers, and systematic supply chain management as a critical success factor for sustainable competitive advantage. In particular, recently, due to the development of computer and telecommunication technology, firms have been attempting to improve the efficiency of transaction between buyer and supplier by information sharing and communication through advanced information technology. Thus, information technology is recognized as a way that buying companies can manage more efficiently their supply chain. In the light of such current change and trend, the deployment and adoption of information technology between buyer and supplier is highlighted as not only a fresh opportunity to obtain competitive strategy, but also a facing task both buyer and supplier should challenge and overcome together.

One of the most important and common findings from the supply chain dynamics research is the well-known phenomenon of demand amplification and inventory fluctuation that are more significant in the upstream of supply chain. One of the major causes of this problem is due to the lack of information sharing between supply chain partners (Lee et al. 1997a, 1997b, 2000). In such a reason, the utilization of information technologies and systems in supply chain management has mainly focused on supply chain integration. Through the utilization of such information systems, companies have been able to attempt the integration of various functions spread over different areas within a company and with external suppliers and customers as well as curtail unnecessary activities. This effort enhances their capability to cope with sophisticated needs of customers and meet the quality standards of products (Bardi *et al.* 1994, Carter and Narasimhan 1995).

However, from the viewpoint of supply chain management, applying the B to B electronic commerce to the relationship between firms may be expected to make major changes. That is, viewed from the perspectives of transaction cost theory and resource dependence theory, Web-based electronic commerce which has totally different characteristics with the existing information technologies and systems, may reduce the excessive dependence on supply chain integration with few key suppliers by reducing various transaction costs and deriving complete competition in electronic market among numerous suppliers. This also means that the actual points of supply chain structural issues related to and focused on just the establishment of SC integration may be changed depending on the level of E-commerce utilization.

However, studying the role of incomplete contracting considerations in determining the optimal number of suppliers suggests that, despite recent declines in search costs and coordination costs due to information technology development, firms do not want to increase the number of suppliers (Bakos and Brynjolfsson 1993), and IT has a significant role in shifting inter-firm relationship structure to the middle between market and hierarchical structures (Clemons et al. 1993). This is because the deployment of advanced information technology may increase the importance of non-contractible investments by buyers, such as quality, responsiveness, and innovation in the perspective of incomplete contract theory, and transaction cost may actually increase, thus bringing out the necessity of close buyer-supplier relationship to reduce the burden of transaction cost increase. This argument implies that when such investments are particularly important, firms will employ fewer suppliers, and this will be true even when search and transaction costs are very low. This emphasizes that other factors should be accounted for in a more complete model of buyer-supplier relationship.

The research of Bensaou (1999) suggests conceptually that product customization level can be a critical factor for explaining such complete model of buyer-supplier relationship. That is, through the suggestion of the portfolio of inter-firm transaction relationship, they stressed that the type of market exchange relations in which the technical and economical dependence of both buyer and supplier on each other is relatively low, is appropriate for highly standardized products. Meanwhile, the type of strategic partnership in which buyer-supplier relationship is strongly connected by considerable transaction-specific assets of both buyer and supplier, is significantly correlated with highly customized products.

Also, Fisher (1997) asserted that the most important strategic issue, which should be considered in the design of such supply chain structure, is the characteristics and strategy of traded products. Specifically, he emphasized that traded products can be classified into efficient product and innovative product, and supply chain appropriate for each product category should be discriminated into physically efficient supply chain and market responsive supply chain. When considering the relationship between buyer-supplier relationship and product strategy Bensaou suggested, such matching of product characteristics/strategy and supply chain structure Fisher identified implies that the strength of buyer-supplier relationship also can be the key strategic issue for constructing efficient supply chain structures. In fact, Anderson et al. (1994) commented that depending on the position and level of negotiation power between buyer and supplier, the overall design and type of supply chain structure could be different, thus supporting the above argument.

Also, many previous studies (Eisenhardt 1985; Hoecstra and Romme 1991; Bakos 1991; Lassar and Kerr 1996; Fisher 1997; Jones et al. 1997) comment that the relationship between product variety level and buyer-supplier relationship can influence supply chain structural issues, and also inversely, depending on such effect on supply chain structural issues, corporate SCM strategies on product customization and buyer-supplier relationship can be changed in terms of performance improvement.

The above arguments imply that information technology deployment for efficient supply chain management should be implemented taking into consideration the interactive, feedback relationships, among product customization level, buyer-supplier relationship, and supply chain structure. In other words, the systematic design of supply chain structure and appropriate application of information technologies can be decided depending on product customization level and the strength of buyer-supplier relationship. Also, the above arguments stress that the role of information technology should be discussed from the perspective that information flows in supply chains can be better utilized by considering 1) various operating environments and characteristics in a supply chain, 2) the characteristics of traded products, and 3) buyer-supplier relationship.

Viewed in this perspective, strategic alignment among key SCM strategic and structural issues, and information technology deployment, should be regarded as the most significant and urgent research theme for the construction of an effective SCM strategy. It is necessary to better understand the role and function of information technology for efficient supply chain management.

However, past research on information technology has mainly focused on the availability and significance of information technology itself. The assertion of Keen (1993) that the difference in competitive and economic benefits which firms can obtain from information technology is dependent on not the difference in technology itself, but the difference in managerial capability, emphasizes the importance of research on the adoption of information technology in supply chain management. This is also a reason that even though the previous works have highlighted the necessity and significance of information sharing in order to remedy the so-called bullwhip effect, practical implementations have fallen short of theoretical recommendations. That is, few companies have succeeded in mitigating or eliminating the bullwhip effect through information sharing, thus supporting Keen's observation. According to the above argument, this study focuses on the suggestion of a set of advisable solutions for the effective investment and utilization of E-technology, by developing and testing a framework that posits the relationships among information technology, product customization level, buyer-supplier relationship, and supply chain structural issues.

1.2 Research Question and Objectives

From the motivation described above, the following research questions emerge:

(1) How does advanced IT deployment affect the balance of bargaining power between buyer and supplier? In other words, how does advanced IT deployment change the number of suppliers, the buyer's bargaining power, and the supplier's bargaining power?

(2) Inversely, how much does a changed position of buyer-supplier bargaining power affect advanced IT deployment?

(3) How much does information sharing by advanced IT deployment alter supply chain structure? In other words, how much does information sharing by advanced IT deployment change overall inventory level, order quantity, order penetration point, and production quantity in the supply chain?

(4) Inversely, how do such changes of supply chain structural issues influence advanced IT deployment?

(5) How do supply chain dynamics influence the feedback relationship between IT level and buyer-supplier relationships? In other words, how do the dynamic changes of supply chain structural issues influence the interactive feedback relationships between advanced IT deployments, number of suppliers, and buyer's bargaining power?

(6) Does product customization level significantly affect such interactive feedback relationships among buyer-supplier relationships, supply chain structure, and advanced IT deployments exist?

The accumulation of these research questions represents some key points that must be considered in the creation of a more effective IT investment model. The first important issue concerns the level of IT deployment. It specifically deals with determining which level of information technology is the most effective for supply chain management in terms of performance improvement. As such, it is necessary to consider the relationship between the levels of various telecommunication/information technologies and the effects of their utilization. The second issue relates to the formation of an appropriate type of buyer-supplier relationship and supply chain structure. Of particular concern is which type of buyer-supplier relationship and supply chain structure is the most effective for IT investment and deployment in terms of performance improvement. The third issue concerns the consideration of interactive relationships. This point is based on the proposition that the advisable IT investment model can be different depending on interactive relationships among product customization level, buyer-supplier relationships, and the type of supply chain structure. Thus, examinations on various cases that can be created from the combination of information technology type and supply chain configurations should be implemented to identify the most effective feature of the IT investment model.

Viewed in light of the above arguments, the first objective of this dissertation is to investigate the response of IT level according to the dynamic changes of buyer-supplier relationships and supply chain structural issues by testing interactive feedback relationships among IT deployment, buyer-supplier relationships, and supply chain structure. The second objective is to identify whether or not product customization level significantly affects such interactive feedback relationships. Based on the successful accomplishment of these objectives, we can suggest a set of advisable supply chain management (SCM) strategies for effective IT investment and deployment for efficient supply chain management.

Doing so would be helpful in suggesting a dynamic E-technology investment and adoption model appropriate for integrated supply chain management. Such efforts should also enable us to provide theoretical foundations and practical guidelines on the role and function of B-to-B electronic commerce for the efficient construction of supply chain integration as mentioned previously.

1.3 Methodology

This dissertation develops a dynamic simulation model of advanced IT deployment considering interactive feedback relationships with product customization level, buyer-supplier relationship, and supply chain structure. This research utilizes the System Dynamics method, a method of studying the world around us by viewing the system as a whole. System Dynamics examines the interaction between all objects or individual parts of a system and their relationship to one another.

System Dynamics has two typical methodological characteristics. First, it focuses on a system's dynamic behavior, that is, the behavioral changes within the system according to the progression of time. Second, System Dynamics analyzes the fundamental reasons for dynamic change through a feedback structure. These characteristics precisely relate to the objectives of this dissertation as mentioned above, which is the identification of the effect of dynamic changes of IT effect by investigating interactive feedback relationships with product customization level, buyer-supplier relationships, and supply chain structure. Thus, this is the reason for using System Dynamics as the methodology for pursuing the objectives of this dissertation.

Traditionally, System Dynamics researchers have used two modeling approaches. One is known as the top-down modeling approach, and the other is known as the bottom-up modeling approach. In the top-down approach that emphasizes 'feedback loop thinking', a causal loop diagram is made, followed by a detailed System Dynamics diagram. In the bottom-up approach that emphasizes 'operational thinking', a System Dynamics diagram is established first by linking individual stock and flow variables, and then a causal loop diagram is completed by gradually expanding the System Dynamics diagram. This research employs the top-down modeling approach. Specifically, System Dynamics analysis of this dissertation is implemented through a three stage simulation modeling process of establishing a causal loop diagram, designing a System Dynamics diagram, and formulating an equation.

1.4 Significance of the Study

From the accomplishment of research objectives through testing the System Dynamics model, this paper anticipates the following major suggestive contributions.

First, it has been generally recognized that information sharing by advanced IT deployment can significantly minimize the problems induced by bullwhip effect, which is defined as distortion in demand information and inventory fluctuation (Bowersox and Closs 1996; Lee et al. 1997a; Lee et al. 1997b; Closs et al. 1998; Lee et al. 2000).

However, Chen (1998) and Grahovac & Chakravarty (2001) suggest a paradox of the previous arguments on the benefit of information sharing. Such paradox implies that the effect of information sharing can be different depending on the detailed characteristics of a SCM system. Moinzadeh (2002) suggests four circumstances in which information-sharing can be most beneficial: (a) the supplier's long lead time (long transit times from the supplier), (b) not large number of suppliers, (c) not too small or not too large order quantities, (d) not too small or not too large ratio of the unit holding cost of the manufacturer to that of the supplier. This dissertation will investigate the validity of Moinzadeh's suggestion. Furthermore, this dissertation will check the possibility of the existence of other system characteristics enduring the benefit of information sharing.

Second, the results of this study can be used for the construction of an E-supply chain progression paradigm. Traditionally, it has been generally accepted that the developmental stage of E-networks would shift from the private network through value-added networks to an open network. Also, EDI, a representative type of inter-organizational telecommunication system, would move from an intra-EDI through a value-added EDI to an Internet-EDI and Web-based EDI. The level of IT development, which is one of this paper's construct variables, represents this shift. As mentioned previously, this study can check the responses of IT deployment level depending on the dynamic change of product customization level, buyer-supplier relationships, and supply chain structural issues through the implementation of the System Dynamics simulation model. Accordingly, if connecting such dynamic changes of SC strategic and structural issues derived from System Dynamics simulation to the shift of the IT developmental stage described above, the construction of an E-supply chain progression paradigm is possible.

Third, this study can identify the existence possibility of a new type of supply chain structure. Fisher (1997), through the revision of product-process literature of Hayes and Wheelwright (1979), argues that typically, according to the characteristics of traded products, supply chain can be classified into two categories; physically efficient and market-responsive. This paper, by considering buyer-supplier relationships and the effect of IT investment other than the characteristics of traded products, investigates the validity of Fisher's argument and further reaches for the likelihood of creating a new type of supply chain structure suitable for supply chain management in an E-commerce era.

Fourth, this study can identify the most compatible sets of the characteristics of traded products and buyer-supplier relationships for effective information technology investment and adoption. Bensaou (1999) showed that the type of market exchange relation in which the technical and economic interdependence of buyer and supplier is relatively low, is appropriate for highly standardized products, while the type of strategic partnership in which buyer-supplier relationship is strongly connected by considerable transaction-specific assets of each party, is significantly correlated with highly customized products. Previous literatures have analyzed the relevance between strategic issues and structural issues in supply chain management, under the general agreement of the above combination. However, as mentioned previously, compatibility between product customization level and buyer-supplier relationship can vary depending on interactive relationships with IT deployment level and supply chain structure. Through the analysis on interactive feedback relationships among such four construct variables, this study investigates the possibility that the matching type of product strategy and buyer-supplier relationship suitable for the E-commerce era may be diverse.

Fifth, this paper examines the likelihood of the implementation of a new dimensional manufacturing strategy framework. Numerous literatures comment on the trade-offs among supply chain structural issues (Pine et al. 1993). For example, as mentioned previously, if lead-time is reduced and distribution time is frequent, overall inventory level is decreased, while transportation is increased. In this scenario, trade-off relationships among various supply chain variables can exist (Magee et al. 1985). However, the deployment of advanced information technology may bring about a change in the traditionally accepted concept of trade-off relationships among various supply chain variables. Specifically, the deployment of advanced information technology may enable buying firms to accept a little longer lead-time relative to the existing lead-time in terms of minimum total cost. This study tests the possibility that advanced IT deployment mitigates the trade-off relationships among supply chain structural issues.

1.5 Organization of the Dissertation

This dissertation is organized as follows. Chapter 1 describes the motivation of this research, main research questions and objectives, methodology, and the significance of this dissertation. Chapter 2 discusses the various research and literature streams leading to the development of a research model for testing. Gaps in the literature are identified and analyzed. Chapter 3 develops a conceptual framework based on literature and the rationale behind the research propositions. Chapter 4 describes research scope and methodology, and develops a causal-loop diagram and System Dynamics simulation model, with the selection of key constructs and decision parameters. Chapter 5 analyzes the dynamic effects of IT adoption in various SC strategic and structural perspectives through the implementation of the System Dynamics model, and discusses theoretical and managerial implications derived from the analysis. Chapter 6 concludes this research with a discussion of the research contributions, limitations, and directions for future investigation.

CHAPTER 2. LITERATURE REVIEW

2.1 Information Technology and Buyer-Supplier Relationship

2.1.1 Buyer-Supplier Relationship

In response to intense global competition and shrinking product life cycles, organizations have downsized to focus on core competencies and have attempted to achieve a competitive advantage by forming mutually beneficial relationships with suppliers to capitalize on their capabilities and technology. SCM evolved when firms entered into strategic buyer-supplier alliances, and integrated their distribution and transportation activities in conjunction with logistics providers.

It has been generally recognized that buyer-supplier relationships can provide a strategic source of efficiency and even competitive advantage if managed appropriately. Recently, business managers have pursued the quantification of the benefit that might be extracted from the efficient management of such associations (Cooper and Slagmulder 1999). Buying firms are actualizing important chances for competitiveness through transaction with suppliers, which can provide benefit by helping lower a buying firm's expenses (Cannon and Homburg 2001).

Even from an academic perspective, buyer-supplier relationships have been emphasized increasingly in the perspective of new management philosophies that indicate that effective liaisons will open up innovative competitive environments and significantly contribute to a firm's strategic success. Many previous articles in both practitioner and academic journals demonstrate that the buyer-supplier relationship has played a considerably significant role in the success of many organizations over the past few years (Dowlatshahi 1999).

2.1.2 Theoretical Backgrounds on Buyer-Supplier Relationship

2.1.2.1 Transaction Cost Theory

The focus of transaction cost theory is that the inter-firm relationship should be established in the perspective of minimizing transaction costs. Even though it was initiated in an economic background, transaction cost theory provides a fundamental basis in the research on supply chain management. This is because the most important factor for supply chain competitiveness is the achievement of the economics of networking and the basic unit for achieving the economics of networking is the optimization of the inter-firm transaction relationship.

The expenditures related to the decision to select an optimal inter-firm relationship include production costs, transaction costs, operating costs, and sunk costs. Optimal inter-firm relationships should be decided in the viewpoint of minimizing the sum of these costs. Among these costs, production costs pertain to the costs for preparing and proceeding with production, while sunk costs are costs related to investment for a specific transaction. Particularly, high sunk costs can have a significant influence on the level of inter-firm relationships in that the cost for withdrawing from the existing specific transaction relationship is very high. Operating costs, (with the exception of the above two costs in the manufacturing process) are related to business type or the characteristics of product and process technologies. Transaction costs are the costs for gathering information from a possible transaction partner, which includes the costs for seeking out an available transaction partner, negotiating and contracting a specific transaction, and monitoring the implementation of the contract. Therefore, transaction costs increase under a high level of incomplete information, bounded rationality, environmental complexity and uncertainty, and opportunistic behavior (Williamson 1985).

The studies of Williamson (1975, 1985, 1981) and Grossman and Hart (1986), which are the representatives of transaction cost theory, assume that an inter-firm contract under complexity is always incomplete. Because of such incomplete contractual agreements, firms with investment in relationship-specific assets may be deprived of additional benefits from relationship-specific assets of transaction partners. One way for the stable security of benefits in this case is the internalization of transaction partners. In other words, by integrating transaction partners, this approach removes opportunistic behaviors from partners. A less extreme alternative relative to internalization is the reciprocal buying agreement. In a reciprocal buying agreement, an individual transaction party should minimize its own opportunistic behaviors and clarify the scope of benefits through the exchange or partial ownership agreement of hostages. Transaction cost theory suggests a logical foundation for viewing the relevance and characteristics of such transaction relationship types in terms of transaction costs. Consequently, transaction cost theory places the focus of the research on the suggestion of explanations of how to select transaction partners in order to minimize transaction costs and how to maximize the effect of investment on the relationship-specific assets.

2.1.2.2 Resource Dependence Theory

The central theme of resource dependence theory is that firms try to secure resources and reduce environmental uncertainty by establishing a relationship with the environment or a party that possesses critical resources necessary for surviving in an uncertain environment. Inter-firm relationships are regarded as the response to uncertainty and dependence.

In the case that any kind of mutual dependency between firms in a supply chain exists, a high level of co-specialization in the inter-firm relationship is inevitable. The level of inter-firm relationship co-specialization will vary according to decision-making for investment on transaction-specific assets. Resource-based competition theory asserts that such transaction-specific assets can be a source of competitive advantage in case that it is impossible to replace and very difficult to imitate. However, investment on un-imitable transaction-specific assets may become sunk costs, and thus increase the likelihood of opportunistic behavior by a transaction partner. This means that once investment on transaction-specific assets is implemented, mutual dependency between transaction parties becomes high, and the cost for the suspension of the existing transaction as well as the cost for any new transaction with an alternative partner increases. Thus, it is emphasized that relevant countermeasures for preventing such opportunistic behaviors should be carefully arranged according to the level of specific assets. Williamson (1979) classified specific assets into three types: site asset specificity, physical asset specificity, and human asset specificity. Dyer (1996) set up and measured empirically the detailed dimensions of these three specific assets as indicated in table 2-1.

Resource dependence theory is not incompatible with transaction cost theory. But, the relationship-specific asset addressed in transaction cost theory makes it very difficult to change transaction partners easily or requires a high burden of cost to change partners. Accordingly, the level of relationship-specific assets is proportional to the strength of inter-firm dependency, thus emphasizing the relevance between the two theories.

Table 2-1: Asset Specificity

	Definition (Williamson 1979)	*Measures (Dyer 1996)*
Site Specificity	The situation whereby successive production stages are located in close proximity to one another to improve coordination and economize on inventory and transportation cost	The physical distance between buyer and supplier
Physical Asset Specificity	Transaction-specific capital investments (e.g., in customized machinery, tools, dies)	The percentage of the supplier's total capital investments which would have to be scrapped if the supplier were prohibited from conducting transaction
Human Asset Specificity	Transaction-specific know-how accumulated by transactors through long-standing buyer-supplier relationships (e.g., dedicated supplier engineers who learn the systems, procedures, and individuals that are idiosyncratic to buyer)	The ratio of the annual man days that spent in face to face contact of buyer-supplier to total annual man days The ratio of the average no. of co-located or 'guest' engineers to total engineers

(Source: Dyer, 1996).

2.1.2.3 Incomplete Contract Theory

Transaction cost theory as mentioned above, addresses the type of inter-firm relationship by using the principle of cost minimization under economic background. However, when considering that quality, flexibility, and time-based competition beyond cost dimension are emphasized as the key competitive factors in the recent market, transaction cost theory cannot flawlessly determine the most suitable type of transaction relationship, even though it provides the starting point for discussion.

An inter-firm cooperative relationship pursues not only financial benefits such as cost efficiency, but also the improvement of non-financial aspects such as quality, responsiveness, defect rate, innovation, technology acquisition, reliability, and information sharing. In order to improve such non-financial factors, a certain level of investment by suppliers is required, and such investment may be difficult to describe accurately in a contract. These non-financial factors are generally referred to as non-contractible factors. Buyers can pursue the improvement of supply chain performance by supporting some incentives for investment on non-contractible factors, because buyers cannot effectively claim the investment to suppliers by way of a contract. With the suggestion that an emphasis on quality is the necessary condition for the successful utilization of advanced manufacturing technologies and facilities, Milgrom and Roberts (1990) stress that buyers should derive the investment on non-contractible factors from suppliers by providing incentives for the investment in order to deal with changing market situations because contracts and operating rules cannot always be altered.

Bakos and Brynjolfsson (1993) assert that the number of suppliers is inversely proportional to supplier's incentives for investment on non-contractible factors. Furthermore, where the importance of quality, responsiveness and innovation is increased, contracts having a small number of suppliers are the optimal choice. This argument means that the investment on non-contractible factors can be considered as a key factor for the decision of an optimal number of suppliers with transaction costs and relationship-specific assets mentioned previously, thus implying the significant effect of incomplete contract theory on the buyer-supplier relationship.

2.1.3 The Portfolio of Buyer-Supplier Relationship

The components used to determine the most suitable type of inter-firm transaction relationships can be largely classified into four segments; the level of relationship-specific assets, the level of uncertainty on transaction environment or partner's behavior, the level of complexity of inter-firm contracts, and the frequency of inter-firm transactions. However, even though all four factors can be regarded as key dimensions deciding the type of inter-firm relationship, previous research (Williamson 1979; Dyer 1996) has mainly pointed out that the level of relationship-specific assets is the most important factor. As mentioned in the preceding sub-section, Williamson (1985) defines relationship-specific assets as durable investment for supporting a specified transaction relationship, or the opportunity costs of investment when using optimal alternative transaction rather than the existing transaction or when suspending the existing transaction. Such relationship-specific assets include mutually specialized physical assets, human assets, R&D, and knowledge and capability of specified partners.

The type of inter-firm relationship suggested in transaction cost theory also focuses on relationship-specific assets. One extreme of the relationship type is 'pure market structure' as in the case of the transaction of standardized commodities. In pure market structure, price is the most powerful tool for inducing the incentives of transaction and the main criterion for the maintenance or suspension of a transaction. However, in the case that the relationship-specific asset is strongly required and the size of the supplier market is small, mutual adjustment on investment is advisable, and co-ownership on transaction assets may be more effective. The other extreme of relationship type is vertical integrative or hierarchical structure. This transaction type with unified ownership is relevant in the case where the prevention of opportunistic behavior on relationship-specific assets from partners and the close adjustment of decision-making between firms are required. However, such a hierarchical structure may reduce the incentives of partner's profit maximization and induce additional bureaucratic costs relative to decentralized structures (Milgrom and Roberts 1990). There exist various intermediate inter-firm relationship types between pure market structure and hierarchical structure. Such intermediate types include various kinds of contracts and partial ownership contracts. In such a perspective, Bensaou (1999) suggest the use of a portfolio for the inter-firm transaction relationship by utilizing the level of investment on relationship-specific assets as classification criteria for the relationship type. Tables 2-2 and 2-3 organize the portfolio of the inter-firm relationship.

Table 2-2: Contextual Profiles

		Supplier's Specific Investment	
		Low	*High*
Buyer's Specific Investment	*High*	**Captive Buyer** Product characteristics •Technically complex •Based on mature, well-understood technology •Little innovation and improvements to the product Market characteristics •Stable demand with limited market growth •Concentrated market with few established players •Buyers maintain an internal manufacturing capability Supplier characteristics •Large supply houses •Supplier proprietary technology •Few strongly established suppliers •Strong bargaining power •Automakers heavily depend on these suppliers, their technology and skills	**Strategic Partnership** Product characteristics •High level of customization required •Close to buyer's core competency •Tight mutual adjustments needed in key processes •Technically complex part or integrated subsystem •Based on new technology •Innovation leaps in technology, product, or process •Frequent design changes •Strong engineering expertise required •Large capital investments required Market characteristics •Strong demand and high growth market •Very competitive and concentrated market •Frequent changes in competitors due to unstable or lack of dominant design •Buyer maintains in-house design and testing capability Partner characteristics •Large multiproduct supply houses •Strong supplier proprietary technology •Active in research and innovation (i.e., R&D costs) •Strong recognized skills and capabilities in design, engineering, and manufacturing
	Low	**Market Exchange** Product characteristics •Highly standardized products •Mature technology •Little innovation and rare design changes •Technically simple product or well-structured complex manufacturing process •Little or no customization to buyer's final product •Low engineering effort and expertise •Small capital investments required Market characteristics •Stable or declining demand •Highly competitive market •Many capable suppliers •Same players over time Supplier Characteristics •Small 'mom' and 'pop' shops •No proprietary technology •Low switching costs •Low bargaining power •Strong economic reliance on auto-business	**Captive Supplier** Product characteristics •Technically complex products •Based on new technology (developed by suppliers) •Important and frequent innovations and new functionalities in the product category •Significant engineering effort and expertise •Heavy capital investments required Market characteristics •High-growth market segment •Fierce competition •Few qualified players •Unstable market with shifts between suppliers Supplier characteristics •Strong supplier proprietary technology •Suppliers with strong financial capabilities and good R&D skills •Low supplier bargaining power •Heavy supplier dependency on the buyer and economic reliance on the auto-sector

(Source: Bensaou, B.M., 1999, Portfolios of Buyer-Supplier Relationships, *Sloan Management Review* **40**(4), 35-44)

Table 2-3: Management Profile for Each Contextual Profiles

		Supplier's Specific Investment	
		Low	*High*
Buyer's Specific Investment	*Low*	**Captive Buyer** Information sharing mechanisms' •"Broadband" and important exchange of detailed information on a continuos basis •Frequent and regular mutual visits Boundary spanners' task characteristics •Structured task, highly predictable •Large amount of time spent by buyer's purchasing agents and engineers with supplier Climate and process characteristics •Tense climate, lack of mutual trust •No early supplier involvement in design •Strong effort by buyer toward cooperation •Supplier does not necessarily have a good reputation	**Strategic Partnership** Information-sharing mechanisms •"Broadband," frequent and "rich media" exchange •Regular mutual visits end practice of guest engineers Boundary spanners' task characteristics •Highly ill defined, ill structured •Nonroutine, frequent unexpected events •Large amount of time spent with supplier's staff, mostly on coordinating issues Climate and process characteristics •High mutual trust and commitment to relationship •Strong sense of buyer fairness •Early supplier involvement in design •Extensive joint action and cooperation •Supplier has excellent reputation
	High	**Market Exchange** Information-sharing mechanisms •"Narrow-bend" and limited information exchange, heavy at time of contract negotiation •Operational coordination and monitoring along structured routines Boundary spanners' task characteristics •Limited time spent directly with supplier staff •Highly routine aid structured task with little interdependence with supplier's staff Climate and process characteristics •Positive social climate •No systematic joint effort and cooperation •No early supplier involvement in design •Supplier fairly treated by the buyer •Supplier has a good reputation and track record	**Captive Supplier** Information-sharing mechanisms •Little exchange of information •Few mutual visits, mostly from supplier to buyer Boundary spanners' task characteristics •Limited time allocated by buyer's staff to the supplier •Mostly complex, coordinating tasks Climate and process characteristics •High mutual trust, but limited direct joint action and cooperation •Greater burden put on the supplier

(Source: Bensaou, B.M., 1999, Portfolios of Buyer-Supplier Relationships, *Sloan Management Review* **40**(4), 35-44)

2.1.4 The Effect of Information Technology on Buyer-Supplier Relationship

2.1.4.1 IS Effect in the Perspective of Transaction Cost Theory

The primary goal of buyers in pursuing a market exchange relationship is to minimize cost and leverage economies of scale through large volumes relying on a large number of suppliers. Buyers preferring a strategic partnership structure emphasize the development of a close, long-term relationship with a few key suppliers. This means that determining the optimal number of suppliers can be a natural extension of the "make versus buy" or "markets versus hierarchies" decision. Both questions can be analyzed by focusing on transaction costs.

Generally, in analyzing the effect of information technology on the number of suppliers, researchers have centered on, in the viewpoint of transactional considerations, investigating trade-offs between the increased costs necessary to search out a large number of suppliers and the increased probability of finding a better price or a superior product by reviewing a larger number of suppliers. As a result, it has been recognized that technological developments reducing the cost of achieving information related to prices and product characteristics should lead to an increase in the number of suppliers, particularly in markets with differentiated goods (Bakos 1991). In other words, information technology and inter-organizational information systems should lead to an increase in the number of suppliers employed by buying companies because they tend to reduce search costs (Malone 1985; Bakos 1987; Clemons and Row 1989; Bakos and Brynjolfsson 1993).

Malone et al. (1987) support the above argument. They insist that because the nature of coordination entails communication and processing information, the utilization of information technology seems likely to lower coordination costs. Therefore, IT will facilitate a shift from the single-supplier system within the firm that leads to hierarchical structure to the multiple-supplier system that drives market structure. Also, they argue that IT development heightens the capability of controlling the complexity of product description through the improvement of inter-organizational information processing, and that the introduction of a flexible manufacturing system increases the ratio of market exchange structure by lowering transaction-specific assets and subsequently, entire transaction costs.

2.1.4.2 IS Effect in the Perspective of Incomplete Contract Theory

Even though there are theoretical arguments for a move from a single-supplier system (hierarchical structure) to a multiple supplier system (market structure) (Johnston and Lawrence 1988; Brynjofsson et al. 1991), an increase in the *number* of suppliers has not been actually observed. On the contrary, there is recent evidence that there has been a decrease in the number of suppliers, in spite of considerable reductions in transaction costs due to IT development (Bakos and Brynolfsson 1993). This move to fewer suppliers in the face of declining transaction costs suggests a paradox in the context of the arguments relating to IT effect from the perspective of transaction cost theory.

Bakos and Brynjolfsson (1993) present two comprehensible explanations for such shift to fewer suppliers. One is that transaction costs including search and coordination costs have actually increased. If predetermined technological and organizational investments are required when connecting with a supplier, a firm may want to restrict the number of suppliers in order to cut down on these fixed costs. Similarly, if investments on IT development are confined to a specific supplier and are not transferable to new inter-firm relationships, switching costs involved in changing suppliers may restrict the desirable number of suppliers. For example, investment on an inter-organizational system for the exchange of component blueprints in a CAD format utilized by a specific supplier may restrict the capability of the buyer to search out new potential suppliers.

Another explanation focuses on the benefits that smaller and tighter networks of suppliers have on quality and responsiveness, innovation and technology adoption, defect rates, trust, and information exchanges (Johnston and Lawrence 1988; McMillan 1990; Cusumano and Takeishi 1991; Helper 1991a, 1991b). All these characteristics include investments by suppliers that are difficult or impossible to specify in advance on a contract. Furthermore, they provide advantages that are confined to a specific buyer-supplier relationship. Thus, offering incentives for such investments requires particular tasks. IT is likely to increase the significance of non-contractible factors, such as innovation, speed, responsiveness, and flexibility, stressing the necessity of these tasks.

When investments are non-contractible and specific, a buyer's bargaining power and/or the willingness of their suppliers to share the burden of non-contractible investments are required. Current literature does not explicitly deal with the question of how to suggest incentives for supplier investment in quality, responsiveness, and innovation, and, particularly, how the number of suppliers influences the incentives to derive such investments (Bakos and Brynojolfsson 1993). However, controlling the number of suppliers, and thereby increasing supplier's bargaining power to some degree, as a competitive strategy, runs counter not only to standard neoclassical economic models, but to widely used competitive strategy models as well (Porter 1980).

Conclusively, past studies indicate that it can be advantageous to restrict the number of suppliers a buyer considers when providing incentives to induce suppliers to make non-contractible investments. This argument implies that if a buyer does not have too many alternative suppliers, a supplier can accumulate more benefits generated by non-contractible investment relative to the individual buyer. Accordingly, the supplier will have greater bargaining power and, therefore, more incentives to make non-contractible investments, such as quality, responsiveness and innovation. This argument provides a theoretical background for bringing out the necessity of a strategic partnership between buyers and suppliers (Henderson and Venkatraman 1990; Johnston and Lawrence 1988), which underscores the advantages of a closer relationship with fewer suppliers.

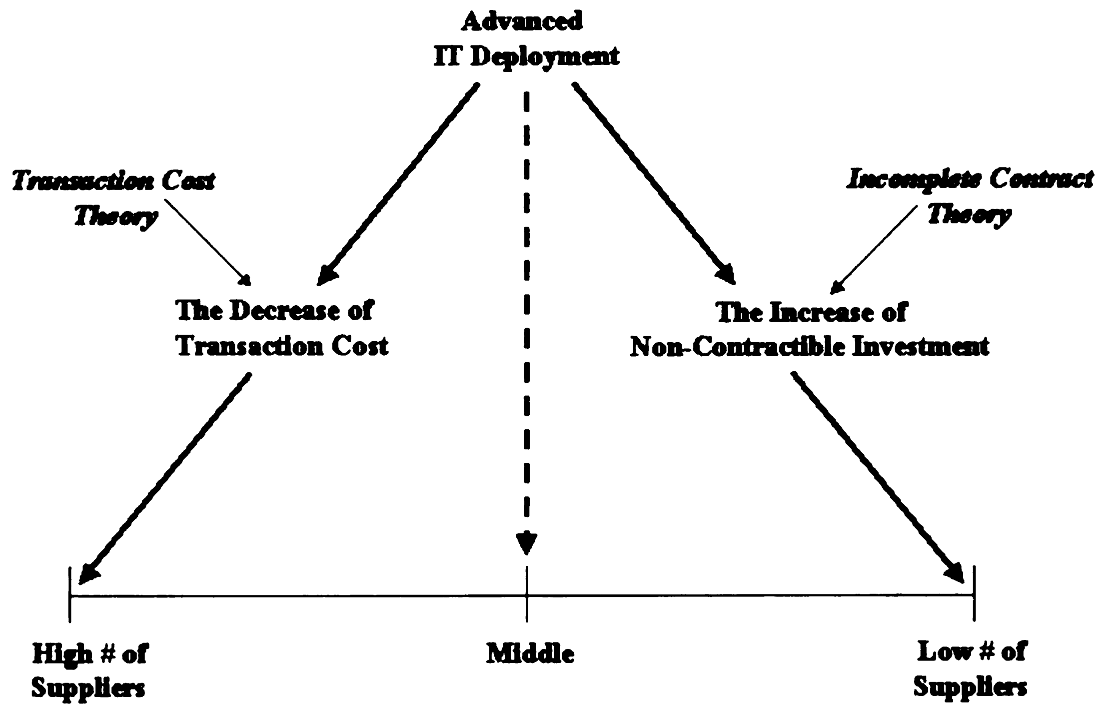


Figure 2-1: Relationship between IT Deployment and Buyer-Supplier Relationship

Viewed in this perspective, even if transaction costs decline radically due to IT development, it can still be advisable for a buyer to restrict the number of suppliers it employs. The analysis on the role of incomplete contracting considerations in deciding the optimal number of suppliers provides not only an alternative viewpoint to transaction cost theory, but also an additional argument that information technology facilitates the "move to the middle." In other words, the combination of decreased transaction costs and an increased need for non-contractible investments leads to a shift to the intermediate level of supplier numbers (Bakos and Brynjolfsson 1993). Clemons et al. (1993) support the above argument commenting that IT plays a significant role in shifting the inter-firm relationship to a middle ground between market and hierarchical structures (Figure 2-1).

2.2 Information Technology and Supply Chain Dynamics

2.2.1 The Significance of Supply Chain Integration

A supply chain includes those activities necessary to produce and deliver products and services to a customer; it may start with a supplier's supplier and end with a customer's customer. Chopra and Meindl (2001) define SCM as the management of flows between the stages in a supply chain to maximize total profitability. Such flows include not only the flow of overall materials such as the procurement of raw materials, the transformation into intermediaries, and the distribution of finished products, but also information flow focused on ordering (Bowersox and Closs 1996, Disney et al. 1997, Lee et al. 1997, Cooper and Ellram 1993, Hoekstra and Romme 1991, Lambert et al. 1998). When successfully managed, a supply chain delivers the right products, at the right time, at the right place, and at a competitive price (Zheng et al. 2001). Vollmann et al. (2000) suggest that the term 'supply chain' is no longer appropriate given the recent emphasis on customer service. They prefer 'demand chain' and identify several management issues including flawless execution, outsourcing, supply base development, and partnership implementation. The literature in supply chain management has addressed a wide spectrum of issues from the analytical design of production-distribution networks to the management of these processes (Cohen and Mallik 1997).

Two strategic issues in SCM are integration and coordination (Bowersox and Closs 1996; Lee et al. 1997). Supply chain integration links a firm with its customers, suppliers, and other channel members by integrating their relationships, activities, functions, processes, and locations. Such integration supports the current movement from conventional, arms-length and often conflict-laden relationships to cooperative, long-term business partnerships and strategic alliances (Morash and Clinton 1998). Integration involves the design of the supply chain network to ensure that the segmented activities associated with a dispersed network of suppliers can operate as a 'virtual' organization. In spite of the increasing necessity of integrated SCM, the establishment of integrated SCM cannot be accomplished in a short period, and thus requires a gradual and stepwise approach (Stevens 1989; Wikner et al. 1991; Bowersox and Closs 1996). Coordination, in its role as an intermediary stage for integrated SCM, is a process that manages the flow of materials, information and funds among supply chain partners and may link decision making across all nodes of the supply chain network.

Wikner et al. (1991) assert that coordination should be implemented in the first stage to adjust the role and responsibility of individual supply chain participants, followed by the integration of manufacturing functions in the second stage, the integration of distribution functions in the third stage, and the integration of entire supply chains in the final stage. These four integration stages are consistent with Bowersox's integration stages for SCM. Bowersox (1989) asserts that the process of supply chain integration should progress from the integration of internal logistics processes to external integration with suppliers and customers, and such internal and external integration can be accomplished by the continuous automation and standardization of each internal logistics function and by efficient information sharing and strategic linkage with suppliers and customers. Stevens (1989), Byrne and Markham (1991), and Hewitt (1994) express the same view as Bowersox in that they assert that the improvement of each internal function in the internal integration stage should precede the external connection with suppliers and customers in the external integration stage. Stevens suggests four developmental stages in supply chains; independent operation, functional integration, internal integration, and external integration. Further, he asserts that a staged approach to SCM can remove the barriers between functions or organizations, and that IS utilization can strengthen the linkage among functions and organizations.

Forrester (1961) advocated that the demand-supply unbalance between supply chain parties is the most critical problem in integrated SCM. Lee et al. (1997) refers to this distortion in information as the "bullwhip effect". The bullwhip effect is essentially the phenomenon of demand variability amplification along a supply chain that includes retailers, distributors, manufacturers, manufacturers' suppliers, and so on. Lee et al. characterized this phenomenon as *demand distortion,* which can create problems for suppliers, such as grossly inaccurate demand forecasts, low capacity utilization, excessive inventory, and poor customer service. Price fluctuation, order batching, and shortage gaming between participants can be recognized as the key explanations of the bullwhip effect (Lee et al. 1997).

As the demand distortion dilemma expands gradually to become a problem at the inter-organizational level, supply chains need to be evaluated and managed as a unit in order to be successful in the long term. This is consistent with the necessity of managing various demand distortions in the integrative, long-term, and systematic perspectives (Bowersox and Closs 1996, Hoekstra and Romme 1991, Jones et al. 1997).

2.2.2 The Effect of Information Technology on Supply Chain Dynamics

If a network of customers and suppliers is not effectively integrated and coordinated, various predicaments such as ordering delays, lower quality, high in-process inventories, long customer lead-times, and product obsolescence due to lengthy order cycles (Cohen and Mallik 1997; Buxbaum 2000; Shore 2001) can occur. Bowersox and Closs (1996) assert that the capability and eagerness of a firm's functional areas such as marketing, purchasing, operations, and logistics to share critical planning and operational information are preconditions for internal integration. Similarly, supply chain partners should be able and willing to share important information to accomplish external integration (Bowersox and Daugherty 1995). By sharing information, all supply chain members can reduce the dependence on forecasts that too often display significant error. Instead, firms may get very accurate estimates of customer demand when supply chain partners successively exchange accurate, timely sales information (Closs et al. 1998).

As clearly described in Forrester's (1961) classic depiction of demand amplification, the failure to share information with supply chain partners may lead to the substantial amplification of a slight disturbance in demand at the retail level as it moves through the channel. This view explains how poor information flow leads to substantial variation in inventory holdings. That is, the failure to share important sales information with other supply chain members causes under-stock of inventory in times of peak demand and over-stock when demand subsides. Lee et al. (1997a, 1997b) define this distortion of information as the "bullwhip effect". Christopher (1994) suggests that by connecting the point-of-sale location directly to the point of production via information technology, the "tidal wave effect" experienced by Forrester's supply chain participants can be softened eventually in the face of demand variability. This direct linkage of point-of-sale locations to other supply chain participants can be generally defined as "response-based" or "pull" logistics systems. On the basis of these arguments, it has been recognized that supply chain participants can accomplish both cost reduction and better customer service by sharing information in a response-based logistics system (Bowersox and Closs 1996; Lee et al. 1997a; Lee et al. 1997b; Closs et al. 1998).

Consequently, it is obvious that information sharing maintains a central role in the integration and coordination of supply chains (Barrett 1986). Furthermore, it has generally been accepted that such supply chain integration and information sharing may effectively manage the 'bullwhip' effect in which demand amplification through the supply chain sequence leads to inaccurate forecasts, low capacity utilization, excessive inventory, and inadequate customer service, and thus significantly improve overall supply chain performance (Lee et al. 1997a; Lee et al. 1997b). These two arguments mean that by substituting inventory with information, the fundamental purpose of information sharing can be met with the reduction of total costs enjoyed by each supply chain member. Through analysis on the high technology industry, Lee et al. (2000) assert that information sharing can significantly minimize the outcomes of the problems induced by the bullwhip effect, thus supporting the above argument.

However, there exists the argument that, in some cases, it may be necessary to change the way the supply chain is managed in order to make complete use of the information flows. Chen (1998) studied the benefits of information flow in a multi-echelon serial inventory system by computing the difference between the costs of using echelon reorder points and installation reorder points. He observed that information sharing benefits decreased with increase in demand variance, increased with increase in the number of stages, and were lowest at moderate values of penalty cost. Moreover, Grahovac and Chakravarty (2001) found that sharing and trans-shipment of items often, but not always, reduces the overall costs of holding, shipping, and waiting for inventory.

Unexpectedly, these cost reductions are sometimes achieved through *increasing* overall inventory levels in the supply chain. They conclude that even though the ability to quickly move inventory within the lowest echelon can reduce the overall cost, this savings may not be always accompanied by a reduction in the overall inventory in the supply chain.

These opposing trends imply that the effect of information sharing can be diverse depending on the detailed characteristics of the SCM system. Moinzadeh (2002) determined that information-sharing is most beneficial in systems that exhibit the following characteristics: (a) Systems where the supplier's lead-time is long compared with other lead-times (i.e., transit times from the supplier to the retailers) in the system; (b) Systems where the number of retailers is not large (this is clearly a function of system parameters, such as costs, demand rates, and lead-times); (c) Systems where the order quantities are of average size; and, (d) Systems where the ratio of the unit holding cost of the retailers to that of the supplier is medium sized. This supports the above argument that SCM characteristics play an important role when considering the effect of information sharing.

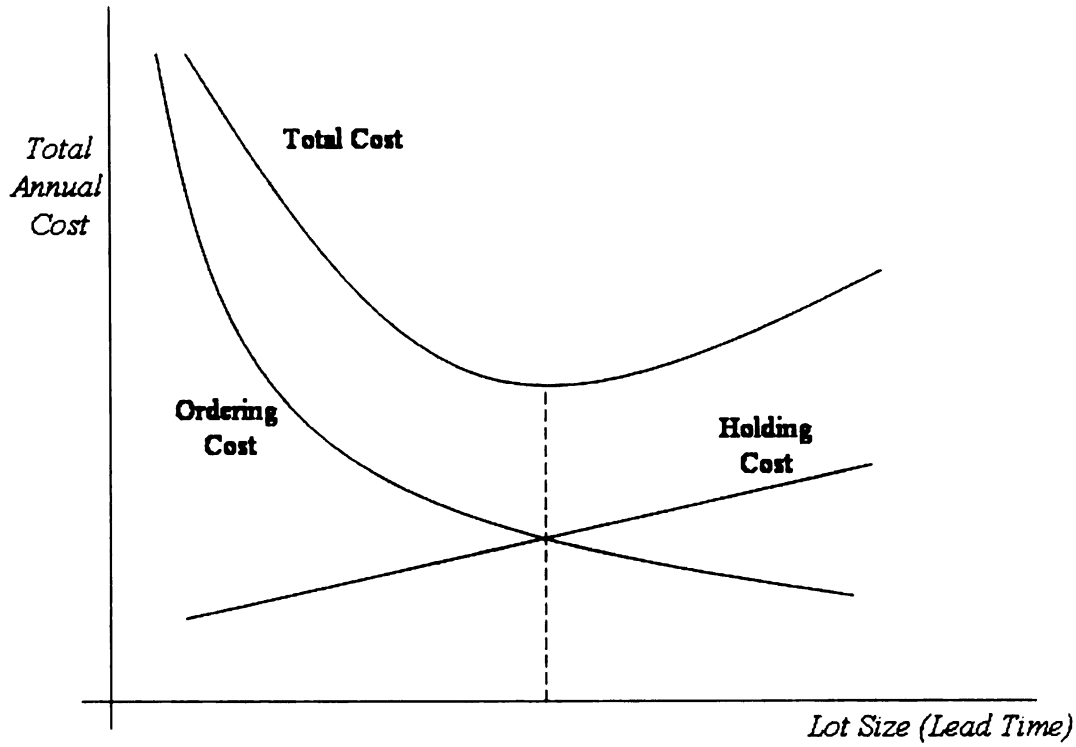


Figure 2-2: Traditional Trade-off Relationship between Inventory and Transportation Costs

Cachon and Fisher (2000) also illuminate the dissimilar effects of information sharing from a different perspective. They find substantial savings from lead-time and batch size reductions, both of which are facilitated by the implementation of information technology. They conclude that the observed benefits of information technology in practice are due more to the impact of information technology on lead-time and batch size than in facilitating information sharing. Many previous researchers assert that the reduction of lead-time is an important factor in competitiveness (Stalk and Hout 1990; Christopher 1992; Krajewski and Ritzman 2000). However, lead-time may also have influences on other kinds of supply chain related activities. That is, the reduction of supply chain lead-time can lead to the reduction of safety stock, order frequency, and order batch size. However, that results in an increase in transportation costs. The reduction of supply chain lead-time may induce trade-off relationships among various supply chain variables (Magee et al. 1985) and furthermore it may not have any significant effect on the reduction of total costs.

Even though information sharing is essential to the integration and coordination of supply chains, it does not guarantee the improvements of all aspects of performance. This means that the strategy of information sharing should be changed depending on whether the focus of SCM is just minimizing specific cost or total costs by balancing among various kinds of cost reduction, which kind of information should be considered for sharing, whether the underlying demand process is complex or stationary, and what is the specific structural characteristics of SCM system. The above argument also stresses the necessity of discussions on the role of information technology and its capacity to change the operating policies of a supply chain in order to maximize the effect of information flows within the chain, and the external drivers that have significant impacts on the efficient utilization of IT for information sharing.

2.3 Interactive Relationships among IT, Buyer-Supplier Relationship and SC Structure

2.3.1 The Alignment among Product Customization Level, Supply Chain Structure, and Buyer-Supplier Relationship

Even though the necessity of integrated supply chain management has consistently been emphasized, research on the overall structure of supply chain, which is the starting point for supply chain management, and theoretical relevance between such supply chain structure and supply chain strategic issues, is at the beginning stage.

The most important strategic issue, which should be considered in the design of such supply chain structure, is the characteristics and strategy of traded products (Fisher 1997). Fisher (1997) asserted that traded products can be classified into efficient product and innovative product, and supply chain appropriate for each product category should be designed. Lassar and Kerr (1996) examined the relationship between a company's supply chain structure and primary product strategy such as differentiation, cost leader, and focused strategies. Fisher (1997) emphasized the length and thickness of supply chain in the design of supply chain, while Lassar and Kerr (1996) considered mainly the partnership between manufacturer and distributor and the regional intensity of distribution. Bensaou (1999) showed that the characteristics/strategy of traded product can be closely related to the strength of buyer-supplier relationship, through the suggestion of the portfolio of inter-firm transaction relationship by the level of investment on the transaction-specific asset of buyer or supplier. That is, they suggested that the type of market exchange relations in which the technical and economic dependence of both buyer and supplier on each other is relatively low, is appropriate for highly standardized products, while the type of strategic partnership in which buyer-supplier relationship is strongly connected by considerable transaction-specific assets of both buyer and supplier, is significantly correlated with highly customized products. When considering the relationship between a company's supply chain structure and product strategy Fisher and Lassar/Kerr identified, such matching of product characteristics/strategy and buyer-supplier relationship implies that the strength of buyer-supplier relationship also can be the key strategic issue for constructing efficiently supply chain structure. In fact, Anderson et al. (1994) commented that depending on the position and level of negotiation power between buyer and supplier, the overall design and type of supply chain structure can be different, thus supporting the above argument.

Previous researches on the relevance between the tier of supply chain and strategic issues (Eisenhardt 1985; Anderson and Gatignon 1986; Miller 1988; Lassar and Kerr 1996) have agreed that in case of standardized/cost-leader focused product appropriate for market exchange relations structure, the necessity of controlling the number of participants in a supply chain is relatively low due to the low weights of monitoring and cooperation on supply chain, while in case of customized/differentiation focused product, systematic monitoring and cooperation on supply chain is more emphasized in order to support various types of services to customers. Thus, in case of customized/differentiation focused product connected to strategic partnership structure, the possibility that a firm attempts to reduce intermediate supply chain participants and increase monitoring and trust among supply chain members is higher.

Also, Bakos (1991) suggests a meaningful argument on the relevance between the number of suppliers and strategic issues. That is, in terms of buyers, in case of standardized/cost leader focused product appropriate for market exchange relations structure, the number of transaction-available supplier is expected to increase, because the change of supply line is relatively easy due to the low level of dependence on supplier, transaction-specific asset, and changeover cost. In case of customized/ differentiation focused product connected to strategic partnership structure, the significance of increasing the number of supplier may be reduced, because the incentives for improving non-contractible factors except price is more strongly required.

The necessity of supply chain integration can be also different depending on the type of product strategy and buyer-supplier relationship. That is, in case of standardized/cost leader focused product suitable for market exchange relations structure, managerial independence may be guaranteed, because it is expected that result-based contract among supply chain members is emphasized and the necessity of monitoring/promotion on supply chain members is low (Lassar and Kerr 1996). Meanwhile, in case of customized/differentiation focused product aligned with strategic partnership structure, product life cycle is relatively short and various kinds of competitive factors (technology, design, service) except product price should be supported. Also, the demand of finished product is considerably unstable. Accordingly, buyer should support various types of promotion activities (Winter 1993; Lassar and Kerr 1996), and accomplish high level of cooperation or integration with other supply chain members by providing high margin (Porter 1980; Anderson and Schmittlein 1984; Anderson and Gatignon 1986; Miller 1987, 1988; Lassar and Kerr 1996). Also, systematic training for differentiated product/service and buying firm's monitoring on distributor are more strongly required, because there are a large amount of information which should be processed (Galbraith 1973) and a high possibility of decision-making's delay (Govindarajan 1985). Therefore, the possibility of behavior-based contract among supply chain members is very high (Lassar and Kerr 1996). In other words, there is very much possibility that buyer pursues high level of cooperation and integration with external supply chain members even with enduring high burden of integration costs and political conflicts.

The approaches for reducing lead time also should be changed depending on the type of product strategy and buyer-supplier relationship. In case of customized/differentiation focused product and strategic partnership structure, the type of supplying immediately products when necessary may be preferred to that of placing a large amount of inventories on distributors or retailers, because margin rate and value added are high. Thus, in order to pursue high customer service with low inventory level, quick response logistics system should be constructed. Also, in case of customized/differentiation focused product, a wide range of product lines should be completed and the necessity of consistent product innovation and R&D is high. Because of such characteristics of product variety, it is very difficult for distributors or retailers to hold and control properly the inventories of various kinds of products in their warehouses or sales shops (Fisher 1997). Accordingly, in this case, it is advisable to reduce supply chain lead time in order to deal with effectively immediate demand. However, in case of standardized/cost leader focused product suitable for market exchange relations structure, it is expected that most orders are made by the type of batch, because the responsibility of demand uncertainty may be shifted onto other supply chain members through result-based contract among supply chain members as mentioned previously. Accordingly, in case of such order with batch type, supply chain lead time may be relatively long.

A manufacturing firm should try to establish an optimal response point by considering the characteristics of traded products, product strategy, and related environmental factors (Hoekstra and Romme 1991; Macbeth and Ferguson 1994; Jones et al. 1997). In the case of standardized/cost leader focused product, the level of product variety is not high (Hambrick 1983), demand is stable (Miller 1988), and demand area is generally wide (Porter 1980; Miller 1987). Also, the strength of buyer-supplier relationship may be relatively weak because market governance structure is expected to appear dominantly as mentioned previously. Thus, the likelihood that response point is built in the upstream of supply chain is high. In the case of customized/differentiation focused product, the level of product variety is high (Porter 1980; Miller 1987), demand is unstable (Miller 1988). Also, the level of support and cooperation among supply chain members for dealing with effectively demand uncertainty is relatively high (Anderson and Gatignon 1986; Miller and Friesen 1986; Ward et al. 1996; Lassar and Kerr 1996), because it is expected that hierarchical governance structure by strategic partnership between buyer and supplier and behavior-based contract among supply chain members are mainly shaped (Eisenhardt 1985; Lassar and Kerr 1996). According to these characteristics, firms with customized/differentiation focused product would try to obtain information on final demand more quickly than firms with standardized/cost leader focused product. Thus, the likelihood that response point is established in the downstream of supply chain is strong.

In case of standardized/cost leader focused product, the characteristics of demand stability and the availability of multi-suppliers by taking market governance structure can induce the reduction of safety stock. Meanwhile, in case of customized/differentiation focused product, safety stock may be maintained consistently as high level, because high customer service is pursued, demand uncertainty is inherent, and the unexpected accident of key supplier can lead to the difficulty of immediate response to customer orders when pursuing excessively strategic partnership with key supplier.

2.3.2 *The Effect of IT on the Alignment among Product Customization Level, Supply Chain Structure, and Buyer-Supplier Relationship*

As discussed above, the key issues for the design of supply chain structure may be influenced by the characteristics/strategy of traded products and buyer-supplier relationship. In other words, depending on which type of product strategy and buyer-supplier relationship are combined with supply chain structural issues, the direction itself for designing supply chain structure can be totally different, and further the effect of supply chain structure on performance can be also diverse.

The introduction of B to B E-commerce can contribute to the efficiency improvement of supply chain structure, because it can provide product information, inventory level, shipping information, and information on customer requirements, on a real-time pull basis (Radstaak and Ketelaar 1998). Particularly, because the buying company can establish cooperative planning on demand forecasting and production schedule with supplying company through information sharing by E-commerce, the potential of E-commerce for the efficient design of supply chain structure is tremendous (Karoway 1997). Additionally, E-commerce makes 'pull' supply chain management possible by linking effectively each function in a supply chain and customer's demand information (Kalakota and Whinston 1997).

However, the introduction of E-commerce may somewhat change the type of relevance between the width of supply chain and strategic issues which Bakos (1991) argues. That is, like the argument of Malone et al. (1987) that the ratio of electronic market structure to inter-firm relationship will be increased according to the development of telecommunication technology, it is predicted that Web-based E-commerce adoption may increase the number of supplier within a limited scope, even in strategically important customized products. Therefore, we can expect that even though the effort for maintaining cooperative relationship on strategically important customized products by reducing the number of supplier will be continued, the intensity will be weakened according to the introduction of Web-based E-commerce. Such kind of change also may be indicated in the relationship between the length of supply chain and strategic issues. That is, in case of customized/differentiation focused product emphasizing more systematic monitoring and cooperation on supply chain by strategic hierarchical partnership structure in order to support various types of services to customers, the likelihood that a firm attempts to reduce intermediate supply chain participants is higher. However, E-commerce adoption may decrease the necessity of reducing intermediate participants compulsorily with enduring the burden of related costs by reducing the level of dependence on physically contacted-monitoring and increasing the capability of real-time information sharing. Consequently, the introduction of Internet or Web-based E-commerce enables buyers to pursue moderate electronic market structure even on strategically important customized products and maintain the proper number of intermediate supply chain participants.

Such introduction of E-commerce also may have an influence on the relevance between the level of supply chain integration and strategic issues. That is, E-commerce adoption may make it possible for buying firms to obtain the effects of integration simultaneously with guaranteeing somewhat the managerial independence of other chain members, by supporting the capability of continuous and consistent remote monitoring/promotion of supply chain members. Therefore, it can be foreseen that buying firms with high level of E-commerce adoption do not need to pursue excessive supply chain integration even on customized/differentiation focused product.

Table 2-4: The Effect of E-Commerce Adoption on Supply Chain Management

Structural Issues	The Effect of E-Commerce	Related Literatures
No. of Suppliers	Because the ratio of electronic market structure to inter-firm relationship will be increased according to the development of telecommunication technology, it is predicted that Web-based E-commerce adoption may increase the number of supplier within a limited scope, even in strategically important customized products.	**Malone et al. (1987)**
No. of SC Paths	EC adoption may decrease the necessity of reducing intermediate participants compulsorily with enduring the burden of related costs by reducing the level of dependence on physically contacted -monitoring and increasing the capability of real-time information sharing, even in strategically important customized products.	**Malone et al. (1987)**
The Level of SCI	By acquiring the capability of continuous and consistent remote monitoring/ promotion on supply chain members, it can be foreseen that buying firms with high level of E-commerce adoption do not need to pursue excessive supply chain integration even on customized/differentiation focused product.	**Lassar and Kerr (1996)**
Order Penetration Point	Even firms with customized/ differentiation focused product may pursue the shift of response point into more upstream level of supply chain by improving the capability of remote monitoring and precise prediction on demand information, product variety, and market situation through the utilization of E-commerce.	**Krajewski and Ritzman (2000) Berry et al. (1994)**
Lead Time	The development of E-commerce technology can lead to the consecutive reductions of total transportation cost and total inventory cost by grafting advanced information technology onto logistics and inventory processing activities. Such consecutive reductions should shift the minimum point of total cost into left and down side. Therefore, the development of EC may enable buying firms to accept a little longer lead time, even in customized products.	**Fisher (1997)**
Safety Stock	If both the shift of response point into more upstream level and the construction of automatic quick-response logistics system can be accomplished successfully through the utilization of Internet or Web-based E-commerce as mentioned previously, even firms with customized/ differentiation focused product may expect the benefits from the reduction of safety stock.	**Hoecstra and Romme (1991) Jones et al. (1997) Bowersox and Closs (1996)**

Also, the development of E-commerce technology requires the change of concept on trade-off relationships among lead time, distribution frequency, inventory level, and transportation cost, which has been accepted traditionally. That is, the development of E-commerce technology can lead to the consecutive reductions of total transportation cost and total inventory cost by grafting advanced information technology onto logistics and inventory processing activities. Such consecutive reductions should shift the minimum point of total cost into left and down. Therefore, the development of E-commerce may enable buying firms to accept a little longer lead time relative to the existing lead time in terms of minimum total cost. According to this logic, it can be anticipated that if the level of E-commerce adoption is relatively high, the significance of reducing the lead time of supply chain will be less even in customized/differentiation focused product and strategic partnership structure.

The utilization of E-commerce may change traditional perspectives on the response point of supply chain. That is, Internet or Web-based E-commerce adoption can improve the capability of remote monitoring and precise prediction on demand information, product variety, and market situation. Accordingly, it is expected that even firms with customized/differentiation focused product may pursue the shift of response point into more upstream level of supply chain through the utilization of E-commerce. This makes it possible for manufacturing firms to accomplish the proper balance between the shift of order penetration point into upstream for quick switch to new product for dealing with effectively demand uncertainty and the maintenance of quick response capability on customers, which Berry et al. (1994) emphasizes.

Such argument on the relationship between E-commerce adoption and the response point of supply chain also can explain the effect of E-commerce on the relationship between safety stock and the characteristics of traded product or buyer-supplier relationship. If order penetration point is shifted to upstream by E-commerce adoption as mentioned previously, overall inventory in a supply chain is expected to reduce, but average safety stock in a supply chain may increase in order to establish quick-response logistics system. This is because the weight of push-type management will be decreased, while the weight of pull-type management is anticipated to increase (Hoekstra and Romme 1991; Jones et al. 1997). However, if both the shift of response point into more upstream level and the construction of automatic quick-response logistics system can be accomplished successfully through the utilization of Internet or Web-based E-commerce, even firms with customized/differentiation focused product may expect the benefits from the reduction of safety stock. This means that traditional perspectives on the relationship between safety stock and strategic issues also can be changed depending on the level of E-commerce adoption. Of course, in order to derive the above argument, the analysis on trade-off relationship between additional costs and improved benefits induced by the change of response point and the reduction of safety stock in the perspective of total cost minimization should be preceded (Bowersox and Closs 1996). Generally, it is predicted that under total cost minimum approaches, improved benefits are superior to additional costs.

CHAPTER 3. RESEARCH FRAMEWORK

The literature review in the preceding chapter identified the limitations and gaps in several research streams that are related to the effect of information technology adoption on buyer-supplier relationship and supply chain dynamics. The gaps and limitations in literature helped identifying research questions and the potential solutions to these questions in this dissertation. This chapter describes a research framework for the study derived from literature review.

3.1 Conceptual Framework

As discussed in the literature review, there are two contradictory arguments in the effect of IT on buyer-supplier relationship. Transaction cost theory suggests that information technology and inter-organizational information systems can reduce transaction-specific asset and the cost of achieving information about prices and product characteristics, and such reduction should lead to an increase in the number of suppliers, particularly in markets with differentiated products. However, studying the role of incomplete contracting considerations in determining the optimal number of suppliers provides that, despite recent declines in search costs and coordination costs due to information technology development, firms do not want to increase the number of suppliers (Bakos and Brynjolfsson 1993). This is because information technology development may increase the importance of non-contractible investments by suppliers, such as quality, responsiveness, and innovation in the perspective of incomplete contract theory, thus bringing out the necessity of close buyer-supplier relationship. Accordingly, when such investments are particularly important, firms will employ fewer suppliers, and this will be true even when search and transaction costs are very low. Such conflict between transaction cost theory and incomplete contract theory implies that IT has a significant role in shifting inter-firm relationship structure to the middle between market and hierarchical structures (Clemons et al. 1993). This also emphasizes that other forces should be accounted for in a more complete model of buyer-supplier relationship.

Bensaou and Venkatraman (1996) suggest the likelihood that product customization level can be a critical factor for explaining such complete model of buyer-supplier relationship. They emphasized that the type of market exchange relationship in which the technical and economical dependence of both buyer and supplier on each other is relatively low, is appropriate for highly standardized products. Meanwhile, the type of strategic partnership in which buyer-supplier relationship is strongly connected by considerable transaction-specific assets of both buyer and supplier, is significantly correlated with highly customized products.

Also, Fisher (1997) asserted that such product customization level should be considered as one of the most important strategic issue for the design of supply chain structure. That is, he emphasized that traded products can be classified into efficient product and innovative product, and supply chain appropriate for each product category should be also classified into physically efficient supply chain and market responsive supply chain. Lassar and Kerr (1996) examined the relationship between a company's supply chain structure and primary product strategy such as differentiation, cost leader, and focused strategies. When considering the relationship between buyer-supplier relationship and product strategy Bensaou and Venkatraman suggested, such matching of product characteristics/strategy and supply chain structure Fisher identified implies that supply chain structure can be also an important factor for explaining the complete model of buyer-supplier relationship. In fact, Anderson et al. (1994) commented that depending on the position and level of negotiation power between buyer and supplier, the overall design and type of supply chain structure can be different, thus supporting the above argument.

Also, much prior literature (Eisenhardt 1985; Hoecstra and Romme 1991; Bakos 1991; Lassar and Kerr 1996; Fisher 1997; Jones et al. 1997) notes that the relationship between product customization level and buyer-supplier relationship can influence supply chain structural issues, and also inversely, depending on such effect on supply chain structural issues, corporate SCM strategies on product customization and buyer-supplier relationship can be changed in terms of performance improvement.

All of the above arguments imply that information technology deployment for the establishment of efficient supply chain structure should be implemented under the consideration on the interactive feedback relationships with the characteristics of traded products and buyer-supplier relationship. This stresses that the role of information technology should be discussed from the perspective that information flows in supply chains can be better utilized by considering 1) various operating environments and characteristics in a supply chain, 2) the characteristics of traded products, and 3) buyer-supplier relationship.

Also, the above argument suggests that firms can acquire the competitive and economic benefits of advanced information technology, specifically, E-technology not from the effect of technology itself, but from managerial capability on such technology (Keen 1993). This provides a persuasive reason on why there exists a gap between practical implementations and theoretical recommendations about the effect of information sharing on supply chain dynamics. That is, it has generally been accepted that information sharing by advanced information technology can manage effectively the 'bullwhip' effect and minimize the outcomes of demand distortion due to such bullwhip effect (Lee et al. 1997a; Lee et al. 1997b; Lee et al. 2000). However, according to some previous researchers, the benefits of information sharing decrease with increase in demand variance and may not be always accompanied by a reduction in the overall inventory in the supply chain. Also, the observed benefits of information technology in practice are derived not from facilitating information sharing itself, but from the impact of information technology on supply chain structural issues such as lead time and batch size (Chen 1998; Cachon and Fisher 2000; Grahovac and Chakravarty 2001). These opposing trends imply that the effect of information sharing can be different depending on the detailed characteristics of a SCM system and how such characteristics are managed, thus emphasizing the significance of managerial capability on information technology (Moinzadeh 2002).

Viewed in this perspective, strategic alignment among key SCM strategic and structural issues, and advanced IT deployment, should be regarded as the most significant and urgent research theme for the construction of an effective SCM strategy. This study attempts to suggest the shape of such effective SCM strategy through the development and testing of a framework for investigating the relationships among information technology, product customization level, buyer-supplier relationship, and supply chain structural issues. Figure 3-1 indicates the conceptual framework based on the selected arguments discussed above.

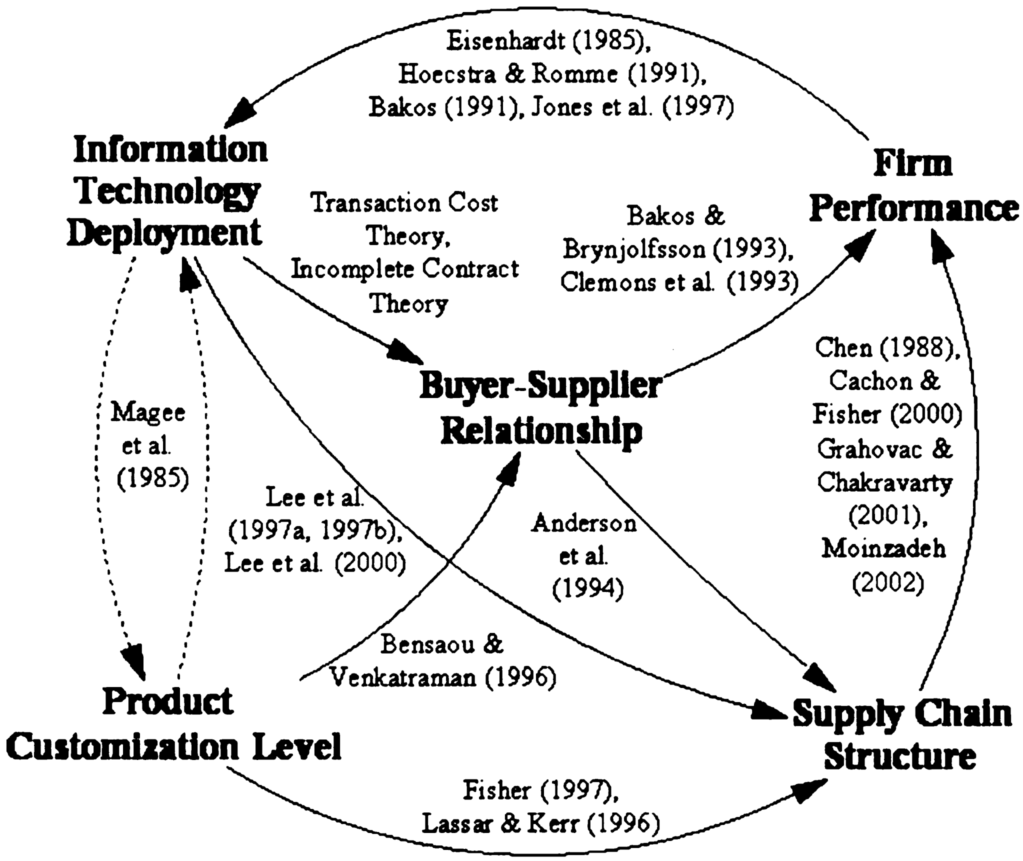


Figure 3-1 : Conceptual Framework

One thing to be noted is that, as can be seen in the above figure, the relationship between information technology deployment and product customization level is indicated not by a solid, but by a dotted line. This is because it was relatively difficult to find related previous research supporting the relationship. However, this relationship also deserves further investigation.

As mentioned previously, previous literature comments that there exists the trade-offs among supply chain structural issues (Magee et al. 1985; Pine et al. 1993). For example, as mentioned previously, if lead-time is reduced and distribution occasions are frequent, overall inventory level is decreased, while transportation is increased. However, the deployment of advanced information technology may change traditional concept on such trade-off relationships. That is, the deployment of advanced IT may enable buying firms to accept a little longer lead-time relative to the existing lead-time in terms of minimum total cost. Accordingly, if a firm's IT adoption level is relatively high, the firm's effort for reducing the lead time of supply chain may be less required even in customized/differentiation focused product. This suggests the existence probability of the relationship between information technology deployment and product customization level. This research will investigate such probability.

3.2 Research Scope

Supply chain management is concerned with "the flow of material, work-in-process, and finished inventory." (Bowersox and Closs 1996) Thus, the demand for logistics services is connected to the shift of inventory throughout the supply chain. From the manufacturer's perspective, finished good orders stimulate the need for outbound logistics services from manufacturers to customers. Raw materials, components, or resale goods create the need for inbound logistics services to manufacturers.

This paper confines the scope of this study to inbound logistics, because this study focuses on Business-to-Business IT adoption with the consideration of inter-organizational buyer-supplier relationships. There are many reasons, both operational and strategic, why the concentration on inbound logistics is so important. First, the firm is taking a holistic view of its own role in the supply chain. But, further, it enables the firm to seize initiative in the supply chain. Information technology's effect on inventory management can also be observed in the perspective of effective inbound logistics. The technology is utilized to manage the acquisition of the right amount of parts at the right place at the right time. Such efforts can result in the elimination of the disadvantages of carrying excessive inventory or stocking out of raw materials. The capability to effectively manage inbound logistics by information technologies can lower the need for safety stocks, inventory cost, and disturbances in production due to a lack of raw materials. Indeed, it leads to a higher level of service and greater customer satisfaction.

This study does not consider detailed manufacturing capability characteristics such as production planning, capacity, process type, and workforce as input variables for the System Dynamics model. In addition, beyond the analysis on the benefit of IT adoption just in terms of cost savings, this study captures the benefits in various perspectives such as inventory or safety stock reductions, demand amplification, order penetration point, lead-time of supply chain, product price, and investment.

CHAPTER 4. RESEARCH DESIGN

4.1 System Dynamics

In order to fully address the above mentioned research questions and objectives, more sophisticated models must be constructed and more comprehensive simulations must be carried out. Thus, this dissertation will develop a dynamic simulation model of advanced IT deployment considering interactive feedback relationships with product customization level, buyer-supplier relationship, and supply chain structure.

This research uses the System Dynamics method. In the 1960s, Massachusetts Institute of Technology Professor Jay W. Forrester (1961) created Systems Dynamics, a method of studying the world around us by viewing the system as a whole. Systems Dynamics examines the interaction of all objects or individual parts of a system and their relationship to one another. Basic system structures are assessed to better understand the cause and effect that may be produced. Many of these systems can be built as computerized models and are able to perform reliable calculations at a much greater speed than the human-mind based model.

Even though the application scope and focus of System Dynamics have changed continuously, the typical methodological characteristics of System Dynamics have still remained strong during the last 40 years. The first characteristic is that System Dynamics focuses on the dynamic behavior of systems, that is, the behavioral changes of systems according to the progression of time. This implies that System Dynamics emphasizes practical perspectives such as the change, evolution, development, and decline of systems. The second feature of System Dynamics is that it analyzes the fundamental reasons of dynamic change through feedback structure. Feedback structure means that a closed loop is established by linking causal relationships among variables (Richardson 1991). Emphasizing feedback loop indicates that the dynamic change of a system is analyzed through endogenous variables rather than exogenous variables. Explaining the change of a system by exogenous variables makes it difficult to alter the behavior of a system strategically. However, the utilization of endogenous variables makes it possible to change the behavior of a system within a model. Another strong point of the feedback structure is to analyze the change of a system in terms of the overall structure of the system rather than the change of parameter related to a specific variable. These characteristics precisely correspond to the objective of this dissertation as mentioned above, which is the identification of dynamic changes of IT effect by investigating interactive feedback relationships with product customization levels, buyer-supplier relationships, and supply chain structure. This provides the reason for using System Dynamics as the methodology to pursue the objectives of this dissertation.

4.2 System Dynamics Modeling Process

The simulation modeling process by the System Dynamics method can be largely classified into three stages; establishing a causal loop diagram, designing a System Dynamics diagram, and formulating an equation.

Stage 1: Establishing a causal loop diagram

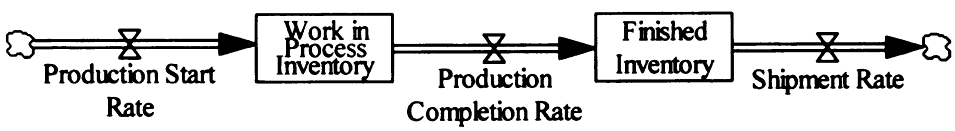
A causal loop diagram is the map identifying the feedback structure of a system and organizes the cause and effect that may be produced in a system by indicating the feedback structure on a two-dimensional diagram. A causal loop diagram is established by a set of causal propositions or hypotheses on the shape of relationships among selected construct variables.

Stage 2: Designing a System Dynamics diagram

A System Dynamics diagram is the map quantitatively actualizing the feedback relationships derived from a causal loop diagram through the consideration of two concepts on system behavior such as system state and system activity. System state is indicated as the values of all variables constructing a system at time t. Such values are the changing values obtained as a result of activities occurred between time t-1 and t. Also, information on such system state leads to the change of future activity by feedback.

For example, consider the flow of a product through a supply chain from producer to customer. The product shifts through a network of stocks (inventories) and flows (shipment and delivery rates). System dynamics diagram for this process is indicated in the bottom of Figure 4-1. As can be seen in the figure, production starts add to the stock of work in process (WIP) inventory. The production completion rate decreases the stock of WIP and increases the stock of finished inventory. Shipment to customers decreases finished inventory. In other words, WIP inventory increases when production start rate exceeds production completion rate, and finished inventory also increases when production completion rate exceeds shipment rate. Causal loop diagram indicated in the top of Figure 4-1 makes it difficult to check such physical flow of product through the system and the conservation of material in the stock and flow chain. The establishment of system dynamics diagram can supplement such pitfall of causal loop diagram to indicate the stock/flow distinction.

Causal Loop Diagram for a Manufacturing Process



System Dynamics Diagram for the Manufacturing Process

(Source: Sterman, 2000)

Figure 4-1: Causal Loop Diagram vs. System Dynamics Diagram

Stage 3: Formulating an equation

In this stage, equations corresponding to system state and system activity indicated in the System Dynamics diagram are formulated by computer simulation language. Such formulation of equations is completed through supplementation by several test runs of the simulation model.

4.2.1 Causal Loop Diagram

The explanation on the causal loop diagram in this dissertation starts from the impact of IT on buyer-supplier relationships. In the perspective of transaction cost theory, Malone et al. (1987) and Bakos (1987) insist that IT will facilitate a move from single-supplier arrangements within the firm ("hierarchies") to multiple supplier arrangements ("markets") because it reduces transaction costs with suppliers. According to this logic, technological developments lowering the cost of acquiring information about prices and product characteristics in a given market may reduce the excessive dependence on few key suppliers by reducing transaction-specific assets and subsequently entire transaction costs, and this should lead to an increase in the number of suppliers considered.

Such a shift to multiple supplier arrangements can provide greater *ex post* bargaining power to a buyer, because a buyer can have many alternative suppliers. Also, such a buyer's increasing bargaining power can deduce the decrease of material price, thus leading to the increase of a buyer's profit. If a buyer's profit is increased, the buyer can increase the investment for advanced IT deployment, thus making a connection to the increase of IT level. Figure 4-2 indicates a feedback loop reflecting the above argument. The feedback loop in Figure 4-2 shows that there is a mutual positive feedback relationship among IT level, the number of suppliers and buyer's bargaining power in the perspective of transaction cost theory. In other words, continuous advanced IT deployment ultimately can derive complete competition in the electronic market among numerous suppliers, and such an electronic market structure can provide the capability enabling pursuit of the deployment of more advanced IT to the buyer.

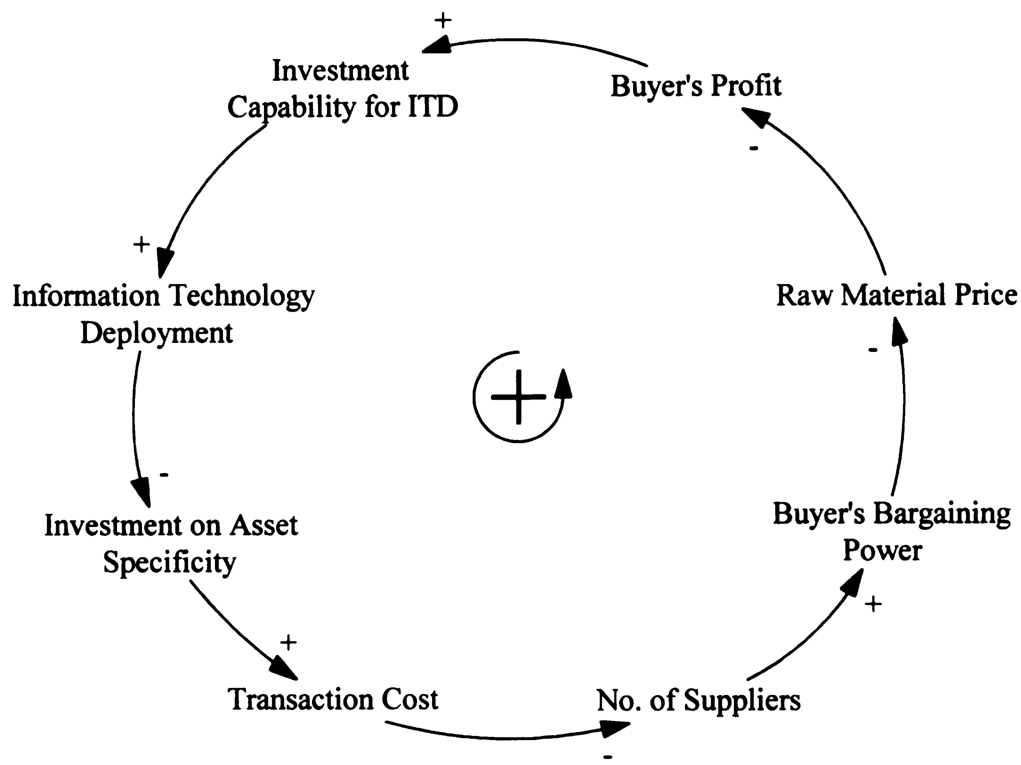


Figure 4-2: Causal Loop Diagram for IT effect on Buyer-Supplier Relationship in the perspective of Transaction Cost Theory

However, the perspective of incomplete contract theory suggests a paradox of such positive feedback relationship among IT level, the number of suppliers, and buyer's bargaining power under the viewpoint of transaction cost theory. That is, the decrease of material price induced by the increase of buyer's bargaining power obviously leads to the increase in buyer's profit, but simultaneously drives a decrease in supplier's profit. Such decrease in supplier's profit may reduce incentives for suppliers to make non-contractible investments in areas such as quality, innovation, speed, responsiveness, and flexibility. The reduction of supplier's incentives to make non-contractible investments increases the burden on the buyer to make non-contractible investments. As a result, transaction costs may actually increase in spite of the decline of investment on transaction-specific assets due to IT development. Accordingly, buyers must depend on close relationships with suppliers to reduce the burden of increasing transaction costs, and this should lead to a decrease in the number of suppliers considered. Also, such shift to fewer key supplier arrangements provides great bargaining power to suppliers, and this increase can induce an increase in material price, subsequently followed by a decrease in buyer's profit, the decrease of investment for IT deployment, and ultimately the reduction of desired IT level. Conclusively, the above argument means that there is a negative feedback relationship among IT level, the number of suppliers, and buyer's bargaining power in the perspective of incomplete contract theory unlike in the perspective of transaction cost theory. In other words, continuous IT deployment cannot lead to a persistent increase in the number of suppliers, and inversely, such stagnation in the number of suppliers prevents the continuous improvement of IT level, and thus each factor consisting of feedback loop is self-regulated and stabilized.

Actually, Bakos and Brynjolfsson (1993) assert that IT is likely to increase the importance of non-contractible factors, and Clemons et al. (1993) note that a positive relationship between IT level and non-contractible investment shifts the structure of buyer-supplier relationship to the middle ground between market and hierarchical structures, thus supporting the above argument (See Figure 4-3).

Negative feedback loop can also be found in the effect of IT on supply chain dynamics. Information sharing by the utilization of advanced IT can reduce distortion in demand information between buyer and supplier, which is referred to as the "bullwhip effect" (Lee et al. 1997; Christopher 1994). Such decrease of demand variability enables accurate forecasting, and this can lead to the decrease of target raw material (RM) level.

This lowering of target RM level can deduce the reduction of periodic RM order quantity, subsequently followed by the decline of RM inventory level and finished good (FG) inventory level. This logic is consistent with the argument of previous researches (Lee et al. 1997a; Lee et al. 1997b; Lee et al. 2000) asserting that information sharing can significantly minimize the problem of excessive inventory.

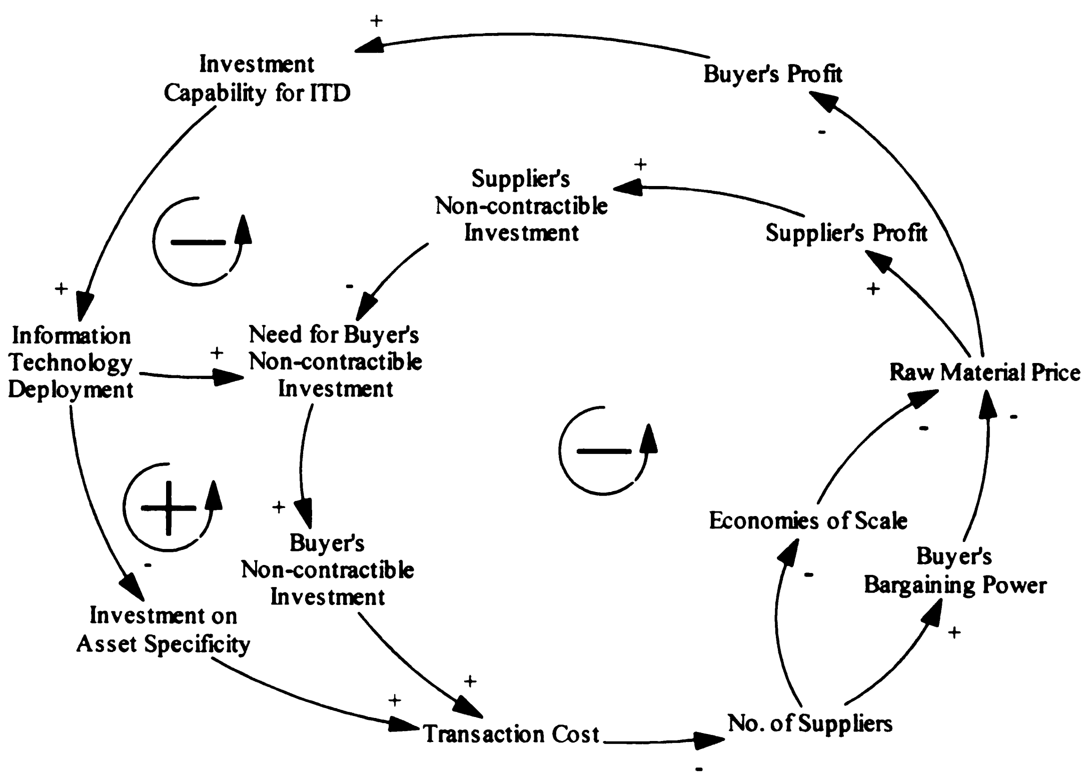


Figure 4-3: Causal Loop Diagram with IT effect on Buyer-Supplier Relationship in the perspective of Incomplete Contract Theory

However, as Grahovac and Chakravarty (2001) mentioned, decreasing overall inventory levels in the supply chain may not always be beneficial. In other words, in order to reduce overall costs and maximize profit, increasing inventory levels may be necessary. This is due to the fact that there is a probability that too low a level of inventory results in under-stocks of inventory in times of peak demand. Such probability increases the need for safety stock. Particularly, in the case of customized/differentiation focused product in which the level of product customization and variety is high (Porter 1980; Miller 1987), and demand is unstable (Miller 1988), the need for safety stock may be higher, because high customer service and responsiveness is required. Such need for safety stock brings the increase of production quantity, and subsequently this should lead to the increase of RM backorder necessary for the production of required quantity. When considering that this sequence is initiated from a low inventory level, the increase of RM backorder means that demand for RM is greater than the supply capability of RM, thus leading to the increase in RM pricing. As mentioned in the feedback loop for IT effect on buyer-supplier relationships, the increase of RM price subsequently leads to the decline in buyer's profit, the reduction of investment capability for IT development, and ultimately the reduction of desired IT level (See Figure 4-4).

Negative feedback loop representing IT effect on supply chain dynamics in Figure 4-4 indicates that information sharing by the utilization of advanced IT may not guarantee persistent cost reduction or profit increase through entire supply chain sequence. As mentioned previously, these opposing trends imply that the effect of information-sharing can be different depending on the detailed characteristics of the SCM system. Chen (1998) observed that information sharing benefits decreased with an increase in demand variance, thus supporting the above argument.

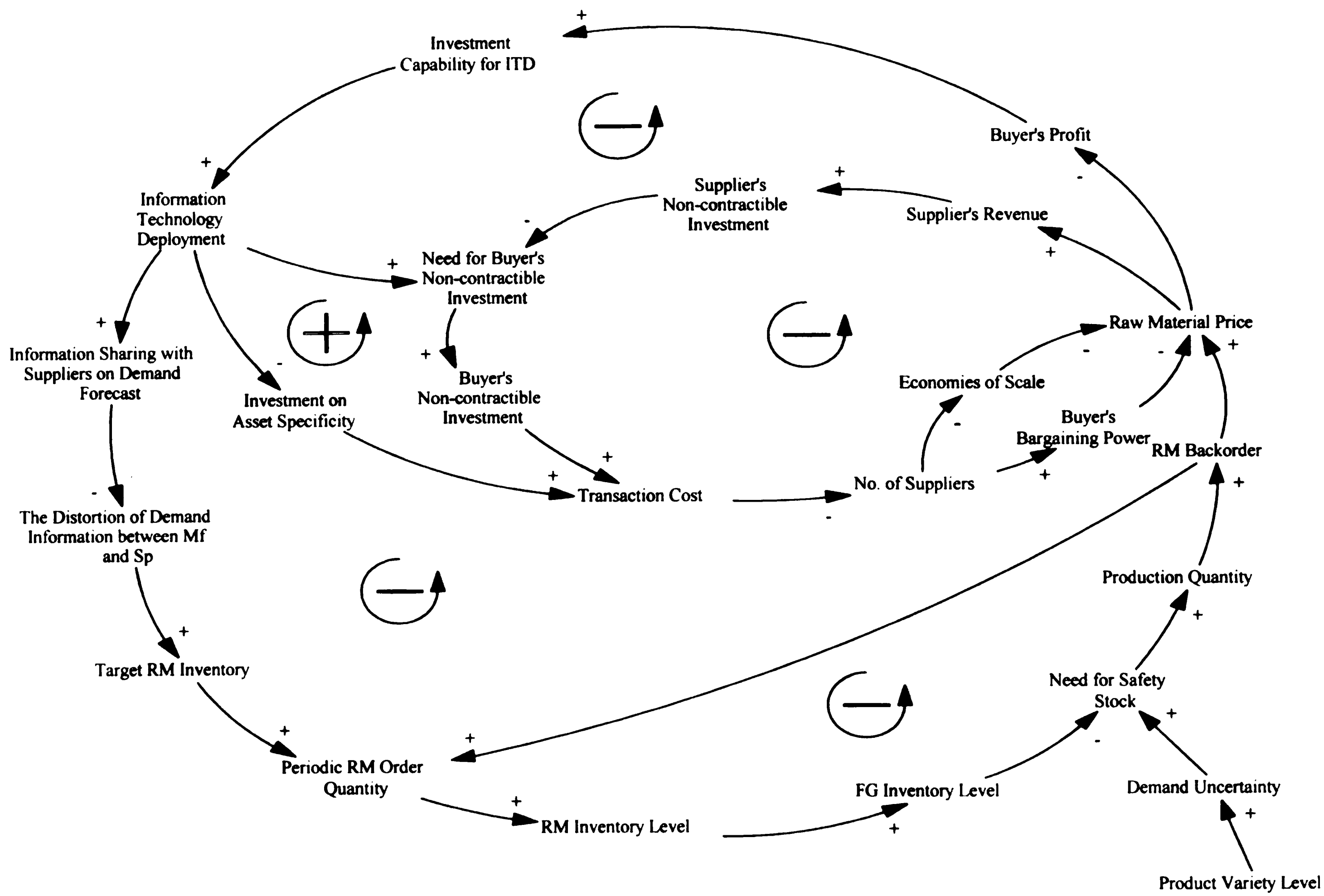


Figure 4-4: Causal Loop Diagram with IT effect on Supply Chain Dynamics (Full Model)

The effect of IT investment in supply chain management can differ depending on the interaction among feedback loops representing IT effect on buyer-supplier relationships and reflecting the effect of IT on supply chain dynamics. In other words, depending on how the described feedback loops affect each other or which feedback loop is most dominant, the effect of IT investment can vary.

4.2.2 System Dynamics Diagram

4.2.2.1 Overview of System Dynamics Diagram

In order to simulate the causal loop diagram described above by computer, two kinds of computer program are required. First is simulator, which runs system dynamics model by computer and suggests the results by table or graph. Second is simulation program, which represents the specific operating principles of system as a system dynamics model. Generally, simulation program is made under the simulator. This simulation program is called the system dynamics diagram.

This dissertation uses VENSIM, one of system dynamics software, in order to make system dynamics diagram based on the causal loop diagram described above. System dynamics uses a particular diagramming notation for variables (Figure 4-5) (Sterman 2000). Variables represented by rectangles are stocks. Stocks are accumulations. They describe the state of the system and create the information on which decisions and actions are based. Stocks give systems inactivity and provide them with memory. Stocks generate delays by accumulating the difference between the inflow to a process and its outflow. Pipes pointing into and out of the stock indicate inflows and outflows respectively. Valves manage such flows. By decoupling rates of flows, stocks are the source of disequilibrium dynamics in systems.

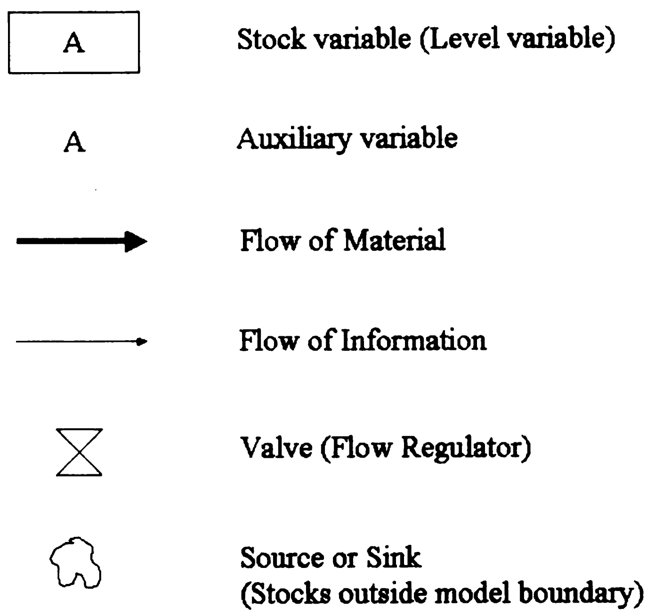


Figure 4-5: System Dynamics Diagramming Notation

The difference between stocks and flows can be recognized in many regulations and various areas (Table 4-1). In order to discriminate more clearly between stocks and flows, we can use the snapshot approach which takes a picture on a system. Stocks would be those things we can count or measure in the picture, including psychological states and other intangible variables. For example, if taking a picture on river, something we can quantify in the picture is the stock of water. We cannot check whether the water level is increasing or decreasing. Similarly, if taking a picture on workers within a firm, we can count the number of workers, but cannot count the number of hired or fired workers. Like this, stocks represent the state of system at a particular point, while flows mean the change of system state.

Clouds in Figure 4-5 indicate the sources and sinks for the flows. A source indicates the stock from which a flow generating outside the boundary of the model comes up. A sink indicates the stocks into which flows leaving the model boundary. It is assumed that sources and sinks have infinite capacity and cannot restrict the flows they support. Auxiliaries are the variables which are used as a intermediate variable in order to clarify and simplify the calculation of flow variables. Such auxiliary variables consist of functions of stocks (and constants or exogenous inputs) (Sterman 2000). These variables set the boundaries for the simulation model.

Table 4-1: Terminology for Identifying Stocks and Flows

Area	Stocks	Flows
Mathematics, Physics and Engineering	Integrals, states, state variables, stocks	Derivatives, rates of change, flows
Chemistry	Reaction products	Reaction rates
Manufacturing	Buffers, inventories	Throughput
Economics	Levels	Rates
Accounting	Stocks, balance sheet items	Flows, cash flow or income statement items
Biology, physiology	Compartments	Diffusion rates, flows
Medicine, epidemiology	Prevalence, reservoirs	Incidence, infection, morbidity and mortality rates

(Source: Sterman, 2000)

4.2.2.2 System Dynamics Model of this Dissertation

Appendices 1-3 indicate the System Dynamics diagram of this dissertation.

Appendix 1 is a System Dynamics diagram representing the effect of IT investment on buyer-supplier relationships, while Appendix 2 reflects the effect of IT investment and information sharing on supply chain dynamics. Also, Appendix 3 shows the diagram for analyzing the effect of IT investment derived from both diagrams in Appendices 1 and 2, in terms of profit. Even though three System Dynamics diagrams are detailed in Appendices 1-3, they are all connected to each other by the shadow variable, which means the copied variable of the original variable. For example, the IT level can be found in both appendices 1 and 2. The IT level in Appendix 2 is the shadow variable of that in Appendix 1, or in other words, the identical variable. Thus, both diagrams in Appendices 1 and 2 are connected by this IT level variable. Similarly, the FG sales in Appendix 1 are the shadow variable of that in Appendix 2, thus connecting both diagrams in Appendices 1 and 2. In addition, the profit variable in Appendix 1 is the shadow variable of that in Appendix 3, and buyer's revenue, RM price, RM shipping, FG sales, FG inventory, and RM inventory in Appendix 3 are the shadow variables of those in Appendix 1 and 2. By connecting the diagrams by shadow variable, a complete feedback loop is established.

The diagram in Appendix 1 representing the effect of IT investment on buyer-supplier relationships was totally created by this dissertation based on previous literatures (Bakos and Brynjolfsson 1993; Clemons et al. 1993) as mentioned above. In the case of the diagram in Appendix 2 reflecting the effect of IT investment and information sharing on supply chain dynamics, this dissertation modified Kim's two-level information sharing model (1998) on the basis of Sterman's (2000) and Coyle's (1977) supply chain dynamics models. This is because Kim's model was interpreted as the model representing most effectively the sequence and effect of information sharing in the supply chain among various supply chain dynamics models. Also, the diagram in Appendix 3 analyzing the effect of IT investment in terms of profit was modified from the model suggested in Sterman's '*Business Dynamics*' (2000).

One thing to be noted is that cost variables in the diagram of Appendix 3 are not indicated in the causal loop diagram. This is because such variables in this research are not mainstream, which can be backed up theoretically by previous literatures. So, for the sake of brevity, we omit presentation of such cost variables in the causal loop diagram. However, we know that a buying firm's profit can be influenced by not only raw material price, but also selling price of finished products and operating costs for manufacturing such finished products. Accordingly, for purposes of realism, this research considers such variables in the System Dynamics diagram in order to investigate more precisely the effect of IT deployment in the perspective of profit.

As shown in Appendix 1, this dissertation assumes that IT deployment level is determined by lookup function with investment budget for IT deployment (Figure 4-6). Lookup function can specify an arbitrary nonlinear relationship between two construct variables. Put simply, a Lookup is a list of numbers representing an x axis and a y axis. The inputs to the Lookup are positioned relative to the x axis, and the output is read from the y axis. Lookups can be used to create your own specialized functions. Lookups are also referred to as "Lookup Functions," "Tables," "Lookup Tables," "Table Functions," and sometimes "Graphical Functions." Lookups can be declared as x,y pairs or by specifying the x-axis followed by the y-axis. The format for declaring a Lookup is:

LOOKUP NAME([(Xmin,Xmax)-(Ymin,Ymax), (Xref1,Yref1), (Xref2,Yref2), ...
(Xrefn, Yrefn)] (X1, Y1), (X2,Y2), . . .(Xn, Yn))   ~ Units ~ Description |

or:

LOOKUP NAME(X1, X2, X3,....Xn, Y1, Y2, Y3,.... Yn)   ~ Units ~ Description |

Table 4-2 gives guidelines for specifying the shapes and estimating the values of table functions. This dissertation tried to specify the shapes of table functions according to the guidelines in the table. Sensitivity analysis in stage 9 will be noted specifically in the subsection for model validation test in this chapter.

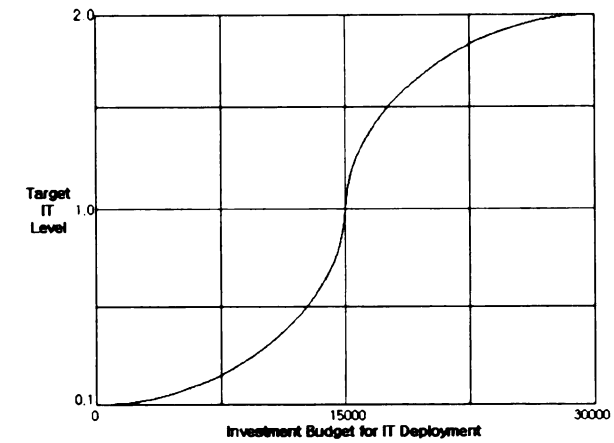
Table 4-2: Guidelines for formulating Table Functions

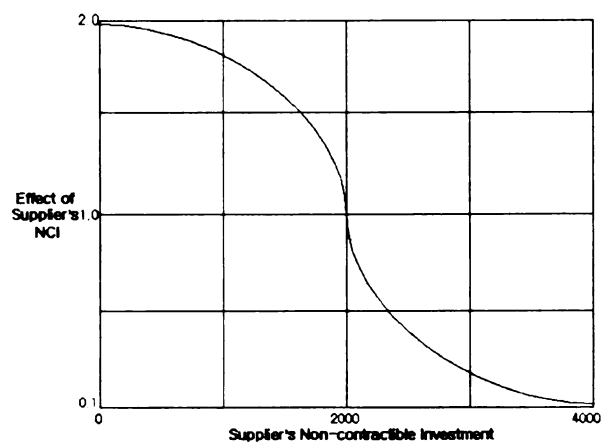
Stage	***Description***
1	Normalize the input and output. Instead of Y = f(X), normalize the function so that the input is the dimensionless ratio of the input to a reference value X* and the output is a dimensionless effect modifying the reference value Y*, Y = Y*f(X/X*).
2	Identify the reference points where the values of the function are determined by definition. For example, in normalized functions of the form Y = Y*f(X/X*), the function usually must pass through the point (1,1) so that Y = Y* when X = X*.
3	Identify reference policies. Reference policies are lines or curves corresponding to standard or extreme policies. The reference policy f(X/X*) = 1 represents the policy that X has no effect on Y. The 45 degree line represents the policy that Y varies 1% for every 1% change in X and is often a meaningful reference policy. Use the reference policy curves to rule out infeasible regions.
4	Consider extreme conditions. What values must the function take at extremes such as $-\infty$, 0, and $+\infty$? If there are multiple nonlinear effects in the formulation, check that the formulation makes sense for all combinations of extreme values and that the slopes of the effects at the normal operating points conform to any reference policies and constraints on the overall response of the output.
5	Specify the domain for the independent variable so that it includes the full range of possible values, including extreme conditions, not only the normal operating region.
6	Identify the plausible shapes for the function within the feasible region defined by the extreme conditions, reference points, and reference policy lines. Select the shape you believe best corresponds to the data (numerical and qualitative). Justify any inflection points. Interpret the shapes in terms of the physical constraints and policies.
7	Specify the values for your best estimate of the function. Use increments small enough to get the smoothness you require. Examine the increments between values to make sure there are no kinks you cannot justify. If numerical data are available you can often estimate the values statistically. If numerical data are not available, make a judgmental estimate using the best information you have. Often, judgmental estimates provide sufficient accuracy, particularly early in a project, and help focus subsequent modeling and data collection efforts.
8	Run the model and test to make sure the behavior of the formulation and nonlinear function is reasonable. Check that the input varies over the appropriate range (e.g. that the input is not operating off the ends of the function at all times).
9	Test the sensitivity of your results to plausible variations in the values of the function. If sensitivity analysis shows that the results change significantly over the range of uncertainty in the relationship, you need to gather more data to reduce the uncertainty. If the results are not sensitive to the assumed values, then you do not need to spend additional resources to estimate the function more accurately.

(Source: Sterman, 2000)

Investment budget for IT deployment is secured from a buyer's cumulative profit, which is the sum of the weekly profits, as described in the causal loop diagram, by multiplying the fraction variable indicating the ratio of profit invested for IT deployment to buyer's cumulative profit. A buyer's weekly profit is calculated by subtracting the total cost from the buyer's revenue. Total cost consists of production costs, inventory costs, RM purchasing costs, logistics costs including transport and processing costs, transaction costs, investment for IT deployment, buyer's non-contractible investment, and investment on asset specificity (See Appendix 3). The RM purchasing cost is computed by multiplying RM shipping quantities with the RM unit price. The value obtained from multiplying the RM shipping quantities with the RM unit price then becomes the supplier's revenue. By subtracting the supplier's total cost from the supplier's revenue, the supplier's weekly profit and the supplier's cumulative profit are obtained. The supplier's total costs consist of production and inventory costs. The RM shipping cost is not included in the supplier's total cost, because it is assumed as the burden of the buyer.

The supplier's cumulative profit dictates the level of the supplier's non-contractible investment by using the fraction variable indicating the ratio of the supplier's profit invested for non-contractible investment to the supplier's total profit. As Bakos and Brynjolfsson (1993) mentioned, the supplier's non-contractible investment has a significant effect on the buyer's non-contractible investment. In this perspective, the buyer's non-contractible investment is determined by lookup function with the supplier's non-contractible investment (Figure 4-6). The buyer's non-contractible investment is determined by multiplying the buyer's cumulative profit with the fraction variable indicating the level of the buyer's profit invested to non-contractible investment as well as the effect of the supplier's non-contractible investment by lookup function. Investment on asset specificity is determined by lookup function with IT level (Figure 4-6). Transaction cost is decided by lookup function with the buyer's investment on asset specificity and non-contractible investment, and the desired number of suppliers is dictated by lookup function with such transaction cost (Figure 4-7). The desired number of suppliers adjusts the current number of suppliers through adjustment time.





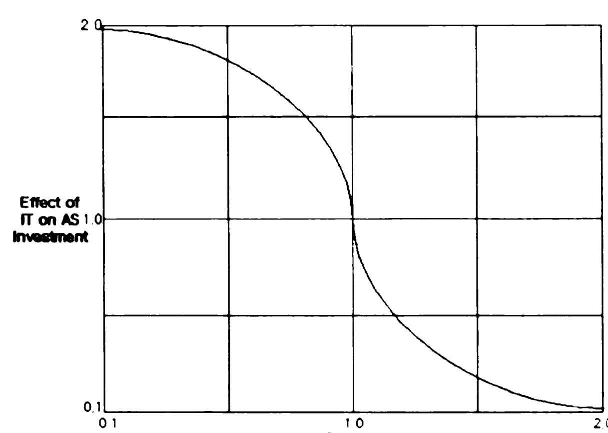


Figure 4-6: Lookup Functions (1)

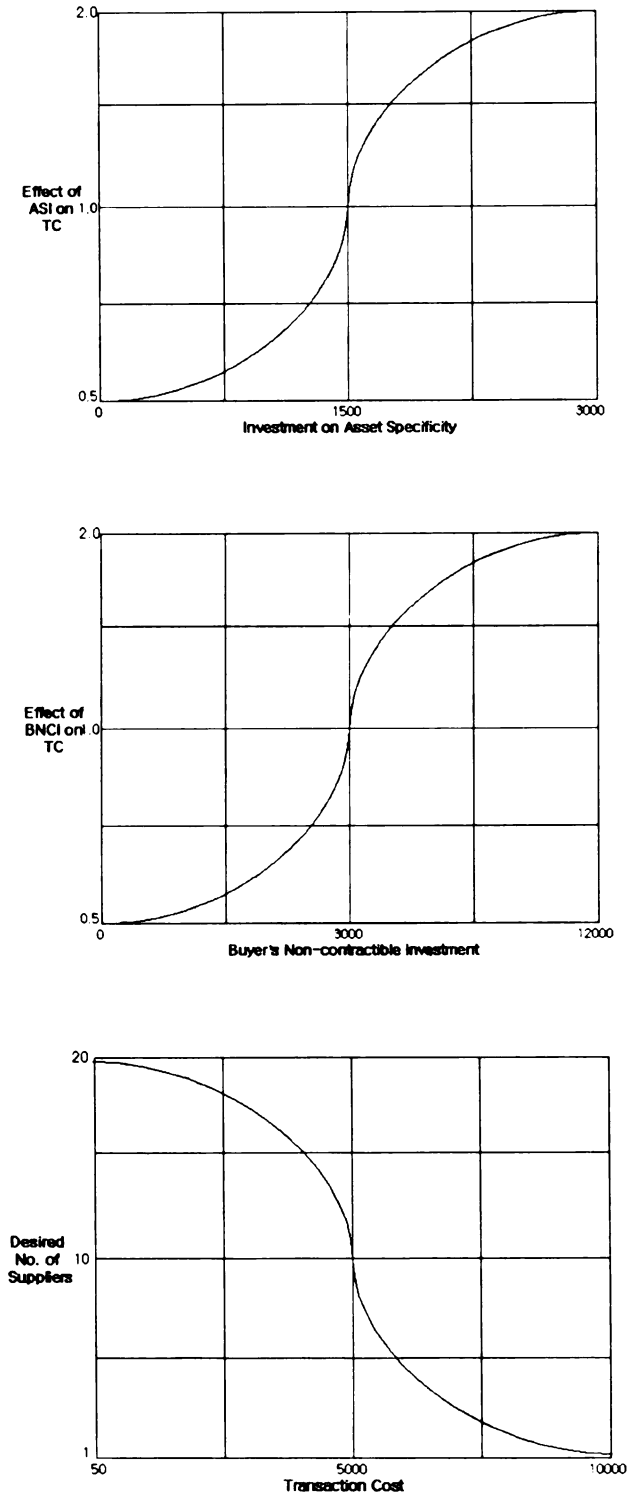


Figure 4-7: Lookup Functions (2)

The actual number of suppliers adjusted from the desired number of suppliers determines the levels of bargaining power of both buyer and supplier by lookup function (Figure 4-8). By the ratio of supplier's bargaining power to buyer's bargaining power, the effect of bargaining power is weighed. This bargaining power effect can be reflected in the modification of the RM price as mentioned previously. The RM price is decided by the effect of economies of scale and the effect of the RM demand-supply balance other than the effect of bargaining power. The effect of economies of scale is determined by lookup function with the number of suppliers (Figure 4-8). The effect of the RM demand-supply balance is measured by relative inventory coverage (the ratio of buyer's RM demand quantity to supplier's inventory quantity). Prices are assumed to respond to the balance of demand and supply, without specifying how supply and demand are perceived by market participants. Inventory coverage (the ratio of shipments to available inventory) is an excellent measure of both inventory-carrying costs for producers and the ability of buyers to receive reliable, timely deliveries. Consistent with many commodity models and substantial empirical evidence, price is adjusted above (below) the expected equilibrium level as inventory coverage rises (falls) relative to a normal, or reference level. Also, price depends on perceived coverage, not instantaneous coverage, because the instantaneous shipment rate is unknown. It takes time to gather and report data on inventory and shipments. For simplicity, perceived coverage is modeled with first-order smoothing. The coverage perception time would be short in markets with very good data or high sensitivity of storage costs to inventory levels and longer in markets with poor quality data or less sensitivity to storage costs (Sterman 2000). The indicated RM price decided by the above three effects adjusts the current RM price through adjustment time.

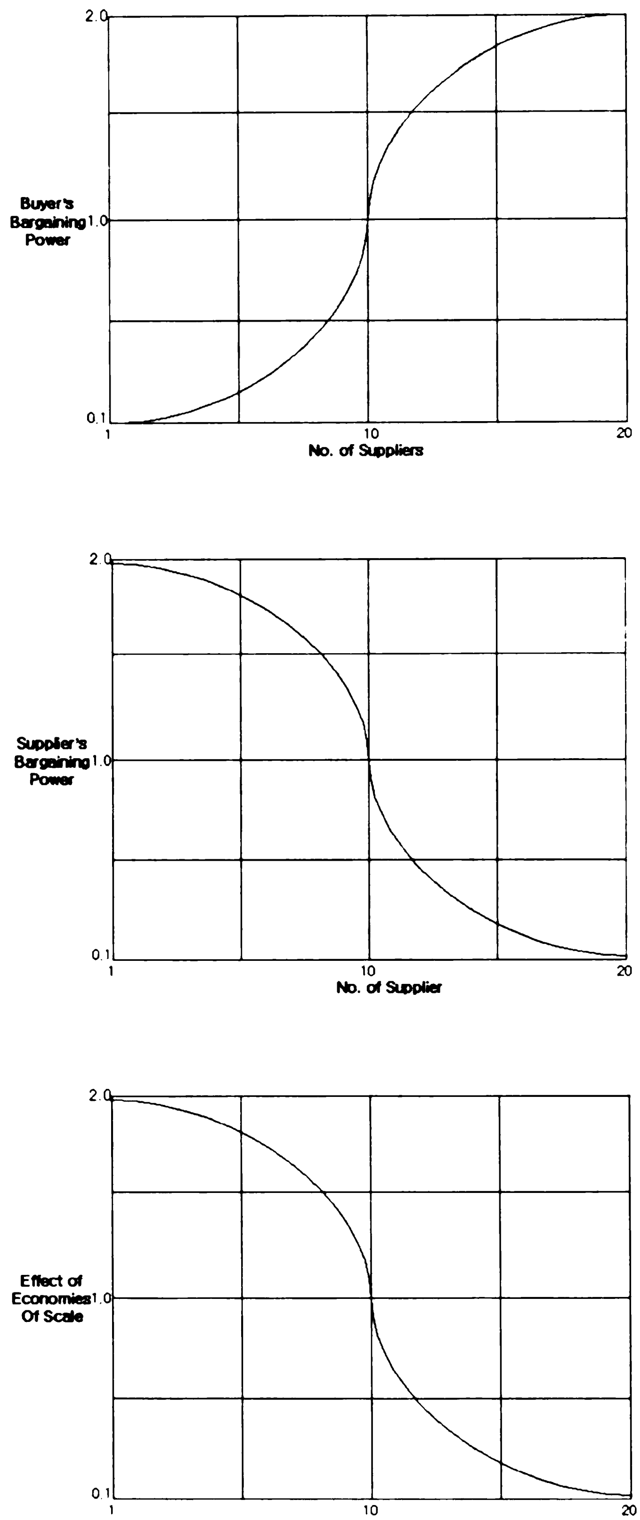


Figure 4-8: Lookup Functions (3)

Similarly, the indicated FG item price is decided by the effect of the FG demand-supply balance that is measured by relative inventory coverage (the ratio of FG demand quantity to FG inventory quantity). Reference inventory coverage level is determined at the point leading to equilibrium in which the indicated FG price is equal to FG price, in other words, the net rate of change of FG price must be zero, when it is assumed that demand is stationary. The explanation on equilibrium situation will be addressed at the end of this chapter.

As can be seen in Appendix 2, we consider a two-level supply chain that consists of RM supplier and manufacturer. In the model, manufacturer determines its order quantity as follows: 1) Manufacturer uses a periodic inventory control policy (order-up-to S. policy). 2) In each period, manufacturer realizes demand. If manufacturer has enough stock, the demand will be satisfied immediately. The unmet demand will be backordered.

Based on the actual demand (D_t) the manufacturer forecasts the demand for the next period by an adaptive expectation (i.e., exponential smoothing). When the smoothing time constant is T units of time, the forecast for the next calculation time, F_{t+dt}, will be:

$$F_{t+dt} = F_t + dt/T\,(D_t - F_t)$$

Thus, the forecast for the next time unit, t + 1, will be:

$$F_{t+dt} = \sum_{i=1}^{1/dt} dt/T\,(1-dt/T)^{i-1} D_t + (1-dt/T)^{1/dt} F_t$$

$$= [1-(1-dt/T)^{1/dt}]\, D_t + (1-dt/T)^{1/dt} F_t$$

Note that d is the interval of time between calculations. Therefore, our simulation model recalculates its numerical values every $1/dt$ of unit time.

The target FG inventory level at time t, S_t, is determined by:

$$S_t = F_t L + z\sigma_t(L)^{1/2}$$
$$= F_t[L + z\sigma_t/F_t(L)^{1/2}]$$
$$= F_t[L + Z(L)^{1/2}]$$

where F_t is the mean demand forecast, σ_t is the standard error of demand forecast, and L is the sum of the inventory review period, the transit lead time, and the manufacturing lead time. The manufacturer assumes that the coefficient of variation of the demand remains constant. Thus, she determines the amount of safety stock by a pre-specified constant z. The safety stock must cover demand uncertainty for a longer period of time. When using a normal probability distribution, we multiply the desired standard deviations to implement the cycle-service level, z, by the standard deviation of demand during the protection interval, σ_{P+L}(P: inventory review period, L: lead time). The value of z is the same as for a continuous inventory review system with the same cycle-service level (Krajewski and Ritzman 2000).

The manufacturer places an order for RM with the supplier and plans the production quantity to bring his FG inventory level to the target level. Also, the manufacturer will receive the shipment of the order for RM after a certain transit lead-time. The transit lead-time is fixed. However, the manufacturer will not receive the same amount as it ordered, if the supplier does not have enough stock to fill the order. The production rate is adjusted continuously. There is a yield loss in production. The number of non-defective finished items follows a binomial distribution $(n, 1 - \delta)$, where n is the number of items started at the manufacturing facility and δ is the defect rate. Since the manufacturer knows the defect rate, the number of items started is adjusted (or divided by $1 - \delta$) so that the expected number of non-defective finished items is equal to the amount to bring the

FG inventory level to the target level. Manufacturer determines weekly production quantity according to the following equation:

Average FG Production Qty + (Target FG Inventory-FG Inventory)/FG Inventory Adjustment Time + (Demand Backlog-Desired Demand Backlog)/Time to adjust Demand Backlog + (Desired Work In Process -Work In Process)/FG WIP Adjustment Time
*(Note: Desired Demand Backlog=Average Demand Rate*Normal FG Delivery Delay, Desired Work In Process=Average Sales Rate*Mf Lead Time)*

The supplier handles the manufacturer's orders as follows. First, the manufacturer's order will be immediately shipped from the supplier's inventory if the supplier has enough stock. The unmet order will be backordered, and delivery delay is considered. Second, the supplier forecasts the order for the next period by an adaptive expectation (i.e., exponential smoothing) based on day-to-day demand information obtained from information sharing with manufacturer. Generally, it can be recognized that the effect of information sharing can be different depending on the level of information technology. In other words, if more advanced IT is deployed, more accurate and timely sharing of manufacturer's forecast on daily demand becomes possible. Inversely, if IT level is relatively low, the possibility of demand distortion due to a lack of information sharing may increase. In order to reflect such argument, this dissertation creates the fraction variable indicating the level of accurately reflecting manufacturer's sales forecast to the decision of supplier's target inventory level by lookup function with IT level (Figure 4-9). That is, the target RM inventory level is determined by multiplying the above fraction variable with the same equation as the manufacturer determines the target FG inventory level to be.

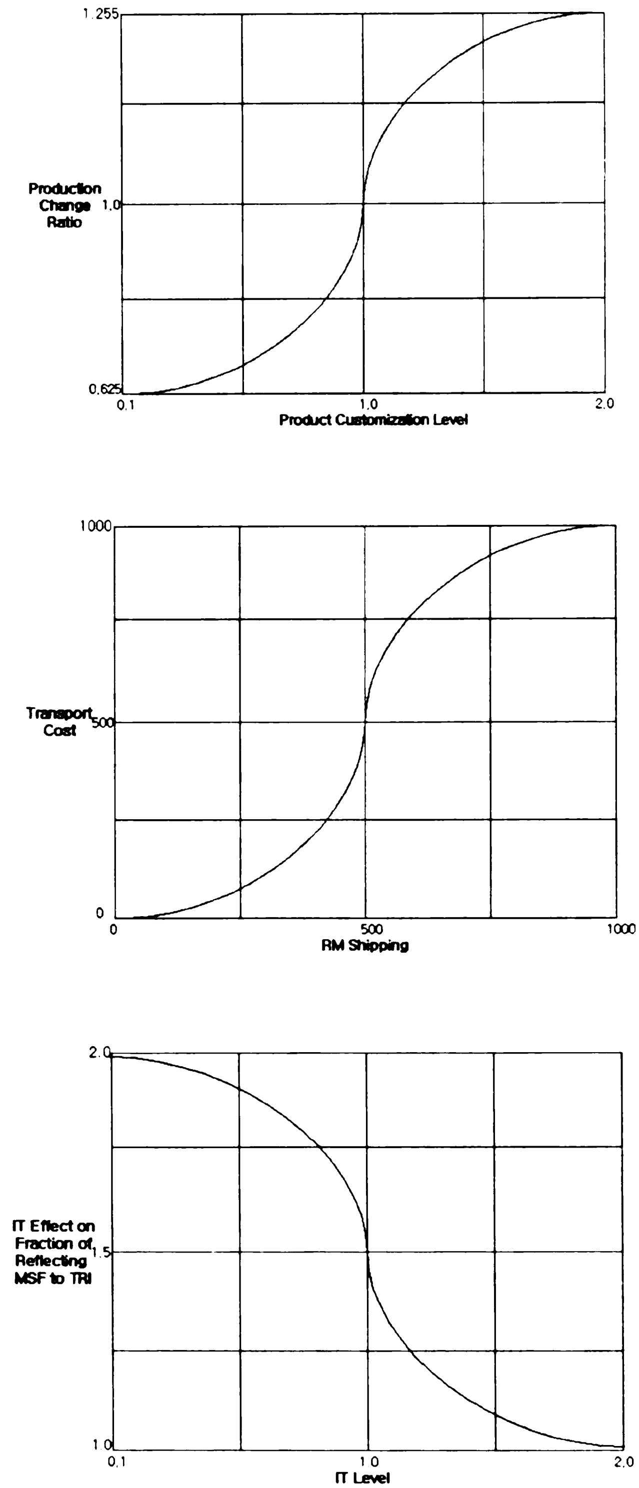


Figure 4-9: Lookup Functions (4)

Also, similarly with the manufacturer, the supplier plans the production quantity to bring his RM inventory level to the target level. The production rate is adjusted continuously. Weekly production quantity is decided by the same equation as the manufacturer determines as follows:

Average RM Production Qty + (Target RM Inventory-Sp Inventory)/Sp Inventory Adjustment Time + (RM Backlog-Desired RM Backlog)/Time to adjust RM Backlog + (Desired Sp Work In Process –Sp Work In Process)/Sp WIP Adjustment Time

*(Note: Desired RM Backlog= Average RM Order Rate*Normal RM Delivery Delay, Desired Sp Work In Process=Average RM Shipment Rate*Sp PD Lead Time)*

We assume an infinite and instant production of raw material by the supplier. Also, we consider a case when no member in the supply chain has the perfect information about the demand. (i.e., no one knows the type of demand distribution or its parameters.) Therefore, every member should "forecast" the demand. We believe our model will more adequately capture the benefits of information sharing since, in real situations, neither the manufacturer nor the supplier has the perfect information about the demand and the real demand distributions are often non-stationary in many industries.

Since the demand forecasting is one of the critical factors in analyzing the benefits of information sharing, we consider various types of demand distribution and their impact on the benefits. Bourland et al. (1996) and Gavirneni et al. (1996) consider a stationary demand distribution whose parameters (mean and variance) are known to every member in the supply chain. Lee et al. (1997) consider a non-stationary (autoregressive) demand distribution whose parameters are known to every member in the supply chain. They suggest that the benefits of information sharing occur in almost every case since the demand distribution is non-stationary. In this dissertation, we consider non-stationary demand distributions.

4.2.3 Formulation of Equation

In order to implement the System Dynamics model described above, formulating its associated computer (mathematical) equations is required. This is followed by selecting 'reasonable parameter and stock values' for initial starting values for the simulation.

As mentioned previously, one of the most important points in system dynamics modeling is how to set reasonable initial starting points for parameter values. Thus, the estimation of parameter values receives a great deal of attention in SD modeling. The basic choice is formal statistical estimation from previous numerical data. However, it's not easy to get numerical data appropriate for all parameter values. Such limitations on numerical data availability mean it is often impossible to estimate all parameters in a model. So, in order to estimate parameters more realistically and find reasonable initial starting point, this dissertation collected the qualitative and quantitative data from the case study, because the case study can provide the insights necessary to develop the analytical models that are needed in the simulation. Case studies were implemented on several US manufacturing companies in North America and the North America corporations of Korea's large manufacturing companies, which are engaged in automobile, electrics/electronics, food, and telecommunication industries. Equations for stock, flow, and auxiliary variables used in the model are listed in Appendix 4.

As can be seen in Appendix 4, this dissertation sets the initial FG item price as \$350 and the RM unit price as \$100. If the demand remains constant, then bullwhip effect scarcely occurs. So, in order to make a more realistic model, it is assumed that FG demand is irregular within mean demand ± standard deviation multiplied by product customization level. In this dissertation, mean and standard deviation are set as 200 and

20 respectively. Standard deviation is multiplied by product customization level in order to consider the positive influence of product customization level on demand uncertainty discussed in the literature portion.

The level of information technology ranges from 0.1 to 2.0, and the fraction of cumulative profit to investment on IT deployment is defined as 0.05, which means that 5% of cumulative profit per week is assigned as investment budget for IT deployment. Product customization level is also assumed to increase by increments of 0.1 from 0.1 to 2.0. Such scale for product customization level is based on the approach of Kraljic (1983) who classified product characteristics into two factors such as the level of market complexity and the level of strategic dependence on product, and using the sum of weights for these two factors as the level of product variety. The amount of normal investment on asset specificity is set as $1500 per week and investment on asset specificity is determined by multiplying such normal investment on asset specificity to the effect of IT level on asset specificity ranged from 0.1 to 2.0. The fractions of supplier's and buyer's cumulative profit to non-contractible investment are defined as 0.01 respectively, which means that 1% of supplier's and buyer's cumulative profit per week is budgeted for non-contractible investment respectively. Normal transaction cost is set as $5000 per week and changes according to the effects of buyer's non-contractible investment and asset specificity investment on transaction cost. The number of suppliers is decided within the range of 1 and 20. Buyer's bargaining power, supplier's bargaining power, and effect of economies of scales are set to have a range from 0.1 to 2.0 in order to assume the equal effect of those three variables on the indicated RM price.

Supplier's and manufacturer's unit costs for producing and holding the RM are defined as \$13 and \$16 respectively. These lead to the initial equilibrium point at which supplier's and manufacturer's revenues are equal to their costs respectively, that is, the net rate of profit is zero. Equilibrium point will be noted again in the later part of this chapter. The rationale behind manufacturer's ratio of item cost to initial item price being set as less than the supplier's ratio is to reflect that FG manufacturing requires greater efforts in fulfilling customer's demands than RM manufacturing, and entire inventory management after RM shipping from supplier and investment on IT deployment are assumed as the burden of manufacturer in this dissertation. Both RM and FG holding costs remain constant regardless of time flow, but the FG manufacturing cost is assumed to change according to product customization level (Figure 4-9) by considering that, in reality, cost or time saving (loss) may occur when changing production according to the decrease (increase) of product customization level. Transport cost, one of two variables composing logistics costs, is determined by lookup function with transport late (Figure 4-9), and processing cost is assumed to remain constant at \$20. These two definitions were modified from the model suggested by Sterman (2000).

RM manufacturing lead-time, FG manufacturing lead-time, and transit lead-time from RM supplier to manufacturer are each set at 2 weeks. One of the options for determining the manufacturer's inventory review period (P) is to base P on the cost trade-offs of the economic order quantity (EOQ). In other words, P can be set equal to the average time between orders for the EOQ. Because demand is variable, some orders will be larger than the EOQ and some will be smaller. However, over an extended period of time, the average lot size should equal the EOQ. Using such logic, we can divide the

EOQ by the annual demand, D, and use this ratio as P (Krajewski and Ritzman 2000). From the above procedure, the inventory review period is set at 2 weeks. Inventory adjustment and backlog adjustment times are defined as 8 weeks respectively, and WIP adjustment time is set at 4 weeks. Times to average production, shipment, and order rates are defined at 4 weeks. As mentioned previously, safety stocks for both RM supplier and manufacturer are decided by the equation $z\sigma_t(L)^{1/2}$. Standard deviation is set at 20 as mentioned previously, and z is defined as 1.28 for a 90 percent cycle-service level. The exponential smoothing time constant is defined at 4 weeks. Defect rate is set as 0%, and both supplier's and manufacturer's production capacities are assumed to be infinite.

As mentioned previously, this dissertation utilizes many lookup functions in order to arbitrarily specify a nonlinear relationship between two construct variables that cannot be indicated quantitatively. Lookup functions utilized in this dissertation are indicated in Figure 4-6, 4-7, 4-8, and 4-9.

One of the important formulation techniques that will be used in the System Dynamics model is the initialization of the levels to an equilibrium or steady state value. This is needed to test the sensitivity to perturbations, that is, sensitivity to changes in variables and in loop structure. A stock is in equilibrium when it is unchanging (a system is in equilibrium when all its stocks are unchanging). For a stock to be in equilibrium the net rate of change must be zero, implying the total inflow is balanced by the total outflow (Sterman 2000). In other words, in equilibrium, the total inflows and outflows of each stock must be equal. We can use this logic when trying to compute an initial value for each stock variable. That is, initial stock value is decided at the point in which the total inflows and outflows are equal. However, as mentioned previously, this dissertation assumed that demand is randomly distributed. As such, it is very difficult to locate an initial stock point leading to equilibrium. Accordingly, in order to find an initial stock point, we observed the dynamic behavior of variables when demand remained constant at 215 units - that is the initial starting demand rate as well as the annual average demand rate in a non-stationary demand model. Key initial stock points derived from the above procedure are indicated in Table 4-3.

Table 4-3: Initial Stock Points

Stock Variable	*Initial Point*	*Stock Variable*	*Initial Point*
IT level	1	**No. of supplier**	10
RM price	$100	**FG price**	$350
Manufacturer's cumulative profit	$300,000	**Supplier's cumulative profit**	$200,000
Supplier's WIP inventory	*Average RM Shipment Rate*Sp PD Lead Time (Desired WIP)*	**Manufacturer's WIP inventory**	*Average Sales Rate*Mf Lead Time (Desired WIP)*
Supplier's inventory	Target RM inventory	**Manufacturer's inventory**	Target FG inventory
Average RM production quantity	200	**Average FG production quantity**	200
Average RM shipment rate	RM shipping	**Average RM order rate**	Manufacturer's RM order in
RM backlog	Desired RM backlog	**FG backlog**	Desired demand backlog
RM in transit	400	**RM inventory**	400
Average sales rate	FG sales	**Average demand rate**	Demand
AR: Last demand	0		

It is unnecessary to initialize structure in equilibrium, but it can be very helpful. It is very common for the early part of a simulation run to be dominated by adjustments from imbalances in levels and rates. The dynamics generated by this imbalance do not tend to have intrinsic importance and can severely hamper the understanding of model dynamics.

Running time for simulation is set as 150 weeks. Unit for time is week, and time step is 1 week.

4.3 Validity of System Dynamics Model

4.3.1 The Meaning of Validation

This section describes model-testing process by which we can build confidence that the SD model mentioned above is valid for the purpose of this dissertation. In other words, this section explains specific tests and procedures you should follow to test the validity of a model for this dissertation's purpose, uncover flaws, and improve the reality of this dissertation's SD model.

Many modelers talk about model "validation" or argue to have "verified" a model. In fact, validation and verification of models is impossible. In other words, no model can ever be verified or validated, because all models are wrong. All model, mental or formal, are limited, simplified representations of the real world. They differ from reality in ways large and small, infinite in number. The only statements that can be validated-shown to be true-are pure analytic statements, propositions derived from the axioms of a closed logical system. The impossibility of validation and verification is also applied to computer models. Any theory that refers to the world relies on imperfectly measured data, abstractions, aggregations, and simplifications, whether the theory is embodied in a large-scale computer model, consists of the simplest equations, or is entirely literary. The differences between analytic theories and computer simulations are differences of degree only (Sterman 2000).

If validation is impossible and all models are wrong, why do we should build them? We must recognize that our important decision to use a model-mental or formal- is never whether to use a model but only which model to use. That is, our responsibility is to use the best model appropriate for the purpose at hand in spite of its inevitable limitations. The decision to delay action in the vain quest for a perfect model is itself a decision, with its own set of consequences. Experienced modelers likewise recognize that the goal is to help their clients make better decisions, decisions informed by the best available model. Instead of seeking a single test of validity models either pass or fail, good modelers seek multiple points of contact between the model and reality by drawing on many sources of data and a wide range of tests. Instead of viewing validation as a testing step after a model is completed, they recognize that theory building and theory testing are intimately intertwined in an iterative loop. Instead of presenting evidence that the model is valid, good modelers focus the client on the limitations of the model so it can be improved and so clients will not misuse it.

Once we recognize that all models are wrong and abandon the black and white dualism of truth and falsification, we can focus on the important questions: Is the model useful? Do its shortcomings matter? To answer these questions you must first ask: Useful for what purpose? Matter to whom?

Model users must critically assess the model's boundary, time horizon, and level of aggregation in light of their purpose. The model boundary determines which variables are treated endogenously, which are treated exogenously, and which are excluded altogether.

Factors relevant to the purpose must be captured endogenously. Treating a concept as exogenous, or omitting it, cuts all feedbacks involving that variable. Models with narrow boundaries don't capture the system's responses to policies, leaving the clients to discover them as unforeseen side effects in the real world. Narrow model boundaries are the single greatest source of policy resistance in systems.

This section discusses tests to help answer questions about model purpose and boundary, physical and decision-making structure, and sensitivity analysis. This section focuses on the practical and political issues of modeling.

4.3.2 Model Validation Test

System dynamics modelers have developed a wide variety of specific tests to uncover flaws and improve models (e.g., Forrester 1973; Forrester and Senge 1980; Barlas 1989, 1990, 1996). Levine and Fitzgerald (1992) established three types of tests to verify system dynamics models: structural tests, behavioral tests, and policy tests. Structural tests include structural verification, parameter verification, dimensional consistency, and boundary adequacy. Behavioral tests include behavior reproduction, behavior prediction, behavior anomaly, surprise behavior, extreme policy, generalizability, and boundary sensitivity. Policy tests include changed behavior prediction, boundary commission, and system improvement.

The purpose of these tests is to determine the robustness of the model to normal and extreme situations and to ensure that no relevant paths have been omitted from the model nor have extraneous paths been added. Internal and external validity involves adding/deleting exogenous and endogenous variables to the model to determine their effects on the system (Janszen 2000).

4.2.3.1 Structural Tests

(1) Boundary Adequacy Test

Boundary adequacy tests assess the appropriateness of the model boundary for the purpose at hand. These tests consider whether there are potentially important feedback omitted from the model. Of course, the list of omitted concepts and variables is infinite. So, the focus of boundary adequacy test should be placed on whether any feedbacks omitted from the model, if included, might be important given the purpose of the model. With the appropriateness of the model boundary, we should check the validity of the model feature itself. That is, we should ask whether or not the overall feature of the model makes sense and the process and hypothesis for constructing feedback loops are valid. Review of the relevant literature and archival materials, interview with outside experts, and direct experience with the system may suggest some significant points for validating model boundary and feature.

This dissertation made three key feedback loops representing IT effect on buyer-supplier relationship and supply chain dynamics on the basis of previous key articles (Bakos and Brynjolfsson 1993; Clemons et al. 1993; Lee et al. 1997a, 1997b, 2000; Sterman 2000; Grahovac and Chakravarty 2001) suggesting direct causal relationship among variables constructing the causal loop diagram described previously. The boundary validation of this dissertation's SD model was checked and modified from few U.S. and Korean supply chain managers who have direct experience with SCM system and top-level executives of sales, production, or planning department who was well acquainted with supply chain policies and corporate strategy of the firm. Also, the committee members of this dissertation screened the boundary validation of the model.

(2) Relationship Validity Test

Relationship validity test check whether the direct relationship between variables constructing the feedback loops in this dissertation's SD model was appropriately established. Such relationship validity test can be largely classified into two parts. First is to test whether the direction of causal links between variables was appropriately defined and moving direction between variables assigned as positive or negative was properly indicated. Second is to examine the validity of equations indicating specific relationship between variables.

The validity of causal links can be identified from previous researches (Bakos and Brynjolfsson 1993; Clemons et al. 1993; Lee et al. 1997a, 1997b, 2000; Sterman 2000; Grahovac and Chakravarty 2001) suggesting direct causal relationship among variables constructing the causal loop diagram similarly with boundary adequacy test. The validity of equations is also verified by previous supply chain dynamics models (Coyle 1977; Narasimhan 1979; Kim 1998; Sterman 2000).

However, as mentioned in the causal loop diagram, this dissertation's SD model includes the diagram representing the effect of IT investment on buyer-supplier relationship which was totally created by this dissertation based on previous literatures (Bakos and Brynjolfsson 1993; Clemons et al. 1993) other than the diagram reflecting the effect of IT investment on supply chain dynamics. Also, such diagram includes many non-linear relationships between variables. As mentioned previously, this dissertation used lookup function in order to specify an arbitrary nonlinear relationship between two construct variables. It is very important to test the sensitivity of the results in order to identify plausible variations in the assumed shape and values of all non-linear functions. If sensitivity analysis shows that the results change significantly over the range of uncertainty in the relationship, we need to spend additional resources to estimate the non-linear function more accurately. In order to identify whether or not the diverse shapes of non-linear relationships lead to different simulation results, sensitivity analyses with various types of lookup functions were implemented, and the variance among the simulation results was investigated by the ANOVA and Duncan multiple range tests. The results showed that there was no significant difference in either the magnitude of fluctuation or the trend of behavioral change.

(3) Structure Assessment Test

Structure assessment test considers whether the model is consistent with knowledge of the real system relevant to the purpose. Structure assessment focuses on the level of aggregation, the conformance of the model to basic physical realities such as conservation laws, and the realism of the decision rules for the agents (Sterman 2000).

Violations of physical laws such as conservation of matter or energy usually arise because the model does not appropriately capture the stock and flow structure of the system. As mentioned previously, in order to discriminate more precisely between stocks and flows, this dissertation used the snapshot approach that takes a picture on a system and distinguish stocks and flows depending on whether we can count or measure in the picture. Another approach for discriminating between stocks and flows is to suppose the situation that all business transactions are suddenly stopped. Stocks would be those things we can identify subsistence. For example, if business transaction is stopped, buyer's and supplier's profits at that moment should be zero. But, cumulative profit subsists. Similarly, when business transaction between buyer and supplier is stopped, we can count the number of existing suppliers, but the number of currently desired suppliers is zero. Through double screens by the two approaches described above, this dissertation captured the stock and flow structure of the system.

Other common violations of physical law involve stocks that can become negative. Real quantities such as inventories, populations, and cash balances cannot be negative. Therefore the outflows from all such stocks must approach zero as the stock approaches zero. This means that there must be a first-order negative feedback loop that restricts all the outflows from real stocks so that the flow is zero when the stock is zero. These loops must be first-order because any time delay in the loop could cause the rate to continue even after the stock reaches zero, a physical impossibility. We can check for the presence of first-order control by direct inspection of the equations. Also, partial model tests can demonstrate the intended rationality of the individual decision rules. In a partial model test, each organizational function or decision point is isolated from its environment until environment is consistent with the mental model that underlies the decision rule. The subsystem can then be challenged with various exogenous patterns in its inputs (Sterman 2000). Through equation inspections and partial model tests, this dissertation checked whether or not the abovementioned violations exist among total 21 stock variables in this dissertation's SD model. As a result, any abnormal violation was not found.

(4) Dimensional Consistency Test

Dimensional consistency is one of the most basic tests that we should do first. We should always specify the units of measure for each variable as you build your models.

More often, units error reveal important flaws in your understanding of the structure or decision process you are trying to model.

Vensim, which is one of simulation software package for system dynamics, implements automated dimensional analysis. Thus, we can test for dimensional errors with a single command. This dissertation investigated the existence of dimensional errors by the command, and as a result, no error messages were discovered.

(5) Parameter Assessment Test

Model constancy arises either because dynamics affecting the state of the system are so slow that change is imperceptible or because there are powerful negative feedback processes keeping the state of the system nearly constant even in the face of environmental disturbances. The uncertainty in parameter values is important and must be tested. Sensitivity analysis checks whether our conclusions change in ways important to your purpose when assumptions are varied over the plausible range of uncertainty.

In assessing sensitivity to parametric assumptions we should first identify the plausible range of uncertainty in the values of each parameter or nonlinear relationship. Then, we should test the sensitivity to those parameters over a much wider range. Vensim includes automated sensitivity analysis tools. First, we specify which parameters to vary, and then provide a range of values for each. Vensim then runs the model as many times as we like, using the specified values for each parameter, either one at a time (univariate testing) or all at once (multivariate testing).

This dissertation identified the robustness of the model through the implementation of sensitivity analysis. One common method for sensitivity analysis is to define extreme situations represented by highest and lowest values. This involves manipulating the rate and exogenous variables from normal to extreme situations represented by highest and lowest values. Models should be robust in extreme conditions. Robustness under extreme conditions means that the model should behave in a realistic and consistent fashion no matter how extreme the inputs or policies imposed on it may be. Sensitivity analysis checks whether models behave appropriately and consistently when the inputs take on extreme values. Thus, sensitivity analyses were conducted on all parameters in the model. As a result, the behavioral patterns of endogenous variables in the cases of highest and lowest values for each parameter were the same with base case even though a little difference in the magnitudes of variables among two extreme cases and base case exists. This means that the change of parameter value does not have a significant influence on the behavioral change of overall system, even though the implication in terms of magnitude can be different. In other words, this testing process indicates that parameter does not significantly change the constructs or the propositions that are to be tested in this dissertation, thus verifying the robustness of the model.

(6) Time-step Error Test

The results of SD model should not be sensitive to the choice of time step. In other words, the wrong time step can introduce spurious dynamics into SD model. One method for testing such time step (DT) error is to cut the time step in half and running the model again. If the results change in ways that matter, the time step should be modified, and such modification continues until the results are no longer sensitive to the choice of time step (Sterman 2000). By the abovementioned procedure, this dissertation confirmed that the change of time step does not change simulation results.

4.2.3.2 Behavioral Tests

(1) Dynamic Behavior Test

There are many available methods to evaluate a model's ability reproducing the behavior of a system. Most common method is to use descriptive statistics to assess the point-by-point fit. Point-by-point metrics calculate some measure of the error between an actual data series and the model output at every point for which data exist and then report some sort of average over the relevant time horizon (Sterman 2000). The most representative measures of point-by-point fit are the Coefficient of Determination (R^2), Mean Absolute Error (MAE), Mean Absolute Precent Error (MAPE), Mean Absolute Error as a fraction of the mean (MAE/Mean), Root Mean Square Error (RMSE), and Theil's inequality Statitics decomposing MSE into three components : bias (U^M), unequal variation (U^S), and unequal covariation (U^C); $U^M + U^S + U^C = 1$.

Unfortunately, this dissertation does not have actual data series available to assess point-by-point fit. In such a reason, it's impossible to implement behavior reproduction test. Instead, we can think about an alternative in which the SD models suggested in previous research related to supply chain dynamics are used as reference model for assessing the validity of system behavior. In other words, through the comparison in system behavior between this dissertation's SD model and those of previous researches, the validity of system behavior within this dissertation's SD model may be indirectly identified. The researches of Narasimhan (1979), Christopher (1994), and Lee et al. (1997, 2000) can be suggested as the most representative reference models. Those researches emphasize consistently that information sharing by the utilization of advanced IT can reduce distortion in demand information between buyer and supplier, specifically, inventory and production fluctuations are softened gradually according to time flow in case of perfect information sharing between buyer and supplier. Figure 5-5 (See p.100) indicates that the system behavior of SD model suggested in this dissertation is consistent with the previous research's emphasis described above. This provides the validity of system behavior of this dissertation's SD model.

However, as can be seen in Figure 5-5, not only supplier's inventory fluctuation is softened, but also supplier's entire inventory level is reduced, as the level of IT increases. This is clearly different from the results of previous research. This is because this dissertation assumes that the effect of information sharing can be different depending on the level of information technology, unlike previous research that analyzed just the difference in effect between two extreme situations such as perfect information sharing and imperfect information sharing. Such difference between this dissertation and previous research brings out the necessity of point-by-point comparison with actual data series to assess more precisely the validity of system behavior. This deserves further investigation in the future.

(2) Behavior Anomaly Test

The abovementioned data limitation makes it difficult to test the statistical significance of important relationships or formulations. Behavior anomaly test examines the significance of relationships or formulations by considering whether anomalous behavior arises when the relationship is deleted or modified. Anomalous behavior derived from the deletion of a relationship provides the evidence for its significance (Sterman 2000). From the implementation of such behavior anomaly test, the significance of each relationship established in this dissertation was verified.

(3) Extreme Condition Test

Models should be robust in extreme conditions. Robustness under extreme conditions means that the model behave in a realistic fashion mo matter how extreme the inputs or policies imposed on it may be. For example, inventory cannot drop below zero, and production cannot occur without raw materials. Extreme condition test checks whether models behave appropriately when the inputs take on extreme values such as zero or infinity (Sterman 2000). This dissertation carried out extreme condition test by automated "reality check" tool which Vensim provides.

4.2.3.3 Policy Tests

(1) System Improvement Test

System improvement test checks whether the modeling process helped change the system for the better. To pass the test, the modeling process must identify policies that can lead to improvement. In system dynamics, such policies are called as 'policy leverage'. Policy leverage means the point that can produce better performance within a limited and insignificant change of the magnitude with keeping the shape derived from base run. Such policy leverage can be classified into parameter adjustment policy and structural adjustment policy. Parameter adjustment policy means changing artificially parameter values in a SD model. Structural adjustment policy means changing feedback loops in a SD model. In chapter 5, this dissertation suggests policy leverage leading to better performance of the system (See pp.118-126), thus providing the validity of the SD model suggested in this dissertation in terms of system improvement.

CHAPTER 5. RESULTS OF SIMULATION

5.1 The Relationships among IT Level, Buyer-Supplier Relationship, and Supply Chain Dynamics

In this section, we first investigate the results of simulation run on the System Dynamics model that was discussed in the preceding chapter. From now, we will refer to this as the base model. As mentioned in the preceding chapter, in this dissertation, we consider non-stationary demand distributions. To generate non-stationary demand streams, we use a simple AR(1) process. The demand at time t at the retailer is

$$D_t = d + \rho D_{t-1} + \varepsilon_t$$

where $d > 0$, $-1 < \rho < 1$, and ε_t follows a normal distribution with mean zero and standard deviation σ. Note that $\rho = 0$ corresponds to the special case where the demand for each period is an *i.i.d.* normal distribution with mean d and standard deviation σ. Since the mean and the variance of the above AR(1) process depends not only on d and σ, but also on the autoregression coefficient, ρ, we adjust d and σ according to ρ as follows:

$$d = (1 - \rho)\, E(D)$$
$$\sigma^2 = (1 - \rho^2)\, Var(D)$$

In this section, we observe the results of experiments when setting $\rho = 0$.

As mentioned previously, mean and standard deviation are set as 200 and 20 respectively. Standard deviation is multiplied by product customization level.

Figure 5-1 shows demand stream derived from a simulation run on the base model under the above assumption for non-stationary demand distributions.

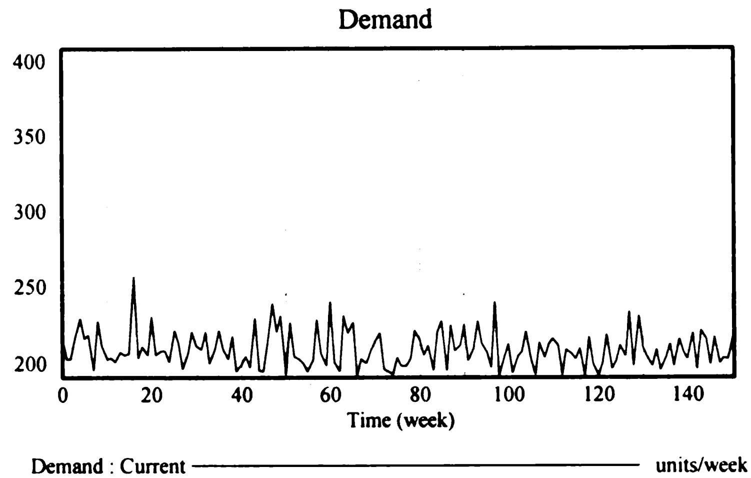


Figure 5-1: Demand Stream

5.1.1 The Relationship between IT level and Buyer-Supplier Relationship

Figure 5-2 indicates the changes of IT level according to time flow.

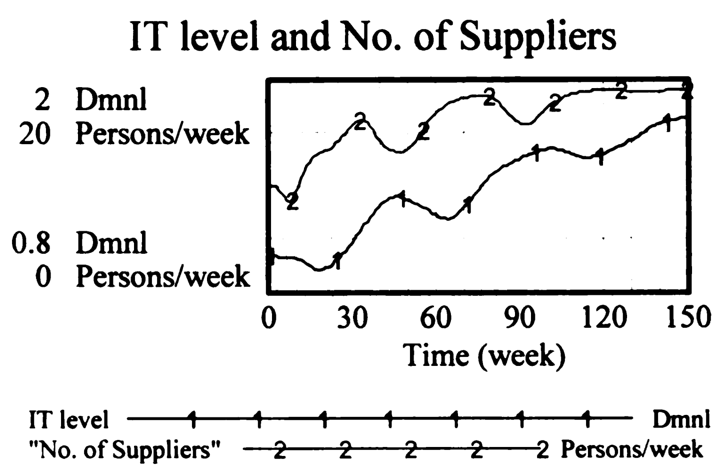


Figure 5-2: The Change of IT Level and No. of Suppliers

As can be seen in the figure, both IT level and the number of suppliers continuously increase after going through three transient recession periods. This is an unexpected result in the perspective of incomplete contract theory emphasizing that continuous IT deployment cannot lead to persistent increase in the number of suppliers, and inversely, such stagnation in the number of suppliers prevents the continuous improvement of IT level. The reason of such unexpected result can be explained by the interactive relationship between buyer's profit and supplier's profit. As mentioned previously, in this dissertation, it was assumed that IT level is decided by investment budget for IT deployment, and such investment budget is obtained from buyer's cumulative profit. This means that IT level is influenced by buyer's cumulative profit. In such instance, we need to check the dynamic change of buyer's cumulative profit.

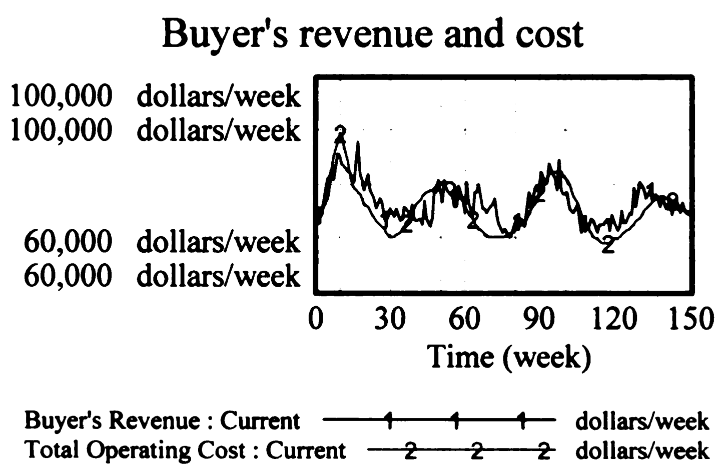


Figure 5-3: The Change of Buyer's Revenue and Cost

As can be seen in Figure 5-3, even though this dissertation ran simulation at the point leading to equilibrium in which revenue and cost are equal, buyer's revenue becomes slightly greater than buyer's cost according to time flow. This is because a slight difference exists between buyer's revenue and cost at initial stages due to randomly distributed demand variations according to time flow, and such slight difference is accumulated through a continuous feedback process with other construct variables. Thus, this leads to the gradual increase of buyer's cumulative profit (Figure 5-4), and is subsequently followed by the increase of IT level as shown in Figure 5-2.

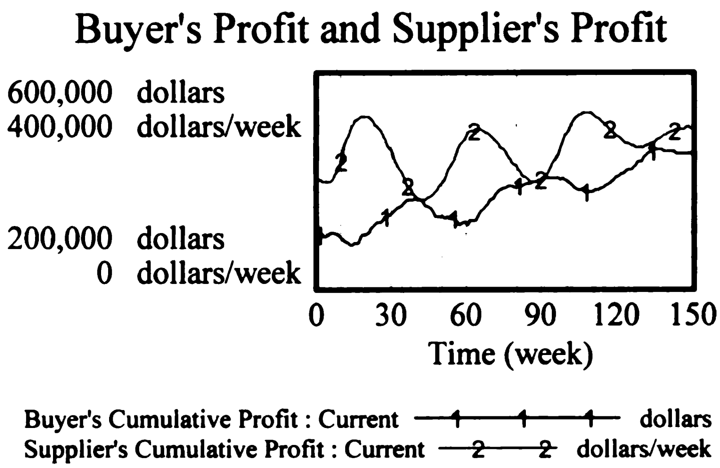


Figure 5-4: The Change of Profit

Such increase of IT level ultimately leads to the continuous increase of buyer's profit through the consecutive reductions of investment on transaction specific assets and transaction costs, an increase in the number of suppliers, the increase of buyer's bargaining power, and the decline of raw material price, as discussed in the causal loop diagram and SD model. Accordingly, the result in Figure 5-2 shows the existence of a mutual positive feedback relationship among IT level, number of suppliers, and buyer's profit.

The above result is inconsistent with the perspective of incomplete contract theory based on the concept of the zero sum game between buyer and supplier. The key argument of incomplete contract theory is that the increase of buyer's profit by the decrease of RM price cannot be persistent due to subsequent responses such as the decrease of supplier's profit, the reduction of supplier's incentives to make non-contractible investments, the actual increase of buyer's transaction costs, a decrease in the number of suppliers, the increase of supplier's bargaining power, and the increase of material price. However, unlike anticipation, supplier's profit does not decrease as much as buyer's profit increases as can be seen in Figure 5-4. In the figure, supplier's cumulative profit is shifted inversely with buyer's cumulative profit. That is, when supplier's cumulative profit arrives at the point of diminishing return, buyer's cumulative profit is at the point of increasing return, and vice versa. However, such diminishing or increasing return point in supplier's cumulative profit also increases in a similar fashion with buyer's cumulative profit, thus indicating that supplier's cumulative profit increases continuously.

This implies that supplier's decrease in profit does not coincide exactly with the buyer's increase in profit. We can explain the reason of this result from the effect of IT on supply chain dynamics.

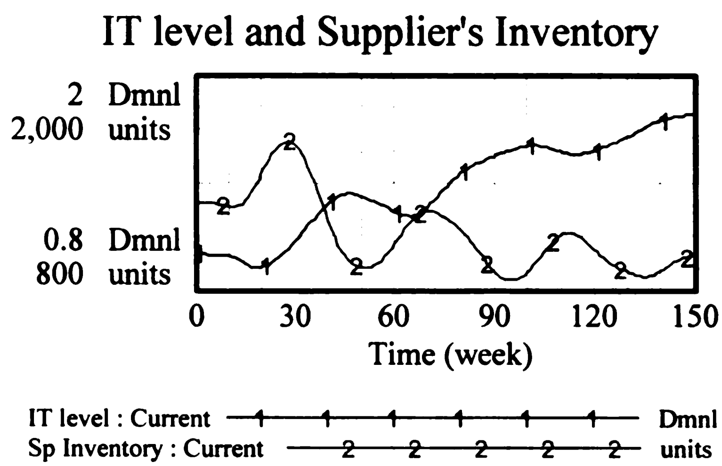


Figure 5-5: The Change of IT level and Supplier's Inventory

Figure 5-5 indicates that the increase of IT level drives not only the decrease of inventory fluctuation, but also the decrease of the entire inventory level. That is, information sharing by the utilization of advanced IT can reduce distortion in demand information between buyer and supplier, which is referred to as the "bullwhip effect" (Lee et al. 1997; Christopher 1994). Such decrease in demand variability enables accurate forecasting, and this can lead to the decrease of supplier's target raw material (RM) level. This lowering in supplier's target RM level may deduce the decline of supplier's inventory level. Such decline in supplier's inventory can lead to the decrease of supplier's holding cost and total cost, and such decrease may offset the decline of supplier's revenue. Actually, as can be seen in Figure 5-6, the diminishing return point of supplier's revenue decreases continuously. This is because RM price decreases gradually due to the increase of buyer's bargaining power by the increase in the number of suppliers, as can be seen in Figure 5-7. However, supplier's total cost also decreases gradually due to the decrease of supplier's holding cost, and Figure 5-6 indicates that such decrease of supplier's total cost may offset the decrease of supplier's revenue, thus leading to the gradual increase of supplier's cumulative profit.

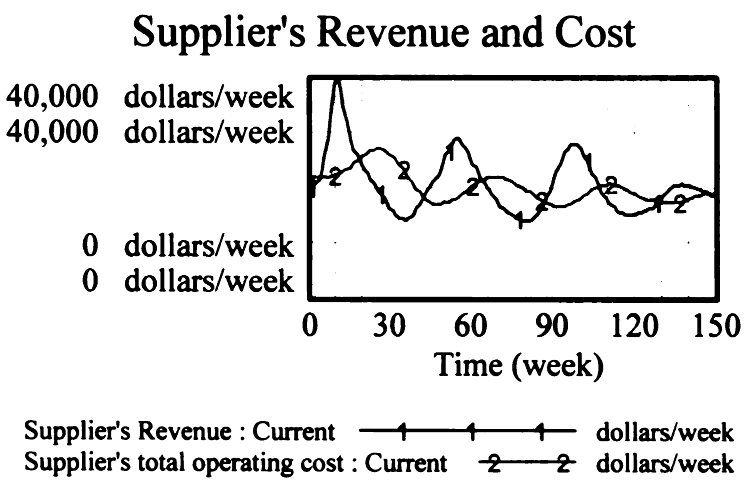


Figure 5-6: The Change of Supplier's Revenue and Cost

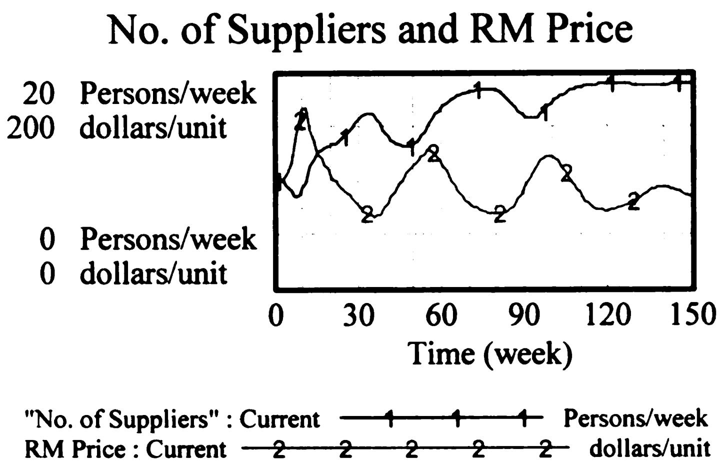


Figure 5-7: The Change of No. of Suppliers and RM Price

Such increase of supplier's profit leads to the increase of supplier's incentives for non-contractible investment, and such increase of supplier's incentives may reduce buyer's burden for non-contractible investment.

According to incomplete contract theory, the increase of buyer's profit by advanced IT deployment cannot be persistent because the increase of burden for buyer's non-contractible investment offsets the reduction of transaction cost due to IT development. As shown in Figure 5-8, the effect of asset-specificity investment (ASI) on transaction cost (TC) decreases radically after week 18, and does not indicate any significant increase. This is an expected result according to the continuous increase of IT level. However, the effect of buyer's non-contractible investment (BNCI) on TC does not increase unlike our expectation, and on the contrary, after week 100, stabilizes at a very low level. We can recognize easily that the reason for this is due to the decrease of buyer's burden for non-contractible investment by the unexpected subsequent increases of supplier's cumulative profit and supplier's non-contractible investment.

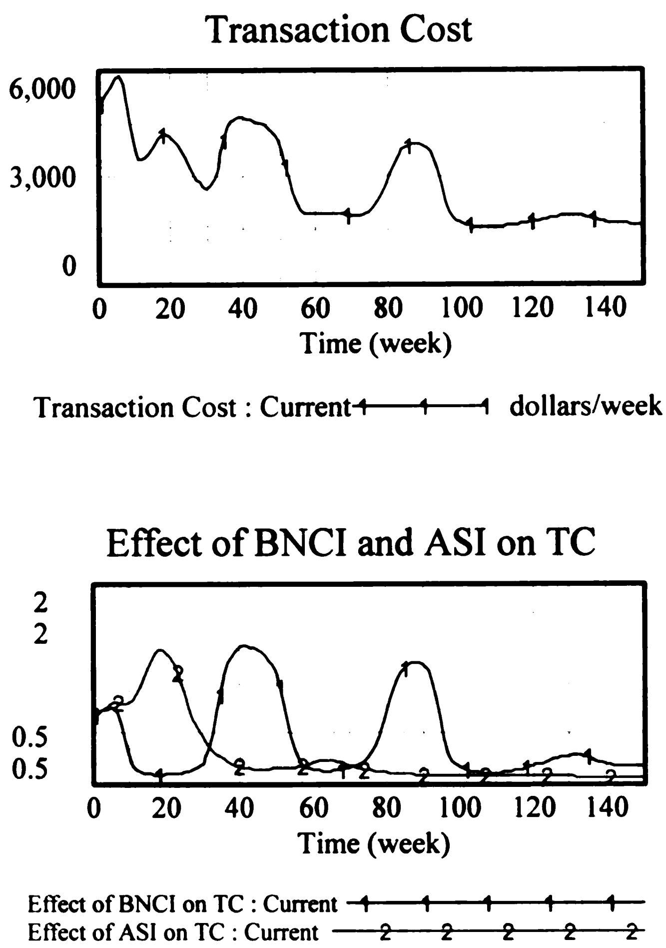


Figure 5-8: The Change of Transaction Cost and Effects of BNCI and ASI

The decrease of RM price inducing the decrease of supplier's revenue and the increase of buyer's profit can be derived from the low level of transaction cost (the first figure in Figure 5-8) through the above interaction between the effects of buyer's non-contractible investment and asset specificity investment on transaction cost. That is, the decrease of transaction cost by the interaction between the effects of buyer's non-contractible investment and asset specificity investment on transaction cost subsequently leads to an increase in the number of suppliers and an increase of buyer's bargaining power, thus ultimately connected to the decrease of RM price.

The continuous increase of buyer's cumulative profit shown in Figure 5-4 can be explained by the decrease of supplier's revenue due to the decrease of RM price. Supplier's revenue in Figure 5-6 is the purchasing cost in terms of buyer, which is one of the buyer's cost factors. This means that the decrease of supplier's revenue mentioned previously may lead to the decrease of buyer's cost, because purchasing costs combined with holding costs place a large part of the total cost.

Conclusively, all of the above results indicate that the improvement of IT level reduces supplier's revenue by the decrease of RM price due to an increase in the number of suppliers as expected. However, such decrease of supplier's revenue is offset by the decrease of supplier's inventory cost due to the improvement in the level of IT. Thus, supplier's cumulative profit does not decrease as much as the reduction of supplier's revenue even during a recession period. Such a less than anticipated decrease prevents too great a reduction in the number of suppliers and in buyer's profit. This drives a gradual increase in the amount of supplier and buyer profits, thus leading to the continuous improvement of IT level. This means that continuous advanced IT deployment can ultimately derive complete competition in the electronic market among numerous suppliers, and such electronic market structure can provide the capability to persistently deploy more advanced IT to the buyer. That is, there is a mutual positive feedback relationship between IT level and buyer's bargaining power, thus supporting transaction cost theory. However, such positive feedback relationship is not derived solely from the relationship between IT level and buyer-supplier relationship. The above results show that the decrease of supplier's inventory level and inventory cost due to more accurate and timely information sharing by advanced IT plays a significant role in the positive feedback relationship between IT level and buyer's bargaining power. This implies that supply chain dynamics may have a significant influence on the relationship between IT level and buyer-supplier relationship, thus supporting this dissertation's key proposition that interactive feedback relationships among IT level, buyer-supplier relationship, and supply chain dynamics should be considered for IT investment and deployment for efficient supply chain management.

5.1.2 The Relationship between IT level and Supply Chain Dynamics

Previous literatures (Lee, et al. 1997, 2000; Christopher 1994) emphasize that information sharing by the utilization of advanced IT can reduce distortion in demand information between buyer and supplier, which is referred to as the "bullwhip effect", and thus can significantly minimize the outcomes of the problems induced by bullwhip effect. This dissertation agrees with previous literatures concerning the effect of information sharing on bullwhip effect. But, the perspective of this dissertation on information sharing is a little different from those of previous literatures. Previous literatures analyzed only the difference in effect between two extreme situations such as when information sharing is achieved and when information sharing is not implemented. That is, previous literatures did not comment that the level of information sharing might be different according to IT level. This dissertation assumes that the effect of information sharing can be different depending on the level of information technology. In other words, if more advanced IT is deployed, more accurate and timely sharing of manufacturer's forecasts on day-to-day demand may be possible. Inversely, if IT level is relatively low, the possibility of demand distortion due to the lack of information sharing may increase. As mentioned previously, this dissertation's SD model reflects such an argument, and the result is indicated in Figure 5-5.

Figure 5-5 indicates that as the level of IT increases, not only is supplier's inventory fluctuation softened, but supplier's entire inventory level is reduced. This means that the improvement of information sharing capability by continuous deployment of advanced IT can reduce supplier's total cost more than anticipated by not only minimizing substantial variation in inventory holdings induced by bullwhip effect, but also lowering the absolute level of supplier's inventory. Such reduction of supplier's absolute inventory level can be the critical factor driving the gradual increase of both buyer's and supplier's profits, IT level, and buyer's bargaining power as mentioned previously.

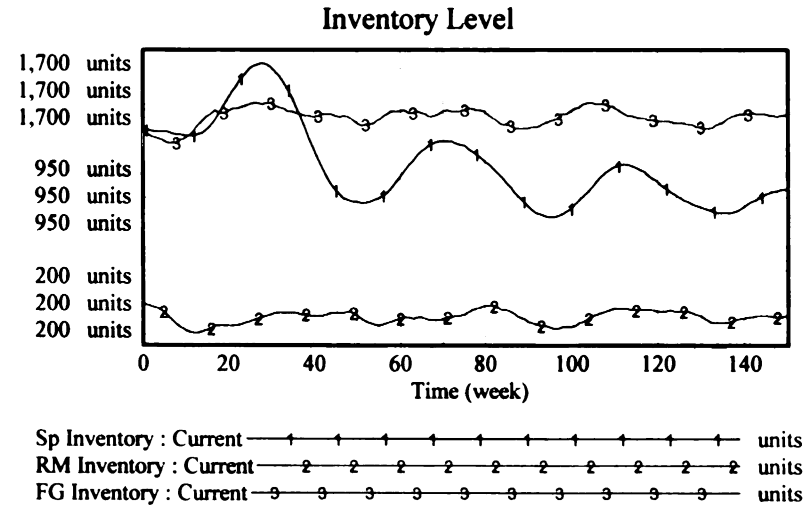


Figure 5-9: The Change of Inventory Level

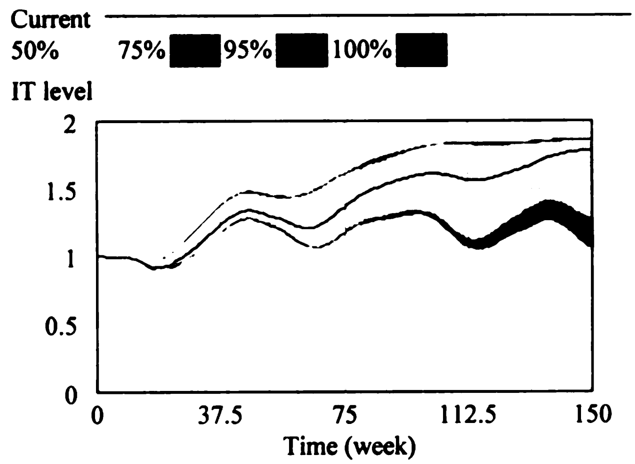
However, the benefit of inventory reduction due to the improvement of IT level is not applied to the buyer. As can be seen in Figure 5-9, buyer's RM and FG inventory levels do not change substantially. This means that there is no significant direct relationship between IT level and buyer's inventory level, thus implying that the buyer may not anticipate the effect of advanced IT deployment in terms of buyer's inventory reduction. Nevertheless, we can assert that making investment for advanced IT deployment is needed, because it is still beneficial in terms of the buyer. As mentioned previously, the improvement of IT level induces the reduction of supplier's revenue due to an increase in the number of suppliers and the decline of RM price, and also drives the reduction of supplier's inventory cost, which is more than enough to offset the decline of supplier's revenue. Accordingly, even if a supplier accepts the fall of RM price, the supplier's *ex ante* incentives to make non-contractible investment may not be declined significantly, and thus the buyer can enjoy the benefit of RM price reduction derived from low transaction cost and high buyer's bargaining power in the long run.

Conclusively, the above argument implies that the buyer-supplier relationship may not necessarily be a zero-sum game. John Gossman, Vice-President of materials management at AlliedSignal, has emphasized that competition is no longer company to company, but supply chain to supply chain (Gossman 1997), and such an observation brings out the importance of a win-win strategy in which both buyer and supplier can co-exist. The above result suggests the existence possibility of such a win-win SCM strategy. One point to be identified from the results of base run is that a win-win strategy in which both buyer and supplier can co-exist is not derived just from the relationship between IT level and buyer-supplier relationship. That is, the buyer-supplier relationship in this dissertation was modeled under the perspective of transaction cost theory and incomplete contract theory, which are based on the concept of a zero-sum game between buyer and supplier. Viewed in this perspective, the possibility of a win-win strategy can be suggested when feedback loop representing IT effect on supply chain dynamics affects or further dominates feedback loop reflecting IT effect on buyer-supplier relationships. The results of base run discussed previously support such an argument. This also provides the likelihood that the change of supply chain structural issues and the role of IT in such change of supply chain structural issues may alter the feature of buyer-supplier relationship based on the zero-sum game. Such possibility will be examined in the suggestion of policy leverage, which will be noted later.

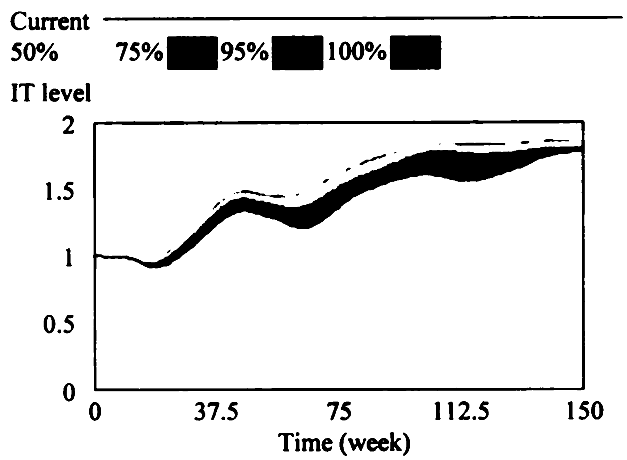
5.1.3 The Effect of Product Variety Level on the Interactions among Feedback Loops

As observed in the preceding section, the effect of IT on buyer-supplier relationships cannot be explained only by the conflict between transaction cost theory and incomplete contract theory. This suggests that other forces like supply chain dynamics should be accounted for in a more complete model of buyer-supplier relationship. Product customization (PC) level can also be an important factor for explaining such a complete model of buyer-supplier relationship.

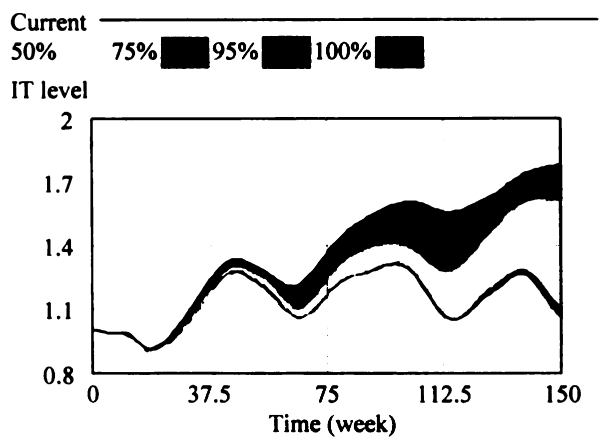
In order to examine such possibility, we implemented sensitivity analysis on the responses of key variables by product customization level, which is a parameter value in this dissertation's SD model. Figure 5-10 indicates the result of sensitivity analysis on IT level by PC level. The solid line indicated inside the bounds in the first figure is the result of the base run.



(Overall)



(Low Product Variety Level)

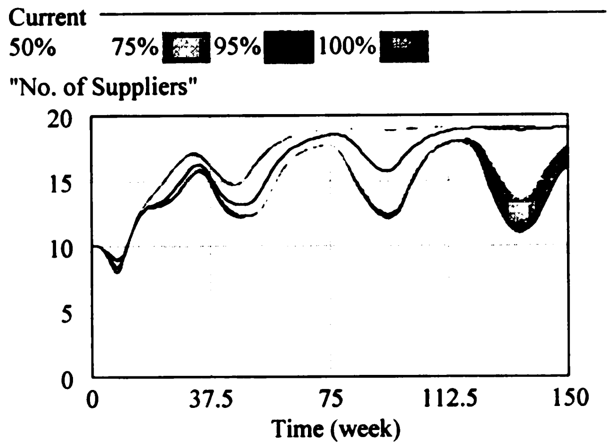


(High Product Variety Level)

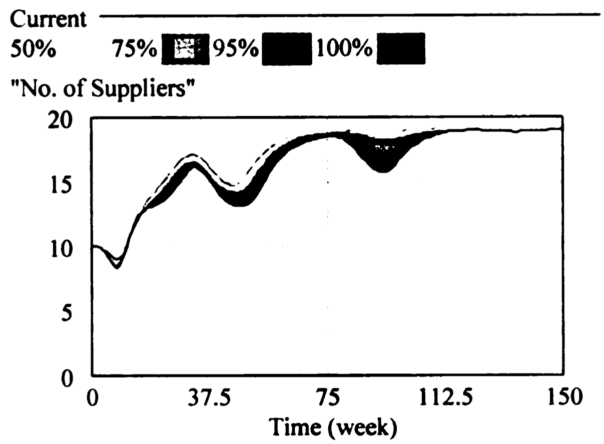
Figure 5-10: Sensitivity Analysis on IT level by Product Variety Level

A graph indicates confidence bounds for all the output values of IT level when PC level is randomly varied about their distributions. The outer bounds (100%) mean maximum and minimum values of PC level's distribution. 50% indicates the medium value of the distribution. As shown in the figure, according to the change of PC level, IT level and number of suppliers have different magnitudes even though they show similar shapes. In order to identify more clearly the effect of PC level, we divided the first figure into two parts based on the result of the base run.

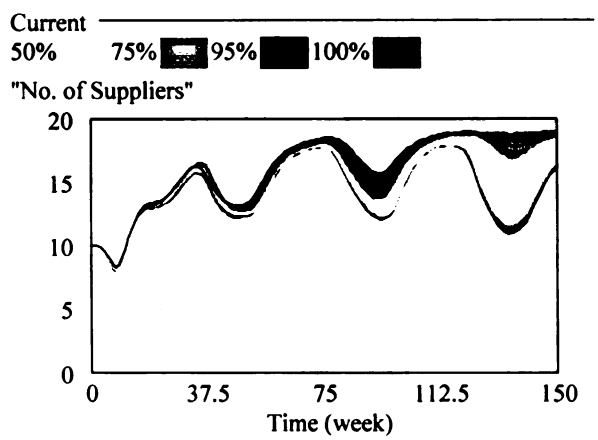
As can be seen in the second and third figures, as PC level decreases relative to base model, the magnitude of IT level increases while keeping the shape derived from the base run. Meanwhile, as PC level increases relative to the base model, the magnitude of IT level decreases with the same shape as that in the base run, and at the highest level of product variety, IT level fluctuates continuously within the scope of 1.0 and 1.3. We need to compare the above results with the results of sensitivity analysis on the number of suppliers by product variety level. Figure 5-11 indicates the result of sensitivity analysis on the number of suppliers by product customization level. As can be seen in the figure, as PC level decreases relative to the base model, number of suppliers changes immensely, similar to the case of the base run, but its magnitude is a little higher than that of the base run. Meanwhile, as PC level increases relative to the base model, the number of suppliers continues to show large fluctuations after week 50, and increasing return point decreases gradually by small steps. The above two results indicate that as PC level increases, it becomes increasingly difficult to realize any mutual positive feedback relationship among IT level, the number of suppliers, and buyer's bargaining power. As well, the IT level and number of suppliers tends to return to the initial middle level.



(Overall)



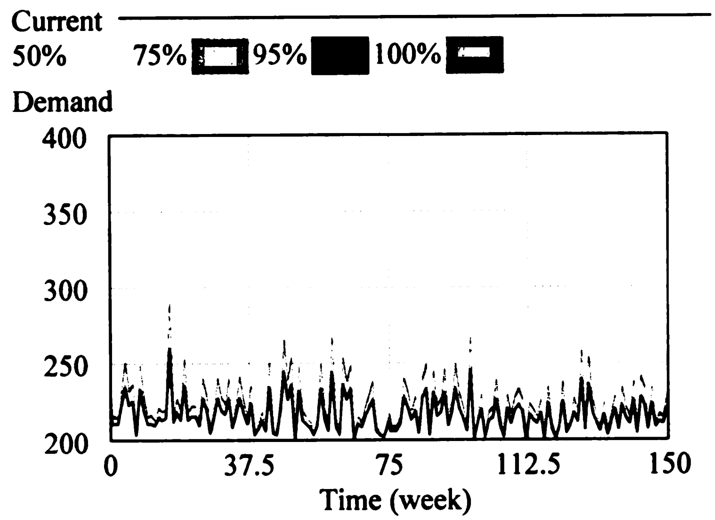
(Low Product Variety Level)

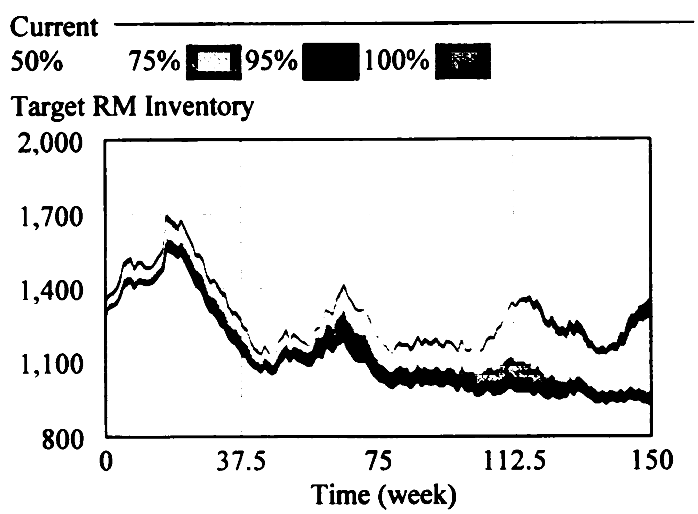


(High Product Variety Level)

Figure 5-11: Sensitivity Analysis on No. of Supplier by Product Variety Level

We already know from the discussion in the preceding section that the above responses of IT level and number of supplier in the case of high product customization level were derived from the interaction with the inventory level of the entire supply chain. Figure 5-12 indicates the result of sensitivity analysis of demand and target inventory level in the case of high product customization level. As can be seen in the figure, the decreasing trend of target RM inventory level slows down gradually. This is because the need for safety stock increases due to high demand uncertainty in customized/differentiation focused products in which the level of product customization and variety is high (See the first figure in Figure 5-12). The entire level of FG inventory also increases even though the shape is very similar to that of the base model. Such gradual increase of target inventory level leads to the increase of supplier's inventory level and buyer's FG inventory level as shown in Figures 5-13 and 5-14 indicating the changes of key variables driving the responses of IT level and number of suppliers in the case of high product customization level. That is, after week 40, as product variety level increases, supplier's inventory level shows large fluctuations without any significant change of increasing and diminishing return points. Such response of supplier's inventory level may induce the blunting of supplier's profit growth due to the increase of supplier's inventory cost (See the second figure in Figure 5-13). As mentioned previously, the blunting of supplier's profit growth prevents the increase of supplier's non-contractible investment, and subsequently increases the buyer's burden for non-contractible investment. Consequently, actual transaction cost increases relative to the base model (See the third figure in Figure 5-13), thus slowing down the increasing trend in the number of suppliers shown in the third figure in Figure 5-11.





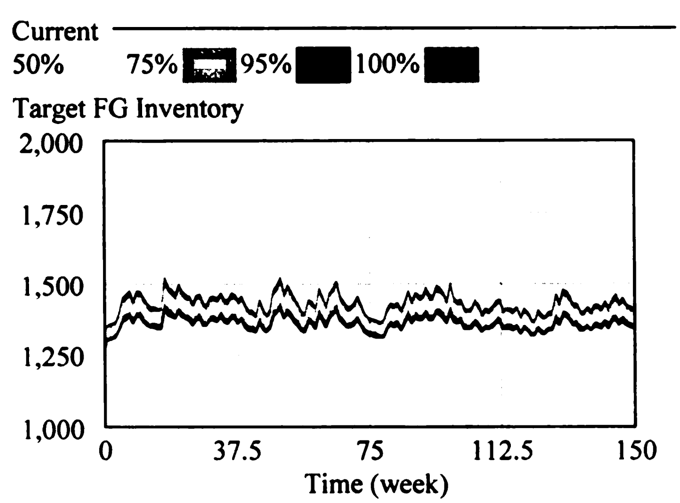


Figure 5-12: Sensitivity Analysis on Demand and Target Inventory
(In case of High product variety level)

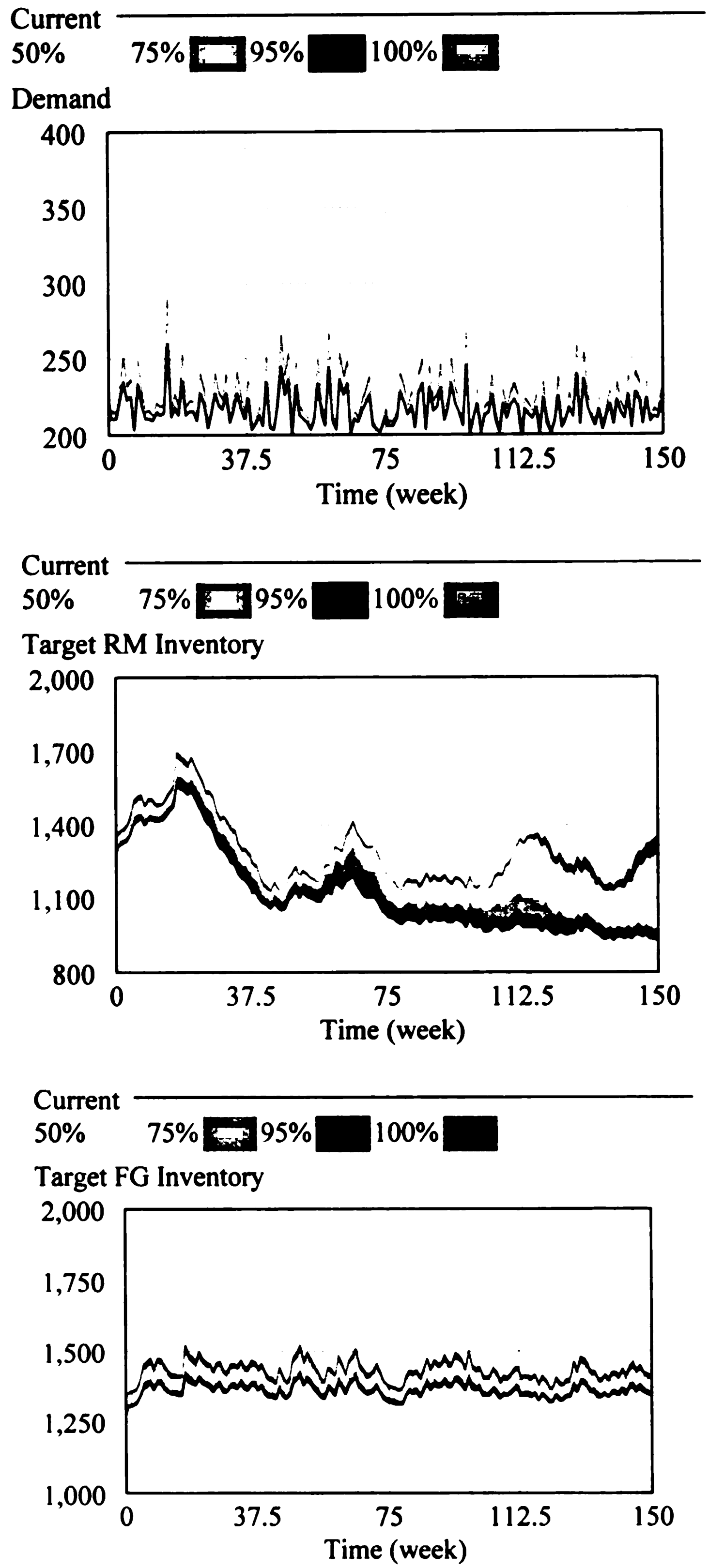


Figure 5-12: Sensitivity Analysis on Demand and Target Inventory
(In case of High product variety level)

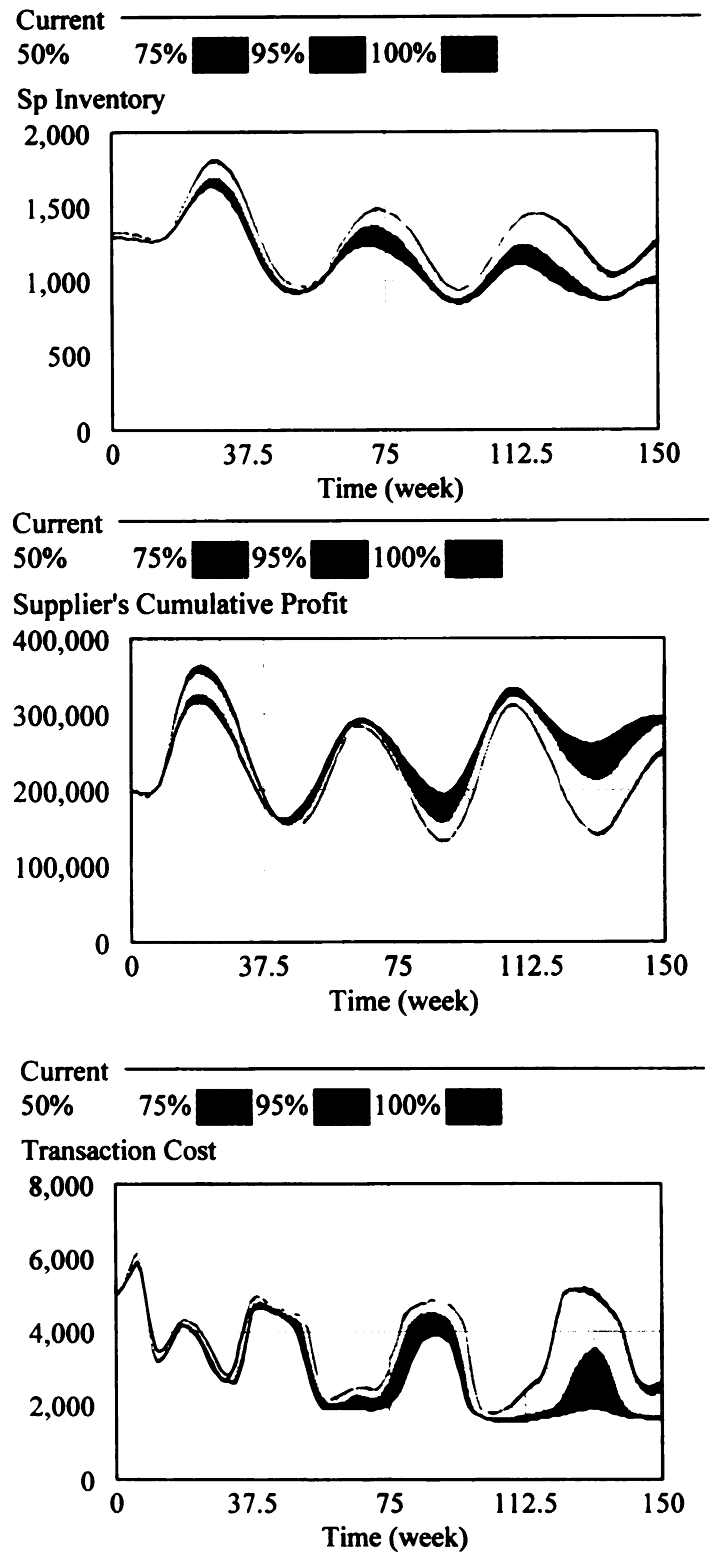


Figure 5-13: Key Variables driving the Change of No. of Suppliers
(In case of High product variety level)

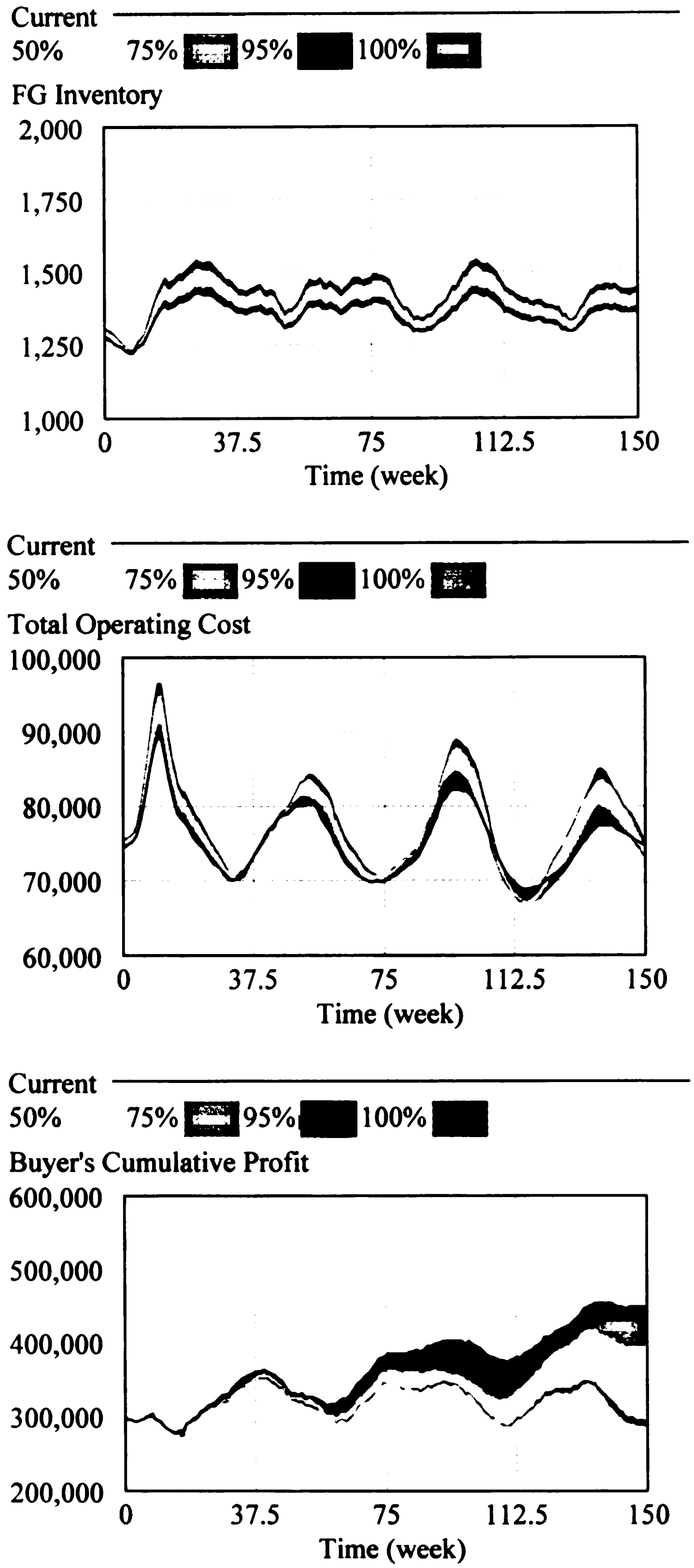


Figure 5-14: Key Variables driving the Change of IT level
(In case of High product variety level)

As can be seen in the first figure in Figure 5-14, as product customization level increases, the entire level of buyer's FG inventory increases while maintaining the shape of the base run. Such increase in FG inventory level leads to the substantial increase of buyer's total cost due to the increase of inventory cost, and such increase of total cost is connected to the subsequent reduction in buyer's profit growth (See the third figure in Figure 5-14) and IT level as shown in Figure 5-10.

One thing to be noted is that slowing down the increasing trend in the number of suppliers is not connected to the substantial increase of RM price and supplier's revenue, which is enough to offset the increase of total cost due to the increase of inventory level. Figure 5-15 suggests an explanation for this trend. As can be seen in the figure, as product customization level increases, supplier's bargaining power gradually increases according to the reduction in the number of suppliers. However, as product customization level increases, the ratio of RM shipping to supplier's inventory decreases according to the increase of supplier's inventory level. Accordingly, RM price does not show a significant increase relative to that of the base run as much as expected from limiting the increasing trend in the number of suppliers. Also, due to such stagnation of RM price, the buyer's profit may not decrease below the initial point, and then fluctuate continuously within a certain limited range.

Conclusively, in the case of low product variety level, mutual positive feedback relationship among IT level and buyer's bargaining power in the perspective of transaction cost theory dominates, while in the case of high product variety level, negative feedback relationship among IT level and buyer's bargaining power in the perspective of incomplete contract theory dominates.

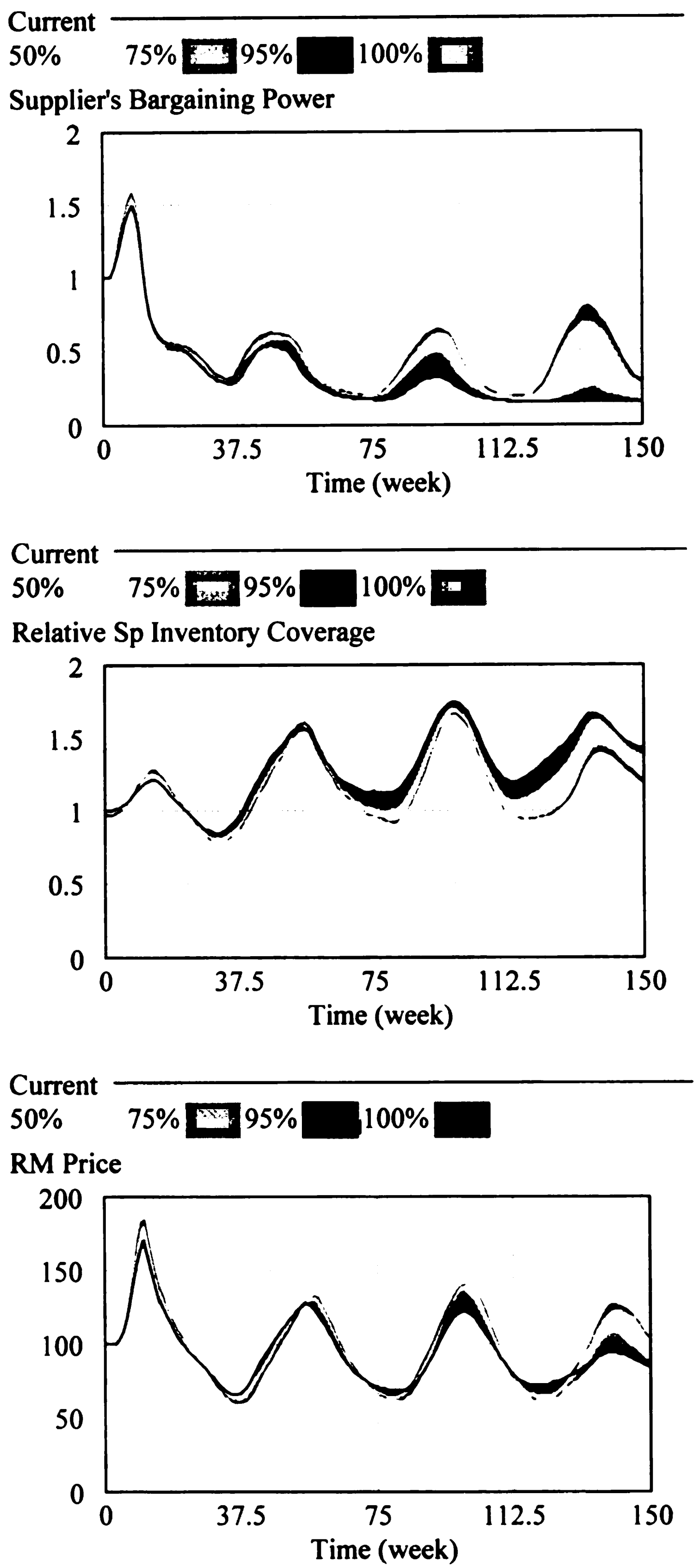


Figure 5-15: The Changes of RM price and related variables
(In case of High product variety level)

This argument is consistent with the suggestion of Bensaou and Venkatraman (1996) emphasizing that the type of market exchange relationship in which the technical and economical dependence of both buyer and supplier on each other is relatively low, is appropriate for highly standardized products. Meanwhile, the type of strategic partnership in which buyer-supplier relationship is strongly connected by considerable transaction-specific assets of both buyer and supplier is significantly correlated with highly customized products.

Conclusively, all of the above results indicate that the change of feedback relationship between IT level and buyer's bargaining power is influenced by interactive relationships among information sharing by advanced IT, product customization level, and supply chain dynamics. This means that depending on how the described feedback relationships affect each other or which feedback relationship is dominant, the effect of IT investment can vary. This provides the validity of this research's key proposition that information technology investment and deployment for efficient supply chain management should be implemented taking into consideration the interactive feedback relationships among IT level, product customization level, buyer-supplier relationship, and supply chain structure.

5.2 The Suggestion of Policy Leverage

5.2.1 The Necessity of Policy Leverage

As discussed in the preceding section, as product customization level increases, it becomes difficult to realize mutual positive feedback relationships among IT level, the number of suppliers, and buyer's bargaining power relative to the base model, and IT level and number of suppliers tends to return to the initial middle level. In other words, in the case of highly customized products, it is difficult to bring out the existence of a win-win strategy in which both the buyer and supplier can co-exist. The source of such result is the increase in supplier's total cost due to the increase of supplier's inventory level, which slows down the increasing trend in supplier's profit. Consequently, such increase of supplier's inventory level prevents the continuous improvement of IT level. Inversely, due to such stagnation of the IT level, the effect of information sharing between buyer and supplier cannot be demonstrated properly.

Viewed in this perspective, the question of how to reduce inventory level effectively can be the most critical factor that enables pursuing a win-win strategy even in highly customized products. Accordingly, policies for reducing inventory level effectively in highly customized products should be considered. In System Dynamics, such policies are referred to as 'policy leverage'. Policy leverage means a policy interruption point that can produce considerable effects with little input of limited policy resources. That is, policy leverage is a variable or the relationship between variables that enables the entire system to demonstrate considerable dynamics with little effort. Policy leverage can be classified into parameter adjustment policy and structural adjustment policy. Parameter adjustment policy means altering artificial parameter values in a SD model. Structural adjustment policy means altering feedback loops in a SD model.

5.2.2 Parameter Adjustment Policy

As discussed in the results of sensitivity analysis by product customization level in the previous section, the beginning of the result leading to increasing trends of IT level and the number of suppliers becoming blunt is the increase of target RM and FG inventory levels, which comes from the increase in the need for safety stock due to high demand uncertainty in customized/differentiation focused products. This means that the effort for finding policy leverage should start from the consideration on policies reducing target inventory levels. Policies for reducing target inventory levels can be inferred from equations for target RM inventory level and target FG inventory level.

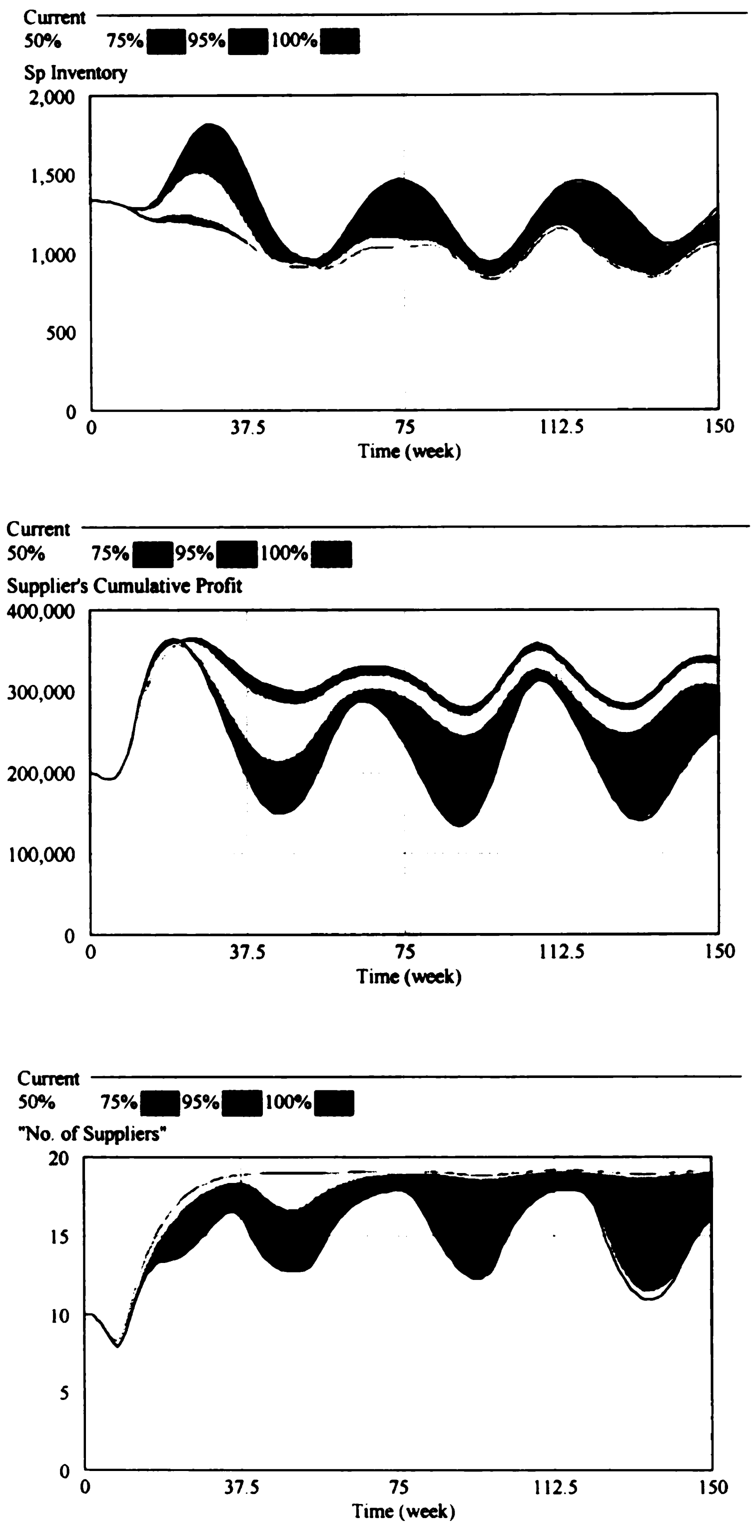
Target RM Inventory Level = Fraction of reflecting Mfg Sales Forecast to Target RM Inventory(Mfg Sales Forecast*(Sp Production Lead Time + Mf Review Period)+ "SF:Sp"*sqrt(Sp Production Lead Time + Mf Review Period))*
Target FG Inventory Level = Mfg Sales Forecast(Transit Lead Time + Mf Lead Time + Mf Review Period)+"SF: Mf"*sqrt(Transit Lead Time + Mf Lead Time + Mf Review Period)*

The above equations indicate that transit lead-time from RM supplier to manufacturer may have significant influences on target inventory level. Actually, Fisher (1997) suggests that the approaches for reducing lead-time should also be changed depending on the type of product strategy and buyer-supplier relationship. That is, in case of customized/differentiation focused products and strategic partnership structure, the type that immediately supplies products upon demand may be preferred to that of placing a large amount of inventories on distributors or retailers, because the margin rate and added value are high. Thus, in order to pursue high quality customer service with low inventory level, a quick response logistics system should be constructed. Also, in case of customized/differentiation focused products, a wide range of product lines should be completed and the necessity of consistent product innovation and R&D is high. Because of such characteristics of product variety, it is very difficult for distributors or retailers to hold and control properly the inventories of various kinds of products in their warehouses or sales shops. Accordingly, in this case, it is advisable to reduce supply chain lead-time in order to deal effectively with immediate demand. The above argument means that the reduction of parameter values related to transit lead-time might be considered as the policy for reducing target inventory level.

Another thing to be noted in the equation for target RM inventory level is the fraction variable for reflecting manufacturer's sales forecast to the decision of target RM inventory. As mentioned in chapter 4, this variable reflects that the effect of information sharing can be different depending on the level of information technology. That is, if more advanced IT is deployed, more accurate and timely sharing of manufacturer's forecasts on daily demand may be possible. Inversely, if IT level is relatively low, the possibility of demand distortion due to the lack of information sharing may increase. When considering that IT level is directly influenced by investment budget for advanced IT deployment, and such investment budget is decided by multiplying the fraction of buyer's profit invested for IT to buyer's cumulative profit in this dissertation's SD model, the above argument means that the increase of parameters related to the fraction of buyer's profit invested for IT may have a significant effect on the reduction of target inventory level, thus deserving another policy for reducing target inventory level.

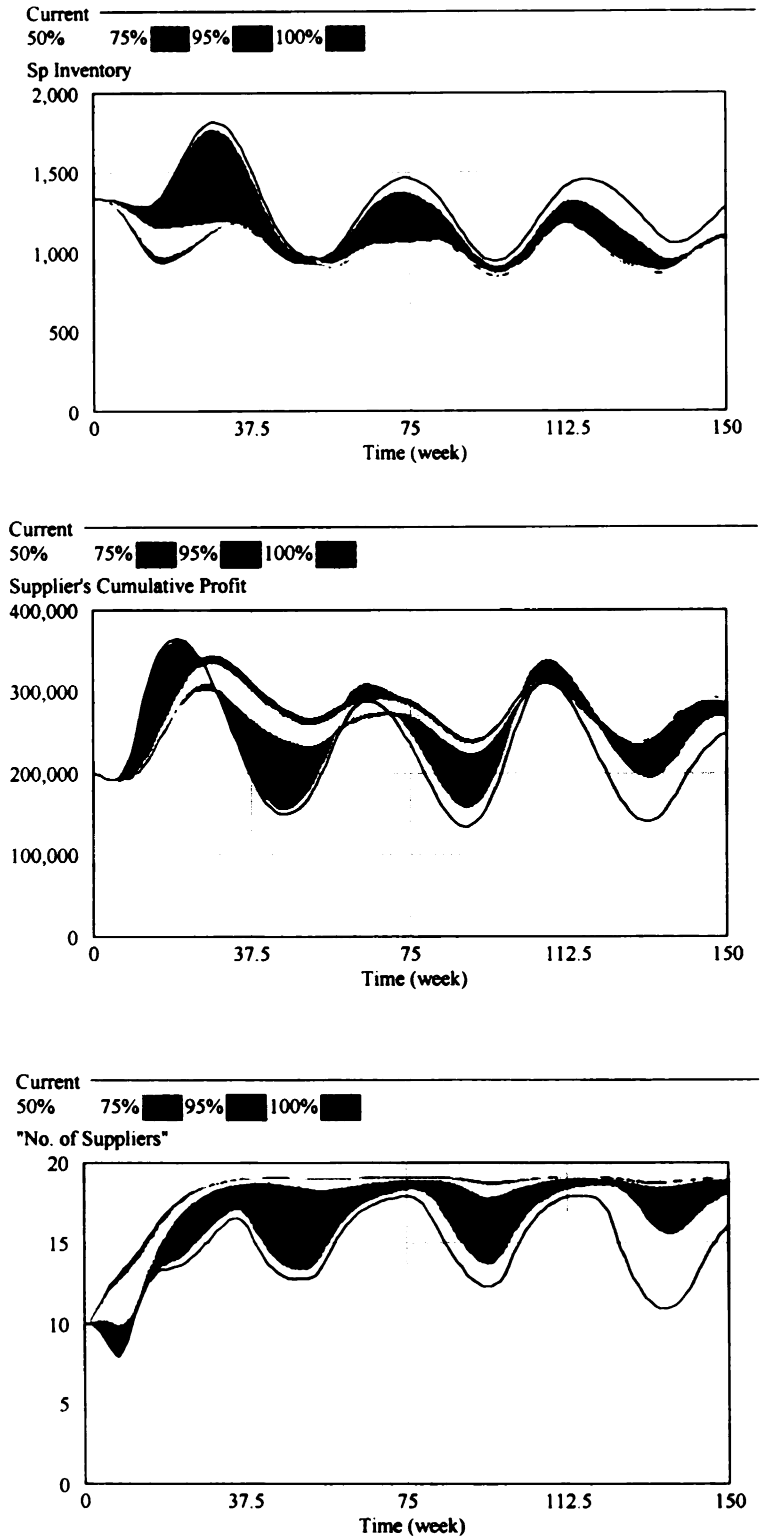
The comparison between the above two kinds of policies is another interesting issue. The change of parameter for the fraction of buyer's profit to IT investment is needed to test the importance of the improvement of information technology itself, while the change of parameter values for transit lead-time reflects the analysis on the significance of managerial capability on information technology. From such comparison between two types of policies, we can identify the validity of Keen's (1993) assertion that the difference in competitive and economic benefits, which firms can obtain from information technology, is dependent not on the difference in technology itself, but the difference in managerial capability.

Figures 5-16, 5-17, 5-18, and 5-19 indicate the result of sensitivity analysis on the responses of key variables by the reduction of transit lead-time and the increase in fraction of buyer's profit to IT investment. In order to compare more precisely the effects of the two policies, we set the rate of change for the two parameters related to the two policies as identical. Figures 5-16 and 5-17 consists of key variables driving the change in the number of suppliers, while Figures 5-18 and 5-19is composed of key variables driving the change of IT level. As can be seen in Figures 5-16 and 5-17, both the reduction of transit lead-time and the increase in fraction of buyer's profit to IT investment lead to the increase in supplier's profit. As discussed previously, such increase in supplier's profit is derived from the reduction of inventory holding cost due to the decrease of supplier's RM inventory level as shown in the first figure. Also, such increase in supplier's profit ultimately leads to the increase in the number of suppliers through the increase of supplier's incentives for non-contractible investment, the decrease of buyer's burden for non-contractible investment, and the decrease of transaction cost (See the third figure in Figures 5-16 and 5-17).



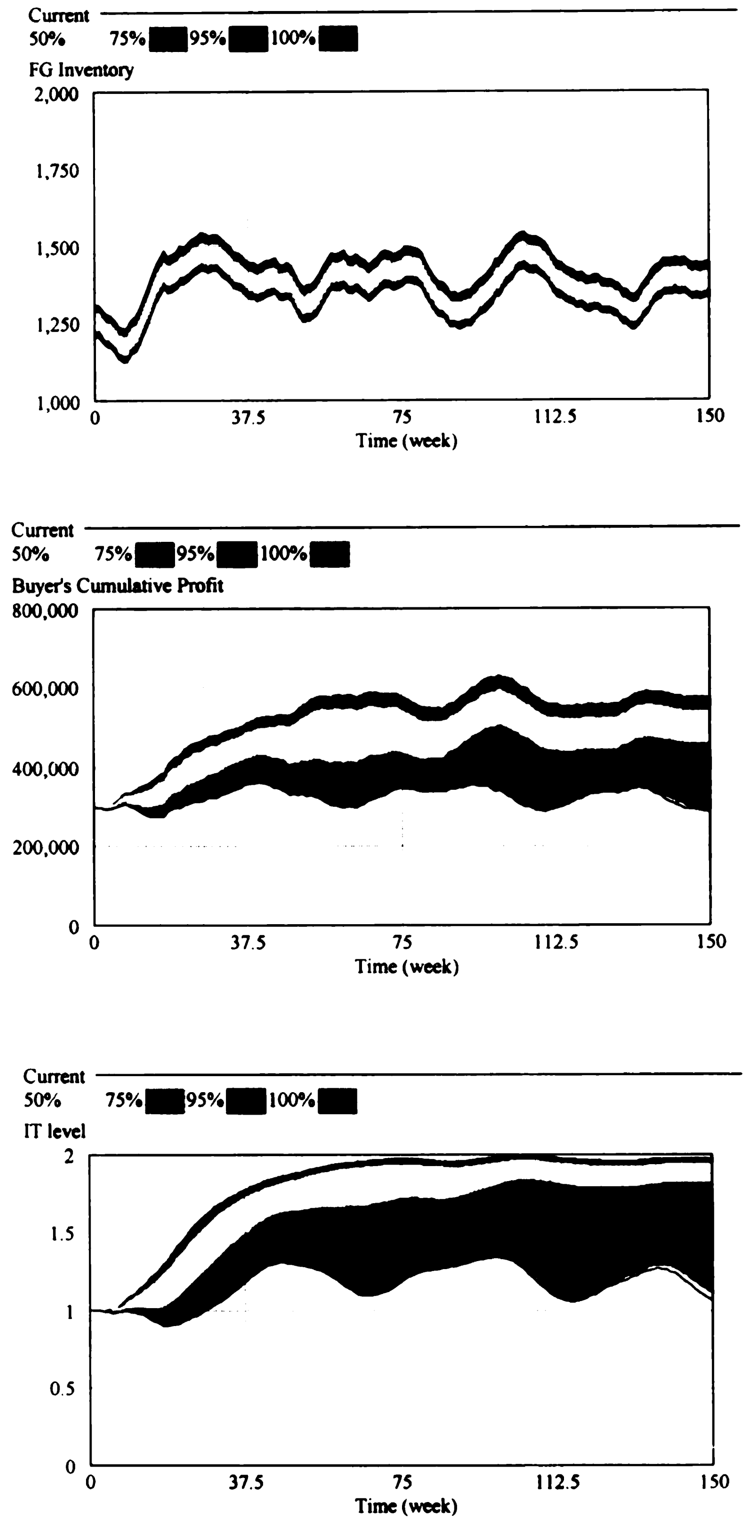
(by the reduction of transit lead-time)

Figure 5-16: Sensitivity Analysis on Key Variables by Parameter Adjustment (1)



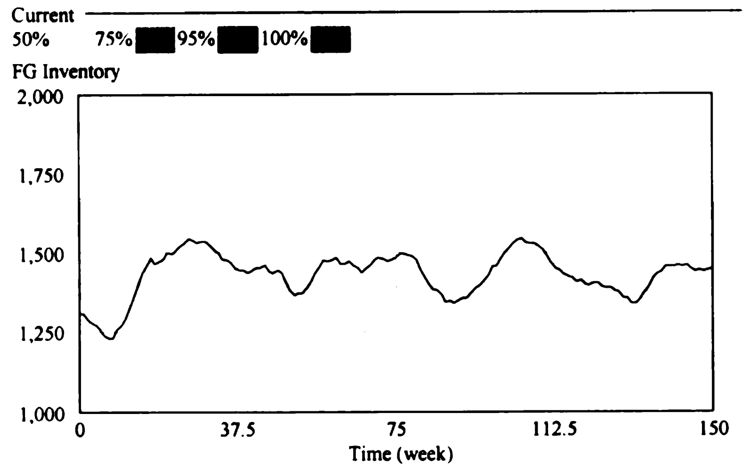
(by the increase of fraction of profit to IT)

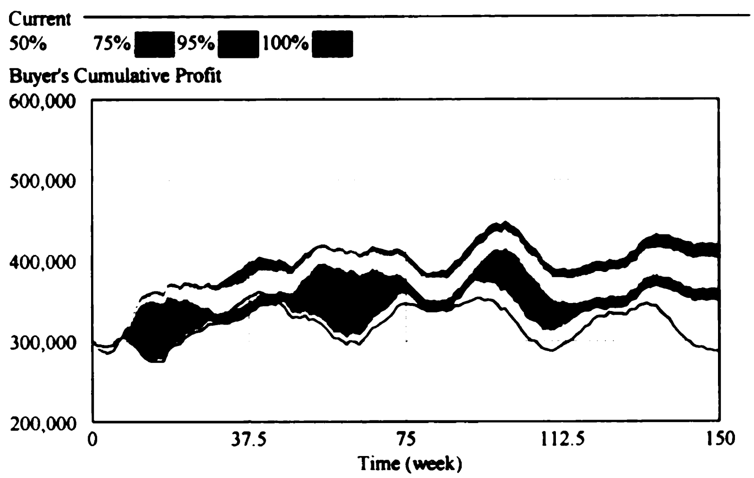
Figure 5-17: Sensitivity Analysis on Key Variables by Parameter Adjustment (2)

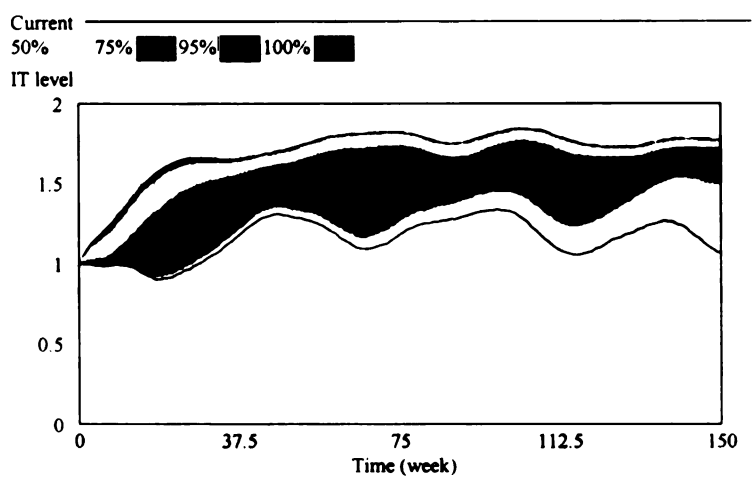


(by the reduction of transit lead-time)

Figure 5-18: Sensitivity Analysis on Key Variables by Parameter Adjustment (3)







(by the increase of fraction of profit to IT)

Figure 5-19: Sensitivity Analysis on Key Variables by Parameter Adjustment (4)

However, unlike anticipated, it is very difficult to find a significant difference between the effects of both policies. When considering that the sources of the results in Figures 5-16 and 5-17 started from supplier inventory level, this means that in terms of supplier, there does not exist a significant difference in benefit between two policies. However, in terms of buyer, there exists a substantial difference in effect between the two policies. As can be seen in Figures 5-18 and 5-19, even though both the reduction of transit lead-time and the increase in fraction of buyer's profit to IT investment lead to the subsequent increases of buyer's profit and IT level, there exists a clear difference in the magnitude of effect between the two policies. That is, the effect of transit lead-time reduction indicates to be greater than that of the increase of fraction of profit to IT investment. Such result can be also explained by the interaction with inventory level. As can be seen in the first figure in Figures 5-18 and 5-19, in case of transit lead-time reduction, the magnitude of buyer's FG inventory level decreases substantially while keeping the shape derived from the base model, while in the case of the increase of fraction of profit to IT investment, the magnitude of buyer's FG inventory does not change at all relative to the result of the base model. This result is reasonable because we already discussed from Figure 5-9 that there does not exist a significant direct relationship between IT level and buyer's inventory level, and thus the buyer may not anticipate the effect of advanced IT deployment in terms of buyer's inventory reduction. Such difference in buyer's FG inventory level drives the substantial difference in the effect on buyer's profit and IT level between transit lead-time reduction and the increase of fraction of profit to IT investment. This means that in terms of the buyer, the change of supply chain structural issue such as the reduction of transit lead-time may be more beneficial and effective than the increase of investment for the improvement of IT itself. This supports the argument of Keen (1993) emphasizing the significance of appropriate adoption of information technology rather than the availability of information technology itself.

CHAPTER 6. IMPLICATION AND CONCLUSION

6.1 Contribution

This research starts from the following fundamental research question. Is the development of advanced information technology always beneficial for efficient supply chain management? The assertion of Keen (1993) that the difference in competitive and economic benefits which firms can obtain from E-commerce technology is dependent on not the difference in technology itself, but the difference in managerial capability, emphasizes the importance of research on IT adoption in supply chain management rather than the availability of IT itself. In order to test the validity of this argument, this research posits that information technology investment and deployment for efficient supply chain management should be implemented taking into consideration the interactive, feedback relationships among IT level, product customization level, buyer-supplier relationship, and supply chain structure. Through dynamic simulation analysis by system dynamics on three kinds of feedback loops representing the effect of IT on buyer-supplier relationship and supply chain dynamics, this research disclosed that the effect of IT investment in supply chain management can be different depending on the interaction among the above three feedback relationships. In other words, depending on how the described three feedback relationships affect each other or which feedback relationship mostly dominates, the effect of IT investment can have a different shape. This provides the validity of this research's key proposition above described. This important insight bears on several significant implications relating to effective IT investment and deployment for efficient supply chain management.

6.1.1 Positive Feedback Relationship between IT Level and Buyer's Bargaining Power

Specifically, simulation results indicate that there is a mutual positive feedback relationship between IT level and buyer's bargaining power. In other words, continuous advanced IT deployment ultimately can derive complete competition in electronic market among numerous suppliers, and inversely such electronic market structure can provide the capability for persistent deployment of more advanced IT to buyer. This is consistent with the perspective of transaction cost theory. However, such positive feedback relationship is not derived just from the relationship between IT level and buyer-supplier relationship. The results of this research show that the decrease of supplier's inventory level and inventory cost due to more accurate and timely information sharing by advanced IT plays a significant role in the positive feedback relationship between IT level and buyer's bargaining power. This implies that supply chain dynamics may have a significant influence on the relationship between IT level and buyer-supplier relationship, thus supporting empirically this dissertation's theoretical proposition that interactive, feedback relationships among IT level, buyer-supplier relationship, and supply chain dynamics should be considered for IT investment and deployment for efficient supply chain management. This is the first contribution of this dissertation.

6.1.2 Change of Information Sharing Level according to IT Level

Previous literatures (Lee et al. 1997, 2000; Christopher 1994) did not comment that the level of information sharing might be different according to IT level. That is, previous literatures analyzed just the difference in effect between two extreme situations such as when information is shared and when information is not shared. This dissertation assumes that the effect of information sharing can be different depending on the level of information technology. In other words, if more advanced IT is deployed, more accurate and timely sharing of manufacturer's forecast on day-to-day demand may be possible. Inversely, if IT level is relatively low, the possibility of demand distortion due to the lack of information sharing may increase. This dissertation's SD model reflects such argument, and from such effort, suggests that the improvement of information sharing capability by continuous deployment of advanced IT can reduce supplier's total cost more than anticipated by not only minimizing substantial variation in inventory holdings induced by bullwhip effect, but also lowering the absolute level of supplier's inventory. This suggestion discriminates the value of this dissertation from previous researches. However, one thing to be noted is that this dissertation used two-level information sharing model, while some previous researches deal with three or four-level information sharing model. It is very interesting to examine whether this dissertation's result described above can be shown even in three or four-level model. This deserves further investigation.

6.1.3 Existence Possibility of Win-Win Strategy

This research also reveals that the reduction of supplier's absolute inventory level above described can be the critical factor driving the gradual increase of both buyer's and supplier's profits. This implies that buyer-supplier relationship may not be necessarily zero-sum game, thus emphasizing the significance of win-win strategy in which both buyer and supplier can live together. The results of this research suggest the existence possibility of such win-win SCM strategy. However, win-win strategy in which both buyer and supplier can live together is not derived from the relationship between IT level and buyer-supplier relationship under the perspective of transaction cost theory and incomplete contract theory, which are based on the concept of zero-sum game between buyer and supplier. The results of base run discloses that the possibility of win-win strategy can be suggested when feedback loop representing IT effect on supply chain dynamics affects or further dominates feedback loop reflecting IT effect on buyer-supplier relationship. Such finding deserves another contribution of this dissertation.

6.1.4 Validity of the Portfolio of Inter-Firm Transaction Relationship

As mentioned previously, the effect of IT on buyer-supplier relationship cannot be explained only by the conflict between transaction cost theory and incomplete contract theory. This suggests that other forces like supply chain dynamics should be accounted for in a more complete model of buyer-supplier relationship. The results of sensitivity analysis on the responses of key variables by product variety level find that product variety level can be also an important factor for explaining such complete model of buyer-supplier relationship. That is, as product variety level decreases relative to base model, the magnitude of IT level and the number of supplier increase with keeping the shape derived from base run. Meanwhile, as product variety level increases relative to base model, the magnitude of IT level and the number of supplier decrease with the same shape as that in base run. The above result means that in case of low product variety level, the establishment of electronic market structure can be still derived from mutual positive feedback relationship among IT level and buyer's bargaining power. However, in case of high product variety level, we cannot expect the persistence of such electronic market structure due to the domination of negative feedback relationship among IT level and buyer's bargaining power. This argument is logically consistent with the portfolio of inter-firm transaction relationship of Bensaou and Venkatraman (1996) emphasizing that the type of market exchange relationship in which the technical and economical dependence of both buyer and supplier on each other is relatively low, is appropriate for highly standardized products. Meanwhile, the type of strategic partnership in which buyer-supplier relationship is strongly connected by considerable transaction-specific assets of both buyer and supplier, is significantly correlated with highly customized products. However, the portfolio of Bensaou and Venkatraman (1996) is based on theoretical suggestion, while this dissertation tested empirically the validity of Bensaou and Venkatraman (1996)'s argument. This is another contribution of this dissertation.

6.1.5 The Availability of Information Technology Itself vs. The Significance of Managerial Capability on Information Technology

The possibility of win-win strategy in which both buyer and supplier can live together above described also provides the likelihood that the change of supply chain structural issues and the role of IT in such change of supply chain structural issues may alter the feature of buyer-supplier relationship based on zero-sum game, even in highly customized and differentiation-focused product. Specifically, the results of this research reveals that depending on how to manage more efficiently supplier's and buyer's inventory level, the effect of IT investment on buyer-supplier relationship and supply chain dynamics can be different. As a way for managing inventory level, we can consider the change of lead-time and IT investment budget.

The comparison between the above two ways is very interesting issue. Keen (1993) insists that the difference in competitive and economic benefits which firms can obtain from information technology is dependent on not the difference in technology itself, but the difference in managerial capability. This research identifies the validity of Keen (1993)'s assertion. The result of sensitivity analysis on the responses of key variables by the reduction of transit lead-time and the increase of fraction of buyer's profit to IT investment indicates that even though both the reduction of transit lead-time and the increase of fraction of buyer's profit to IT investment lead to the subsequent increases of buyer's profit and IT level, the effect of transit lead-time reduction is greater than that of the increase of fraction of profit to IT investment. This means that the change of supply chain structural issue such as the reduction of transit lead-time may be more beneficial and effective than the increase of investment for the improvement of IT itself. This supports the argument of Keen (1993) emphasizing the significance of appropriate adoption of information technology rather than the availability of information technology itself.

6.2 Future Research

In this dissertation, we considered just the changes of transit lead-time and fraction of buyer's profit to IT investment as the subjects of parameter adjustment policy. However, we cannot deny the possibility that according to the changes of other parameter values, we may get different results and more advisable suggestions relative to previous discussions. Also, the behavioral changes of key variables according to the interactions among parameter values also cannot be ignored. This should be addressed in future research.

As mentioned previously, policy leverage can be classified into parameter adjustment policy and structural adjustment policy. Parameter adjustment policy means changing artificially parameter values in a SD model, as we already discussed above. Structural adjustment policy means changing feedback loops in a SD model.

As an approach for managing inventory in the dimension of structural adjustment policy, we can think about the change of inventory review system. This research assumes that both buyer and supplier review inventory level by periodic inventory review system in which the item's inventory position *IP* every *P* time periods is reviewed (not continuously), and an order equal to $(T - IP)$, where *T* is the target inventory, that is, the desired *IP* just after placing a new order is placed. However, we can consider the case that both or either buyer or supplier use continuous inventory review system in which whenever a withdrawal brings *IP* down to the reorder point (*R*), an order for *Q* (fixed) units is placed. It will be very interesting to compare the results under the assumption of both inventory review system.

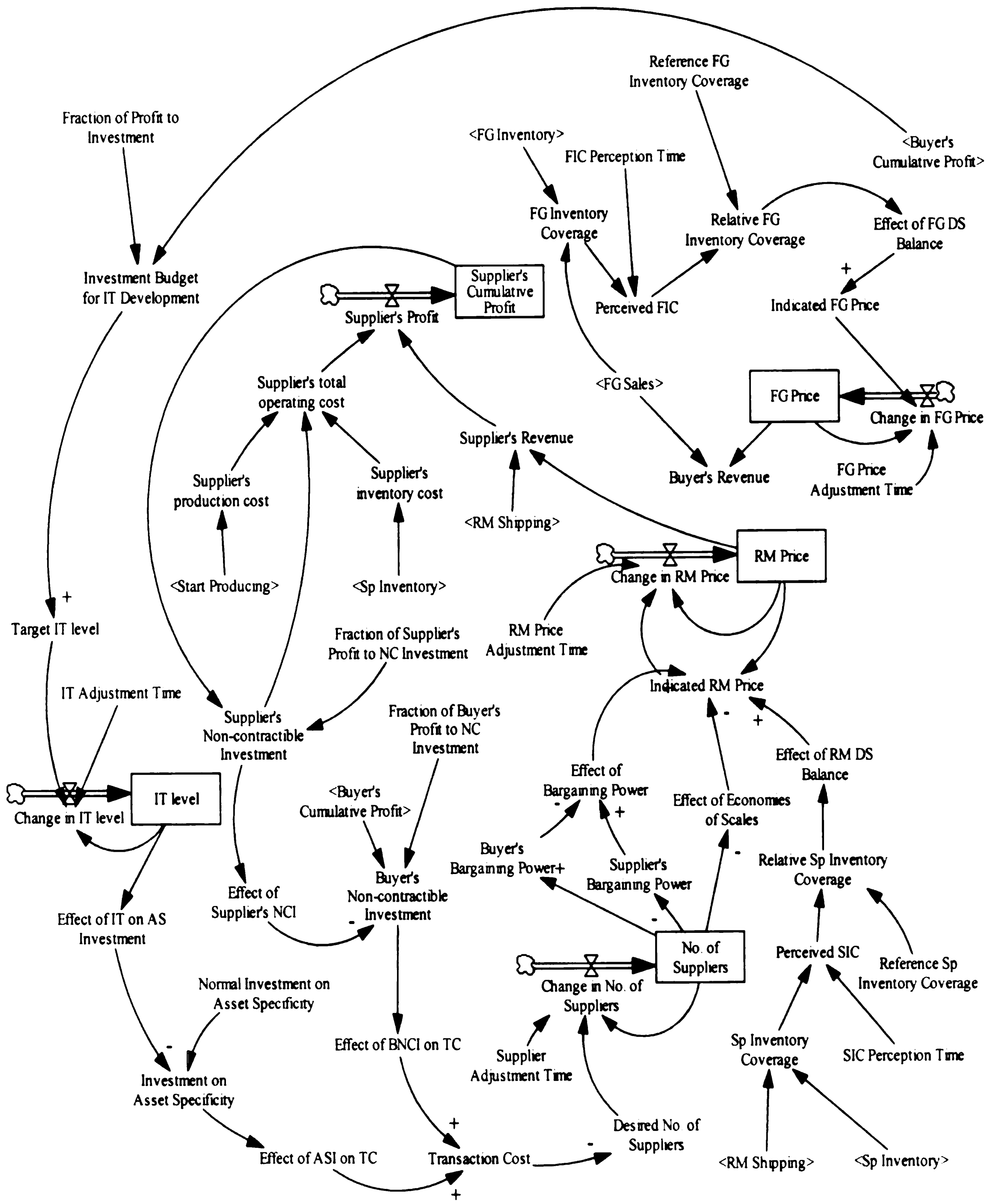
Another interesting research theme in structural adjustment policy is the effect of information sharing in a response-based logistics system. As mentioned in the literature review part, Christopher (1994) suggests that "response-based" or "pull" logistics systems which represent the direct connection of point-of-sale location to the point of production via information technology, can reduce demand distortion and inventory fluctuation. This argument emphasizes that supply chain participants can accomplish both cost reduction and better customer service by sharing information in a response-based logistics system (Bowersox and Closs 1996; Lee et al. 1997a; Lee et al. 1997b; Closs et al. 1998). Such possibility also deserves further investigation in policy experiment.

The model of this dissertation is confined to two-level serial supply chain model between RM supplier and FG manufacturer. The expansion of model into three-level supply chain model (RM Supplier → Manufacturer → Retailer) and non-serial supply chain model (1:N, N:1, N:N) will suggest more impressive results. Also, the simulation analysis on the case that demand is randomly distributed with increasing or decreasing trends will be addressed in future research.

System dynamics models rest on the theory of nonlinear dynamics, an area in which tremendous progress has been made over the past two decades (Sterman 2000). This dissertation's SD model includes many nonlinear relationships among the construct variables. The issue on how do we represent such nonlinear relationship more reliably and realistically is a big challenge for the generalization and future development of this dissertation's proposed model. The cross-validation process of applying the model to data from empirical survey with a sample of U.S. and European firms and evaluating its goodness of fit by analyzing the structural relationships can generalize the proposed model. This should strengthen the external validity of this study's results.

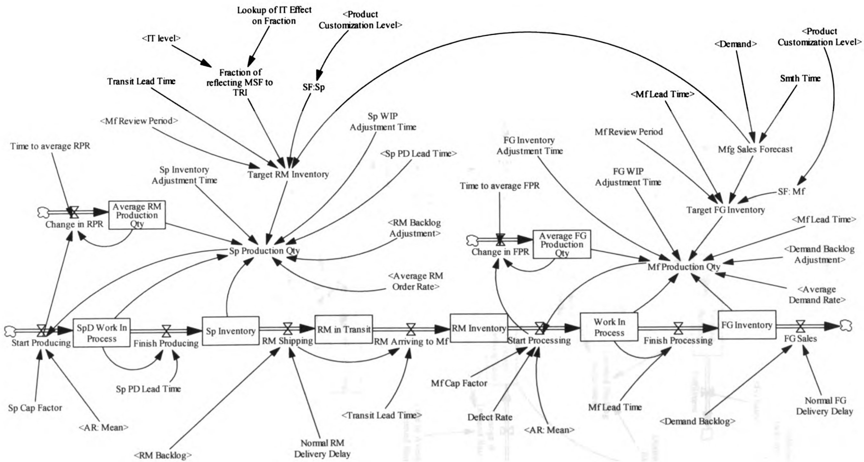
APPENDICES

APPENDIX 1:
System Dynamics Diagram (1)



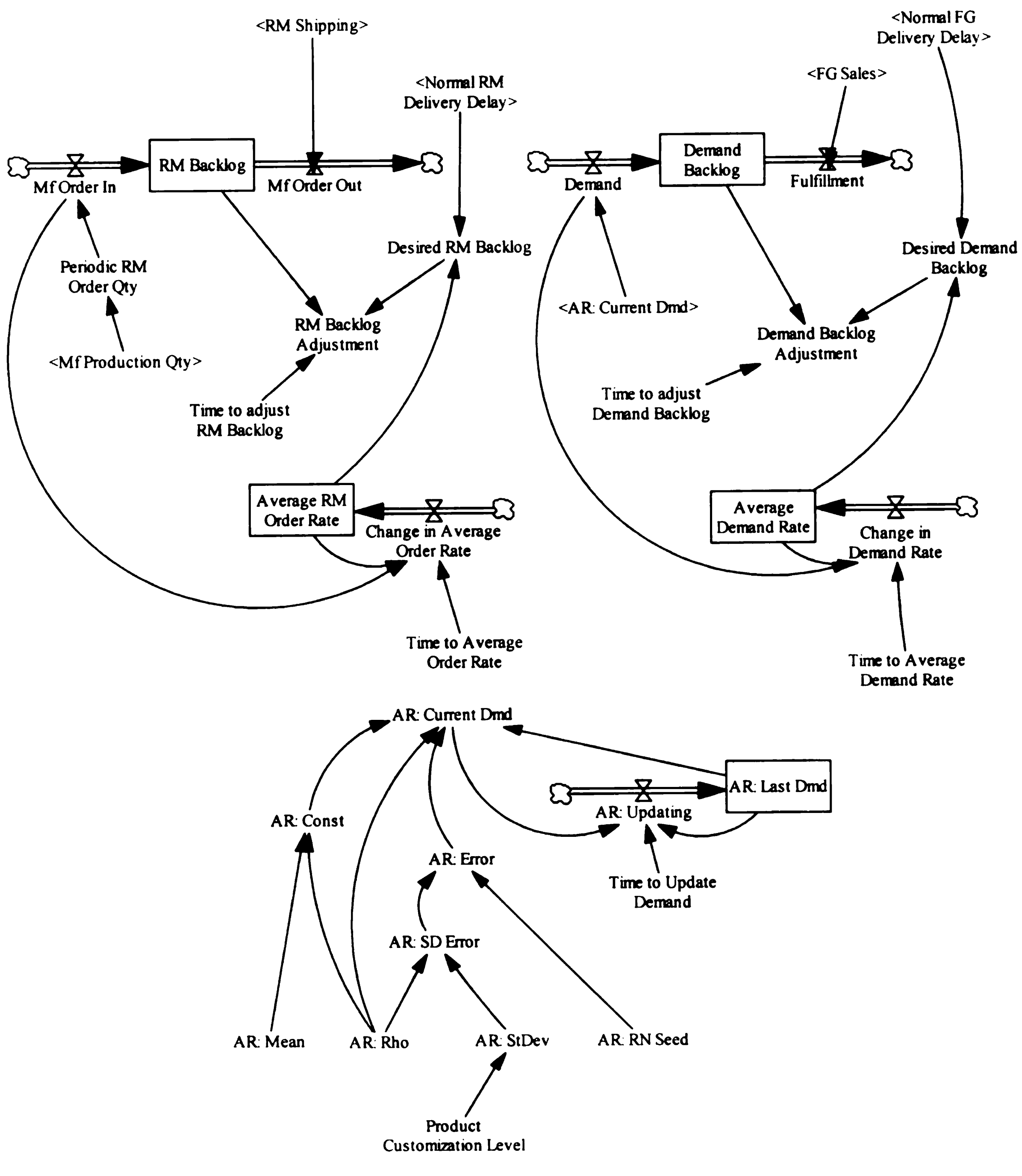
APPENDIX 2

System Dynamics Diagram (2-1)



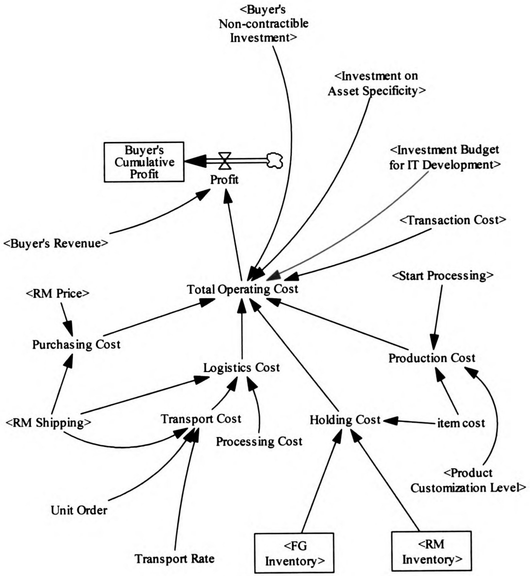
APPENDIX 2 (cont'd)

System Dynamics Diagram (2-2)



APPENDIX 3

System Dynamics Diagram (3)



APPENDIX 4

Equation

(001) "AR: Const"= (1-"AR: Rho")*"AR: Mean"
Units: units/week

(002) "AR: Current Dmd"= "AR: Const"+"AR: Rho"*"AR: Last Dmd"+"AR: Error"
Units: units/week

(003) "AR: Error"= RANDOM NORMAL(0,100,0,"AR: SD Error","AR: RN Seed")
Units: units/week

(004) "AR: Last Dmd"= INTEG ("AR: Updating", 0)
Units: units/week

(005) "AR: Mean"= 200
Units: units/week

(006) "AR: Rho"= 0
Units: Dmnl

(007) "AR: RN Seed"=1.5
Units: Dmnl

(008) "AR: SD Error"=sqrt(1-"AR: Rho"^2)*"AR: StDev"
Units: units/week

(009) "AR: StDev"= 20*Product Customization Level
Units: units/week

(010) "AR: Updating"=("AR: Current Dmd"-"AR: Last Dmd")/Time to Update Demand
Units: units/week/week

(011) Average Demand Rate= INTEG (Change in Demand Rate, Demand)
Units: units

(012) Average FG Production Qty= INTEG (Change in FPR, 200)
Units: units

(013) Average RM Order Rate= INTEG (Change in Average Order Rate, Mf Order In)
Units: units

(014) Average RM Production Qty= INTEG (Change in RPR, 200)
Units: units

(015) Average RM Shipment Rate= INTEG ((RM Shipping-Average RM Shipment Rate)/Time to average RM shipment, RM Shipping)
Units: units

(016) Average Sales Rate= INTEG ((FG Sales-Average Sales Rate)/Time to average sales, FG Sales)
Units: units

(017) Buyer's Bargaining Power = WITH LOOKUP ("No. of Suppliers", ([(1,0.1)-(20,2)],(1,0.1),(3.61468,0.191667),(5.76453,0.325),(7.74006,0.516667),(9.07645,0.716667),(10,1),(11.4587,1.39167),(13.0856,1.65833),(15.2936,1.81667),(17.6177,1.925),(20,2)))
Units: Dmnl

(018) Buyer's Cumulative Profit= INTEG (Profit, 300000)
Units: dollars

(019) "Buyer's Non-contractible Investment"=IF THEN ELSE(Buyer's Cumulative Profit<0, 0, Buyer's Cumulative Profit*Fraction of Buyer's Profit to NC Investment*Effect of Supplier's NCI)
Units: dollars/week

(020) Buyer's Revenue=FG Sales*FG Price
Units: dollars/week

(021) Change in Average Order Rate=(Mf Order In-Average RM Order Rate)/Time to Average Order Rate
Units: units/week

(022) Change in Demand Rate=
(Demand-Average Demand Rate)/Time to Average Demand Rate
Units: units/week

(023) Change in FG Price=
(Indicated FG Price-FG Price)/FG Price Adjustment Time
Units: dollars/unit/week

(024) Change in FPR=
(Start Processing-Average FG Production Qty)/Time to average FPR
Units: units/week

(025) Change in IT level=
(Target IT level-IT level)/IT Adjustment Time
Units: Dmnl

(026) "Change in No. of Suppliers"=("Desired No. of Suppliers"-"No. of

Suppliers")/Supplier Adjustment Time
Units: Persons/unit/week

(027) Change in RM Price=(Indicated RM Price-RM Price)/RM Price Adjustment Time
Units: dollars/unit/week

(028) Change in RPR=(Start Producing-Average RM Production Qty)/Time to average RPR
Units: units/week

(029) Defect Rate=0
Units: Dmnl

(030) Demand="AR: Current Dmd"
Units: units/week

(031) Demand Backlog= INTEG (Demand-Fulfillment, Desired Demand Backlog)
Units: units

(032) Demand Backlog Adjustment=(Demand Backlog-Desired Demand Backlog)/Time to adjust Demand Backlog
Units: units/week

(033) Desired Demand Backlog=Average Demand Rate*Normal FG Delivery Delay
Units: units

(034) Desired FG Production=FG Inventory Adjustment+Average Demand Rate
Units: units

(035) Desired FGWIP=Desired FG Production*Mf Lead Time
Units: units

(036) "Desired No. of Suppliers" = WITH LOOKUP (Transaction Cost, ([(50,1)-(10000,20)],(50,20),(1449.69,19.25),(2575.54,17.9167),(3579.66, 15.6667),(4370.79,13.0833),(5000,10),(5527.06,7.16667),(6287.77,4.5),(7322.32 ,2.75),(8630.73,1.75),(10000,1)))
Units: Persons/week

(037) Desired RM Backlog=Average RM Order Rate*Normal RM Delivery Delay
Units: units

(038) Desired RM Production=RM Inventory Adjustment+Average RM Order Rate
Units: units

(039) Desired RMWIP=Average RM Shipment Rate*Sp PD Lead Time
Units: units

(040) Effect of ASI on TC = WITH LOOKUP (Investment on Asset Specificity, ([(0,0.5)-(3000,2)],(0,0.5),(403.67,0.552632),(752.294,0.625),(1027.52,0.717105),(1302.75,0.848684),(1500,1),(1715.6,1.29167),(1935.78,1.56667),(2238.53, 1.8),(2614.68,1.925),(3000,2)))
Units: Dmnl

(041) Effect of Bargaining Power= Supplier's Bargaining Power/Buyer's Bargaining Power
Units: Dmnl

(042) Effect of BNCI on TC = WITH LOOKUP ("Buyer's Non-contractible Investment", ([(0,0.5)-(12000,2)],(0,0.5),(917.431,0.565789),(1724.77,0.638158),(2275.23 ,0.743421),(2715.6,0.861842),(3000,1),(3853.21,1.35),(5834.86,1.64167),(8000 ,1.81667),(9944.95,1.925),(12000,2)))
Units: Dmnl

(043) Effect of Economies of Scales = WITH LOOKUP ("No. of Suppliers", ([(1,0.1)-(20,2)],(1,2),(3.14985,1.88333),(5.4159,1.75),(7.27523,1.55833),(8.72783,1.3),(10,1),(10.8777,0.675),(12.3303,0.441667),(14.3058,0.283333),(17.0948,0.183333),(20,0.1)))
Units: Dmnl

(044) Effect of FG DS Balance=Relative FG Inventory Coverage
Units: Dmnl

(045) Effect of IT on AS Investment = WITH LOOKUP (IT level, ([(0.1,0.1)-(2,2)],(0.1,2),(0.314985,1.89167),(0.547401,1.79167),(0.739144 ,1.625),(0.878593,1.35833),(1,1),(1.13425,0.691667),(1.29113,0.441667),(1.5003 1,0.291667),(1.74434,0.183333),(2,0.1)))
Units: Dmnl

(046) Effect of RM DS Balance=Relative Sp Inventory Coverage
Units: Dmnl

(047) Effect of Supplier's NCI = WITH LOOKUP ("Supplier's Non-contractible Investment", ([(0,0.1)-(4000,2)],(0,2),(501.529,1.9),(917.431,1.76667),(1333.33,1.575),(1688.07,1.35833),(2000,1),(2250.76,0.775),(2532.11,0.491667),(2948.01,0.325),(3412.84,0.191667),(4000,0.1)))
Units: Dmnl

(048) EOQ=sqrt(2*Average Demand Rate*52*RM Price/item cost)
Units: units

(049) FG Inventory= INTEG (+Finish Processing-FG Sales, Target FG Inventory)

Units: units

(050) FG Inventory Adjustment= (Target FG Inventory-FG Inventory)/FG Inventory Adjustment Time
Units: units/week

(051) FG Inventory Adjustment Time=8
Units: weeks

(052) FG Inventory Coverage=FG Sales/FG Inventory
Units: Dimensionless

(053) FG Price= INTEG (Change in FG Price, 350)
Units: dollars/unit

(054) FG Price Adjustment Time=4
Units: week

(055) FG Sales=Demand Backlog/Normal FG Delivery Delay
Units: units/week

(056) FG WIP Adjustment Time=6
Units: weeks

(057) FGWIP Adjustment=(Desired FGWIP-Work In Process)/FG WIP Adjustment Time
Units: units/week

(058) FIC Perception Time=2
Units: weeks

(059) FINAL TIME = 150
Units: week The final time for the simulation.

(060) Finish Processing=Work In Process/Mf Lead Time
Units: units/week

(061) Finish Producing=SpD Work In Process/Sp PD Lead Time
Units: units/week

(062) Fraction of Buyer's Profit to NC Investment=0.01
Units: Dmnl

(063) Fraction of Profit to Investment=0.05
Units: Dmnl

(064) Fraction of reflecting MSF to TRI=Lookup of IT Effect on Fraction(IT level)
Units: Dimensionless

(065) Fraction of Supplier's Profit to NC Investment=0.01
Units: Dmnl

(066) Fulfillment=FG Sales
Units: units/week

(067) Holding Cost=(FG Inventory+RM Inventory)*item cost
Units: dollars/week

(068) Indicated FG Price=350*Effect of FG DS Balance
Units: dollars/unit

(069) Indicated RM Price=100*Effect of Bargaining Power*Effect of RM DS Balance/Effect of Economies of Scales
Units: dollars/unit

(070) INITIAL TIME = 0
Units: week The initial time for the simulation.

(071) Investment Budget for IT Development=IF THEN ELSE(Buyer's Cumulative Profit<0, 0, Buyer's Cumulative Profit*Fraction of Profit to Investment)
Units: dollars

(072) Investment on Asset Specificity=Normal Investment on Asset Specificity*Effect of IT on AS Investment
Units: dollars/week

(073) IT Adjustment Time= 10
Units: weeks

(074) IT level= INTEG (Change in IT level, 1)
Units: Dmnl

(075) item cost=16.004
Units: dollars/unit

(076) Logistics Cost=IF THEN ELSE(RM Shipping>0, Processing Cost+Transport Cost, 0)
Units: dollars/week

(077) Lookup of IT Effect on Fraction(
(0.1,1)-(2,2)],(0.1,2),(0.355657,1.94737),(0.553211,1.89035),(0.756575,1.79386

),(0.901835,1.67105),(1,1.5),(1.09939,1.35965),(1.24465,1.2193),(1.45963,1.109
65),(1.7211,1.03509),(2,1))
Units: Dmnl

(078) Manufacturing Cost=item cost*Start Processing*Production Change Ratio
Units: dollars/week

(079) Mf Cap Factor=10
Units: Dmnl

(080) Mf Lead Time=2
Units: weeks

(081) Mf Order In=Periodic RM Order Qty
Units: units/week

(082) Mf Order Out=RM Shipping
Units: units/week

(083) Mf Production Qty=Average FG Production Qty+(Target FG Inventory-FG Inventory)/FG Inventory Adjustment Time+Demand Backlog Adjustment+(Average Sales Rate*Mf Lead Time-Work In Process)/FG WIP Adjustment Time
Units: units/week

(084) Mf Review Period=2
Units: weeks

(085) Mf Review Period2=(EOQ/(Average Demand Rate*52))*52
Units: weeks

(086) Mfg Sales Forecast=SMOOTH(Demand, Smth Time)
Units: units/week

(087) "No. of Suppliers"= INTEG ("Change in No. of Suppliers", 10)
Units: Persons/week

(088) Normal FG Delivery Delay=2
Units: weeks

(089) Normal Investment on Asset Specificity=1500
Units: dollars/week

(090) Normal RM Delivery Delay= 2
Units: weeks

(091) Perceived FIC=SMOOTH(FG Inventory Coverage, FIC Perception Time)
Units: Dmnl

(092) Perceived SIC=SMOOTH(Sp Inventory Coverage, SIC Perception Time)
Units: Dmnl

(093) Periodic RM Order Qty=Mf Production Qty
Units: units/week

(094) Processing Cost=20
Units: dollars/week

(095) Product Customization Level=1
Units: Dmnl

(096) Production Change Ratio = WITH LOOKUP (Product Customization Level, ([(0.1,0.625)-(2,1.255)],(0.1,0.625),(0.367278,0.667873),(0.599694,0.723355),(0.779817,0.799013),(0.890214,0.892325),(1,1),(1.14006,1.08368),(1.34924,1.14724),(1.55841,1.19145),(1.77339,1.22737),(2,1.255)))
Units: Dmnl

(097) Profit=Buyer's Revenue-Total Operating Cost
Units: dollars/week

(098) Purchasing Cost=RM Price*RM Shipping
Units: dollars/week

(099) Reference FG Inventory Coverage=0.158447
Units: Dimensionless

(100) Reference Sp Inventory Coverage=0.155574
Units: Dimensionless

(101) Relative FG Inventory Coverage=Perceived FIC/Reference FG Inventory Coverage
Units: Dmnl

(102) Relative Sp Inventory Coverage=Perceived SIC/Reference Sp Inventory Coverage
Units: Dmnl

(103) RM Arriving to Mf=RM in Transit/Transit Lead Time
Units: units/week

(104) RM Backlog= INTEG (Mf Order In-Mf Order Out, Desired RM Backlog)
Units: units

(105) RM Backlog Adjustment=(RM Backlog-Desired RM Backlog)/Time to adjust RM Backlog
Units: units/week

(106) RM in Transit= INTEG (+RM Shipping-RM Arriving to Mf, 400)
Units: units

(107) RM Inventory= INTEG (RM Arriving to Mf-Start Processing, 400)
Units: units

(108) RM Inventory Adjustment=(Target RM Inventory-Sp Inventory)/Sp Inventory Adjustment Time
Units: units/week

(109) RM Price= INTEG (Change in RM Price, 100)
Units: dollars/unit

(110) RM Price Adjustment Time= 4
Units: week

(111) RM Shipping=RM Backlog/Normal RM Delivery Delay
Units: units/week

(112) RMWIP Adjustment=(Desired RMWIP-SpD Work In Process)/Sp WIP Adjustment Time
Units: units/week

(113) SAVEPER = TIME STEP
Units: week [0,?] The frequency with which output is stored.

(114) "SF: Mf"=1.28*"AR: StDev"
Units: Dmnl

(115) "SF:Sp"=1.28*"AR: StDev"
Units: Dmnl

(116) SIC Perception Time=2
Units: weeks

(117) Smth Time=4
Units: weeks

(118) Sp Cap Factor=10
Units: Dmnl

(119) Sp Inventory= INTEG (Finish Producing-RM Shipping, Target RM Inventory)
Units: units

(120) Sp Inventory Adjustment Time=8
Units: weeks

(121) Sp Inventory Coverage=RM Shipping/Sp Inventory
Units: Dimensionless

(122) Sp PD Lead Time=2
Units: weeks

(123) Sp Production Qty=Average RM Production Qty+(Target RM Inventory-Sp Inventory)/Sp Inventory Adjustment Time+RM Backlog Adjustment+(Average RM Shipment Rate*Sp PD Lead Time-SpD Work In Process)/Sp WIP Adjustment Time
Units: units/week

(124) Sp WIP Adjustment Time=6
Units: weeks

(125) SpD Work In Process= INTEG (+Start Producing-Finish Producing, Average RM Shipment Rate*Sp PD Lead Time)
Units: units

(126) Start Processing=MIN(Mf Production Qty/(1-Defect Rate), "AR: Mean"*Mf Cap Factor)
Units: units/week

(127) Start Producing=MIN(Sp Production Qty, "AR: Mean"*Sp Cap Factor)
Units: units/week

(128) Supplier Adjustment Time=8
Units: weeks

(129) Supplier's Bargaining Power = WITH LOOKUP ("No. of Suppliers", ([(1,0.1)-(20,2)],(1,2),(3.32416,1.925),(5.53211,1.81667),(7.85627,1.59167),(9.13456,1.30833),(10,1),(11.2844,0.725),(13.1437,0.533333),(15.2355,0.35),(17.5596,0.208333),(20,0.1)))
Units: Dmnl

(130) Supplier's Cumulative Profit= INTEG (Supplier's Profit, 200000)
Units: dollars/week

(131) Supplier's inventory cost=13.151*Sp Inventory
Units: dollars/unit

(132) Supplier's manufacturing cost=13.151*Start Producing
Units: dollars/unit

(133) "Supplier's Non-contractible Investment"=IF THEN ELSE(Supplier's Cumulative Profit<0 , 0 , Supplier's Cumulative Profit*Fraction of Supplier's Profit to NC Investment)
Units: dollars/week

(134) Supplier's Profit=Supplier's Revenue-Supplier's total operating cost
Units: dollars/week/week

(135) Supplier's Revenue=RM Price*RM Shipping
Units: dollars/week

(136) Supplier's total operating cost=Supplier's manufacturing cost+Supplier's inventory cost+"Supplier's Non-contractible Investment"
Units: dollars/week

(137) Target FG Inventory= Mfg Sales Forecast*(Transit Lead Time+Mf Lead Time+Mf Review Period)+"SF: Mf"*sqrt(Transit Lead Time+Mf Lead Time+Mf Review Period)
Units: units

(138) Target IT level = WITH LOOKUP (Investment Budget for IT Development, ([(0,0.1)-(30000,2)],(0,0.1),(3853.21,0.183333),(7339.45,0.3),(10550.5,0.483333),(13211,0.716667),(15000,1),(16880.7,1.3),(19266.1,1.575),(22293.6,1.79167),(25779.8,1.90833),(30000,2)))
Units: Dmnl

(139) Target RM Inventory=Fraction of reflecting MSF to TRI*(Mfg Sales Forecast*(Sp PD Lead Time+Mf Review Period)+"SF:Sp"*sqrt(Sp PD Lead Time+Mf Review Period))
Units: units

(140) TIME STEP = 1
Units: week [0,?] The time step for the simulation.

(141) Time to adjust Demand Backlog=8
Units: weeks

(142) Time to adjust RM Backlog=8
Units: weeks

(143) Time to Average Demand Rate=4
Units: weeks

(144) Time to average FPR=4
Units: weeks

(145) Time to Average Order Rate=4
Units: weeks

(146) Time to average RM shipment=4
Units: weeks

(147) Time to average RPR=4
Units: weeks

(148) Time to average sales=4
Units: weeks

(149) Time to Update Demand=2
Units: weeks

(150) Total Operating Cost=Manufacturing Cost + Holding Cost + Logistics Cost + Purchasing Cost+Investment Budget for IT Development+Transaction Cost+Investment on Asset Specificity+"Buyer's Non-contractible Investment"
Units: dollars/week

(151) Transaction Cost=5000*Effect of ASI on TC*Effect of BNCI on TC
Units: dollars/week

(152) Transit Lead Time=2
Units: weeks

(153) Transport Cost=Transport Rate(RM Shipping/Unit Order)
Units: dollars/week

(154) Transport Rate((0,0)-(1000,1000)],(0,0),(110.092,61.4035),(200,123.154),(321.101,210.526),(437.309,355.263),(500,500),(571.865,653.509),(666.667,771.93),(770.642,868.421),(877.676,942.982),(1000,1000))
Units: dollars/week

(155) Unit Order=1
Units: unit/week

(156) Work In Process= INTEG (+Start Processing-Finish Processing, Average Sales Rate*Mf Lead Time)
Units: units

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