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CUSTOMER FOCUSED TEXTILE AND APPAREL MANUFACTURING SYSTEMS: TOWARD AN EFFECTIVE E-COMMERCE MODEL

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ABSTRACT

Environmental changes, including intensive international competition, unpredictable consumer demand, and market trends of variety and short product life cycles, compel the U.S. textile and apparel industry to focus increasingly on the consumer as a way to meet these challenges. Quick response has established new business strategies, new relationships and new procedures to speed the flow of information and merchandise between retailers and manufacturers of apparel and textiles, all driven by the customer. With such a customer responsive system in place, the industry began expanding into mass customization. Mass customization uses information technology, flexible processes, and organizational structures to deliver a wide range of products and services that meet specific needs of individual customers but on a mass scale. This paper examines Quick Response and mass customization manufacturing strategies used in the textile and apparel industry, examines how existing technologies can support these strategies, and investigates how mass customization can be undertaken through e-commerce.

Keywords: Mass customization, Manufacturing systems, E-commerce, CAD/CAM system

1. INTRODUCTION

The rapidly changing culture, politics and economics of modern life deeply affect the industrial environment, especially consumer industries such as textiles and clothing (Lowson, King & Hunter 1999). One of the impacts is that the contemporary North American and European textile and apparel industries suffer immense competition from foreign producers (Yan & Fiorito 2002). As early as the mid-1980s, imports were estimated to account for close to 50% of consumption (Lowson, King & Hunter 1999). As most imported textiles are produced with very low labor expense, huge amounts of inexpensive products can be supplied in the domestic market. Considering this situation, competitiveness in cost and quality continue to be key issues for textile manufacturers. In order to significantly reduce time and cost in the supply chain, the industry needed to become more focused on consumers by developing a supply chain management process that would be demand driven and production that would be synchronized to replenish product at the consumer's pull rate (Lovejoy 2001). Today, consumers desire to personalize the style, fit and color of the clothes they buy, and require high-quality customized products at low prices with faster delivery (Lee & Chen 1999). New manufacturing technologies such as 3D body scanners, CAD/CAM systems, and digital textile printers have played a key role in increasing the effectiveness, flexibility, agility, and precision of production.

New business strategies were introduced to increase competitiveness in the industry. One of those strategies, Quick Response (QR), was formulated as an improved way of conducting business in the US textile /apparel pipeline by the American Apparel Manufacturers Association (AAMA). It can be defined shortly as "a comprehensive business strategy incorporating time-based competition, agility, and partnering to optimize the supply system, and service to customers" (ITAI News 1997). QR required a drastic reduction in the time taken to convert fiber to fabric, fabric to garment and then to deliver the garment to the customer. Such a reduction called for the use of a wide variety of electronic and mechanical technologies, the integration of manufacturing technologies, changes in management practices, and a higher level of trust and cooperation between industry segments. This paper examines Quick Response and Mass Customization manufacturing strategies used in the textile and apparel industry, evaluates how existing technologies can support these strategies, and examines specific applications through case studies.

2. MANAGEMENT STRATEGIES – Quick Response

2. 1 Background

Throughout the 1970s, the industry was characterized by an emphasis on mass-markets and high volume manufacture of a slowly changing range of garments with low design content. In the mass production system, all input and output are standardized to reduce defects, and variety of the product is minimized (Lowson, King & Hunter 1999). In 1984, a study conducted to analyze the textile and clothing industry in the U.S., showed 55 weeks of inventory time within the 66 weeks supply pipeline (Hunter, King & Lowson 2002). This high level of inventory time can be explained by the fact that, throughout the pipeline, products are held by a supplier as finished goods, and additional stocks are held by the customer as raw material. Thus, there are duplications of stockholding between various processing steps, reflecting the lack of communication between the supply channel segments. The stockholding cost and the time delays in the system cause a substantial competitive disadvantage in many markets. Hunter, King & Lowson (2002) showed the revenue losses expressed as a percentage of retail sales. The biggest item of lost associated revenue was forced markdown, with the total losses amounting to over 14 % of retail sales. Stockouts account for another 4.0% and inventory 6.4%. To reduce unnecessary markdowns, one solution is compression of the pipeline. Pipeline compression makes it possible for retailers to reassess the demand while the season is under way, make small and frequent re-orders, and feed more accurate information about customer wants back to the manufacturing process. The QR methodology was founded as a way to address the various pressures upon the industry (Hunter, King & Lowson 2002).

2.2 QR Strategy and advantages

Traditionally, orders for products are made four, six or eight months in advance, based on forecasts in terms of volume, product mix and so on. That means the probability that these forecasts effectively reflect the reality is very low. It is impossible to satisfy the expectations of the final customer completely with advance orders of six months or more. Therefore, it is necessary to keep high cost inventory.

The fundamental principle of QR is that all activities within an enterprise should be paced to demand and customer behavior. Products and services are produced and delivered according to the variety and volume of demand. Consequently, it is important to understand these demand patterns. QR is a time-based competitive strategy which focuses on the compression of response time, and which emphasizes collaboration between all the business partners from the textile producer to the final customer.

The strategic advantages of the application of QR are numerous. First, the risk caused by incorrect forecasts can be reduced due to decision making closer to the season. A substantial reduction in sales forecast error can be made by shortening the design process. The fewer months ahead of the season that style and color predictions are made, the less the forecast error (Hunter, King & Lowson 2002). If the product design times were reduced, demand and customer preference could be predicted more accurately. Second, adoption of QR makes it possible to improve the level of service by satisfying the variety of customer expectations and preferences with maximum efficiency in terms of elimination of risk, waste, and cost. A study of the advantages of QR systems between textile producers, clothing manufacturing, and distribution showed that sales increased up to 50 percent, and stockholding dropped between 20 and 40 percent (Forza & Vinelli 1997).

2.3 Technologies to support QR

QR includes the use of bar codes on merchandise and shipping cartons, the use of computer-aided design and manufacturing systems, the receiving and sharing of product information, and the sending of orders and other forms electronically.

2.3.1 Bar Coding

For a global, consumer-driven, Point of Sale (PoS) system, standards for bar coding have been developed in the U.S. and Canada by the Voluntary Industry Communication Committee, and published by the Uniform Code Council as the *Data Communication Guidelines for Retail and General Merchandise*. A bar code is one unique 12-digit number represented by a Universal Product Code (UPC), a symbology which includes the style number, the national retail federation (NRF) color number, and the NRF size number (Hunter, King & Lowson 2002). PoS data acquired by scanning bar coding, allows comparison of buyer forecasts and pre-season orders with the actual consumer preferences as reflected in their purchases. Accurate data acquisition is important, and analyses of PoS data must occur frequently (Hunter, King & Lowson 2002). Use of POS data can help retailers and manufacturers through building more accurate item inventory and sales records, reducing or eliminating out-of-stocks through improved order planning, reducing forced markdowns via better reorder management, reducing the need for stock counts, and helping assure that the right goods can be provided to the customer in the right place.

One problem with using UPC coding is that global standards do not comply with the NRF size and color standard reference table (Hunter & Valentino 1995). Data compatibility standards among countries need to be established to create a Quick Response environment that supports co-ordinated global demand-activated manufacturing responses (Hunter, King & Lowson 2002).

Radio Frequency Identification, or RFID, is an emerging technology which can substitute for a barcode with some advantages. RFID technology has microchip tags that carry data such as manufacturer ID, SKU, and an item unique code (Chandary 2005). This system can protect designer originals efficiently, prevent counterfeiting, monitor work-in-process, expedite international processing, manage inventory, out-of-stocks and markdowns, conduct quick check-outs, and facilitate convenient returns in retail (Hartenstine 2004). As of January 2005, Wal-Mart and Target both required that their 100 largest suppliers, including some apparel suppliers, label cartons with RFID tags (Chandary 2005), so the technology is making inroads.

2.3.2 Computer-Aided Design (CAD)/Computer-Aided Manufacturing (CAM)

Kincade (1998) indicated that automation of production processes using computers was a method for reducing time in the pipeline, and achieving shorter lead time and faster turn around. CAD/CAM systems allow a design to be generated rapidly and adjusted equally quickly without diminishing creativity, and provide better communication and integration between product development systems (Istook 2000). AAMA's Apparel Research Committee (ARC) developed standards for apparel and sewn products automation to support efficient communication between the production systems in different companies (Hiegel, 2005).

CAD systems are also having an important impact on the merchandise planning of the retail buyer. The closer a designer or buyer is to the opening of a season, the greater the accuracy of the predictions of style demand. The Boston Consulting Group investigated the relationship between order lead time and how well the merchandise plan correlates with actual consumer purchases. Based on the six garments investigated, the longer the lead time the greater the error (Hunter 1990). Though results varied depending on the type of merchandise, if the pipeline can be compacted sufficiently, the possibility of reorder becomes feasible with lower forecast error (Hunter 1990; Hunter, King & Lowson 2002; Lowson, King & Hunter 1999).

2.3.3 Electronic Data Interchange (EDI)

One method to enhance the communication of information between trading partners is electronic data interchange (EDI). With EDI technology, business data once communicated by mail or fax can be transmitted electronically. This system allows replacing paper documents with electronic documents as well as eliminating the time delay associated with using mail services and paper handling.

Quick Response is a pull system based on the flow of timely and accurate information about consumers' wants and needs. High process agility, flexibility, and integration can be achieved through adoption of Quick Response strategies. In such a manufacturing environment, mass customization systems can be implemented. Mass customization can be defined as the ability to provide individually designed products and services to the customers on a mass scale.

3. MASS CUSTOMIZATION - TEXTILE APARREL INDUSTRY

3.1 Mass Customization Concepts and Consumer Demand

A short-cycle manufacturing environment that is applied to an individual customer's preference is called the mass customization manufacturing environment (Burns & Bryant 2002). Mass customization uses information technology, flexible processes, and organizational structures to deliver a wide range of products and services that meet specific needs of individual customers (Silveria, Borenstein & Fogliatto 2001; Radder 1999). Several researchers described different approaches to customization. Silveria, Borenstein & Fogliatto (2001) combined these frameworks to eight generic levels of mass customization ranging from pure customization to pure standardization. Silveria's highest level, design, encompasses collaborative projects, with manufacturing and delivering of products according to individual customer preference. Fabrication, the second level, refers to manufacturing of customer-tailored products based on basic predefined designs. Next, assembly deals with customization through arranging modular components into different configurations according to customer orders. In the middle three levels, mass customization is accomplished by adding custom work or services to standard products, or customized distributing and packaging of standard products. At the lowest level of customization, mass customization occurs after delivery by using products for different functions or situations. (Silveria, Borenstein & Fogliatto 2001).

For the manufacturer and retailer, the advantages to mass customization include reducing large inventories, minimizing returns, reducing distribution costs, building strong customer relationships, and identifying customer preferences. There is limited empirical research on consumer acceptance of mass customization. Huffman and Kahn (1998) evaluated consumer ability and interest in selecting among extensive product choices. They concluded that consumers were more satisfied with selecting attributes within a choice set than having either extensive or few choices. Piller and Muller (2004) reviewed the consumer perception of mass customization in the footwear industry concluding that consumers were curious about the customization concept, realized the benefits, and were willing to pay a premium for those benefits (Piller & Muller 2004).

For the textile and apparel industry, mass customization was investigated as a competitive strategy. Anderson-Connell, Ulrich and Brannon (2002) developed a consumer driven model incorporating technologies such as body scanning, a Smart Card, and computer-driven shopping with four versions of collaborative customization. They found that consumers were interested in the customization of purchase related services including expanded individual search and selection capability.

Fiore, Lee, Kunz, and Campbell (2001) found high interest in mass customization after describing body scanning and the co-design process to subjects. Their results showed that the level of stimulation with the types of products, services, and experiences was positively correlated with desire to customize products, and that consumers preferred to participate in mass customization of products (i.e., jeans, swim wear), and product features (i.e., fit and size) rather than color and garment details (Fiore, Lee, Kunz, & Campbell 2001).

3.2 Mass Customization Implementation with technologies in Textile and Apparel Industry

Mass customization manufacturing reflects the current market conditions and trends. As consumers with varied lifestyles, cultural ties, and physical characteristics demand greater product differentiation, it is logical that manufacturers or retailers within the integrated textile complex may want to consider the mass customization strategy (Anderson-Connell, Ulrich, & Brannon 2002). In the mass customization manufacturing environment, the customer becomes a co-designer, using the firm's capability to create an individualized unique solution. A customized product can satisfy the consumer's preference and provide differentiation from mass produced import goods. Mass customization has expanded greatly with the continued development of electronically linked body measuring, pattern making, single-ply cutting, and production technology (Burns & Bryant 2002).

Three levels of mass customization found in the apparel industry are personalization of the product, customization of fit and customization of design (Burns & Bryant 2000; IT Strategies). Each level of mass customization is introduced in the following sections, including the relevant technologies.

3.2.1 Personalization

Product personalization is an application of Silveria, Borenstein & Fogliatto's (2001) generic level of "additional custom work". One example of personalization is to modify a finished product. For instance, Levi's San Francisco retail store offers customizing services such as embroidery, laser etching, and fabric ornamentation to purchased items. This appeals to customers by providing individuality with a minimum of expense and waiting time (Burns & Bryant 2002). Also, a set of swimsuits or uniforms customized with the Olympic logo for the Olympic Games is an example of a finished product which is personalized and produced in bulk (Chenemilla 2001).

3.2.2 Fit Customization-3D body scanning system

Fit customization represents a higher level of customization, what Silveria, Borenstein & Fogliatto called "fabrication'. Holusha (1996) reported researchers at [TC][2] said that about 50% of all Americans cannot find well fitting clothes in the current sizing system. 3D body scanning systems provided several approaches to achieving better customized fit attributes (Xu, Huang and Chen. 2002). One of the applications of 3-D body scanning systems in the apparel industry is the refinement of standard size systems (Mastnak). Most systems for sizing ready-to-wear garments have been based on very limited information. The 3-D body scanning data obtained from different countries or regions can be used as a bank of information about current customer sizes. The CAESAR (Civilian American and European Surface Anthropometry Resource) database was designed to provide the most current measurements of the population from U.S. and Europe (SAE). The Textile and Clothing Technology Corporation, [TC] [2], collected scans of men and women around the United States to create a database, called SizeUSA that gives a better understanding of the current human sizes and shapes in order to develop sizing systems that fit most of the population (ExploreCornell 2003). Also, 3-D scanning technology can be applied to develop apparel industry advanced ready-to wear processes. At the retail store, body measurements of the customer could be taken by a 3-D computerized body-imaging system, then and a customer could choose from the available styles and materials. Garments could be then made to order. This integrated process would allow for the communication of subjective fit preferences by the customer to augment objective fit data from the scanner. As its most extended purpose, 3-D body scanning technology can facilitate the achievement of full customized garment manufacturing. In this scenario, a customer is scanned and then either designs a custom garment from simple template designs or chooses a variety of prototype collections as a starting point for the development of their own garments (ExploreCornell 2003).

3-D scanning systems and computer application makes it possible to demonstrate the virtual try-on concept. Before body scan data was available, this system was useful only for style selection, but body scan data merged with scans of garments can show how a garment fits. An early version of the virtual try-on concept is being offered by Land's End, Levi Strauss, Lane Bryant and the Wedding Channel via My Virtual Model at www.MVM.com. When body scan data are introduced into this process, more realistic and accurate virtual images will be possible. Researchers at Cornell have demonstrated how body scan data and 3D virtual representations of garments can be used in a virtual fitting process (Ashdown & Loker, 2004)

A range of scanning technologies are available and in development. The body scanning system from [TC] [2] uses a white light phase measurement profilometry (PMP) approach. Four stationary sensors in the scanning booth are used to project a pattern of light on the body. Through the projection of light, the sensors are able to capture images from which 3D data points can be determined. In the laser scanning methods, the scanner projects a line of laser light around the body. The laser line is reflected into cameras located in each of the scan heads. Sensors record the deformations and create a digitized image of the subject (Istook & Hwang 2001). Compared with the physical measurement process, this technology has the potential to obtain an unlimited number of measurements quickly and precisely. Though scanning time varies, most body scanners can measure and extract data within 2 minutes. It is possible to create a 3-d shape from the measurement information. Also, the digital format measurements can be transferred into apparel CAD systems without the human intervention that takes additional time and can introduce errors (Istook & Hwang 2001). However, Simmons & Istook (2003) found that there is significant variance among the available scanners regarding how each captures specific body measurements. In addition, there are no standards on the interpretation of measurements or measurement terms. The lack of standard format means that no commercially available CAD/CAM system or measurement extraction algorithmic process which can be integrated with the body scan data exists (Istook, Little, Hong & May-Plumlee 2003). Thus, for global production practices and efficient mass customization in the apparel industry, new standards of measurement, terminology and compatibility of measurements need to be established for 3-D body scanning systems.

3.2.3 Design Customization-CAD/CAM system

Design customization may reflect Silveria, Borenstein & Fogliatto's "assembly" or "fabrication" levels depending on the approach. Computer-aided-design (CAD) and computer-aided-manufacturing (CAM) systems create the opportunity for customization as they allow designs to be adapted and changed throughout the design and production process. They have been instrumental in reducing lead times, improving accuracy, and putting apparel products in retail stores much closer to the time they are needed by the consumer. The basic functions of CAD systems include pattern manipulation, generation of an entire range of sizes following 'grade rules', and marker making to develop the most economic cutting arrangement for patterns (Balasubramanian & Vijay 2000; Russell 1997). CAD vendors in the textile products industry have recently focused on the conversion between 3-D and 2-D. This technology allows reducing product approval and production times, and cost of producing multiple iterations of sample garments, by enabling the entire supply chain to visualize products virtually (Gerber Technology, Inc. 2004). This concept has been adapted into textile products such as apparel, furniture, automotive car seats and shoes.

Hong Kong's TPC has introduced methods to generate a 2D pattern from 3D body scan data (TPC Limited 2002). Wentzel (2005) explained that from body scan data, a 3D virtual body is created, the measurements for the construction of a garment are extracted, and then 3D pattern constructions are automatically converted into 2D pattern blocks. The garment shape is displayed on the figure and simultaneously on a flat pattern representation (Wentzel 2005; TPC Limited 2002). Also, [TC]^2 has developed a 3D to 2D data conversion CAD system where the shape of the 3D body surface remains inherent within the 2D pattern, enabling accurate reconstruction of the garment surface in a quantifiable relationship to the 3D body surface (Munro 2001).

In upholstery manufacturing, 3D to 2D conversion systems makes it possible to produce 2D pattern pieces directly from a 3D design virtual model without full size physical prototypes. These systems decrease development time and cost dramatically and increase speed to market. Gerber, Lectra and Optitex offer 3D to 2D systems, which are successfully used in transportation seating manufacture (Anonymous 2005). Shoemaster is a 3D CAD/CAM system for the shoemaking industry (CMS International Lit. 2004). Using this software, shoe styles can be created and viewed in 3D on a virtual last. Then, the integrated flattening system can translate the 3D last to 2D pattern engineering. The last making, pattern engineering, and grading in a virtual environment can reduce the costs associated with rework, and maximize the productivity and efficiency of the design and development process.

CAD vendors have tried to integrate CAD/CAM systems with 3D body scanners, 2D pattern creation, marker making, and automated cutting as well as textile CAD. Most recently, Gerber Technology added a fabric testing kit that will enable a user to test the mechanical properties of fabrics and use that data to simulate the draping of garments based on the fabric properties (Gerber Technology, Inc. 2005).

Even though CAD technology has shown tremendous possibilities in enhancing product development and production process integration for the textile products industry, the reproduction of accurate color in CAD systems is still challenging. Color is a prime attractor for consumers, and even slight differences in shade or depth can be important within a color group. Additionally, color preferences change rapidly. A simple software should be developed which would allow discussion and modification of colors between computer users. As an adjunct to a CAD/CAM system, such software would allow customers to input their views on color. There remain problems of color perception between a CRT monitor and the actual good. However, much progress has been made toward improving the differences.

3.2.4 E-Commerce for Mass Customization

The growth and wide acceptance of the Internet has developed a technological environment which can support the integration of computing resources in business and manufacturing (Ghiaassi & Spera 2003). Internet and Intranet technologies can enhance co-operation and interaction within the supply chain, and allow companies to build affordable links directly with customers and suppliers (Daly & Bruce 2002). Core activities such as design, resource planning, factory automation, and supply chain management can be re-engineered to utilize E-commerce, achieving significant cost savings and reduction in lead time (Helander & Jiao 2002). E-commerce can be divided into four categories: business to business (B2B), business to consumer (B2C), business to administration, and consumer to administration, the latter two not yet being used broadly (Turowski 2002).

B2B E-commerce concerns all transactions among retailers, manufacturers, and suppliers, which can be improved by EDI. Software vendors have developed web-based Product Document Management (PDM) software that allows organizing and communicating product specifications both within a factory and globally. Faster access to documents makes it possible to quickly locate and share information, and speed up design development and modification (Russell 1997). For example, in Gerber Technology WebPDM, product development tasks including design, engineering, costing and manufacturing planning are connected through a centralized database supporting instantaneous collaboration anywhere in the world (Gerber Technology Inc. 2004).

In the textile and apparel industry, B2C E-commerce faced some difficulties in communicating product characteristics such as color, touch, feel, or garment fit, and defining return policies can be challenging. These may be reasons that B2C E-commerce is relatively slower growing than B2B E-commerce (Ross 2001). Kamali & Loker examined consumer satisfaction and preference for design involvement in a Web-based mass customization process. Their results suggested high consumer satisfaction with the process as well as very high levels of intent to purchase the products they designed. Acceptance and willingness to pay more for mass customized consumer products are dependent on the product types. Therefore, it is important to evaluate which product types are likely to be worth more to the consumer if customized (Kamali & Loker 2002). Recently, opportunities for customer involvement in customizing product have expanded from catalog-like presentations to interactive offerings (Yamada 2001). Interactive sites offer customers design involvement through selection of design features, color, or fabrics (Target Corp.; IC3D.com). As shown previously, a 3-D virtual model can be adapted to resemble a customer's body shape and then dressed with clothing of interest to that customer. This technology will reduce the risk of ill-fit by providing consumers with a view of the garment on their body. Additionally, 'Zoom' functionality will allow for close-up visualization of fabric and yarn, and color management systems will dramatically improve the accuracy of color rendering on different monitors (Ross 2001). E-marketers can offer enhanced services such as the opportunity to return web-purchased products to a retail location or to view of actual fabric and garment at retail to entice customers (Kamali & Loker 2002; Ross 2001).

3.2.5 Case studies: Mass Customization in the Textile and Apparel Industry

Levi Strauss & Co. was the first large apparel company to offer mass customization through jeans, offering choices in style, fabric, finish, color, and inseam length. Jeans fit is determined by inputting the individual's measurements, acquired manually by a salesperson, and preferences into a computer program then having the customer try on sample jeans. The customized jeans are individually manufactured and shipped to the customer's home, and a record is kept, so that reorders can be made without the try-on step (ExploreCornell 2003). Brooks Brothers also offers a mass customization system at their New York City retail store, integrated with new technologies including a 3D body scanner to collect customer measurements. Style, fabrics, and design features are selected from a computer screen in consultation with a trained sales professional who facilitates the discussion of fit preferences. Brooks Brothers uses a proprietary custom patternmaking system to create an individual pattern based on body measurements. The custom garment is manufactured and shipped to the store where a single fitting ensures customer satisfaction. Scan data and patterns for each customer are stored for reorders. A traditional custom suit can take more than 6-8 weeks, but the Brooks Brothers System can deliver a custom garment in less than 3 business weeks (ExploreCornell; Brook Brothers' Inc.).

Custom-made clothing is now attainable and affordable, made possible by the Internet and changes in traditional manufacturing techniques (Oh, et al. 2004). Following are case studies of online mass customization application in textile and apparel industry. These case studies were compiled by visiting each website and documenting step by step the process encountered. Each application offered a different level of customization.

3.2.5.1 Target Corporation
(www.target.com)

Target is one of the retail companies to provide an online custom-made clothing service for women and men. In their website, a customer can easily move to the 'Target to a "T"' site in order to access the custom-made clothing options. Figure 1 shows the process of a creating a customized garment through the Internet. Currently, Target offers four women's jean, women's chinos, men's chinos, and men's shirts for customization. If a customer visits the site to reorder a garment, previously saved 'Target to a "T"' information can be accessed by signing into the account and used or revised for a new order. Customers can customize fabric, style, and fit of the available products. Production and delivery takes about three to four weeks, providing a customized women's jean for a cost of about $37 and customized men's shirt for a cost of about $45.

Design customization: Fabric

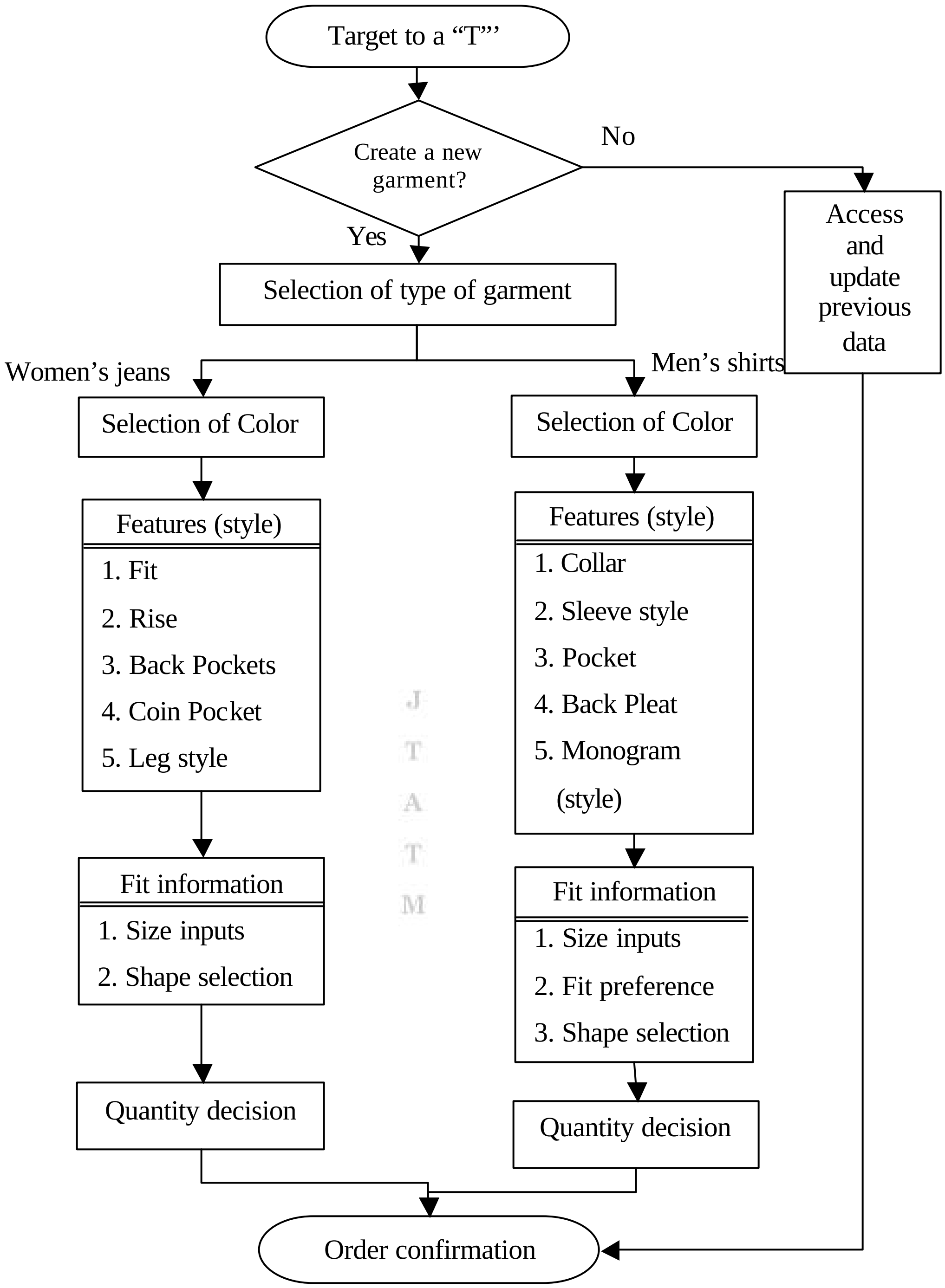
Through the "Target to a "T"' site, customers can select a fabric design and a color from photographic quality sample swatch images enlargeable to show detail. Depending on the type of garment, the number of choices varies. For example, women's jeans are available in three colors, while men's shirts have eight fabric combinations. Men's shirts are offered in 100% cotton fabrics which are treated to resist stains and wrinkles with comfort and breathability.

Design customization: Style

Target's custom-clothing service offers photographs of actual design choices to aid customer selection. The photograph changes instantly by clicking one of the design options, so that customers can compare among the options easily. For women's jean, for example, a customer can choose design features including:

- Three variations of closeness of fit through the hip and thigh,
- Three variations of location on body in relation to the waist,
- Presence of back pockets or a coin pocket, and
- Three variations of cut of jeans through the leg.

Figure 1 Flow chart of Target Corp. Custom-Clothing Service Process



Men's custom shirts provide even more detailed style choices including collar variations, sleeve variations, pocket variations, and two options for back pleat location. Also, the shirt may be personalized by specifying a monogram of up to three letters as well as its position and style.

Fit customization

For the best possible fit, customers input relevant size information including height, weight, bra band size, bra cup size, waist, inseam, and pants size of ready-to-wear as well as answer some questions about life style, such as exercise habits. Also, customers describe the shapes of their stomach, seat, and thighs by selecting one of several choices presented in line drawings. For men's shirts, there are some additional options to specify a customer's preferred fit. For example, a customer can identify the preferred fit around the chest, shoulders, and the upper arms, and the arm shape, chest shape, and body proportions can be selected from line drawings.

Though online customization is more convenient than in-store customization, it is possible for customers to make errors estimating fit. Target uses sizing software from Archetype Solutions, Inc. to calculate the ideal fit (Scardino, 2004; Anonymous, 2003). In addition, Target will try to contact a customer by e-mail for clarification if a body proportion specification isn't suitable to the fit request.

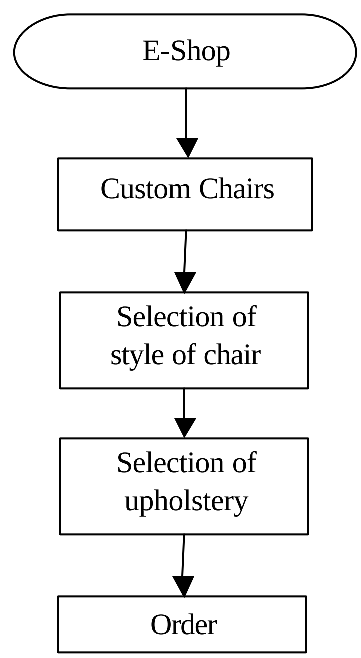
3.2.5.2 Lands' End

Lands' End Inc. first offered customers the ability to customize apparel through the website in 1999 (Ives, 2003), then expanded the service from men's chinos to men's and women's jeans, men's shirts and jackets, and women's chinos, blouses, and outerwear. The basic process of creating custom-made clothing, including fabric and color customization, style customization, and fit customization, is similar to the Target system. Lands' End offers more diverse fabrics for each garment, and depending on the fabric selection, the available colors vary. (Lands' End 2005) Price points for the Lands' End products are higher than those offered via the Target web site, ranging from $75 to $99. Customers can request a free swatch of fabric for selected items including men's and women's jean and women's chino pants. Physical fabric swatches can give tactile information for the final product. Lands' End uses real-time communication to help online shoppers find what they are looking for (Dukcevich, 2002; Wong & Wolverton 2000; Ives, 2003) by providing access to instant support where questions are answered promptly and courteously. Also, customers can modify the fit or features by accessing their account through the website, and then reordering the item. To offer customization, Lands' End uses CAD systems to create electronic patterns, a single ply cutter for cutting an individual garment, and has worked with global manufacturing partners on training and obtaining new machinery (Ives, 2003).

3.2.5.3 Horchow Custom Collection
(www.Horchow.com)

In addition to garments, other customized products are becoming more

Figure 2 Flow chart of Custom Collection Service for chairs



readily available. Horchow Collection is the first luxury mail-order catalog retail company for home furnishing. It offers the newest Horchow Custom Collection service through the web site. Customers can choose to custom upholster frames by selecting a fabric swatch in the website, and can see immediately what the frame will look like in the chosen fabric.

Style customization

At the Horchow website, three categories of custom products are available, chairs, sofas, and specialty furniture such as ottomans, and pillows. Figure 2 provides a flow chart of the custom chair service process. For each product category, several product styles are available for selection. When visiting the site, a customer first chooses one style. All specifications for the product, including size, material contents, and frame, are described. An 'enlarge' option gives the detail for a product and the 'customize' option allows customers to customize the item with their choice of materials.

Design customization

Over 30 materials including leather, premium fabrics, and standard fabrics are available. Images of an upholstered item as well as fabric swatch images are offered for each choice. When the customer chooses a preferred fabric, both product and swatch images are modified to show the product in the new fabric. Customers can receive a free swatch for a fabric they considering, providing them the chance to get tactile information for the final product. The expected shipping date is no longer than two months after an order is confirmed.

E-commerce in home furnishings hasn't appealed to customers in the past because physical comfort and tactile elements are critical for the buying decisions. However, CAD technologies and virtual reality applications expand the possibilities for E-commerce for U.S. furniture industry, (Anonymous, 2005; Oh, Yoon & Hawley 2004) and availability of fabric swatches attempts to address such concerns.

3.2.6 Case Study Learnings

On-line offering of mass customized products seems to be a growing trend in the industry. Internet availability of mass customized products offers great advantages to consumers in terms of convenience and accessibility. Based on the case studies combined with literature review, some conclusions can be reached regarding effectiveness of on-line customization. First, easy navigation of the web site is important. To provide quality information, customers must understand what they are being asked and how to progress through the choices provided. Second, quality visual stimulation is required. The vendors studied used photographs of actual products and product details to represent available choices. Also, if the customized product can be presented to the customer visually, it helps in understanding exactly how the finished product will look. Third, enhanced customer services, such as retaining records for reorder and allowing for product modification following the order, appeal to the customer. Finally, for textiles, providing an opportunity for the customer to experience the fabric through a swatch can alleviate concerns about the hand of the fabric.

Some distinct challenges remain with interactive mass customization systems for textile products. Though photographic stimuli are helpful for visualization, the ability to examine a product virtually in 3D would facilitate comfort level with the purchase decision. Turn around time for customized product remains substantially longer than required for delivery of standard products, many customers do not want to wait. Virtual reality technology may eventually be able to address the concerns related to visualization and the tactile experience of fabric (Oh, Yoon and Hawley 2004) eliminating delays associated with providing swatches on order. For apparel, fit will continue to be a challenge particularly when provided by the customer and based on manual measurement techniques. Finally, management and reproduction of color throughout the process remains an issue. Color issues become an even greater concern at the highest levels of mass customization.

3.2.7 Digital Printing for customization

Achieving Silveria, Borenstein & Fogliatto's (2001) highest level of mass customization, "design", requires integration of textile design technology. Apparel textiles account for around 60-65 % of all fabric printing applications, or some 18 billion m^2 per annum worldwide (Byrne, 2003). The conventional printing process using rotary screen technology has been based on the mass-production system. For the next season, the color and style forecast for a new product are offered and the customer demand is predicted according to the previous sales record. To reduce the risk of stock-outs, large amounts of inventory are inevitable. In terms of manufacturing process, the conventional screen printing system requires a long lead time of weeks or months for a new print design, and involves extreme cost to develop printing rollers. Whether the design was put into production or not, it cost almost $30,000 to set up (Istook 2000). Therefore, conventional screen printing limited the possibility for providing a wide range of color-ways or individual garments for mass customization.

New digital textile printing technology has had a significant impact on the industry. With digital printing, consumer preferences can affect the product directly, and various products with diverse color combinations and styles can be printed with optimized fabric usage. Other advantages include: a virtually limitless number of colors, a rapid change-over of design and colorways with a minimum loss of cloth and no waste paste.

Lectra of France developed a system that makes it possible to rapidly produce a wide range of innovative designs and colors on a variety of fabrics, while providing consistency within the supply chain, from initial design to finished product (Lectra 2005). An important component of digital textile printing is a color management system, which provides a key competitive advantage for developing colors and quickly communicating them along the global supply chain. Basically, because a monitor and a printer reproduce colors with different color systems, the calibration of each device and the development of a profile for each are required to obtain consistent resulting colors. In digital textile printing, many variables can affect the resulting color, including the combination of ink and substrate, the conditions of pre- and post-treatment, and the type of substrate. Therefore, the establishment of standards for digital textile printing will be required for improved color consistency in a production line.

Textile CAD systems play a key role in digital textile printing systems, as well as in conventional printing, for reduction of design processing time and quick modification. Textile CAD systems have capabilities including color separation, repeat generation, creation of color ways, and texture mapping. A recent innovation, Lectra offers an option that allows the digital printer to print the garment pieces with the right color and position of the motif. This option includes a dimensional calibration tool to account for the shrinkage of the textile after wet-finishing (Lectra 2005).

In mass customization, there needs to be an integrated solution involving a sequence of operations including pre-treating, printing, post-treating, cutting, and sewing. Rimslow Pty. Ltd (Rimslow Pty. Ltd. 2004), a textile machinery company, makes an integrated manufacturing environment possible by offering a steamer that can be synchronized with the printing of an inkjet printer. The post treatment steaming process for digitally printed fabric is important to fix dye onto the substrate and to obtain better color yield. Rimslow's steamer automatically feeds fabric into the inkjet printer, through its built-in steam curer, then out of the unit and where is automatically rolled. They also offer an integratable unit incorporating washing and coating machines developed for inkjet fabric printing (Rimslow Pty. Ltd. 2004). The integrated automatic system would make it possible to obtain and control consistent output efficiently, and would enable printing of single products.

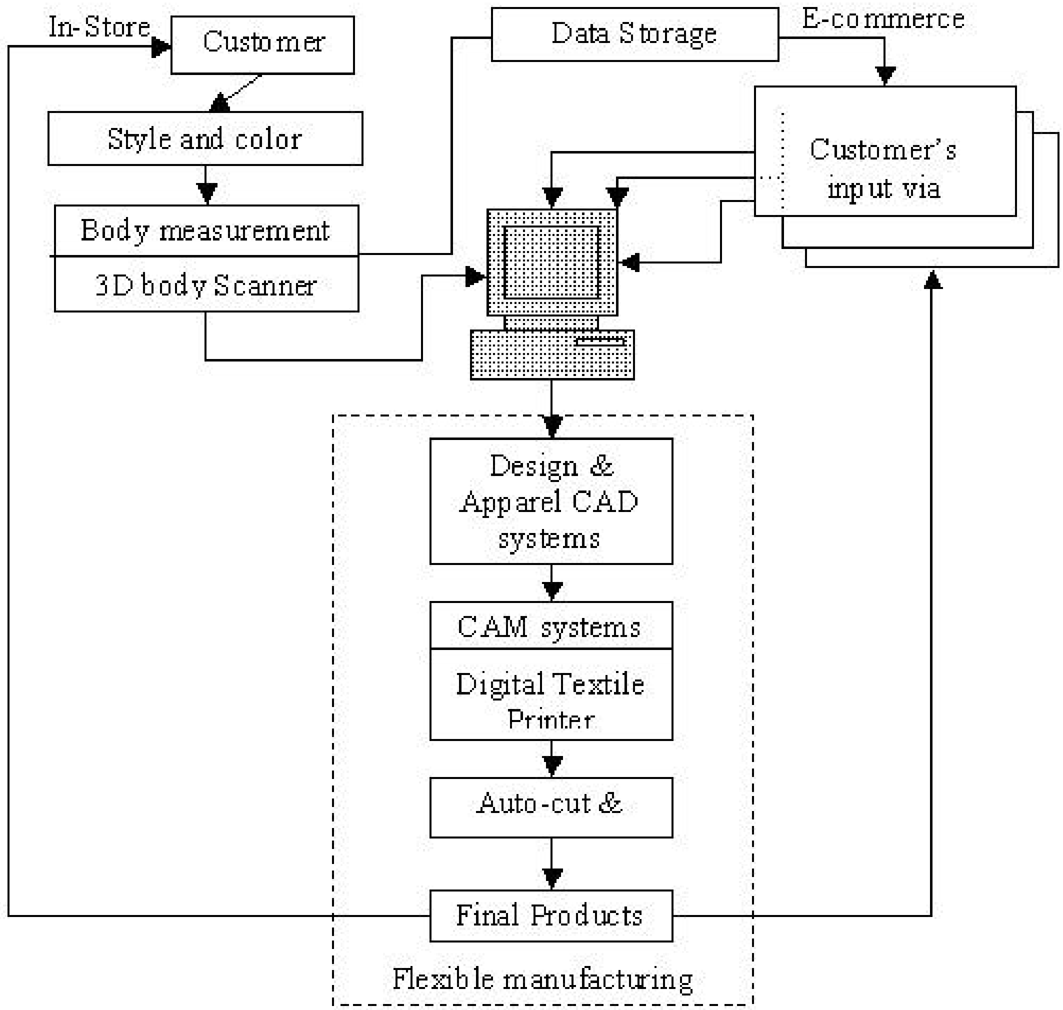
In 1990, Seiren completed an integrated digital inkjet printing system (Yuikawa 2001). Conventional printing systems can create a maximum of 20 colors with limited repeat size, and lot size of at least 2,000m. But, Seiren's system can develop 16.7 million colors with almost no limitation in design, and lot size as small as 1 meter (Rudie 1998). One of the major swim wear makers in Japan used the system in combination with point-of-sale data analysis and reduced unsold stock from 27% to 5% of the total production, and increased sales to 150% (Yuikawa 2001).

4. CONCLUSIONS

Mass customization and quick response management strategies facilitate responding to customer's requests and preferences promptly. Trends of integration and networking in CAD/CAM systems support these strategies by enabling the automatic transfer and feedback of manufacturing information. New manufacturing technologies including 3D body scanners, CAD/CAM systems, digital printing systems, and information technology using barcodes or RFID also support these strategies and bring advantages such as the reduction in time and labor, increase in reliability and precision, improvement in product variety and flexibility, and quality improvement. For effective information flow, collaboration and communication between segments of the supply chain are significant. Business conducted through internet via E-commerce, will be increasingly viable in the future, while web application of mass customization and QR strategies will enable delivery of unique products from anywhere in the world, at anytime. Figure 3 shows a potential future textile manufacturing workflow for delivering mass customized product.

For successful achievement of the integrated system shown, the establishment of standards must become a priority. Among manufacturers or countries, compatible data standards are critical for prompt information exchange in barcodes and EDI systems. The lack of standards can disconnect an efficient flow between CAD/CAM systems, and cause time delays and inaccurate data transformation. For example, standards of measurement, terminology and compatibility of measurements in 3D body scanning are critical for global production practices and efficient fit customization. The reproduction of accurate color in E-commerce is significant to maintain high quality of product and reliable production information. Thus, an integrated color management system with standard color specification must be adapted to the entire management system. Also, it remains challenging to obtain consistent color reproduction within a system. In the future, research focused on improving these problems would enhance viability of mass customization.

Figure 3 Possible Textile manufacturing workflow



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