CHAPTER II

Literature Review

This chapter consists of three sections that report on previous studies pertaining to supply chain management, inventory management, and apparel manufacturing to explore meaningful concepts and variables for the study. The first section includes a general overview of supply chain management (SCM) and SCM activities. The second section provides a general overview of inventory management (i.e., definition, type, and role of inventory, inventory control models) and the review of relationships between SCM and inventory management. The third section provides a general overview of apparel manufacturing followed by the review of SCM and inventory management in apparel industry, and key issues (i.e., product characteristics, production system, retail customers).

Supply Chain Management

Reasons for Forming Supply Chain Management

Practices experienced in the traditional management of the supply chain raised the need for conversion to a new paradigm of supply chain management (SCM). The traditional supply chain and manufacturing processes relied on experience and intuition of managers and were designed with long supply cycle times, large batch sizes, capacity based on annual volumes, volume-driven technology, and numerous suppliers for the same parts on the short-term base contracts. With traditional management processes, the goal of business activities was to maximize the efficiency of an individual functional unit by achieving competitive edges based on cost reduction. Under the traditional supply chain, efforts of manufacturers to meet the increased changing of customer requirements caused decreased margins, poor service performance, increased overhead costs, poor production process reliability, increased downtime due to changeovers, and high inventory levels of raw materials and finished product. None of these conditions are viable in a competitive market. Most product supply systems are out of balance with customer requirements (Lummus, Vokurka, & Alber, 1998). Davis (1993) listed reasons

why SCM needs renewed attention: reduced profit margins due to pressure from increasing competition, needs for administrating multisite manufacturing, cut-throat marketing channels, maturation of the world economy, customer service demands for quick and more reliable delivery, and pressure to reduce inventories. According to Cooper and Ellram (1993), SCM is designed to solve these problems and is important to reduce inventory investment in the chain, to increase customer service, and to help build a competitive advantage for the channel. With a changing management focus, companies also began to realize that maximization of efficiency in one department or one functional unit is less desirable than optimal performance for the whole company. Needs for effective vertical integration and consumers' desire for a wider variety and complexity of products have led to demand for SCM (Lummus, Vokurka, & Alber, 1998).

Definition

The concept of SCM is relatively new to academics and practitioners, appearing first in 1982 (Cooper, Lamber, & Pagh, 1997). Although the term, *supply chain management*, has been used since the 1980s and the academic and trade presses have given extensive attention to the concept, confusion still persists in defining what is SCM (Bechtel & Jayaram, 1997). Many researchers have tried to define the meaning of SCM. Table 2-2 provides the summary of each author's definitions. Although subtle differences are found in the word choice and expression, commonalities contribute to an understanding of core concepts in the definition of SCM. The first component is the range of participants. All of the definitions in Table 2-2 state that all channel members within a company or between companies, including supplier, manufacturer, distributor, and customer, should be involved in the chain activities and collaboration between members. The second component is the flow of materials and information. Agreement across definitions is that materials, whether raw materials or finished goods, and information flow simultaneously both upstream and downstream in the chain. Third, to manage the flow of materials and information and to provide high customer value, integrated and coordinated value-added activities are required (i.e., cross-functional approach, joint planning and forecasting, flexible operations).

Table II-1.

Summary of Definitions of SCM

Authors	Definition
Alber & Walker (1997)	"The global network used to deliver products and services from raw materials to end customers through an engineered flow of information and physical distribution." (p. 203)
Cooper & Ellram (1993)	"An integrative philosophy to manage the total flow of a distribution channel from the supplier to the ultimate user … greater coordination of business processes and activities … across the entire channel and not just between a few channel pairs." (p. 13)
Giunipero & Brand (1996)	"Definitions can be grouped into three major categories: 1) The management of the flow of goods from supplier to final user; 2) The system-wide coordination of product and information flows; and 3) The development of relationships and the integration of all activities that provide customer value throughout the distribution channel." (pp. 29-30)
Jones (as cited in Goffin, Szwejczewski, & New, 1997)	"Managing the entire chain of raw material supply, manufacture, assembly, and distribution to the end customer." (p. 422)
Lee & Ng (1997)	"A network of entities that starts with the suppliers' suppliers and ends with the customers' customers for the production and delivery of goods and services." (p. 191)
Lummus, Vokurka, & Alber (1998)	"A network of entities through which material and information flow. Those entities include suppliers, carriers, manufacturing sites, distribution centers, retailers and customers." (p. 49)
Palevich (1997)	"All of those activities associated with moving goods from raw materials through the end user: sourcing and procurement, production scheduling, order processing, inventory management, transportation, warehousing, and customer service. Importantly, it also embodies the information systems to monitor these activities." (p. 1)
Spekman, Kamauff, & Myhr (1998)	"A process for designing, developing, optimizing, and managing the internal and external components of the supply system, including material supply transforming, materials and distributing finished products or services to customers, that is consistent with overall objectives and strategies." (p. 631)
TICCE (as cited in Cooper, Lambert, & Pagh, 1997)	"The integration of business processes from end user through original suppliers that provides products, services and information that add value for customers." (p. 2)

According to Giunipero and Brand (1996), SCM has evolved by passing through three stages: partnership/relational management, logistics, and SCM. In their study, purchasing practitioners, in the sample, take a narrower view of the supply chain than do the academics. The respondents' interpretation of SCM matches the definition of the first stage (i.e., partnership/relational management) in which initial linkage of two companies in the chain is the main focus of business activities. Although practitioners have a narrow definition of the SCM, examples of significant evidence in some industries can be found that reflect the broad concepts of SCM. Those examples are Quick Response (QR) in apparel industry, Efficient Consumer Response (EQR) in grocery industry and health care products industry, and Efficient Food service Response (EFR) in food services industry (Bechtel & Jayaram, 1997; Lee & Ng, 1997). All these efforts are for better flow of material and information in the supply chain through coordination between companies and across functional boundaries.

Key Management Processes in the Supply Chain

According to Davis (1993), key business processes of SCM can be grouped into three activities: supply, transformation, and demand. *Transformation* refers to a broader meaning than *manufacturing* in that the term encompasses material handling and distribution functions. Harrington (1999) also identified four distinct management processes in the supply chain as plan, source, make, and deliver. In Harrington's discussion, *source, make,* and *deliver* are execution processes that form a link in the supply chain, and *plan* is a process of managing the customer-supplier links. Figure 2-1 depicts the management processes occurring between chain members.   Manufacturers are involved with both the interfaces with second tier suppliers and with customers. The purchasing-manufacturing interface and the manufacturing-warehouse/distribution interface have been most widely studied in the articles which SCM (Bechtel & Jayaram, 1997; Cooper & Ellram, 1993). The role of manufacturers in the supply chain is critical for the efficiency of the whole supply chain because they have to build a direct relationship with suppliers as well as with customers and handle both interfaces efficiently.
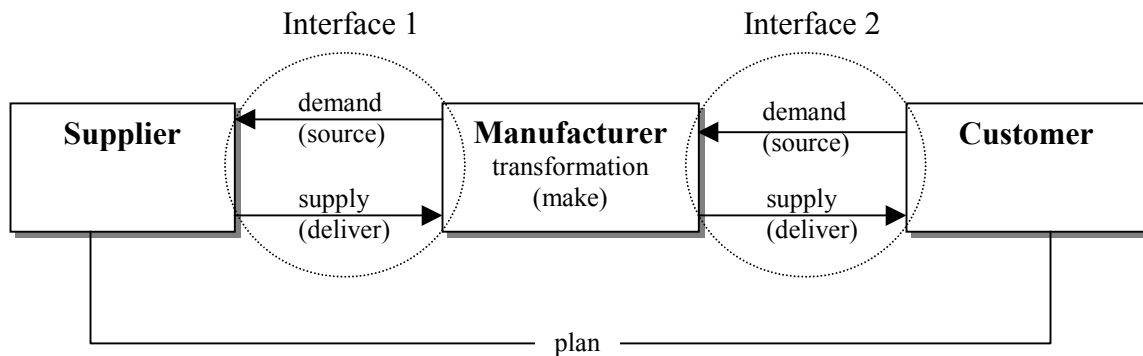
Figure 2-1. Key Management Processes between Chain Members

Benefits

Many previous studies conducted in various industries have revealed tangible benefits generated from efficient SCM (Harrington, 1999; Higginson & Alam, 1997; Alber & Walker, 1997; Palevich, 1997; Giunipero & Brand, 1996; Cooper & Ellram, 1993). The summary of benefits is presented in Table 2-2. These benefits can be categorized into four groups. First, financial benefits were reported: reduction in costs tied with high level of inventory, shipping, and operating costs; cost advantage over competitors; and increased profit margin with lower product costs. These cost reductions were achieved without downsizing, laying off employees, or closing plants. Second, companies' operational activities were improved: reduced cycle times, lower inventory levels, increased stock availability, less stockouts, increased inventory turns, and greater productivity in operations. Third, customer service was increased: more reliable delivery and increased responsiveness to changes. Lastly, closer coordination among channel members is an important benefit. This benefit results in an improvement in the quality of products and information and an increase in the sharing of expertise and risks, which creates a competitive advantage and greater profitability.

Table II-2.

Summary of SCM Benefits

Benefits of SCM	Alber & Walker (1997)	Cooper & Ellram (1993)	Giunipero & Brand (1996)	Harrington (1999)	Higginson & Allram (1997)	Palevich (1997)
	Case study of a food company	Literature analysis	Survey of 52 members of the NAPM [a]	Conceptual work	Literature analysis	Conceptual work
Closer relationships with chain members		*	*		*	*
Cost advantage				*		
Cost reduction			*	*		*
Customer service level improvement	*					
Cycle times reduction	*	*	*		*	*
Inventory reduction			*	*	*	
Inventory turns improvement	*	*				
Productivity improvement			*			
Profit margins improvement	*					
Reliable delivery			*		*	
Responsiveness to changes					*	

[a]: National Association of Purchasing Management

Supply Chain Management Activities

Many authors have studied to clarify the characteristics of SCM through qualitative or quantitative methods. In their discussions, they identify characteristics, key issues, principles, and techniques of SCM. Capabilities of supply chain leaders and impediments of SCM also have been revealed. By reviewing each author's view, specific

dimensions of SCM can be identified. Each dimension may contain multiple activities and the adoption levels of chain members can be assessed.

Cooper and Ellram (1993) reported eleven points of the characteristics of SCM in their conceptual study on SCM. Main focuses refer to efforts for reduction of redundant inventories and cost in the supply chain, amount of information sharing and monitoring, amount of coordination and time horizon to endure relationships between multiple levels of the channel, channel leadership, compatibility of corporate philosophies, breadth of supplier base, and speed of operations. In a study on a sports clothing manufacturer, Team Hanes, Sabath (1995) presented a diagnostics guide by which a company's growth through SCM can be assessed. The level of seamless movement of information throughout the supply chain via electronic links, accurate demand forecasting with every chain members' involvement, information sharing with customers and suppliers, efficiency of measurements to monitor supply chain performance, and coordination of processes to minimize inventories and cycle times indicate how much a company can grow through SCM. Alber and Walker (1997) introduced methods to synchronize supply and demand for better balanced SCM. These methods include processes to align run cycles with customer demand cycles, have batch sizes equal the batch size necessary to meet customer demand, identify demand characterization, be able to manage demand, compare the actual throughput and the capacity utilization against the customer demand profile, communicate point-of-sales (POS) information, eliminate the traditional manufacturing strategy, disseminate information rapidly, and have better planning and control.

In a study of 93 medium-to-small manufacturing in five different industries (i.e., electrical and communication equipment; food and related products; machinery, metal, and building products; automotive parts and accessories; and textiles and clothing), Higginson and Alam (1997) found that the use of SCM techniques varied in extent and between industries. The authors identified common techniques of SCM from the literature. Those techniques included developing strong relationships with chain members, developing high quality products and services, sharing information, building

commitment to SCM, reducing the number of suppliers and carriers, and minimizing inventory levels and cycle times across the chain. In a trade article, Copacino (1998) analyzed the data from eight-industry segments which consists of several rounds of group discussions with experts in the industries. The author identified characteristics and capabilities of leaders who have shown successful performances in SCM. Those characteristics are deep functional excellence in key functional areas such as procurement, manufacturing, transportation and distribution, and customer care; management of unexpected surge and uncertainty caused by poorly planned promotions, product proliferation, product-line complexity, and poorly coordinated new product introductions; world-class information technology; virtual logistics; and ability to integrate channel partners with collaboration across the channel.

In a study of how SCM techniques are applied in a variety of industries which involve the production of consumer durables, component parts, refrigeration products, industrial products, to gain competitive advantages in inventory management through a case study, Jones and Riley (1985) presented three main barriers to a supply chain as the following: (a) tradition, organizational, legal, and non-integrated management systems; (b) independent businesses, vendors, and distributors; and (c) information and control systems. Higginson and Alam (1997) identified barriers to successful use of SCM as the following: (a) lack of strong management commitment and consensus leadership; (b) unclear definitions about SCM; (c) legal issues in sharing data; (d) inefficient information systems, and (e) incompatible systems at channel members. Johnson (1998) also provided five pitfalls that hinder in effective SCM: (a) wrong choice of metrics for performance measurement, (b) poor operational control and execution, (c) lack of information sharing, (d) poor supply chain design, and (e) poor product design. In the discussion, the author suggested the percentage of complete orders shipped on customers' requested dates as a better metric to measure customer satisfaction, which is the ultimate goal of SCM. Also, the author emphasized the importance of finding manufacturing flexibility as a key breakthrough in supply chain efficiency. In brief, lack of top management commitment and leadership, information sharing system, and coordination between chain members are main barriers for companies to grow through SCM. When

barriers are identified as such, the effort to remove the barriers of the company can be part of the SCM activities.

From the previously reviewed research and conceptual articles, the multiple activities can be grouped into six SCM dimensions. The level of SCM activities can be determined by the extent to which supply chain members understand the characteristics and key issues, implement techniques of SCM, and are willing to eliminate the barriers.

The first dimension is the collaborative partnership with chain members. Partnership is defined as "an agreement between a buyer and a supplier that involves a commitment over an extended time period, and includes the sharing of information along with a sharing of the risks and reward of the relationship" (Ellram & Cooper, 1990). A close partnership is not only a prerequisite for SCM, but it can also result from successful SCM. Consolidation in supplier base is one sub-issue required for better quality management, focused business, and long-term relationship. Under a traditional relationship, the biggest concern for buyers is cost reduction and they select the suppliers who offer the lowest cost. Multiple suppliers' competition on cost conceals the quality defect problem because thorough quality inspection adds cost. And, the nature of the relationship with buyers tends to be short-term and adversarial because buyers will switch to other suppliers who offer lower cost to them. Therefore, activities which can enhance the long-term relationship through collaboration between chain members such as joint planning and demand forecasting, accurate and timely information sharing throughout the chain, and technology sharing are required activities to advance to a partnership (Spekman, Kamauff, & Myhr, 1998; Vokurka, 1998). As these activities increase the dependency on each member, a company is less likely to switch to alternative supplier or customer.

The utilization of information technology is the second characteristic to be measured. Examples of the information technology are computer-to-computer communication, electronic data interchange (EDI), POS data communication, and barcoding. Electronic links between suppliers and carriers or customers are critical for

information sharing. Technologies at each stage of the supply chain should be compatible with their partners' to better streamline the information. Types of information fed into this electronic links are data on sales, usage, product changes, promotions, discontinuations, and product and process (Sabath, 1995).

Flexibility of operations is the third dimension. Agile manufacturing is achieved by flexible operations which can handle frequent style changes in the production line. Narasimhan and Das's (1999) study to examine the effect of SCM practices on operational flexibilities and manufacturing agility with 75 purchasing managers in various industries, focused on volume flexibility, modification flexibility, and delivery flexibility as key features of operational flexibility. These three flexibilities can be described as an ability to vary production volumes economically in response to market demands, to implement minor changes in product design for customization purposes, and to reduce delivery lead times, respectively. Increasing the agility of manufacturing operations, just-in-time (JIT) manufacturing, procurement of raw materials on a JIT basis from suppliers, and JIT distribution are required for successful SCM (Higginson & Alam, 1997; Palevich, 1997).

Service and performance measurements established for each stage of the supply chain is the fourth dimension. Performance measurements, as well as financial information, are needed to monitor SCM performances. Examples of key performance indicators are supplier reliability and supplier lead-time to monitor the supply performance. Process reliability, changeover time, and schedule attainment can be measured to monitor the production. Perfect order completion, order fill rate, on-time delivery, and replenishment lead time are used to measured the delivery performance. To monitor demand management, total supply chain inventory and total cycle time are used (Lummus, Vokurka, and Alber's (1998). Importance of metrics to facilitate change or to adopt an innovation in apparel manufacturing is noted by Regan (1997).

The fifth dimension is top management's commitment and leadership. For the success of any new management initiative, top management's awareness of benefits,

willingness to implement, and desire to continue change are required to be a better participant in SCM (Higginson & Alam, 1997; Vass & Kincade, 1999). Top management is responsible for creating the culture of the company. When the outcome of a chain is uncertain to a company, strong leadership relieves employees from insecurity and motivates them to act toward the new direction. Bechtel and Jayaram (1997) noted that the most important barrier to reengineering is people, not systems or technology.

The final and sixth dimension is the knowledge of demand characteristics. Knowledge of demand characteristics determines the success of SCM. Characteristics of demand such as certain and uncertain, dependent or independent, seasonal or staple, are closely associated with key operational decisions. Characterizing demand patterns, aligning supply capabilities with demand cycles, and understanding the operational implications of surge or uncertainty caused by product proliferation and product-line complexity issues are related activities to this dimension (Copacino, 1998).

<u>Inventory Management</u>

Inventory management includes a company's activities to acquire, dispose, and control of inventories that are necessary for the attainment of a company's objectives. The management of inventories concerns the flow to, within, and from the company and the balance between shortages and excesses in an uncertain environment (Tersin, 1988). According to McPharson (1987, p360), in apparel manufacturing, "inventory management systems are designed to obtain concise and accurate information for control and planning of planned goods, issues, cuts, projections, WIP and finished goods." Inventory management has been a concern for academics as well as practitioners, in that overall investment in inventory accounts for relatively large part of a company's assets. Inventory may account for 20 to 40% of total assets (Tersin, 1988; Verwijmeren, Vlist, & Donselaar, 1996). Inventories tie up money, and success or failure in inventory management impacts a company's financial status. Having too much inventory can be as problematic as having too little inventory. Too much inventory requires unnecessary

costs related to issues of storage, markdowns and obsolescence, while too little results in stockouts or disrupted production. Besides, long-run production associated with a high level of inventory conceals production problems (e.g., quality), which can damage a company's long term performance (Vergin, 1998). Therefore, the primary goal of inventory management has been to maximize a company's profitability by minimizing the cost tied up with inventory and at the same time meeting the customer service requirements (Lambert, Stock, & Ellram, 1998).

Traditionally, inventories caused conflicts between functional units within a company or between companies. For example, within a company, purchasing, production, and marketing people want to build a high level of inventory for raw material cost reduction, efficient production run, and customer service level, while warehousing and finance people want to reduce the inventory level for storage space and economic reasons (Tersine, 1988). As global competition between suppliers in the open markets has increased, power has been shifted from suppliers to customers (Verwijmere, Vlist, Donselarr, 1996). Therefore, the customers' need to reduce the inventory based on frequent small lot orders has resulted in their partners holding the inventory (Thomas, 1998).

<u>Definition and Type of Inventory</u>

Inventory can be defined as any idle resource or tangible asset which can be seen, weighed, and counted. This includes supplies, raw materials, work in process (WIP), and finished goods (Tersine, 1988). Goldratt and Cox's (1992) definition is "money the system invests in things that it intends to sell: materials waiting to be processed, work in process, and finished goods" (p. 60). Tersine (1988) defines raw materials, WIP, finished goods and supply. *Raw materials* are items purchased from suppliers to be used as inputs into the production process and modified or transformed into finished goods. *WIP* refers to partially completed final products that are still in the production process. *Finished goods* are final products available for sale, distribution, or storage. *Supplies* are items for maintenance, repair, and operating supplies (i.e., pencils, paper, light bulbs, typewriter

ribbons, and facility maintenance items). Supplies are excluded from this study's discussion because they are not a part of the final product. Of the three classes of inventory that become final products, poor finished goods present the worst problem because finished goods contain the most value and require the highest inventory holding cost. As manufacturing begins, value (i.e., labor, machine, factory overhead expense) is added to the finished goods. At the end of the manufacturing processes, transforming or modifying finished goods into another form is almost impossible or very costly (Pachura, 1998; Tersine, 1988). *Inventory turnover* and *fill rate* are examples of popular indicators for measuring an organization's performance in inventory management (Vergin, 1998; Branam, 1984; Lambert, Stock, & Ellram, 1998). Inventory turnover is the velocity of inventory passing through an organization calculated by dividing the annual sales by the average on hand inventory. Fill rate is the percentage of units available when requested by the customer.

Roles of Inventory

Traditionally, a relatively high level of inventory has been kept in a company. The reasons for building inventory can be found in inventory's five functional roles: economies of scale, balance of supply and demand, specialization in manufacturing, protection from uncertainties, and inventory as buffer (Lambert, Stock, & Ellram, 1998; Schroeder, 1993; Tersine, 1988; Vergin, 1998). First, purchasing or producing a bulk of items (i.e., economies of scale) enables a company to cut costs by allowing setup cost reduction, price discounts, and spreading the factory overhead expenses. Second, inventory provides balance between supply and demand. Supply and demand do not always match at any given time for reasons such as seasonal demand pattern or seasonal supply pattern. To maintain a stable workforce and production scheduling, and to avoid problems due to capacity limits, production can be used to build inventory. Peak demand can be anticipated by building inventories in excess of current demand. Third, inventory enables a manufacturer to specialize in the item by obtaining focused factory and learning-curve effects. Focused factory is a small factory dedicated to a specific product with a single product line to maximize productivity and quality. According to learning-

curve effect, a worker can gain skill and efficiency from their own experience from the repetitious practice with the long product runs. Fourth, inventory serves to protect uncertainties in demand and supply. Inventory is necessary in case demand for finished goods fluctuates or if the suppliers' ability to meet the buyers' demand is not reliable. Raw material inventory is required in case of supply shortage and price increases. WIP inventory is needed to avoid a shutdown and stabilize workflow. Finished goods inventory improves customer service levels by avoiding stockouts due to variability in demand and manufacturing lead-time. Lastly, inventory is used as buffer in the supply chain. It takes time to transit inventory from one operation to another within a company or one node to another in the supply chain (i.e., supplier to manufacturer, manufacturer to distributor, distributor to customer). A certain amount of inventory throughout the chain ensures the independence of each operation team or channel member. Raw materials inventory isolates the supplier from the user, in-process inventory isolates production departments from each other, and finished goods inventory isolates the customer from the manufacturer.

Overview of Inventory Control Model

To help solve the problems of inventory, mathematical models which describe the inventory situation have been developed and applied in many industries. Inventory control models can be used to describe either replenishment from an outside vendor or internal production. Therefore, inventory control and production planning are often synonymous. Examples of these models are Simple Economic Order Quantity (EOQ) model, EOQ with quantity discounts, Material Requirements Planning (MRP), Newsboy model, Lot size - Reorder point (Q, R) model, and Periodic-Review system (Nahmias, 1997). Which model to apply is determined by several factors: order repetitiveness (i.e., single order vs. repeat order), order quantity (i.e., fixed quantity vs. variable quantity), knowledge of demand (i.e., constant demand vs. variable demand, independent demand vs. dependent demand), inventory review frequency (i.e., periodic vs. continuous review), and knowledge of lead time (i.e., constant lead time vs. variable lead time) (Verwijmeren,

Vlist, & Donselaar, 1996; Tersine, 1988). The models are built to answer the basic questions: when to place a reorder and how large an amount to order.

An order can be placed only once if the item is a high fashion item with a very short life cycle. For many products, most items are basic goods and are restocked through repeat orders. When repeating orders, a fixed quantity can be ordered whenever the inventory level drops below a certain point (simple EOQ model). Different quantities can be ordered to raise the inventory to a certain level every constant unit of time ((S, T) models). If an item is a raw material or a component of which demand is dependent upon finished goods, the order quantity and order timing is determined by the production schedule of the finished goods (MRP). The production schedule is based on a company's own demand forecasting method or demand from customers' orders. Newsboy model and (Q, R) model take uncertainties in demand and lead-time into consideration. The inventory control models mentioned above assume that the inventory levels are reviewed continuously. Periodic-Review system is used when the inventory levels are known only at discrete points in time.

In the late 1970s and early 1980s, just-in-time (JIT) manufacturing practice was introduced, which also revolutionized inventory management. Many large manufacturers operate on JIT delivery of piece goods in order to reduce inventory carrying costs. A core concept of JIT pursues waste elimination and zero-inventory by practicing small lot orders on a daily basis and increasing communication between suppliers and customers (Fischer, 1995; Germain & Droge, 1998; Kim, 1991). Studies of JIT impact on inventory performance (Droge & Germain, 1998) revealed that a significant relationship exists between JIT implementation and reduction in inventory level.

JIT and other inventory control models provide direction for inventory management; however, not all U.S. companies have found the answer for the inventory problems. A study with the annual logistics survey conducted by KPMG and University of Tennessee reported that 43% of U.S. companies carry as much or more inventory than they did five years ago (Inventories point, Dec. 1996). Despite the optimistic

interpretation that the remaining 57% of companies have achieved remarkable progress in inventory management, differences among industries was not reported in detail. Vergin's study (1998) on inventory turnover in the Fortune 500 industrial companies for the years of 1986 through 1995 revealed that although inventory turnover ratios have increased by an average of 14.7%, the extent of changes in inventory turnover ratios were significantly different among industries. The oil and gas extraction industry performed best with a 44% increase in the ratio, while the textile mill products industry had a 12% decrease. Vergin (1998) also suggested that the dramatic improvements reported in previous studies through a case study method in a certain company or industry may not be true to another company or industry. These results from a few studies on one inventory metric indicate that more empirical studies with companies or industries, of various characteristics, are needed to generalize the findings.

Decisions on Production and Inventory Management

Many authors have proposed factors which management should consider for better inventory management. Branam (1984) specifically emphasized the importance of in-plant throughput time reduction because throughput time is the ultimate constraint on inventory turnover ratio (inventory turnover ratio = annual cost of goods sold/average on hand inventory), which is one of the major performance indicators in inventory management. The author's interpretation of the in-plant throughput time is the time span from the point of raw material receipt to final assembly. Tersine (1988) pointed out the factors for better inventory management as better forecasting, improved transportation, improved communication, improved technology, better scheduling, and standardization. Pachura (1998) suggested that management should start the process of improving inventory management by determining the manufacturing type, benchmarking the inventory control performance, validating strategy (i.e., make-to-order, make-to-stock, build-to-forecast), determining underlying causes through the use of an operational review, and implementing corrective action. Higginson and Alam (1997) suggested specific techniques for inventory management by focusing on cycle time. Improved communication, suppliers' involvement in forecasting and inventory management,

supplier relationships, production scheduling, and cross-functional approach within a company are the factors noted by Lambert, Stock, and Ellram for improving inventory management (1998). For better performance in inventory management most of the authors pay attention to production activities and time-based strategies, which are the main interests of this study. Production activities are closely related to production volume and timing and consequently raw material purchasing.

Inventory Management in the Supply Chain

Inventory management is one aspect of SCM. The main goal of SCM is to better manage inventory throughout the chain via improved information flow aimed at improved customer service, higher product variety, and lower costs (Lawrence & Varma, 1999; Vergin, 1998). Verwijmeren, Vlist, and Donselaar (1996) used the term "Networked Inventory Management" (p.16) for the inventory aspect of SCM. The efficiency of SCM can be measured by inventory performance such as the speed of inventory passing through the chain and the load of inventory throughout the chain (Jones & Riley, 1985). Inventory of various forms from raw materials through WIP to finished goods is fed into the chain from suppliers, production, and subsequently distribution centers to customers (Alber & Walker, 1997). This flow of inventory requires responsibilities of channel members for the planning, acquisition, storage, movement, and control of materials and final products (Tersine, 1988). High levels of inventory are found when the chain members less communicate due to lack of information sharing between chain members and inefficiency of SCM.

Whether a supply chain is efficiently managed or not well managed can be determined by looking at the indicators of inventory management such as inventory turnover ratio. Inventory turnover ratio has been a useful indicator to measure the efficiency of inventory management of an industry. If other information such as absolute value of total sales volume and on hand inventory is given together, inventory turnover ratio can tell more about the efficiency of a company's performance   (Pearson, 1994).

Manufacturers, the main interest of this study, have the most difficult and complex inventory problem as they deal with raw material acquisition, transformation of the material into final finished goods, and movement to the customer. These consecutive activities require manufacturers to control production scheduling and timing that are not easily accomplished due to uncertainties in supplier performance, manufacturing process, and customer demand. Manufacturers could not reduce their buffer stocks without trusting in their partnerships and sharing forecasting information on actual demand at retail level because of the "bullwhip effect"(Nahmias, 1997, p.791), which means the effect of retail sales fluctuation grows larger as it traverses to upstream chain members. More customer requirements for broader product coverage and greater delivery capabilities escalate manufacturers' problem in production process complexity and forecasting of future demand.

When customers are trying to operate on less inventory, manufacturers can respond in two ways: (a) carrying more inventory to compensate for the shorter lead-times or (b) improving the management of the supply chain (Mirsky, 1997). Tersine (1988) and Pachura (1998) noted that manufacturers tend to respond to their customers' requirement by building more finished goods inventory instead of working to improve their manufacturing capabilities. Increased attention to managing inventory has led to larger manufacturer inventories for some companies because the retailers' demands for manufacturers' self-monitoring and replenishing of the retailer inventory are obtained at the expense of manufacturers' storage burden (Vergin,1998).

A trade article reported that a supplier's decision to cut inventory quantities of raw materials also results in high inventories in manufacturing sites (Good Business, Apr.3, 1997). In case raw materials are available only in a certain period, manufacturers need to order enough to meet the anticipated peak demand of finished goods, which causes the excessive inventory level of raw materials. For these reasons, manufacturers have not only internal problems with inventory, but also problems caused by trading partners on both ends of the supply chain.

Apparel Manufacturing

General Overview

The apparel industry has a long supply chain from raw material suppliers (i.e., fiber manufacturers) to end-use customers (i.e., consumers). The supply chain for apparel is extended to the textile industry, which is the provider of the raw materials for the apparel industry. The supply chain has been called the textile product pipeline, fashion pipeline, textile complex (Dickerson, 1995; Jarnow & Dickerson, 1997). The chain can be divided according to business functions: production, distribution, and consumption. The type of products whether raw material (i.e., fiber, yarn fabric), supplies, or end-use products (apparel), is also used to divide the industry's structure. Jarnow and Dickerson (1997) identified the major segments as component suppliers, finished product suppliers, and retail distributors. Component suppliers refer to fiber, yarn, and fabric manufacturers and finding suppliers; finished product suppliers refer to apparel and accessories manufacturers; and retail distributors include all forms of delivering products to the consumer. Glock and Kunz (1995) divided the organization of the current U.S. apparel industry into four levels: mill level, apparel manufacturing level, retail level, and consumers. Textiles and findings manufacturers are included in the first level, apparel manufacturers and retailers are the main part of the second and the third levels respectively, and consumers form the last level. Hammond (1993) simplified all of these supply chain definitions and illustrated that the industry mainly consists of fiber producer, textile manufacturer, apparel manufacturer, retailer, and consumer.

According to American Apparel Manufacturers Association (AAMA), apparel manufacturers, which occupy the central place in the chain include 25,000 companies that are demographically extremely fragmented (as cited in Jarnow & Dickerson, 1997). The fragmentation is due to the fact that the apparel industry is highly labor-intensive, entry barrier to apparel manufacturing is low, and the required skill level is rather simple. Small apparel manufacturing companies represent approximately 70% of the total apparel manufacturing, with less than 50 employees (Hammond, 1993). The dollar value of domestic apparel production was $50 billion (wholesale) in 1996 (Standard & Poor's,

1998). Employment in apparel and other textile products industries is in the United States, down from 1,361,800 in 1977 to 906,000 in 1996 due to increased overseas production and automation. The largest percentage of the manufacturing establishment workforce was women (U.S. Bureau of the Census, 1996). The products produced by apparel manufacturing companies can be divided by gender and age: men's, women's, and children's apparel. Of these three categories, women's apparel traditionally accounts for the largest sales of apparel products, followed by men's and children's successively. In 1997, Women's Wear Daily reported that women's apparel sales totaled 53%, men's, 30%, and children's, 17% (Standard & Poors, 1998). Jones (1999) divided the apparel industry into four major markets: women's, men's and boy's, children's, and miscellaneous apparel and accessories; in 1995 each market represented approximately 60%, 25%, 10%, and 5% respectively in 1995. Jones (1999) also found by the literature analysis that small apparel manufacturers that hire less than 50 people are more concentrated in the women's wear industry. About 20 sizable apparel companies are introducing branded apparel products, which account for 30% of all U. S. wholesale apparel sales; the remaining part of the sales is attributable to small brands and private label goods (Standard & Poor's, 1998).

Apparel Industry and Supply Chain Management

The apparel industry has practiced the philosophy of SCM in the name of Quick Response (QR). QR was originally initiated by the need to reinforce the U. S. domestic apparel manufacturers' competitive advantages against the global competition from low-labor wage countries in the 1980s (Dickerson, 1995). Depending on how QR is defined, one can argue that SCM is a more sophisticated and evolved form of QR. Some researchers regard QR as identical with SCM (Byrne & Young, 1995). According to the definition repeated by researchers, QR is a concept that requires three key philosophical aspects: communication of information between trading partners, reduction of time in the soft goods pipeline, and consumer responsiveness (Cassill, Thomas, Kincade, & Poindexter, 1990; Kincade, Cassill, & Williamson, 1993; Nuttle, King, & Hunter, 1991; Thompson, Teer, & Christoph, 1991). Ko and Kincade (1998) provide the following

definition in their study: "QR is a new strategy to optimize the flow of information and merchandise between channel members in order to maximize consumer' satisfaction. This strategy is accomplished by close working partnership and new processes (e.g., electronic reorder) in the manufacturing and reorder"(p. 15). QR emphasizes the importance of timely flow information and merchandise between trading partners, and the reduction of lead-time and inventory throughout the chain to maximize the value-added activities in the chain. With these concepts, QR is one example of SCM already executed by the apparel industry; however, the range of the involved members of QR as noted in previous studies is rather focused on the linkage between apparel manufacturers and retailers. This does not include second tier suppliers such as fiber producers or primary textile producers (i.e., yarn, fabric).

With QR implementation, the apparel industry has reported many benefits in the supply chain which are identical to the benefits of efficient SCM. Despite the many advances due to QR, the apparel industry still has problems due to the length of the chain and its traditional culture. These factors have created long lead-times and poor coordination among trading partners (Aron, 1998; Christopher & Peck, 1997; DeWitt, 1994; Iyer & Bergen, 1997). Long lead-time has been the typical problem in many studies. From the point fiber is produced and transformed into yarn, fabric, and finished products and delivered to the retail shop a product takes 56 to 66 weeks (DeWitt, 1994; Hammond, 1993). To be more specific, production lead-time from yarn to finished garments typically ranges from approximately 6 to 16 weeks, depending on product complexity and the planning process (Sorrell, 1984). Between the retail and manufacturing channels, lead-time from a retailer's order placement to the delivery by manufacturer is also very long, approximately 24 to 36 weeks. The time span needed to source materials, convert them into products, and move them into the marketplace is not in line with most consumers' expectations. This excessive lead-time results in too much of the wrong inventory and too little of the right inventory at retailers, and consequently a profit loss due to stockouts and increased markdowns (Dowlatshahi, 1999). QR's emphasis on information sharing about actual customer demand enables chain members to better understand the process at each segment, eliminate non-value activities, and

improve end-to-end chain visibility. Ko's study revealed that retailers take advantage of reduced lead-times through QR implementation (1995).

Traditionally in the apparel industry, each chain member runs its business from separate concerns and interests, sometimes causing conflicts in the relationships with chain partners. Hammond (1992) pointed out that in the apparel industry, there was very little coordination among the companies. Each segment built production schedules based on their own forecasting method, which may not accurately represent the actual demand. Lack of information sharing on actual demand between chain members creates long lead-times and high levels of inventory with consequent risks of obsolescence at each segment. This practice is still prevalent in the apparel industry. According to Aron (1998) and Byrne and Young (1995), retailers do not partner with their vendors well and abuse their powers to secure low prices by threatening suppliers with order withdrawals.

Inventory Management in Apparel Manufacturing

Effective inventory management is a critical element for successful QR. One of the goals of QR implementation is to reduce the inventory level throughout the chain (Kincade, 1995). As in other industries, inventories stored in the apparel supply chain can be raw materials, WIP, and finished goods. How much and which type of inventory is built and stored in a company can be determined by the company's trading policy. Apparel manufacturers can be divided into three groups based on their trading policy: *no stock* company, *fabric stock* company, and *garment stock* company (Tyler, 1991, chap. 2). *No stock* companies follow the make-to-order policy, which initiates the material purchasing and production after they make a contract with a customer. *Fabric stock* companies purchase materials first, in anticipation of customer contracts, and initiate production after the contract is made, complying with the assembly-to-order policy. *Garment stock* companies do their own product development process, finish a complete garment production, and then contact customers to sell the finished goods inventory. This policy complies with the make-to-stock policy. *Fabric stock* companies and *garment stock* companies tend to have redundant stock and higher-than-average stock levels.

These inventory problems can lead to higher costs. However, *fabric stock* companies and *garment stock* companies can reduce their lead-time for raw material acquisition, when compared to the no stock company. When *fabric stock* company and *garment stock* company build inventories of fabrics (i.e., raw material) and garments (i.e., finished goods) respectively, they take a risk of uncertainty in customer demand for their products. If the customer does not want to buy garments made of the fabrics already stored in the *fabric stock* company, or garments already transformed into a finished good and stored in the *garment stock* company, those companies have problem of holding inventories at their own expense. To avoid these unwanted outcomes, apparel manufacturers require a close relationship with their customers so that they can determine the demand directly from the actual demand and develop their products as attractive to actual buyers. They also need an agile and responsive production system to easily change the product design and capacity that enables flexible volume production without a high level of inventory when they recognize that the products are not appealing to customers.

The inventory problems facing apparel manufacturers are ascribed to fluctuation in lead-time and consumer demand, and inefficient production systems, such as bundle system, when producing fashion goods. Too-early commitment to the product development of a specific apparel item results in abnormally long lead-time in procurement, manufacturing, and delivery. This lead-time is needed because of long throughput time caused in Production Bundle system (PBS) and other systems with high level of WIP. Because the total lead-time exceeds the time consumers can wait, manufacturers experience over-stocked or under-stocked situations (Sorrell, 1984). In addition, shortening the lead-time is difficult because of the time needed for obtaining raw materials that are required to be pre-positioned in a warehouse (Fisher, Hammond, Obermeyer, & Raman, 1994). The lead-time for fabric accounts for the longest lead-time in apparel manufacturing because 80% of material costs result from fabric and this node is less agile than apparel (Tyler, 1991). Lead-time for manufacturing is elongated when manufacturers use the bundle system. High inventory level due to the production system is discussed later in this chapter.

Uncertain demand associated with fashion goods also affects inventory. This is especially troublesome to manufacturers who do not acquire enough information about actual demand in the market and for manufacturers who serve retailers with fashion goods. A recent trend toward more fashion goods forces retailers to place small lot orders more frequently, which requires manufacturers to implement a QR program. Lack of coordination between chain members manifests in stockouts of necessary inventories and/or stock piles of unnecessary inventories stored throughout the chain. As retailers grow and obtain more power over manufacturers, retailers with QR initiatives shift the burden of holding inventory to upstream chain members (Christopher & Peck, 1997). This burden is compounded by retailers' demands for more product variety, high quality goods, and more reliable delivery. While QR has benefited retailers in inventory reduction, manufacturers do not seem to gain the same advantage due to the shift of responsibility for inventory.

One new approach to inventory management is vendor-managed inventory. Preferred by large apparel companies, it relies on intensive information-sharing of sales records between manufacturers and retailers. Sender (1998) reported that VF Corp. has successfully tested its own vendor-managed inventory system on VF jeanswear and found that, with the help of retailers, vendor-managed inventory can yield valuable sales, inventory, and marketing information for soft goods. However, a survey done by *Bobbin* of 44 apparel companies on U. S. apparel distribution revealed that only 25% of respondents expected to see an increase in vendor-managed inventory replenishment, while 71. 4% expected more customer system-driven automated replenishment in five years (Rajamanizkam & Jayaraman, 1998). This survey result may imply that most small and medium-sized apparel manufacturers still depend on the customers' replenishment policy and being in charge of replenishment of retailers' inventory is costly.

As manufacturers cope with uncertainty in procurement lead-time, demand fluctuation, and inefficient production system, they might have difficulty in determining the right quantity and timing for production and consequently, quantity and timing for

raw material purchasing. The influence of retailers' QR implementations on manufacturers' inventory management, in relation to raw material procurement and production planning, has not been widely studied. Although many studies and statistics report that apparel manufacturers have experienced reduced inventory level through increased investment in QR technology, the improvement tends to be limited to the large apparel companies (Standard & Poor's, 1998; Ko & Kincade, 1998; Kincade & Cassill, 1993). Small and medium-sized apparel companies are still less motivated and have capital limitation to participate in QR implementation in line with retailers.

Product Characteristics and Demand Uncertainty

Several classification systems are used for apparel products, such as Standard Industrial Classification (SIC), North American Industry Classification System (NAICS), product line classification, and merchandising classification. Apparel products can be classified into several groups according to types, price, styles or other criteria. Every method has limits in its application to represent complex apparel products. Although not perfect, classification is meaningful to governments, researchers, and businesspeople. The classification facilitates reporting and accounting for governments and provides researchers with standardized data for comparison. Also, it helps businesspeople to easily communicate and work with business partners, to better serve customers, and to facilitate product development processes.

SIC and NAICS. The SIC, established by the Department of Commerce, assigns a different number to each industrial group as the first digit, to each industry as the second digit, to each category as the third digit, and each subcategory as the fourth digit. The apparel industry is assigned 23 as the first two digits, and nine categories begin with 23. Classes are generally based on the combination of gender (i.e, men's, women's), age (i.e., men's, boys'), and usage (i.e., outerwear, undergarments). Recently, NAICS has begun to replace the SIC system (U.S. Census Bureau, 1998). NAICS is a six-digit system proposed for the North American countries (i.e., United States, Canada, Mexico) to provide new comparability in statistics about business activity across North America.

The first NAICS-based statistics will be published through 1999 by the U. S. Census Bureau. Most textile and apparel products under SIC code 22 or 23 are matched to NAICS 314 or 315. Table 2-3 summarizes the SIC codes assigned to the apparel industry and their NAICS counterparts. Most apparel manufacturers use this system when reporting income, labor or taxes for government purposes.

Table 2-3.

Standard Industrial Classification (SIC) and North American Industry Classification System (NAICS)

SIC code	Description	NAICS code	Description
		314	textile product mills
		3141	textile furnishings mills
		31411	carpet and rug mills
		31412	curtain and linen mills
		3149	other textile product mills
		31491	textile bag and canvas mills
		31499	all other textile product mills
		315	apparel manufacturing
		3151	apparel knitting mills
		31511	hosiery and sock mills
		31519	other apparel knitting mills
23	Apparel and other textile products	3152	cut and sew apparel manufacturing
231	men's and boys' suits, coats	31521	cut and sew apparel contractors
232	men's and boys' furnishings	31522	men's and boys' cut and sew apparel manufacturing
233	women's and misses' outerwear		
234	women's and children's undergarments	31523	women's and girls' cut and sew apparel manufacturing
235	hats, caps, and millinery	31529	other cut and sew apparel manufacturing
236	girls' and children's outerwear		
237	fur goods	3159	apparel accessories and other apparel manufacturing
238	miscellaneous apparel and accessories		
239	miscellaneous fabricated textile products	31599	apparel accessories and other apparel manufacturing

Product line characteristics. Product line can be defined as "a grouping of related merchandise designed for a specific target market" (Glock and Kunz, 1995, p. 604).

Johnson-Hill (1978) identified four types of product line characteristics according to the degree of style variation, production volume, and frequency of style change from the manufacturer perspective. The four product types are staple, semi-staple, style, and high style. Staple product lines involve one basic garment type with long-run production on the one style and only minor changes in construction for the next long-running style. Semi-staple product lines involve one basic garment type with numerous styles that repeat frequently, small variations in construction, and small batch production. Staple and semi-staple product lines are commonly found in menswear. Style product lines involve one type of garment with quite varied styles in a large batch size. Examples of style products are ladies' and children's outerwear, underwear, and nightwear. Lastly, high-style product lines involve the short-run production of different garments with large style variation such as the production of ladies' outerwear or evening wear.

Lin, Kincade, and Warfield (1994) developed the detailed product line classification based on Johnson-Hill and AAMA special report on manufacturing. They associated the type of product line with type or style change (frequency), and production volume. The four types of product line are staple, semi-staple, fashion, and high-fashion. Staple product line is characterized by a basic style with less than one style change per season and mass production. The frequency of style change of the high-fashion product line is very variable with more than six times of changes per season in a very low production volume.

Glock and Kunz (1995) provided two dimensions of product change in determining product line characteristics. These dimensions are fashionability and seasonality in the demand of the product. According to their classification system, apparel products can be divided into fashion goods and basic goods according to fashionability and also can be divided into seasonal goods and staple goods. Fashion goods involve frequent style changes and a relatively short salable period of one garment style, while the demand for basic goods requires less style change for a longer salable period. Seasonal goods are in demand for a certain time of the year only, while staple goods are in continuous demand throughout the year. Every apparel product is positioned

on the perceptual map of two axes forming four quadrants: basic/stable, fashion/stable, fashion/seasonal, and basic/seasonal.

Georgia Tech (1980) reported the marketing strategies for apparel industry to compete with imports based on four product lines. To group products into four categories, the author used the breadth of customer base as the horizontal axis and the length of manufacturing run per line item as the vertical axis. As the customer base is broader, manufacturers have more responsibility in product design and finished goods inventory risk. As the production run is longer, products' life cycle tends to be long, and seasonality and fashionability to be low.

Staple and semi-staple product lines in Johnson-Hill's classification and Lin, Kincade, and Warfield's classification fall onto the area of basic product line in Glock and Kunz' classification in that those product lines involve a basic garment type. And, these goods tend to have a longer production run and a broader customer base. Style and high-style product lines in Johnson-Hill's and fashion and high-fashion product lines in Lin, Kincade, and Warfield's can be positioned in the fashionable product line area in Glock and Kunz' classification. And these goods tend to have a shorter production runs and a narrower customer base. Although Johnson-Hill and Lin, Kincade, and Warfied's classifications do not concern the production of multiple seasons, Georgia Tech report implies that shorter production run is related with more seasonality; therefore, fashion goods tend to have seasonal demand pattern.

Merchandising classification. According to Donnellan (1996), merchandising classification is used when retailers present products to facilitate consumer selection. Examples of the criteria used for this classification are gender (i.e, men's, women's, boys'), product type (i.e., socks, sweaters, pants), color (i.e., warm color, cool color), fabrication or composition (i.e., silk neckties, satin robes, woven tops), price/quality (i.e., designer, bridge, better, and moderate), consumer use (i.e., dress shoes, casual shoes, and work shoes), fashion level (i.e., basic, missy, contemporary, bridge, fashion forward), and

size (i.e., small, medium, large). More than one criterion can be combined in presenting the merchandise to consumers.

SIC/NAICS classification, product line characteristic classification, and merchandising classification have been used to describe apparel product categories from different perspectives. SIC and NAICS were developed by the government to describe apparel manufacturers according to the products they produce. Product line classification describes apparel products in relation to production processes as well as demand pattern, which can be used by both manufacturers and retailers. Merchandising classification is usually used by retailers in their assortment planning. Some criteria used by SIC/NAICs, product line, and merchandising classifications are overlapping. For example, women's and misses' outerwear with SIC code 233 can be grouped into fashion/seasonal goods according to product line classification, although those two groups are not exactly identical. However, within SIC code 233 products, many sub-classifications are possible by using the merchandising classification. No one category in one classification method is explained by one category in another classification method. SIC classification is less sophisticated to explain the apparel specific characteristics that are meaningful to manufacturers and/or retailers in planning the production and segmenting the target market.

Demand uncertainty. The apparel industry is comprised of a wide variety of fashion and basic producers, and seasonal and non-seasonal producers. Some companies have components of each of these classifications. A recent trend in the apparel industry is the consumers' desire for more fashion in their garments. Even apparel items traditionally regarded as basic goods such as men's wear, sportswear, petite and plus size goods, are shifting to the fashion market (Standard & Poor's, 1998; Feitelberg, 1995). Fashionability and seasonality are closely related to the manufacturing strategy and inventory management of apparel manufacturing companies (AAMA, 1985; Kanakadurga, 1994; GA tech, 1980). When product line characteristics are fashionable and seasonal, uncertainty in demand for the product is increased, which is one reason for building inventory. Uncertainty comes from the fact that the demand for fashion goods is

hard to forecast accurately because market information or sales data on the demand of style are not available in the planning stage. The short product life cycle of fashion goods makes inventory management even more complex. As consumers' demands for more fashion goods rise and competition in the marketplace gets higher, apparel manufacturers are required to be able to produce a broad range of products. Apparel manufacturers need to either build a high level of inventory in the manufacturing sites or make drastic changes in manufacturing strategy with required capital investments (Berg, Appelbaum, Bailey, & Kalleberg, 1996). When the demand for seasonal goods exceeds the capacity of plants, inventory for anticipation can be created in finished goods (Berry & Cooper, 1999). To solve this problem, Fisher, Hammond, Obermeyer, and Raman (1997), in their case study of a skiwear manufacturer, explored the effective response capability of the apparel industry with uncertain demand, and suggested a differentiation of production sequencing strategy. They recommended that low-risk products (i.e., basic goods) be produced in speculative production far ahead of the selling season and high-risk products (i.e., fashion goods) production are postponed until additional market information is gathered. In the same study they also stated that efforts to reduce lead-time could be different according to product line characteristics. For the production of high-risk products, more involvement in efficient SCM is required in material acquisition, and collaborating with suppliers. Otherwise, manufacturers need to hold long lead-time materials in inventory to handle these fashion products.

Retailers' purchasing behavior also differs according to product line characteristics. Regarding products with uncertain demand, retailers would prefer to make a small initial order and place reorders frequently as the selling season proceeds to reduce their inventory level in the store (Aron, 1998). With small frequent reorders, retailers reduce their risk of holding too much inventory during the selling season in their store. Retailers can be more responsive to rapidly changing market trends by replenishing their store shelves with what consumers want.

Production System in Apparel Manufacturing

Until the 1980s, apparel manufacturers' main concern was to compete in the unit cost reduction by implementing mass production systems that are characterized by standardized products, large batches, automated assembly, and long-run time. In this mass production era, companies' strategic management was production-oriented, focusing on manufacturing productivity. Since the 1990s, as companies enter the mass customization era, manufacturers face the need to produce product quickly based on consumer-activated demand. With cost and quality as prerequisites for competition, manufacturers are seeking an increase in the agility of production systems to meet the customer demands and expand market share while maintaining low cost and high quality (Narasimhan & Das, 1999).

In the apparel industry, four types of production systems are commonly studied: bundle system, progressive bundle system (PBS), unit production system (UPS), and modular system. According to Piore and Sabel (as cited in Bailey, 1993) bundle system and PBS are categorized into *mass production* and UPS and modular systems are into *flexible specialization*. In Oliver, Kincade, and Albrecht's (1994) study to analyze the efficiencies of three apparel production systems (i.e., push, kanban, team) by using a simulation model, the authors identified bundle system as *push* and modular system as *team*. Kanakadurga (1994) used five attributes of the production system to classify production systems in the apparel industry into three categories (i.e., bundle, PBS, modular system). Those five attributes are workflow, method of retrieval between workstations, WIP inventory, number of tasks per operator, and interaction between workers. The study found that one production system could be distinguished from another according to these attributes.

Bundle system and PBS. As in other industries, apparel manufacturers since World War II have believed that the best way to be efficient is to achieve economies of scale by implementing standardized mass production. The resulting bundle system enables manufacturers to gain profits through economies of scale. PBS is a variation of

the bundle system. The main characteristics of the systems are one worker with a single skill at a single operation, no interaction between operations, piece rate compensation, maximization of productivity of individual operators, need for extra spaces for material storage, straight lined equipment layout, and manual material movement in large batches (Bailey, 1993; Glock & Kunz, 1995; Lin, Kincade, & Warwfield, 1995). With these systems, operators can make more units at faster speeds, showing high productivity but with less flexibility and more quality problems. These systems trade inventory for idle time and have many weaknesses in spite of productivity maximization. To stabilize the workflow, high levels of buffer inventories (i.e., WIP) that add production costs, not value, are stored between operations, resulting in capital tied in inventories and longer manufacturing lead-time. In these systems, the difference between actual run time and the total manufacturing throughput time is significant (Oliver, Kincade, & Albrecht, 1994). For example, AAMA reported that actual run time is 20 standard minutes of labor for a garment that passes through all the operations from raw material into a finished form, compared to 15 to 20 days of the total manufacturing lead- time (as cited in Bailey, 1993). Moreover, a high level of inventories hides the quality problems.

UPS. UPS is the production system that is one response to competitive pressure in consumer demand and increasing global competition. This system requires an automated overhead transporter system to move individual units from operation to operation instead of human handling of materials in the bundle system. The actual task an operator performs is basically the same as in the bundle system. Parts are moving by one unit not in the bundle and operations are overlapped. The resulting level of WIP and manufacturing throughput time of the UPS are greatly reduced compared to the bundle system (Bailey, 1993; Glock & Kunz, 1995). Although problems pertaining to inventory, labor for material handling, and quality can be solved through this system, UPS is basically adopting the characteristics of a PBS with assembly line, individual piece rate compensation and increased supervisor's monitoring capabilities. Bailey (1993) argued that UPS is an efficient form of mass production technique and not a suitable system for the product line that needs many style variations. UPS is also considered by some to be a method of moving materials, WIP, and supplies, and not a production system.

Modular system. The modular system, which borrows heavily from the production organization found in Japanese auto manufacturing, is regarded as one way to meet the flexibility demands required in the apparel industry. Pressure from increased market segmentation, the need for shortened production development cycles and greater operating flexibility, plus intense competition in standardized product lines from low-wage countries, have forced apparel manufacturers to experiment with this new production system. This system seeks economies of scope not scale. Modules use a cross-training technique, which requires multi-skilled workers and a small cluster of machines to produce a complete garment. A key principle underlying the module concept is employee involvement and team-based organizational technique which require important changes in the industry's human resource practices (Bailey, 1993; Berg, Appelbaum, Bailey, & Kalleberg, 1996; Glock & Kunz, 1995; Lin, Kincade, & Warfield, 1995). Module workers are autonomous, self-motivated, self-regulated, and responsible for quality. Main features of the modular system are groups of workers with multiple skills in one module, group piece rate or hourly rate compensation, U-shaped module, and single-piece hand-offs, which is called Group Technology (GT) or cellular manufacturing (Nahmias, 1997, p. 570). Less material handling in a module drastically reduces inventory level and manufacturing throughput time and also saves the cost for inventory and material handling. More employee involvement leads to a desirable work environment and motivates the workers to participate in self-monitored quality control. Actual run time and throughput time are equivalent in this tystem (Oliver, Kincade, & Albrecht, 1994).

Berg, Appelbaum, and Kalleberg (1996) studied differences in performance between two widely used production systems in the apparel industry (i.e., bundle, module system). They interviewed managers of four plants of two apparel companies and surveyed workers to obtain their attitudes toward and perceptions of the production systems. The result revealed that the modular system led to cost savings, reductions in throughput time, and improvement in a company's ability to provide exactly what retailers want in colors, sizes, and styles in a timely manner.

In implementing the modular system, barriers for manufacturers must be considered. First, costs are involved in training workers to deal with several tasks at one station and in the number of machines the modular system is higher than that of mass production system (Berg, Appelbaum, & Kalleberg, 1996). Second, the modular system requires a high degree of communication and cooperation among operators, mechanics, and supervisors. Heterogeneous features in workforce in apparel manufacturing (i.e., race, gender, ethnicity) may be the reason for management's unwillingness to share power and authority and the reason for discordance in a module (Bailey, 1993). Bailey (1993) also pointed that the high turnover rate typical in the apparel industry also hinders the cooperative teamwork approach of the modular system.

Among these systems, PBS is reported to be the most commonly used system in the apparel industry (Berg, Appelbaum, Bailey, & Kalleberg, 1996; Glock and Kunz,1995; Kanakadurga, 1994; Lin, Kincade, & Warfield, 1994). In Lin, Kinade, and Warfield's (1994) empirical study on the relationship of product line characteristics and sewing systems to calculated productivity, 77% of the respondents (N= 96 apparel manufacturers) used either the conventional bundle system or PBS. In the same study, 85.4% of the respondents indicated that they would not switch their present system to another; however, respondents willing to change the system wanted to adopt more flexible sewing system such as modular system and UPS. Bailey (1993) also stated that modules were used for only a limited cluster of operations and other tasks were carried out using the bundle system. Although the bundle system/PBS and the modular system are the most common production systems found in the apparel industry, neither system is perfect for every product. The bundle system is suggested for the company whose strategic focus is on volume production at minimum cost. The product should be basic goods that have a high volume, few changes in style, and low consumer service requirements. The modular system is recommended for the company whose strategy focus is on meeting consumers' wants and needs. The product would be one with frequent style changes and several annual fashion seasons (Bailey, 1993).

Some empirical studies have examined the product line characteristics related with sewing system, productivity, material purchasing behavior, and adoption of QR technology (Kanakadurga, 1994; Lin, Kincade, & Warfield, 1994; Lin, Kincade, & Warfield, 1995; Priyadarshi, 1996; Ko & Kincade, 1998). Kanakadurga (1994) studied the flexibility of three types of apparel production systems (i.e., bundle, PBS, modular system) with 52 small to medium size apparel manufacturers. In her study, PBS was the most widely adopted production system for producing the fashion product line followed by modular system and bundle system. Although this result is somewhat inconsistent with what is known from the literature analysis, that can be ascribed to the small sample size of the study and unbalanced cell sizes between PBS and modular system adopters.

Lin, Kincade, and Warfield (1994, 1995), in their studies on the relationship between product line characteristics and productivity and sewing system with 96 apparel manufacturers, revealed that the product line characteristics of volume and frequency of style changes are directly related to the type of sewing system used. The bundle system is most efficient for staple goods and mass production. In their study on the relationship between product characteristics and productivity, Lin, Kincade, and Warfield found a higher level of productivity in a higher volume production and basic product lines production (i.e., less frequent style changes). Most apparel manufacturers that participated in their study were involved in more than one type of product line production.

Priyaderashi's (1996) study on the usage of computer technology in fabric materials purchasing by 45 large-size apparel manufacturing companies revealed that when the purchasing situation is either straight rebuy for basic goods or new buy situation for fashion goods, the usage of computer technology is high. Very few manufacturers use computer technology for quantity determination, fabric description, purchase order preparation, and monitor of purchase order status in doing business with their vendors.

Ko and Kincade (1998), in their study on the relationship between product line characteristics and QR implementation with 103 apparel manufacturers, found that

apparel manufacturers of fashion products adopted high levels of QR technologies. From these previous studies, product line characteristics are known to be related closely with the managerial decisions in the apparel industry although the exact relationship is not clear. Therefore, product line characteristics must be considered as an important characteristic of the apparel industry that influences the effect of an innovation such as SCM.

Fabric Suppliers

Buyer-supplier relationships are agreed by researchers to be a key component in determining a company's competitive success (Artz, 1999; Goffin, Szwejczewski, & New, 1997; Provan, 1993). For apparel manufacturing, the major supplier is a fabric supplier because fabric accounts for the largest part of apparel products in terms of production cost and raw materials (McPherson, 1987). Textile mill products sector that includes fabric products is known to be more concentrated in number and specialized in product compared to apparel manufacturing. The number of total establishment of textile mill products assigned SIC code 22 is 6,401, which is approximately 23.5% of the number of total establishment of apparel and other textile products assigned SIC code 23 (US Census Bureau, 1996). However, the number of employees of textile mill product sector is about 69.0% and the annual payroll is 91.3% of apparel and other textile product sector's, which implies that the extent of automation and productivity in textile mill product sector are higher than in the apparel and textile product sector.

For apparel manufacturers to select fabric suppliers, they need to evaluate the suppliers by use of performance indicators. Goffin, Szwejczewski, and New (1997) compared the traditional approach to purchasing and supplier management approach to purchasing. Traditionally, unit price, product quality, and speed of delivery have been main concerns to buyers and the characteristics of buyer-supplier relationships have been transactional or adversarial based on multi-sourcing. Recently, however, more detailed concerns are paid to other performance indicators such as total costs, JIT delivery capabilities, delivery time, financial stability, technological capabilities, and cultural

aspects aiming at long-term and close relationship with suppliers based on trust (Goffin, Szwejczewski, & New, 1997). Artz (1997), in his study of relationships between buyer-supplier performance and an original equipment manufacturer's (OEM) investment in specific assets, listed three key supplier performance indicators: transaction cost economics (TCE), delivery performance, and satisfaction with suppliers. The total costs including unit product price and transaction costs, delivery performance including product and service quality, speed to order completion, reliability in order completion, and the characteristics of relationship between supplier and buyer, can be considered to determine the buyers' performance.

In the apparel industry, how apparel manufacturers select their fabric suppliers or how the characteristics of fabric suppliers can affect apparel manufacturers' performance have not been widely studied. According to Kincade (1995) in a study between textile and apparel sectors, efforts to reduce inventory and wait time, place small lot fabric orders, use EDI, and eliminate redundant tests are being made by complying with the QR philosophy. Suppliers' QR orientation and actual level of QR implementation may be directly connected to apparel manufacturers' performance. Priyadarshi's (1996) study of usage of computer technology in fabric material purchasing by large-size apparel manufacturing firms revealed that very few manufacturers were connected via computers to fabric suppliers when searching for supplier sources or evaluating buyer and vendor performances.

Retail Customers

Manufacturers' business activities can be affected by their customers' characteristics. For apparel manufacturing, the typical customer is a retailer. Sheth (1973) stated that retailers' orientation (i.e., fashion-oriented policy in apparel industry) is one of the organizational characteristics affecting their buying behavior. Hansen and Skytte's (1998) and Park's (1996) literature review of retailer buying behavior found that retailer size, relationships with suppliers, and retailer type have been researched most as the factors that significantly affect the buyers' behavior.

Regarding retailer size, Cooper and Ellram (1993) stated that if a customer commands a sufficient market share of the supplier's business, the supplier might choose to remain in the supply chain even though the share is quite limited. Mudambi and McDowell (1994) also pointed out that if a buyer is large enough, the large buyer can exercise tremendous power over suppliers (as cited in Dowlatshahi, 1999). Park (1996) found that retailer size affected decisions on vendor selection.

As the apparel industry has more actively participated in QR implementation, the importance of a close relationship between apparel manufacturers and retailers has been studied recently in many academic and business articles. Levels of relationships in practice differ, from transactional relationships to a true partnerships (Dowlatshahi, 1999; England,1997; Tate, 1996). Traditional relationships between apparel manufacturers and retailers are considered to be adversarial and transactional, based on short-term contracts, competitive bidding, and multiple sourcing. As more apparel companies implement QR programs, the manufacturer-retailer relationship is required to proceed to a collaborative partnership. Partnership is defined as an agreement between a buyer and a supplier that involves a commitment over an extended time period, and includes the sharing of information, along with a sharing of the risks and rewards of the relationship (Ellarm & Cooper, 1990). When manufacturers collaborate with their partners through advanced technology in communication, uncertainties in the supply chain may be eliminated, and inventory and relevant cost may be also reduced (Harrington, 1999). However, in Dowlatshahi's (1999) conceptual work on buyer-supplier relationships, the author concluded that the shift to partnership from traditional manufacturer-retailer relationship is not always a panacea to manufacturers because accompanying organizational change in technology and culture can be costly and can result in inefficiency in business operations.

Although a clear trend is found toward collaborative partnerships and when a QR program is practiced between manufacturers and retailers, many practitioners view that the traditional relationship in the apparel industry has not changed much ("It's a matter of trust", 1995; Rabon, 1998). Apparel manufacturers feel unfairness in the distribution of

QR benefits. Extra costs are accrued to manufacturers who are forced to hold inventory to keep retail inventories low while at the same time maintaining sufficient flow of inventory at retail to avoid stockouts. A key aspect of QR is the streamlined information flow throughout the supply chain via a computer link between companies (Ostroff, 1995). Information sharing, which is the most critical element of a true partnership, is not being executed as satisfactorily as manufacturers expect. Retailers' special commitment to manufacturers' QR implementation is required to reduce the manufacturers' perception of unfairness, especially in information sharing. An annual survey of retailers' inventory management practices conducted by Senn-Delany reported that soft-goods retailers remain reluctant to share the information with vendors and, only 40% of the retailers surveyed are sharing inventory levels with vendors ("Improving customer satisfaction", 1998). Byrne and Young (1995) also reported that the level of information sharing between customers and suppliers in the clothing industry is surprisingly low. In a study to investigate the incorporation of QR into apparel industry, Kincade (1988) found that information sharing, one key factor of QR, was not significantly associated with the QR unlike the other four factors (i.e, product planning, shade sorting, inventory control, barcoding). Ko's (1995) study of the impact of the QR technologies of 32 apparel retailers on apparel consumer satisfaction/dissatisfaction found that apparel retailers who use QR technologies relevant to information sharing was less than half the sample size.

Many types of apparel retailers exist from which end-users can purchase apparel products. Diamond (1993) classified fashion retailers into eight groups: specialty stores, department stores, catalog operations, boutiques, off-price merchants, fashion manufacturers' specialty stores, franchises and licenses, and flea market vendors. Retailers differentiate themselves by factors such as ownership, existence of actual store, merchandise mix and service level, pricing strategies, and the size and location of facilities (Rabolt & Miller,1997; Donnellan,1996; Jarnow & Dickerson,1997). These factors do not create mutually exclusive categories. Chain stores, independent stores, and franchised and licensed stores are examples of retailer types defined by ownership. Chain stores are multiple retail units usually under common ownership, while independent stores are one retail unit owned by an individual. Franchised or licensed

retailers take advantage of the well-established reputation and know-how of a franchisor (i.e., the entity selling its name) through a contractual arrangement. Franchisees or licensees have less control over their business and limitation in expansion and individual creativity. The existence of an actual store is another criteria to classify the retailers. Non-stored retailers include catalog operations, telemarketing, TV home shopping, internet shopping, and door-to-door selling. Stored retailers own a *brick and mortar* store in which purchasing and selling behaviors are practiced.

Retailers can be also classified based on merchandise mix and service level. Specialty stores and category killers are examples of the retailers who offer a limited merchandise category only (i.e, apparel, jewelry, footwear). Department stores and mass merchandisers, on the other hand, offer a variety of product categories including hard goods (e.g., appliances) and soft goods (e.g., apparel and home furnishings). Off-price merchants, discount stores, and factory outlets are examples of retailers who conduct different pricing strategies and offer products at lower prices. Mom and Pop stores and boutiques are examples of retailers who run the business on a smaller scale than chain stores or department stores. Off-price merchants and manufacturer's outlets are usually located away from the major traditional malls and downtown central districts to avoid conflicts and threats from retailers who offer the products at regular prices.

Retailer type is found to be one factor influencing the manufacturers' QR adoption (Kincade & Cassill,1993; Ko, 1995). Retailer type in these studies was defined by the variety and assortment of the merchandise, which is based on Kotler's (1988) classification: specialty chain stores, department stores, and mass merchants or discount stores, small independent store. Apparel manufacturers whose customer was a limited line retailer had the highest implementation levels of inventory control. Ko (1995) found that small independent stores showed the lowest usage of the QR technology. Shim and Kotsiopulos's (1994) study on the influence of organizational characteristics on retailers' technology innovativeness, found that the higher the retailers' income, the more likely the retailers were to be innovators or earlier adopters of innovation. Innovators/earlier adopters also tended to have a larger sales volume, be located in a bigger city, and be

perceived as more competitive. *Bobbin*'s survey on U. S. apparel distribution found that company size was closely related to the target customer type (Rajamanizkam & Jayaraman, 1998). The small apparel manufacturing companies' customers tended to be independent retailers, specialty stores, and wholesalers. The medium-sized companies targeted independent retailers and department stores, while the larger companies targeted discounters, department stores and independent retailers.

Another trend challenging the manufacturer-retailer relationship is retailers' cost-orientation and manufacturers' ownership of retailers. Regardless of their retailer type, the extent to which they are concerned with the cost might be different. Just as manufacturers can be concerned with the total cost when they select textile producers (Goffin, Szwejczewski, & New, 1997), so retailers may use the cost factor as their primary concern when doing business with manufacturers. Retailers' cost orientation need to be examined for the relationship with apparel manufacturers' management and performance. Manufacturers are increasingly entering the retail area to maximize profitability and productivity, to enhance brand awareness and the company's image, and to showcase new products (Lisanti, 1994). Manufacturers can operate their own specialty stores as well as sell their products via retailers' stores. Retailers are also moving into manufacturing as they become more interested in private label products. Retailers can earn better profit return on private label products than national brands (Jarnow & Dickerson, 1997). The influence of these multi-channel distribution paths on the relationship between manufacturer-retailer relationship has yet to be investigated.

Summary of Literature

SCM is an effort to integrate the supply chain from raw material suppliers to end-use consumers with a streamlined information and material flow by collaboration between supply chain members to maximize the consumer satisfaction while maintaining the minimum operation cost. Many researchers and academics have identified necessary activities, conditions, and barriers to implement SCM. Six dimensions of SCM have been emphasized repeatedly in the literature. Those six dimensions are collaborative

partnership, information technology, operation flexibility, performance measurement, top management's commitment and leadership, and demand characterization. Each dimension requires several key activities.

The supply chain realizes lean inventory management with efficient SCM. Mathematical methods to control the level of inventory, especially to determine the quantity and timing of the reorder, have been studied and applied to many industries. Whether these methods are effectively used by the apparel industry is not clear due to the abnormally extended length of the chain and traditional business practices between chain members.

SCM is not a completely new concept to the apparel industry because QR in the apparel industry is one aspect of SCM. Although the QR is being actively implemented by the apparel industry and has resulted in many desirable benefits, apparel manufacturers are still struggling with inventory management because of uncertainty in the chain from suppliers, manufacturing, and demand. Especially, demand uncertainty is associated with product characteristics of the apparel industry. As more manufacturers deal with both the fashion goods and basic goods, their inventory problem becomes more complicated. In addition, some types of apparel production systems cause conflicts with the effective inventory management. Bundle system and PBS, most widely adopted by apparel manufacturers, build a high level of inventory by the nature of the system. Uncertainty in the supply chain may also be derived from unreliable supplier performance. The extent of supplier performance in terms of total cost, delivery performance, and the characteristics of relationships with fabric suppliers may contribute to apparel manufacturers' performance. Lastly, as the retailers are more concerned with the small lot orders on a daily basis, retailers are shifting the burden of inventory to manufacturers. And the retailers' characteristics such as retailer size, relationship, and type have been found to influence apparel manufacturers' managerial decisions.