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Advanced Mass Customization in Apparel

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ABSTRACT

The apparel industry is undergoing rapid evolutionary changes that have resulted from new technologies, globalization, and consumer demands. Consumers want and expect immediate, personalized service and more variety in product offerings. To survive in the apparel market apparel companies have increased their competitiveness through mass customization which is a new business strategy for goods and services. Today, Internet shopping has increased dramatically, especially for apparel, due to extensive product selection, low shipping costs, and large potential market sizes. Despite the rapid growth in online sales of apparel, some consumers are reluctant to shop for clothing on the Internet. They may perceive risk due to their inability to try on garments, feel the fabric, and read information on care and content labels, so they neglect to online. Therefore, 3D virtual try-on technologies for mass customization were developed by computer aided design systems. The virtual try-on is used to allow consumers the possibility to see themselves or a model matching their body measurements and shape wearing simulated garments online. The purpose of this paper is to review new product development and mass customization. This paper discusses apparel companies for mass customization and the future of advanced mass customization in apparel.

Keywords: mass customization, virtual try-on, new product development, CAD system

1. Introduction

The apparel industry is undergoing rapid evolutionary changes that have resulted from the digital revolution, globalization, and consumer demands. Previously, a lack of product availability required consumers to tolerate products that did not meet their expectations. However, this has changed and consumers want and expect immediate, personalized service and more variety in product offerings (Smith-Outling, 2007). In other words, consumers desire to personalize the style, fit and color of the clothes they choose. Given the changing characteristics of consumer interests, mass production systems cannot satisfy both manufacturers and consumers. One resource that fulfils the consumer's and manufacturer's need for personalization and a low-cost customized product is mass customization (Rosneau & Wilson, 2006). To survive in the apparel market a company must acquire the consumer's attention to purchase its product through customization programs which can produce personalized products. Therefore, many companies have increased competitiveness and obtained tremendous profits through new product development for mass customization which is the most

critical strategy in any competitive industry (Kumar & Phrommathed, 2005). Mass customization in apparel has been studied by many researchers (Burns & Bryant, 1997; Anderson-Connell et al., 1997; Lee & Chen, 1999; Fiore et al., 2001; Anderson-Connell et al., 2002) and apparel companies are already operating at various levels of mass customization.

The Internet, along with the rapidly growing power of computing, has emerged as a compelling channel for sale of garment products (Kim, 2007). Horrigan (2008) described that consumers using online shopping have increased dramatically, especially for apparel, because apparel retail websites are credited with providing consumers with various benefits, including greater time and cost efficiency, 24-hour accessibility, better consistency in service, and a wider variety of product/service choices than brick-and-mortar stores. However, high product return rates persist, and most consumers are still either hesitant to purchase garments online or are unsatisfied with their online shopping experience because they perceive a risk due to their inability to try on garments (Horrigan, 2008). Therefore, computer aided design systems companies have developed virtual try-on visualization techniques for the apparel industry, enabling visualization of garments on three dimension avatars. Virtual try-on is defined as the computer simulation that enables customers to choose garments and try them on 3D mannequins that are adjusted to their body measurements and are assisted to conduct a more successful online purchase of apparel (Cordier et al., 2001). The garment is draped on their 3D avatars, and the consumer can see how the garment looks and fits before the purchase is made (Istook, 2008). Apparel companies currently focus more on providing mass customization and 3D virtual try-on for consumers who shop online. Proper fit is the greatest challenge for Internet vendors.

The purpose of this paper is to provide information on mass customization and 3D virtual try-on for new product development. This paper also discusses real examples where mass customization and virtual try-on are in practice in the apparel industry.

2. New Product Development

New product development is defined as the set of activities beginning with the perception of market opportunities and ending in the production, sale, and delivery of a product (Ulrich & Eppinger, 2004). Belliveau, Abbie, and Stephen (2002) described that new product development is "the overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialization of a new product" (p.450). Brentani (2001) described new product development is essential for exceptional company performance, and research about what leads to new product success and failure has been carried out for both goods and services.

Crawford and Di Benedetto (2003) depicted that new product failure is the reason that companies don't understand consumers' need. Failures also can be linked to inadequate market research, positioning, and timing as well as major changes in technology (Urban & Hauser, 1993).

There are many studies on critical success factors for NPD, but the factors proposed by the studies are not all exactly the same (Urban & Hauser., 1993; Cooper & Kleinschmidt, 1994; Cooper, 2001: Crawford & Di Benedetto, 2003; Ulrich & Eppinger, 2004). Successful new product development allows for market expansion, increases profits, and enhances creativity and leadership. There are many studies on critical success factors for NPD. Several researchers (Cooper, 2001: Crawford & Di Benedetto, 2003; Ulrich & Eppinger, 2004; Urban & Hauser, 1993) have studied the voice of the customer (VOC) as the most important issue in the success of NPD.

According to Choi, Powell, and Cassill (2005), the issues that the target market segment is sufficiently large and competition is manageable are critical success factors in NPD.

2.1. New Product Development Processes

New product development process is defined as "a disciplined and defined set of tasks and steps that describe the normal means by which a company repetitively converts embryonic ideas into salable products or services" (Belliveau et al., 2002). Ulrich and Eppinger (2004) stated, "A new product development process is the sequence of steps or activities that an enterprise employs to conceive, design, and commercialize a product" (p.12).

New product development processes have been developed by several researchers (Kuczmarski, 1992; Urban & Hauser, 1993; Ulrich & Eppinger, 2004; Crawford & Di Benedetto, 2003; Tyler, 2008). Choi et al. (2005) summarized new product development processes identified by previous researchers. They described that each new product development processes model consists of different process arrangements. Even though these models use the different step terminologies, they have similarities in key activities and functions. In other words, the process begins with perception of market opportunities and typically involves identification of customers' needs, design development process, product & market testing, and market launch (Choi et al., 2005).

Kuczmarski (1992) described a new product development which is identified the following approaches as consumer driven, competition driven, or technology driven. Kuczmarski (1992) discussed that a new product development process is usually applied at several steps of an execution process: setting priorities for category selection, concept development, and after business analysis. The first stage of the NPD process management process tells managers who should play in meeting the company's needs. The direction-setting stage of the stage I has several key steps including new product diagnostic audit, new product strategy, and category identification. Once the direction-setting stage is completed, management has a road map to guide development activities. The development process of the stage II has several steps including needs-and wants exploration, idea generation, concept development, business analysis, screening, prototype development, market testing. plan scale-up and manufacturing testing, commercialization, and postlaunch chechup.

Urban and Hauser (1993) suggested that new product development has a five-step decision process including opportunity identification, design, testing, introduction, and profit management for new product development and each of the activity categories of other new product development processes are aligned vertically. Ulrich and Eppinger (2004) explained that product development consists of six phases including planning, concept development, system-level design, Detail design, testing and refinement, and production ramp-up.

Crawford and Di Benedetto (2003) described new product development has five phases including opportunity identification and selection, concept generation, concept/project evaluation, development, and launch. They explained that simultaneous phases of development reduce time to market. Therefore, it is critical to be aware that the product development process is a multi cross-functional program, where all functions work together to accomplish the required task.

Tyler (2008) described how product development might operate using the principle of concurrency. The starting point is a proposal for a new product from a new products team. This feeds into a global design optimization procedure which has several steps including optimization of

manufacture, simplification, materials optimization, environmental analysis, and resource analysis. Tyler (2008) described that tools for NPD are required not only for completing specific tasks, but also for supporting international communication in the global market. Tyler (2008) depicted, "CAD software for pattern specification, grading and marker making has long been used in the industry, and it is difficult to regard these as other than indispensable. Digital information can be communicated easily and in ways that are compatible with a globalised supply chain. Other software tools are used at the design stage, for forecasting, designing and collection planning." (p. 165) This NPD model focused technologists more than others. The precise analysis of consumer's need, market research, adequate positioning, and adequate timing as well as advanced technology is critical for the success of NPD. At this point of view, mass customization which focuses consumer-driven model and advanced technology is important issue to the new product development.

3. Mass Customization

Mass customization (MC) is defined as the integration of standardized processes of mass production with information technology that permits efficiently producing individually tailored products and/or services on a large scale (Anderson-Connell et al., 2002; Zipkin, 2001). Mass customization was first identified by Davis (1987) in his book, *Future Perfect*, as an oxymoron combining the contradictory terms of "mass production (MP)" where large numbers of identical items are produced and "customization" where each product is unique for each customer. A few years later, Pine (1993) connected Davis's description of mass customization to Piore and Sable's (1984) concept of market turbulence which is defined as uncertainly related to conditions in the marketplace.

Pine (1993) described mass customization as a new business strategy where goods and services are customized within the context of a given product line to fulfill an individual's demands in a cost-effective way. Technology applications including computer-aided design, the Internet, and flexible manufacturing have enabled firms to identify and meet a customer's individual needs and wants. Automobile, computer, and entertainment companies have embraced mass customization (Pine, 1993).

Staples (2001) discusses mass customization as an outgrowth of mass product which is a "consumer driven business strategy that uses information and manufacturing technology to efficiently produce goods with maximum differentiation and low-cost production, and characterized by "individualized mass production."

Kamali and Locker (2002) described "the goal of mass customization is to develop, produce, market and deliver products with enough variety so that every consumer finds exactly what he/she wants when he/she wants it". According to Zipkin (2001), elicitation, process flexibility and logistics are the three main components which need to be considered in implementing a successful MC practice. It is also very important that these components are properly integrated to effectively coordinate among order management, manufacturing and distribution. Design technologies such as computer aided design (CAD), virtual reality and multimedia technology enable the customer to design their preference, and then integrate the customers' selection with the firm's assembly and delivery system. These provide a better grasp of customer requirement in elicitation (Berman, 2002).

3.1. Apparel Mass Customization

Mass customization in apparel has been studied by several researchers (Burns & Bryant, 1997; Anderson-Connell et al., 1997; Lee & Chen, 1999; Fiore et al., 2001; Anderson-Connell et al., 2002).

Burns and Bryant (1997) explained that mass customization in apparel is processed by computer technology. These processes are to obtain customer measurements by a sales person with the assistance of a computer, enter the data into a computer and alter specifications as preferred by the customer, sending adjusted measurements to a fabric cutting machine to obtain customized garment pieces with barcode labels, assembled, and retailed (Burns & Bryant, 1997). Kurt Salmon Associates also described apparel customization came in three varieties such as personalization, fit, and design (Ives & Piccoli, 2003).

As Textile & Clothing Technology Corporation $[TC]^2$ discusses, MC for apparel and footwear can be positioned into three main categories including personalization, fit and design. For personalization, products are customized for consumer individual needs. Personalized body measurements and specifications are supplied to the manufacturing process to be individually made to meet the customer selections, e.g. color, fabric, construction, accessories, thread, etc. Then, the product design is accessed as per customer's request (Textile-Clothing-Technology-Corporation, 1998).

According to Anderson-Connell, Brannon, Ulrich, and Marshall (1997), consumer interests in customizing apparel include changing design options and personal fit with the aid of a well-trained assistant, which they called co-design. They found fit to be a critical issue in apparel mass customization. Anderson-Connell, Brannon, Ulrich, Marshall, and Staples (1998) created a model of mass customization for the apparel industry. Based on consumer research, they indicated that digital information and new technology in the process of manufacturing will develop customized apparel with four options: "expanded selection/search;" "design option;" "co-design;" and "total custom." In the "expanded search," a customer is able to access various manufacturers' product lines through intelligent search capabilities. In the "design option," the customer is able to select from manufacturer/retailer's designs, sizing, style options, style details, color, and fabric. "Co-design" offers additional personal fit through the ad design manager, based on the "design option choices." Finally, in "total custom," the customer communicates his or her own designs to manufacturers or retailers in a digital format (Ulrich et al., 2003).

Lee and Chen (1999) described how apparel industries practice mass customization based on the concept of MC defined by Pine (1993). They discussed technologies such as 'smart card', 'body scanner', and information collection. The precise measurements of individual consumers are required to customize apparel products and a consumer is able to be measured by hand, by body scanner, or by video camera. Then, these measurements are entered into the system which consequently adjusts the size of matching points on the pattern prototype (Lee & Chen, 1999). They explained that apparel industries with the manufacturing concepts such as JIT (Just-In-Time) or QR (Quick Response) found new niche markets for the made-to-measure garment and mass customization became a broad trend for apparel industry production and retail (Lee & Chen, 1999). They presented a model explaining the effect of mass customization on the apparel industry. For example, in clothing companies such as Levi Strauss, Second Skin Swimwear, and Custom Foot, mass customization begins in a retail store where a line of ready-to-wear is provided along with mass customization services (Lee & Chen, 1999).

Fiore, Lee, Kunz, and Campbell (2001) described two important options in mass customization are body scanning for better fit and co-design for a unique design. Body scanning involves using electronic measurements of the customer's body form to develop a manufactured product with an individualized fit. In co-design the customer, generally with the aid of CAD technology and/or professional assistance, compiles an individualized product design from a company's style, fabric, color, surface design and size alternatives (Fiore et al., 2001).

Anderson-Connell, Ulrich, and Brannon (2002) found content analysis of participants' comments revealed positive and negative perceptions of mass customization and related technologies. This study described that the construction of a consumer-based model provides an initial framework for researchers and the business community to use in exploring how the paradigm of mass customization could be applied as a business strategy in the apparel industry. They developed a model to depict, for apparel businesses, mass customizing avenues that would mesh with consumer-expressed interests. Their model's paths range from first steps to more complicated strategies for mass customization of apparel. At a more technologically advanced level, body scanning and smart cards would facilitate customized fit and design (Anderson-Connell et al., 2002).

3.2. Apparel Companies for Mass Customization

Mass customization allows the consumer to modify a company's product line to meet individualized design tastes or fit requirements. For example, many companies, including Levi Strauss, Brooks Brothers, Second Skin Swimwear, Custom Foot, etc. are operating at various levels of mass customization (Lee & Chen, 1999). After examining ready-to-wear and perhaps trying on garments to establish fit and sizing, the customer is assisted in developing individualized product specifications. A customer is able to choose individualized combinations of product style, fabric, color, and size from a group of options, create a unique design based on his or her preferences, or achieve personalized size and fit based on physical body measurements or body scanning. Specifications are developed, the customer pays for the product, and the order is sent to the production facility. The product is made and sent to the customer in a few days. Technological developments make mass customization of apparel viable (Scheller & Rabon, 1997). Supporting apparel technologies include body scanning, computer-aided design, single ply cutters, digital printing, and modular production. Body scanning requires highly developed electronic devices to take body measurements. Clothing companies like Levi Strauss and Second Skin Swimwear (Rabon, 1996) use the measurements to customize garment size and fit. The body measurement information can be digitally stored on a smart card for portability (Lee & Chen, 1999).

Levi Strauss & Co.

Founded in 1853 by Bavarian, 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 (Lee & Chen, 1999). In 1995 Levi introduced their "Original Spin" program, which allowed customers to visit a Levi's store to be measured for jeans. The jeans were then custom-tailored and subsequently home delivered (Tedeshi, 2001). In the store, a trained sales person takes four initial measurements of the waist, hip, inseam, and rise. These measurements are entered into the computer system, which suggests a prototype-test garment. The consumer tries the prototype on and fit modifications are

made in any of four areas of the garment, based on the consumer's preferences (such as a tighter fit, looser fit, shorter, and longer). Two or three prototypes are usually required to find the perfect fit for the customer (Lee & Chen, 1999). Also, Levi's attempt to sell merchandise tailored or otherwise, online from their web site was curtailed in November of 1999 when the firm announced its intentions to instead sell through the web sites of two of its major customers, J. C. Penney and Macy.

Brooks Brothers

Founded in 1818, Brooks Brothers 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. In November of 2001, Brooks Brothers introduced a "Digital-Tailoring" system for customized suits, jackets, trousers, and shirts. In 12 seconds the system could scan the customers' body and record 200,000 data points. These data points were then translated into exact measurements for 45 specific tailoring measurements (e.g., collar, neck). The customer could then choose from hundreds of fabrics and a variety of styles. Products were shipped in about three weeks (Colman, 2001). 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 (Tedeshi, 2001).

4. Advanced Mass Customization in Apparel

The Internet along with the rapidly growing power of computing has emerged as a compelling channel for sale of garment products. Consumers that purchase garments online base their purchase and size-selection decisions mostly on 2D photos of garments and sizing charts. However, this method is not precise enough and not interactive enough to provide right sizing and choice. Internet shopping has a limit that consumers can't try on clothing before purchasing (Volino et al., 2005). Therefore, the combination of made-to-measure manufacturing and shopping via the Internet have arisen recently across the world through the emergence of technologies, systems and practices, such as 3D body scanners, the customization of existing styles, and virtual try-on visualization technologies (Volino et al., 2005; Cordier et al., 2001).

4.1. Body Scanning Technology and Fit

Body scanning technologies have certainly achieved significant advancement in the area of sizing, fit, and product visualization and apparel companies have used body scanners for custom fit. For example, Levi Strauss provided customers the opportunity to be scanned for a pair of custom jeans in their San Francisco store. In the 'My Virtual Model Tour 2000' sponsored by Lands' End, the world's first body scanning truck was introduced. Individuals were scanned with an Image Twin scanner and the virtual model with the individual size was created and could be used to try on clothes through the Lands' End catalog and website. Brooks Brothers used to scan customers in-store in New York City to offer customized garments. This process allows the customer to find the best size in their desired fit (Istook, 2008; Chapman, 2001). Many of the scanning hardware manufacturers have developed software to allow automatic measurement extraction from the scanned 3D data. Included in this group are: Cyberware, Hamamatsu, Hamano, TC^2, Telmat, and TecMath (Istook & Hwang, 2001). Three dimension body scanners capture the outside surface of the human body using optical techniques, in combination with light sensitive devices. The laser and light-based systems are the primary types of body scanning systems. The individual measurements and image taken from the 3D body scan can be automatically transferred into a computer database and an

intermediate software program can suitably utilize the information for mass customization or virtual try on technology (Keiser & Garner, 2003).

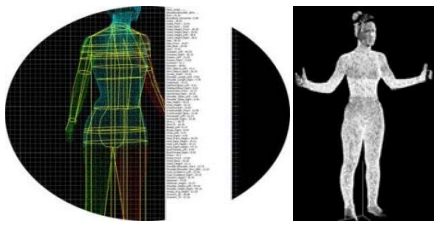

Figure 1. Body Scan [TC]²
Source: www.tc2.com

4.2. Virtual Try-On

Virtual try-on is defined as the computer simulation that customers choose garments and try on 3D mannequins that are adjusted to their body measurements, and are assisted to conduct proper online purchase of apparel (Cordier et al., 2001; Virtual Fashion Technology, 2007). In other words, consumers of the virtual apparel shop are able to simulate chosen garments on virtually animated bodies. Besides seeing the garments fitted on their virtual bodies, customers are able to animate the clothes as well. In an interactive and realistic virtual clothing store, customers are able to choose among different apparel items and then proceed with visualizing them on animated mannequins created using their own measurements (Loker et al., 2008; MIRALab, 2003). Virtual try-on supports operations including automatic adjustment of the 3D mannequin based on an individual body measurement, the selection of different garment items, the online fitting of the garment to the 3D mannequin and real-time simulation of the garment movement (Volino et al., 2005). Loker et al. (2004) discussed virtual design has been considered an important part of the apparel design customization tools, as interest increases in garment customization, e-commerce, and available advancing 3D technology. Kartsounis, Magnenat-Thalmann, and Rodrian (2007) described virtual try-on is used to allow online consumers the possibility to see themselves or a model matching their body measurements and shape wearing simulated garments. This form of digital try-on or modeling assists in the many challenges faced by online merchants of accurately representing products (Kartsounis et al., 2007). The result of virtual try-on technology enables consumers to make better informed purchase decisions through accurate representation, clear images with quick loading times (Fiore et al., 2005).

Several CAD systems including Browzwear, Optitex, Lectra, and others have developed software for the apparel industry enabling visualization of garments on three dimension avatars (Virtual Fashion Technology, 2007). These avatars can be adjusted to generally mimic a specific set of fit measurements by fine-tuning points of measure, such as the bust, waist, hip, abdomen, etc. Virtual garment patterns can be set to sew together on a virtual avatar demonstrating the potential fit of the garment. The virtual try-on technologies allow consumers to try the garment with silhouette, fabric, color, and embellishments on the body with their measurements and evaluate clothing fit over the Internet (Istook, 2008).

Browzwear

Browzwear International develops and manufactures advanced 3D fashion design and communication software for the garment and textile industries. The company, founded in 1999, is headquartered in Tel Aviv (Browzwear International Ltd, 2008). Its vendors distribute its products worldwide to over 160 industry leaders in more than 25 countries. **Browzwear** has won the support of major investors, from textile industry leaders to builders of high-tech companies and economic advisors. This company is committed to its vision of harnessing 3D visualization of models, garments and fabrics to the enhancement of the fashion industry, helping designers, manufacturers and shoppers alike to take the

next major step in the revolution of an evolving industry (Apparel Magazine, 2008). Browzwear's success is its commitment to the 3D generation of software design solutions **such as V-Stitcher™**, **V-Styler™** and **C-Me™** recognized as the best commercial applications on the market for 3D visualization and design of garments and materials (Techexchange.com, 2006, March 2).

Browzwear provides real-time 3D solutions to the growing business-to-business and e-commerce markets for online apparel segments. The company is convinced that the number of returned garments can be reduced by using its 3D virtual design software. The 3D virtual design simulation detail can reduce product approval and production time by allowing the entire supply chain to visualize products and share input simultaneously. This results in accelerating time to market and ultimately increasing profitability (Apparel Magazine, 2008).

Figure 2. Browzwear
http://www.browzwear.com/profile.htm

OptiTex

Founded in 1988, OptiTex specializes in the development of innovative easy-to-operate 2D-3D CAD/CAM solutions and offers the convenient option of purchasing a completely integrated CAD package, including OptiTex software solutions, digitizer, and pen or ink jet plotter (Optitex, 2008). Like other CAD suppliers, OptiTex USA, Inc. also focuses a 3D virtual design and information management via the internet. OptiTex has also made its best-of-breed software even better by enhancing one of its core products, 3D Runway Designer 10, with remote collaboration tools. This system allows production and image files in 2D and 3D to be sent between partners participating in the design process. 3D Runway Designer 10 has new customizable features and options, allowing designers the freedom to change textures, materials, colors and stitches or add logos on screen without using a single piece of fabric. The garment can then be seen "in action" on OptiTex's 3D models, all of which are fully adjustable to reflect any body type. OptiTex's on-screen environment is customizable to enhance the designer's creative process. The accuracy of the images eliminates material, energy and time waste, providing rapid ROI as well as an environmentally friendly application (Techexchange.com, 2008, May 27).

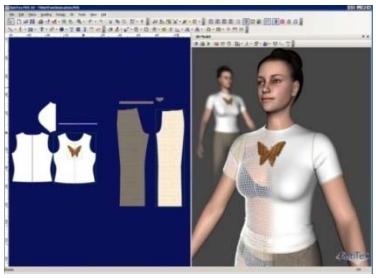

Figure 3. OptiTex
Source: http://www.optitex.com

Lectra Systems, Inc.

Founded in 1973, Lectra Systems, Inc., one of leading CAD/CAM suppliers to the apparel Industry, provides made-to-measure solutions that offers a wide range of pattern, color, fabric, and fit (Lectra System, 2008). Lectra Systems, Inc. announced that the new version of Modaris 3D Fit was the highest performance virtual 3D prototyping solution on the market. Modaris 3D Fit enables pattern-makers, designers, developers, and sales and marketing teams to simulate and visualize their models in 3D on a virtual mannequin, including the colors, motifs, and fabrics originally created in 2D. With Modaris 3D Fit, the look and fit of a garment can be verified, and its style and that of entire collections can be validated.

Virtual 3D prototyping ensures the quality of a garment and its look and fit in all graded sizes, reduces the number of physical prototypes necessary to finalize a model, and makes communication more fluid among the actors in product development (Techexchange.com, 2008, June 12). It thus accelerates the collection development cycle and enables users to overcome the Fast Fashion. Finally, 3D virtual prototyping helps reduce development costs and, as such, is a real competitive advantage for apparel professionals. Modaris 3D Fit stands out as the most advanced solution for the universe of fashion (Lectra Systems, 2008).

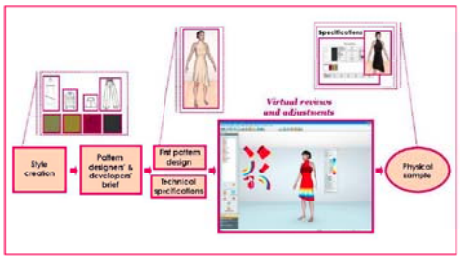

Figure 4. Lectra Systems
Source: www.lectra.com

Tukatech

Tukatech was founded in California in 1997 and it has launched a new CAD product that can help reduce sample approval and production time by allowing the entire supply chain to visualize garments via the Internet and share input simultaneously (Tukatech, 2008). In 2004, Tukatech began work on a new software product that it dubbed the e-fit Simulator by TUKA. The 'e-fit Simulator' software allowed designers, pattern makers and manufacturers to make fit comments and suggest alterations more quickly. It creates a virtual garment from a two-dimensional pattern and drapes this over a 3-D body image with life-like movement capabilities. The same patterns used to cut actual samples are used by e-fit Simulator, and the virtual fit models are created using body scan data of real fit models. Dozens of preset cloth types can be blended together to test garments using the intended fabric, and additional presets can be created by the user. The e-fit Simulator creates virtual prototypes of garments, reducing time to market and increasing efficiency in the apparel product development process (Just-style.com, 2004, September 7).

Figure 5. TUKATECH's e-fit Simulator (Delevan, 2007)

My Virtual Model (MVM)

My Virtual Model™ Incorporated, founded in 1993 as Public Technologies Multimedia Incorporated (PTM), provides retailers and their customers with online apparel shopping technologies and services. Virtual try-on is currently offered to online retailers by My Virtual Model (www.mvm .com), a Canadian company. In 2001, 'My Virtual Model™', so far the most commercially successful try-on technology, offered 'My Virtual Model Dressing Room' and 'My Virtual Model Fit', which enabled users to try on clothes as well as size, mix and match, personalize, and evaluate clothing over the Internet. The company's My Virtual Model Imail™ product, launched in 2002, supports the integration of My Virtual Model Dressing Room with e-mail messages. It allows retailers to send personalized messages to customers (My Virtual Model, 2008).

My Virtual Model is one of the earliest efforts of the virtual try-on concept for customers available online Land's End, Sears, H&M, Adidas, Speedo, Levi Strauss & Co., Nutri/System, Lane Bryant, Crossing Pointe, Kenneth Cole, WeddingChannel.com, Orvis, Plussize.com, and others. These systems were designed for

style selection and the interactive process generally requires customers to enter information about their body shapes, such as small or large bust, waist, and hip, torso length and shoulder width (see Figure 6). The image of the customer's body shape is displayed on the screen for confirmation or modifications, and the clothing consumer choose is put on their body shape. This process allows customers to get an idea of how their garment selection might look on their body shape. My Virtual Model has been used by many apparel companies and consumers have actually used their avatar in the website (Istook, 2008; Loker et al., 2008). Shoppers who use My Virtual Model (MVM) are 26% more likely to purchase and spend 13% more than those who do not use this feature on a site (Nantel, 2004). This indicated that the 3D virtual model technology assists consumers' confidence in their final purchase decision by giving them access to an interactive virtual try-on session. My Virtual Model tried to find concrete solutions for its users and responded to the call by creating 'The Face' that allows consumers to be able to superimpose a photo of their own face onto their 3D virtual model. The Face is available exclusively at www.hm.com. At this site, consumers can personalize their avatars and achieve greater satisfaction in their shopping and social experience (Montréal, 2007).

Figure 6. All Shapes and Sizes from MyVirtualModel.com
Source: www.myvirtualmodel.com

In 1998, landsend.com became the first website to make My Virtual Model software available to online shoppers. Since then, Lands' End has partnered with the IT firm My Virtual Model Inc. to solve the problem of online apparel shopping, with the inception of a realistic virtual model at Lands' End's direct sales website. As Lands' End introduced new product strategies such as MVM software, Internet merchandise sales at landsend.com progressed from $61 million to $138 million to $218 million to $299 million from fiscal 1999-2002 (Ives & Piccoli, 2003). Consumers can see a human model appears on the left side and a clothing catalog appears on the right (see Figure 7).

Figure 7. My Virtual Model of Landsend.com
Source: www.landsend.com

5. Future of Mass Customization in Apparel

To strengthen competitiveness in the global textiles and apparel industry, companies need to effectively build and sustain strategies of new product development (NPD). Currently, consumers want more variety and more direct input into the options that are available and mass customization coupling with the innovative technologies has become a key business strategy for NPD. New product development processes developed by researchers (Kuczmarski, 1992; Urban & Hauser, 1993; Ulrich & Eppinger, 2004; Crawford & Di Benedetto, 2003; Tyler, 2008) present several steps, the process begins with perception of market opportunities and typically involves identification of customers' needs, design development process, product & market testing, and market launch. They stated that the voice of

the customer is the important issue for the NPD. Also, several researchers (Burns & Bryant, 1997; Lee & Chen, 1999; Fiore et al., 2001; Anderson-Connell et al., 2002) concluded that body scanning and co-design process are important issues for mass customization in apparel.

Internet shopping has increased dramatically. However, consumers are reluctant to shop for clothing on the Internet. Because they perceive risk to exist due to their inability to try on garments, feel the fabric, and read information on care and content labels. Therefore, 3D virtual try-on technologies for mass customization were developed by several companies including Browzwear, OptiTex, Lectra Systems, and others. They allow consumers to provide an individual's specific body measurements and other specifications such as silhouette, fabric, color, and embellishments. Consumers can evaluate clothing fit on the Internet. In other words, virtual try-on is used to allow consumers the possibility to see themselves or a model matching their body measurements and shape wearing simulated garments online. This type of total software system integrates garment design, surface design, fit, construction and 3D virtual presentation before a real garment is made.

Virtual try-on is available on My Virtual Model website that supports Land's End, Inc., Sears, H&M, Adidas, Speedo, Levi Strauss & Co., Nutri/System, Lane Bryant, Crossing Pointe, Kenneth Cole, WeddingChannel.com, Orvis, Plussize.com, and others. Although virtual try-on technologies allow consumers to evaluate clothing fit on the Internet, it is not yet widely available and the technologies should be developed to include the use of 3D virtual avatars and garments. Also, creating virtual clothing that drapes and moves with the body like real fabric has been still difficult. However, the studies for the technology using Kawabata test and fabric drape software has beed continued).

In the future, the virtual try-on usage for customized and personalized online products will continue to increase. Consumers may store their body scan on a smart card, as a file on a portable flash drive, or in a private firm or industry-wide database accessed through the Internet. Consumers will be able to store their own scans with their cell phones or i-Pods and then use the virtual fit applications on many apparel web sites.

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