Innovative Mass Customization in the Fashion Industry

Ho-Ting Yeung, Tsan-Ming Choi, and Chun-Hung Chiu

Mass customization (MC) is a popular strategy in the fashion industry. MC aims at satisfying individual customer's needs with customized products and at a cost near that of mass production. In this chapter, we first conduct a comprehensive literature review on MC in the fashion industry. We then propose a scheme to classify the MC practices as traditional and innovative. By exploring many real world cases, we compare and develop insights on the applications of different kinds of MC in the fashion industry. Managerial recommendations are generated. We believe that this chapter can lay a good foundation for future studies on MC.

Keywords Customer involvement · Fashion · Mass customization · Modularity · Technology

1 Introduction

Mass customization (MC) is a widely observed practice in logistics and supply chain management. It is especially prominent now (and will probably be even more significant in the future) owing to the advances in information technology and more demanding consumers. The concept of MC was first coined in the book "Future Shock" by Toffler (Toffler 1970). At a later time, Davis described MC as the hybrid system that accommodates mass production and (craft) customization (Davis 1987). Nowadays, MC usually refers to producing customized products or services for satisfying individuals with the efficiency of mass production (MP) (Silveira et al. 2001; Salvador et al. 2004; Chandra and Grabis 2004c; Piller 2007; Gilmore and Pine 1997). Following this modern definition, Silveira et al. argued that "MC is a system that uses information technology, flexible processes, and organizational structures to

C.-H. Chiu (✉)
Institute of Textiles and Clothing, Faculty of Applied Science and Textiles, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
e-mail: chchiu2000@gmail.com

T.C. Edwin Cheng and T.-M. Choi (eds.), *Innovative Quick Response Programs in Logistics and Supply Chain Management*, International Handbooks on Information Systems, DOI 10.1007/978-3-642-04313-0_21,

deliver a wide range of products and services that meet specific needs of individual customers, at a cost near that of mass-produced items" (Silveira et al. 2001). All in all, the notions of MC are high responsiveness, low cost, and fulfilling the needs of each customer. MC is even coined as a part of future retailing (Retail Forward Inc 2003).

Short life cycle, economic environment, intense competition (Christopher 2000), changing customer needs, rapid technological innovations (Lee and Chen 2000), globalization (Silveira et al. 2001), and market fragmentation (Svensson and Jensen 2003; Tu et al. 2004a), all lead to market turbulence. Meanwhile, more consumers having great purchasing power express their personality and wealth by means of individualized products (Piller and Muller 2004). In order to deal with market uncertainty and demand, MC has become an imperative measure for the industries as it gives flexibility and quick responsiveness to volatile market demand (Silveira et al. 2001; Peters and Saidin 2000).

MC allows firms to respond promptly to changing customer needs (Chandra and Grabis 2004a). Since firms can learn individual consumer preferences during the MC processes, it is argued that MC improves firms' responsiveness to cope with fashion changes (Sullivan and Kang 1999) and enhances their efficiency. In order to implement MC, the respective supply chain (SC) needs to be changed for accomplishing flexibility and responsiveness (Caddy et al. 2002; Pine et al. 1993; Christopher 2000; Radder and Louw 1999).The traditional lengthy and slow-moving SC becomes unsustainable in this sense. A firm with MC may result in the growth of complexity in its SC (Coronado et al. 2004).The issues in supplier relationship, coordination, inventory management, and postponement are reported to be critical in supply chain management (SCM) for achieving a successful MC strategy.

To implement a successful MC in the fashion industry, information is the most critical factor (Reichwald et al. 2000). MC is characterized as "highly information intensive" because of the close interaction between customers and suppliers. On the other hand, MC usually results in an increased cost (Ahlstrom and Westbrook 1999). Such an increased cost is particularly derived from information cost (Reichwald et al. 2000; Piller 2004); as a result, information management is essential in MC (Silveira et al. 2001). For instance, Brooks Brothers reported that MC program provides vital information, which allows tracking customers' measurements, style preferences, and personal data. With the above information, Brooks Brothers notifies customers the new suit styles and updated merchandises selection by sending automated notices (Stacy 1999). Brooks Brothers can therefore update customers with the latest offerings of the company and improve MC as well as its own MP businesses.

Taking into account the importance of MC in the fashion industry, this chapter contributes in a number of ways. First, we conduct a comprehensive literature review on MC in the fashion industry. Second, we propose a scheme to classify the MC practices as traditional and innovative. Third, by exploring many real world cases, we compare and develop additional insights into the applications of different kinds of MC in the fashion industry. Managerial recommendations are generated. To the best of our knowledge, there is little research to date studying the aforementioned topics. We reckon that this chapter can lay a good foundation for future studies on MC.

2 Literature Review

2.1 Mass Customization: Background

MC is not a new strategy, but its presence in the business world is a well-observed global trend nowadays. Companies in industries, such as automotive (e.g., BMW, Land Rover), computer (e.g., Dell, Fujitsu) (Gunasekaran and Ngai 2005), Hewlett-Packard (Feitzinger and Lee 1997), electronics (e.g., Motorola) and fashion (please see Sect. 3) (Aigbedo 2007; Pine 1993) have all been reported to be MC adopters. For example, in the automotive industry, Land Rover allows customers to discuss their specific needs with the special vehicles team (Alford et al. 2000). This team then collaborates with each customer to develop a customized vehicle which is based on the standard Land Rover (but changing some core elements of design). BMW also offers MC (e.g., changing the color), and it only needs 6 days for final assembly (Gunasekaran and Ngai 2005). Dell is regarded as one of the most successful MC adopters in the computer industry (Gunasekaran and Ngai 2005). Dell offers MC via the Internet, thereby helping customers build their own computers by advising their desired configurations online. Dell would quickly deliver the assembled products to customers in a few days. The success of Dell's MC is based on its close collaboration with suppliers, use of modularity (Gunasekaran and Ngai 2005) and web-based configuration for order processing (Ro et al. 2007).

Ahlstrom and Westbrook found that a lot of companies believe that MC is becoming more and more important and more than half of the respondents are reported with a plan to increase MC in the future so as to accommodate the customer demand for a larger variety of products (Ahlstrom and Westbrook 1999). Essentially, reward is promising (Tu et al. 2001) as MC companies are reported to have double-digit sales growth (Piller 2007). MC is a potential means in achieving cost saving by the economies of MC (EMC) (Piller and Muller 2004). EMC implies low cost with the application of single process to produce a greater product variety in a cheaper and quicker manner (i.e., economies of scope). Economies of integration are also substantial in MC owing to the cost savings connected with better access to customer knowledge (Reichwald et al. 2003).

Development of MC. Piller described the evolution of MC as follows (Piller 2004). In the first generation, MC is mainly implemented in a B2B context. Next, MC companies aim at consumer markets and are eager to interact with customers via the Internet (i.e., to reduce communication cost and reach a large number of customers) in the second generation of MC. However, many players would fail in this generation because they cannot provide a sustainable value of their MC programs to their customers. In the third generation, firms use MC to improve MP. By doing so, firms have better customer knowledge (from MC), and thereby, can improve their businesses on a large scale (i.e., MP).

Benefits of MC. Both companies and their customers can be benefited by the presence of MC. On one hand, customers can enjoy a higher satisfaction level because of the individualized offerings and more unique shopping experiences (Taylor et al. 2003). On the other hand, MC increases customer loyalty towards the companies and reduce their switching to other competitors in the market. Piller and Muller mention that a firm is able to acquire knowledge of customers during product configuration (Piller and Muller 2004). If a customer shifts to other MC firms, he/she will be faced with uncertainty in product quality. Firms hence put up a barrier to retain customers. Customers are willing to pay a premium price for the products that fit them better (Piller 2004). As MC is a pull system, the negative impacts brought by sales forecasting error are reduced. Finished product inventory and markdown are then greatly reduced (Taylor et al. 2003), and these are especially meaningful for the fashion industry. In addition, Kumar also claimed that better quality and service are the consequences of MC (Kumar 2004). For more advantages of MC, we refer readers to (Pine et al. 1993) and (Knolmayer 2002).

2.2 Mass Customization and Supply Chain Management

Enhancing flexibility and responsiveness for MC needs altering SC structure, and MC seems to require a more complex SC (Coronado et al. 2004). Unlike a traditional SC, an MC supply chain should spend extra effort on dealing with the issues associated with supplier relationship, coordination, inventory management, and postponement.

Supplier relationship. The shift to MC not only affects the internal operations of a company but also the relationships between the company and its partners in the SC (Blecker and Abdelkafi 2006). MC requires SC members move to a higher level of trust, integration, and cooperation so as to address problems jointly and in a mutually beneficial manner (Chandra and Grabis 2004c; Gunasekaran and Ngai 2005; Caddy et al. 2002). SC structure would then be changed from the traditional practice into new strategic alliances between the firm and other SC members (Blecker and Abdelkafi 2006; Gunasekaran and Ngai 2005). For this reason, greater care and diligence in identifying potential partners and the endeavor to manage relationships between SC partners are inevitable in running MC (Caddy et al. 2002).

Outsourcing is another way to handle the uncertainty of product flow and customer demand in MC (Gooley 1998). Involving more third parties can potentially lead to a higher level of responsiveness and flexibility as a firm focuses on its own core competencies whereas the other tasks are done by outside parties with the right expertise. However, coordination problem then arises (Caddy et al. 2002) and it is especially prominent when the number of partnering firms increases. On that account, achieving MC objectives under outsourcing requires coordination of all members.

Inventory management. Uncertainty in demand and supply is a big challenge for implementing MC. On the supply side, firms are not sure about the amount of different components and parts to keep in inventory for fulfilling the customers' orders. On the demand side, it is also difficult to estimate the number of customer-orders over a given period of time. In this situation, SCM aims to balance supply and demand and allow the pipeline to adjust with respect to the demands of the consumers (Gunasekaran and Ngai 2005). MC aims at achieving low cost, large variety, and short lead time. These objectives seem to be conflicting with one another and pose new challenges. Chandra and Grabis proposed a solution that designs different inventory management approaches for different modules (Chandra and Grabis 2004c). On the other hand, the synchronization of inventory management for all components under MC should also be well-considered. As a result, precise coordination of both inbound and outbound logistics is essential in MC (Gooley 1998).

Postponement. Postponement is an important tool for enabling MC (Helms et al. 2008). Postponement is a principle of designing products using common platforms, components, or modules and then storing products in the semi-finished state. The final assembly or customization will be postponed and processed only when final customer requirement is known (Christopher 2000; Salvador et al. 2004). Postponement allows firms to outsource materials and production activity, and therefore improving flexibility and responsiveness. The ability to increase variety and customization without parallel increases in costs can also be obtained. However, as what Chandra and Grabis reported, there is a tradeoff between inventory cost and delivery time according to the level of postponement (Chandra and Grabis 2004a). Moreover, pursing postponement should concern the issue of facility location (Chandra and Grabis 2004c). This principle may not be achievable if the production facility is geographically distant. This issue is very important in the fashion industry.

Traditional non-MC supply chain VS MC supply chain. The MC supply chain and the traditional non-MC supply chain (such as the MP supply chain) differ in several aspects such as the flow of information and the roles of customers and suppliers (Chandra and Grabis 2004a). A different level of flexibility and responsiveness to changing market requirements hence results if we compare the MC supply chain with the traditional one (Gunasekaran and Ngai 2005).

A traditional non-MC supply chain is a push system while an MC supply chain is a pull system. The former satisfies customer requirements from stocks. Once production is completed, the finished product is stored in warehouse and waits for customer's orders. For that reason, accurate forecast in production level and inventory is fundamental (Christopher 2000). In other words, less involvement of customers is needed in design and production planning and therefore, customers do not have much contact with the firm. For the MC supply chain, production is based on the received orders according to customers' specifications. The firm should hence have efficient communication with the customers accordingly. A long term relationship with customers is necessary so as to collect and explore customer preferences. Under that condition, the information flows upward in MC supply chain (i.e., from customers to manufacturers) whereas information of traditional SC generally flows downward (i.e., from manufacturers to customers). Instantaneously, MC supply chain requires strategic alliances with suppliers (Chandra and Grabis 2004a). Firms need to have tighter integration and coordination with suppliers in order to deal with the changing markets. The functions of MC firms are usually decentralized with various outsourcing functions while traditional non-MC firms still focus more on centralization. Moreover, traditional SC manages the uncertainty in terms of finished goods inventory. However, MC supply chain focuses on managing the component level inventory (Chandra and Grabis 2004a).

2.3 Modularity

Modularity is one of the key elements in MC (Duray et al. 2000). It describes the degree to which a system's component can be separated and recombined, and it refers both to the tightness of coupling between components and the degree to which the system architecture enables the "mixing and matching of components" (Schilling 2000). Baldwin and Clarks described *modularity as an effective manufacturing strategy that enables firms to cope with rapidly changing customer requirements and increasing technical complexity, thus achieving distinctive MC capability* (Baldwin and Clark 1997). Apparently, modularity is considered as a fundamental method for achieving MC. In this sense, costs can be minimized whereas a wide range of end products can be created (Pine et al. 1993). As a remark, computer and automotive industries have been reported to be the leaders in successful application of modularity (Tu et al. 2004a). Modularity in production allows economies of scale and scope across the production lines (Duray 2002) because standard parts (i.e., modules, Starr 1965) can be produced by mass production (Duray et al. 2000). Right after that, the product differentiation and customization through combination, configuration, and modification of those modules will be postponed until the later stages of the process (Feitzinger and Lee 1997).

Modularity is not only applied in product but also in process. With the application of product modularity, the product can be assembled easily by integrating independent modules together (Lee et al. 1997). Internal manufacturing operations may be simplified by outsourcing the production activities (Salvador et al. 2004). In this manner, the operational challenge raised by MC can be addressed. Ulrich and Tung (1991) showed a typology of product modularity that distinguishes among component-swapping modularity (switching options on a standard product), component-sharing modularity (designing products around a base unit of common components), cut-to-fit modularity (dimensional adjustment of a module before combining with the others), bus modularity (adding a module to an existing series), mix modularity (no unique identity if modules are combined), and sectional modularity (arranging standard modules in a unique pattern). In a later work, Ulrich (1995) modified his typology and proposed slot modularity (each interface is different between components, so components cannot be interchanged), bus modularity (different physical components are connected with common bus), and sectional modularity (same type of interface, no single element for attaching other components). For process modularity, the production process can be separated into different sub-processes (Feitzinger and Lee 1997). Flexibility can hence be obtained as product process is not rigid (i.e., can be done with interruption). Process modularity is generally based on three principles – process postponement (delaying the process for differentiation or customization), process re-sequencing (rearranging the order of process), and process standardization (standardizing earlier portions of process).

Modularity benefits both customers and manufacturers. In the viewpoint of customers, product is easier to be configured and customized by applying modularity, and thereby, greater usability and serviceability are achieved (Tu et al. 2004a). For manufacturers, flexibility is allowed as they can make the modules of the product separately. The components' variety can be reduced, but offering more variety of end products (Duray et al. 2000). In addition, modularity decreases cost due to the economies of scale and scope. McCutcheon et al. (1994) suggested that modularity alleviates the customization responsiveness which occurs when customers want to be offered a larger variety of module choices as well as a short lead time simultaneously. Other benefits of modularity include increasing the feasibility of product or component change, reducing the impact of uncertain demand forecasts, ease of product design, upgrade, maintenance, repair and disposal, and so on (Kumar 2004; Coronado et al. 2004; Mukhopadhyay and Setoputro 2005; Ro et al. 2007). However, modular design also raises costs and introduces problem of warranty, reliability, and complicated system testing (Gershenson et al. 1999).

2.4 Customer Involvement

Apart from modularity, customer involvement is the major factor in the successful implementation of MC (Chandra and Grabis 2004b; Duray et al. 2000; Svensson and Jensen 2003). Duray (2002) found that the level of customer involvement in the SC is important to determine the uniqueness of the product and the type of customization. A product is highly customized if the customers are made to participate in the early design stage of the production cycle (Duray et al. 2000). Therefore, customer involvement in the development of the product is critical for satisfying customers' want. Customers can obtain individualized products and special experiences if they are strongly involved in the design stage (Lee and Chen 2000). At the same time, manufacturers will be greatly benefited from the knowledge and utilization of customer information (Pan and Holland 2006). Zipkin stated that a successful MC firm should have the capabilities of elicitation which is a mechanism for interacting with the customer and obtaining specific information (Zipkin 2001). It is simply because customers sometimes are unsure about what they want and are easily overwhelmed by too many available choices. For that reason, it is important to allow the customers to select and give information about their wants easily in the process of MC (Lee and Chen 2000). Some companies would like to offer "co-design" to the customers in stores or on the website so that they can design the products with the aid of designers, e.g., the Nike Sportwear Bespoke program (Nike's official webpage: sportwear bespoke program 2008). Such direct communication and interaction provides a very reliable and first-hand data about customers' preferences (Kumar 2004). Moreover, CRM (customer-relationship management) scheme helps a lot in MC as it provides detailed customer information and preference.

2.5 Technology

Technology is the prerequisite for pursuing MC (Erens and Hegge 1994; Anderson-Connell et al. 2002). Here, technology includes not only the digital computer based information technology, but also the other scientific advances such as that in materials science. Andel stated that "MC requires mass communication" and communication is mediated by technology (Andel 2002). In essence, technology gives the ability to coordinate among SC partners (i.e., external partners, such as customers and suppliers) effectively (Ghiassi and Spera 2003; Zeleny 1996). Meanwhile, the communication between departments can be improved (i.e., internal partners, such as manufacturing and design) (Silveira et al. 2001).Technology helps information transfer from customers to manufacturers for developing customized products (Anderson-Connell et al. 2002; Christopher 2000). With the efficient information transfer, customers can have what they want (Loker and Oh 2002) in a shorter lead time and at a comparatively lower price (Erens and Hegge 1994). Manufacturers are able to attain flexibility and quick responsiveness to changing market (Schwegmann et al. 2003). This is highly desirable in the fashion industry. Schroeder et al. (1989) reported that the fashion industry has not adopted technology as quickly as other industries. It is argued that the main reason is associated with its labor intensive nature. Moreover, costs, needs for technical support, and worker's technical literacy are the other reasons for non-adoption of technology. Moreover, the adoption of design and production technology in large firms is earlier than in small firms (Sullivan and Kang 1999; Kincade 1995). Interestingly, Loker and Oh (2002) found that small firms are significantly more likely to produce higher levels of customized products than larger firms although they may not fully engage in MC. Development in technology also increases the variability of MC strategy (Helms et al. 2008). The enabling technologies for MC are listed below:

Configuration system. A configuration system is a kind of software tool which guides the customers into a valid solution through the configuration process (Piller et al. 2004). Customers can specify the products and then configure products on their own (Andel 2002). Moreover, a configuration system helps orders to be transmitted for production automatically without intermediaries (Blecker and Abdelkafi 2006). A configuration system also plays an important role in the concept of co-design (Von Hippel 2001).

Internet/Email/E-commerce. The increasing popularity of internet facilitates the emergence of MC (Gunasekaran and Ngai 2005). It allows firms to involve customers in the design of MC products effectively because of rapid communication and ease to learn customer requirements in product features (Helms et al. 2008).

Firms can display their product offerings on their websites (Loker and Oh 2002). Also, customers can view the final prototype product online, like NIKEiD program. E-commerce is a vital means to support MC as buying and selling MC products and transmitting information can be done with the internet. External information, says customer preferences and feedbacks, can then be captured.

CAD/CAM. Computer-aided design (CAD) and computer-aided manufacturing (CAM) systems are considered as the primary tools to support MC (Piller 2007). On one hand, CAD enables the customer's design to be changed and deployed into production instructions quickly. On the other hand, CAM aims to maximize the use of machine with the effective handling in the diversity of parts ordering. In apparel pattern making, CAD/CAM allows the automatic alteration of patterns for individual body measurement specifically (Helms et al. 2008). Those systems alter the patterns automatically according to specific measurement data, without the permanent change in the original garment pattern. Unfortunately, Lee and Chen (2000) manifested that the compatibility between CAD systems and software and hardware systems from different vendors is still a challenging problem in the industry.

Body-scanning technology. With regard to fit customization, body scanning is a critical instrument. Body scanning captures customers with personal and an unlimited number of body measurement for apparel design and pattern drafting (Anderson-Connell et al., 2002). Lee and Chen (2000) claimed that this data collection method gives precise, accurate, and repeatable data in order to create specific garments as different styles of garments need different data points. Customers gain a unique shopping experience in this manner as well. The measurement information of customers can be stored in a central database for many other applications (Helms et al. 2008).

Product data management (PDM). PDM software keeps track of engineering data and documents for managing changes because MC products accelerate the rate of change in product engineering (Zeleny 1996). Hence, it can control the product development and production process in an effective manner as the complexities in managing varieties and volumes of data on MC can be greatly minimized (Pan and Holland 2006). Additionally, it is a common platform for design and production teams to integrate and access the information for MC (Alford et al. 2000).

Apart from the above technologies, other technologies, such as, made to measure software, digital printing (Anderson-Connell et al. 2002), single ply cutters (Lee and Chen 2000), enterprise resource planning (ERP) system (Gunasekaran and Ngai 2005), and electronic data interchange (Silveira et al. 2001), are prominent in the implementation of MC.

2.6 Classifications of Mass Customization

Several authors classified MC with regard to different factors, such as customer involvement, modularity, type of process, and technology. Moreover, some of the scholars identified different levels of MC based on empirical observation. Let us review some of them as follows.

First, Duray (2000) demonstrated an MC typology based on two important identifiers, point of customer involvement in stages (i.e., design, fabrication, assembly, and use) and modularity, and suggested four MC archetypes – fabricators, involver, modularizers, and assemblers — in order to distinguish the level of MC strategies being used by firms. "Fabricator" is similar to pure customization strategy but employing modularity to gain commonality of product as both customer involvement and modularity occur during the design and fabrication stages. Hence, unique products can be created. When customer involvement appears in the design and fabrication stages but uses modularity during the assembly and delivery stages, it is called "involver" as no new modules are made for customers. The third type is "modularizer" which involves customers in assembly and delivery stages but uses modularity in design and fabrication stages. Customers do not specify their requirements until the assembly and use stages. Assembler is found when both customer involvement and modularity occur in the assembly and use stages. In this manner, products have been designed and customers are involved only in specifying the products.

The second classification is suggested by Gilmore and Pine (1997). They identified four customization levels based on empirical observation – collaborative, adaptive, cosmetic, and transparent customization. In collaborative customization, a firm establishes a dialogue with each customer so that his/her respective needs can be identified. Precise and customized products are then offered to customers. Adaptive customizer designs a standard product to customer, but he/she can alter it himself/herself. For cosmetic customization, one standard product is given but presented differently to different customers by methods such as packaging. Transparent customizers offer unique products to individual customers without letting them know explicitly that those products and services have been customized for them.

Lampel and Mintzberg (1996) defined a continuum of five MC strategies based on the configuration of process, product, and customer interaction in the production cycle. The first strategy is "pure standardization" which is similar to mass production due to the use of standard parts and manufacturing procedures without customer involvement in design. "Segmented standardization" offers a few choices on a basic product without customer involvement in design. In "customized standardization," customers can affect the assembly and distribution of product, but not in design and production. Products are manufactured on the basis of standard and mass-produced components. "Tailored customization" is defined as customizing fabrication, assembly, and distribution. Manufacturers still control over design, but may modify the design to meet customers' need. When customization can be found in every design, fabrication, assembly, and distribution step, it is called "pure customization."

Anderson-Connell et al. (1997) created a model for apparel MC specifically. They found that digital information technology applied in the manufacturing process leads to four options of customizing apparels. In "expanded search," each customer is able to access different manufacturers' product lines with intelligent searching capability. The next level is "design option" which means customer designs a garment in the modular selection through CAD. The other level, "co-design" offers fit customization with the help of managers, based on the choices of "design option." Finally, "total custom" enables customers to create a totally customized garment with the use of computer technology.

2.7 Performance Measures

In order to measure the performance of MC, time-based performance measures (e.g., days in inventory, work-in-process, delivery time, order response time), instead of financial measures (e.g., sales volume in dollars or pieces, profitability), are the preferred benchmarks (Loker and Oh 2002; Chandra and Grabis 2004c). The reason is because financial measures are usually biased against the size of firms. In Tu et al. (2004b), the performance in terms of MC capability, which is the ability of a firm to manufacture products that meet a variety of specific customer requirements quickly at a cost that is comparable to MP products, is studied. They stated that customization cost effectiveness (producing customized products without increasing cost significantly), volume effectiveness (enlarging product variety without diminishing production volume), and system responsiveness (reducing the delivery time and reorganizing production processes quickly in response to customization requests) are the major components of MC capability. They further showed that three of the manufacturing practices (re-engineering set-ups, preventive maintenance, and cellular manufacturing) enable firms to increase MC capability. Moreover, these manufacturing practices tend to have a greater impact on MC capability when environmental uncertainty is higher. Tu et al. (2001) also verified that time-based manufacturing practices (including shopfloor employee involvement in problem solving, reengineering setup, cellular manufacturing, preventive maintenance, quality improvement efforts, dependable suppliers, and pull production) have a direct impact on MC capability. Additionally, positive relationships have been found among customer closeness, modularity-based manufacturing practices (dynamic teaming, product modularity, and process modularity), and MC capability (Tu et al. 2004a).

Mchunu et al. (2003) suggested five variables to characterize MC capability. Those variables include effective product variety management, communication and information management efficiency, support from top level management, SCM efficiency, and new product development ability. These measures, though relatively intangible, provide another framework for studying the performance of MC.

2.8 Challenges of Mass Customization

We follow Blecker and Abdelkafi (2006) and discuss the challenges of MC in two dimensions as follows.

2.8.1 External Complexity

Svensson and Jensen (2003) stated that customer is the major, but also the limiting, factor in pursuing MC. As a wide range of product varieties are available in MC, customers are often confused. They are easily overwhelmed by the product selection process. Finally, they may be incapable of deciding what they want (Zipkin 2001). Blecker and Abdelkafi (2006) indicated that limited information processing capacity of humans, lack of customer knowledge about the product, and customer ignorance about his/her real individual needs are the main factors of external complexity. In order to reduce external complexity, firms require a solution to understand the needs of customers. They hence suggested that a configurator (i.e., configuration system) can help in this situation. Nevertheless, Piller (2007) reported that few firms have used configurators in MC in reality.

2.8.2 Internal Complexity

Employee. In the exploitation of MC, trained salesperson is an important issue (Lee and Chen 2000). In the customization process, a salesperson should identify the customers' needs and help them configure their own products. Taylor et al. (2003) indicated that having salespeople equipped with knowledge and skills is a way to gain the customers' trust and confidence to buy an MC product. However, retail industry is always characterized by having a high turnover rate of salespeople. Investment in training salespeople hence becomes a barrier in MC (Svensson and Jensen 2003). MC induces the proliferation of product variety (Aigbedo 2007) and hence, increases the complexity of operational and manufacturing related tasks (Blecker et al. 2005). Ahlstrom and Westbook reported that operational problems such as higher inventories and high manufacturing costs are evoked by MC (Ahlstrom and Westbrook 1999). Instantaneously, MC increases planning and scheduling and SC performance pressures as customers require quick delivery (Aigbedo 2007). It is the reason why effective SCM is needed so as to manage the inventory well. It is a relatively simple concept, but not easy to implement in reality.

Specification. Defining and configuring product variants is a big challenge in MC as different departments may have totally different specifications towards one product (Andel 2002). For example, information for production may be interpreted incorrectly and delivery time may be delayed. Consequently, customers may not be satisfied with the end products (Lee and Chen 2000).

Changes. Broekhuizen and Alsem noted that the requirement for a change in existing business models is the fundamental reason for the low adoption rate of MC (Broekhuizen and Alsem 2002). In particular, MC involves changes in systems, manufacturing processes, organizational structure, and SC structure in order to respond to individual orders (Pine 1996; Caddy et al. 2002). However, the changes can be costly, time consuming, and demanding (Piller and Muller 2004). Meanwhile, MC must be periodically evaluated and amended for the sake of market changes, nature of business, competition, and technology (Pine et al. 1993). More challenges in MC are exhibited in the works of Eastwood (1996), Alford et al. (2000), Knolmayer (2002), and Svensson and Jensen (2003).

3 MC in the Fashion Industry

A recent survey by Fedex Corp. on the apparel industry reported that more than 90% of the respondents had agreed that MC would play a more important role in the near future (Piller and Muller 2004). According to Kurt Salmon Associates Annual Consumer Outlook Survey for [TC]^2 (a leading research and development, and education firm for the sewn products industry), there are three varieties in the apparel MC, namely (1) personalization, (2) fit, and (3) design (Ives and Piccoli 2003; Sussman 1998). In apparel MC, customers can order mass-produced products and then customize them based on their own preferences (personalization). They can also provide individual body measurement for creating products that fit them well (fit). Anderson-Connell et al. (1997) noted that “fit” is considered as the most critical issue in apparel MC. Each customer can take part in the design or coloring in the meantime (design). For MC, the fashion industry mainly focuses on dimensional and modular customizations (Lee and Chen 2000). In the dimensional (fit) customization, fit of products can be well-delivered to customers as the products are based on their body measurement. Firms acquire customers’ measurement data with various approaches, for instance, by body-scanning the customers (e.g., Brooks Brothers), requiring customers to enter measurement data into website (e.g., Lands’ End), or letting customers try on the prototypes and making alteration (e.g., Levi’s). The modular customization is also predominantly adopted in the fashion industry (e.g., JC Penney, Ralph Lauren). Customers can pick modules (e.g., components) and then create individualized products. Table 1 shows some MC practices in the fashion industry.

Notwithstanding that MC is not a new strategy in fashion industry, Loker and Oh (2002) argued that most fashion companies are not fully engaged in MC. Some firms have combined MP and MC for their business strategy. Besides, they showed that small firms are more likely to produce a higher percentage of customized products. Lee and Chen (2000) also mentioned that reducing cost is the foremost important objective in apparel MC, instead of fulfilling customers’ needs. In the present MC practice, the styles that customers choose are usually limited which are already within a broad style framework prescribed by the firms. In order to reduce costs, the pattern is always based on a “standard size” of the target customers, and hence adjustment of this pattern is required for fitting individual customer specification.

Table 1 Brief descriptions of MC examples in fashion industry

Examples	Brief descriptions
Proper cloth propercloth.com	Proper Cloth was founded in 2008 and its headquarters is located in New York. This company offers high-end customized men's shirts. Customers can first choose fabric pattern, color, collar style, cuff style, and pocket. Next, customers can provide body measurement with three options: (1) Standard sizing (select from S to XXL and type of fit), (2) selecting the similar brand sizing (which is a kind of reverse engineering as customers can specify their shirt's size by selecting another shirt's size they like) (3) entering body measurement into website (e.g., neck around, arm length, shoulder width, chest around). The advanced 3D modeling software allows customers preview their own customized garments. All shirts are manufactured in the US factory.
Beyond clothing beyondclothing.com	Beyond Clothing is a manufacturer of customized outdoor apparels (BeyondFleece.com) and protective combat uniforms (BeyondTactical.com). It offers more than 100 items, for example, pullovers, shorts, vests, pants, and fleece jackets. Customers can order products online or by phone. Beyond Clothing allows customers select fabrics and colors among the preset options. Customers can also add features and components (e.g., pocket, hoods, zippers, and enhanced components) on their own products. In particular, customers can submit sizing information and their own preferences so as to produce best-fit products. The computerized pattern maker software then analyzes the information and changes pattern to accommodate the measurement. The automated cutting system is employed to cut the pattern precisely. Lastly, the garment is hand-sewn by a trained sewing worker. All the products are made in the US. With the help of configurator, customers can preview the final customized product virtually. Tracking order status is also allowed on the website. The lead time is around 6 weeks.
JC Penney jcpenney.com/custom	JC Penney (JCP) currently offers four products – jeans, khakis, dress shirts, and dress trousers for men to customize. Take customized dress shirt as an example, customers can choose one style among several options, for example, collar style, sleeve length and its style, and pleat style, to build their own shirt. JCP's MC is similar to Lands' End – partnering with ASI. Each product will be delivered to customers in approximately 4 weeks.
Zazzle.com	Zazzle gives more than 360 products online for MC, like apparels, accessories, and ties. A wide variety of fabrics, colors, and styles are offered. However, fit customization is not provided, so customers

(*Continued*)

Table 1 (Continued)

Examples	Brief descriptions
	should choose from the given standard sizes. Customers can upload photos or texts onto website and then create their own products. MC of Zazzle enjoys a high degree of automation. Zazzle has instant communication so order information can be transmitted to the production floor promptly. The data, material, production flow, printing, quality assurance, packaging, and shipping are automated. In the production department, Zazzle uses only direct-to-garment in-jet printers driven by centralized software. This printer is networked and highly automated (Murphy and Shuler 2007). In order to ease the online design process, Zazzle uses the web-based configurator called Ajax. This configurator preloads web content so that users can change text, crop and move pictures, and add multicolored borders immediately (Barret 2006). The final customized products can be previewed. Zazzle is the first company in the industry to offer on-demand embroidery with advanced system. Customers are able to preview the embroidery designs in real-time through 3D Zazzle's innovative Stitch Player (Zazzle's official webpage 2008). To develop MC, Zazzle has more than 250 partners, including Walt Disney Co. Images (DeWeese 2005). Zazzle also partners with technology company called Pitney Bowers in order to manage the information flows, mails, documents, and packages for Zazzle (Zazzle's official webpage 2008). Social networking is important in the success of Zazzle. Zazzle has cooperated with Facebook. Users can design their own products on Zazzle and make them available for sales in Zazzle. Moreover, users can promote them on Facebook (Zazzle's official webpage 2007). Integrated with My Space, a social-networking unit, Zazzle enables musicians with My Space pages to create virtual stores for t-shirts, posters, and other merchandise in Zazzle. With the use of artwork and graphic, their fans can customize them in Zazzle. (Smith 2007).
Ralph Lauren ralphlauren.com	Ralph Lauren (RL) is now offering a wide variety of customized products (e.g., polo tee, tie, dress, and robe) for men, women, boys, girls, and also babies online. Customers can select fabrics and pony-logo colors among the available options. Customers can preview the final products in a real time using an advanced configurator. RL promises customers that their products will be delivered within 1 week. In between, customers can track the orders on the website. Apart from online ordering, RL also gives customer the ability to customize purple label and Polo Ralph Lauren shirt and suit in selected stores. Trained sales associates measure customers manually and customers are able to select from 50 exclusive fabrics (Nygaard 2006), cuff and collar styles for creating personally fitted shirts and suits.

(*Continued*)

Table 1 (Continued)

Examples	Brief descriptions
Ascot Chang ascotchang.com	Ascot Chang (AS) is a Hong Kong-based high-end tailoring shop and has branch shops in the US, China, and Philippines. AS permits ordering MC shirts by mail, fax, and also in stores. Customers are measured by trained tailors in stores whereas they enter measurement data onto web site for online ordering. Customers create their own shirts from a combination of fabrics, collar and cuff style, pockets, pleats, and monogram. Some pictures of components or styles are not shown as a real product (i.e., computerized drawing only). The final customized product cannot be shown (i.e., can preview separate component or options only). AS takes approximately 3–5 weeks to process customers' orders.
Café press Cafepress.com	Café Press gives more than 50 types of customized apparel products (e.g., tracksuit, hoodies, underwear, and t-shirt) for men, women, kids, as well as babies. Customers are able to choose fabric colour and size (i.e., standard sizing). In addition, photos and images can be uploaded so as to create their own products. The instant preview of final customized products and order tracking service are provided. All the products are produced in the US. The lead time is around 2 days. Similar to Zazzle, customers are able to open virtual shops in Café Press for selling their own designed products.
QVC qvc.com/customfit	QVC is one of the largest multimedia retailers in the world. QVC provides customized jeans and twills online. MC of QVC is done in the same manner as Lands' End and JCP – partnering with ASI. Customers can pick up the choice in fabric type, colors, and features (e.g., rise, fly, back pocket, and leg style) and enter body measurement and ask self-assessment questions for making their own product. However, the virtual preview of final product is not available (customers can preview the choice in text format only). Customer is able to track order status online.
Interactive custom clothes company (IC3D) ic3d.com	Interactive Custom Clothes Company (IC3D) offers customized jeans and pants to both men and women. Customers can select fabric, color, leg style, ankle style, waist style, loops, pocket types, fly, trimmings, label, and thread color. IC3D relied on Genetic Engineered Neural Network (GENN) to make customized patterns in short time. GENN is a neural network which uses genetic algorithms. With the use of non-linear multi-variable solution, searching and sizing algorithm that chooses from and alters pre-existing patterns can run quickly. IC3D enjoys a higher degree of automation in production as the production and inventory replenishment processes are highly automated. All pre-production decisions and marker making are done by computer. However, sewing, finishing and shipping are carried out manually. Besides, customer service is computerized because adaptive behavior over the internet is provided by GENN. All the products are made in the US.

4 Traditional MC and Innovative MC

It is known that different industries would adopt different kinds and levels of innovation in MC (Zipkin 2001). As our focus is on the fashion industry, we will make use of the respective industrial cases for our discussions. In this section, we first define and compare the traditional MC and the innovative MC with four factors – supplier relationship, customer involvement, modularity, and technology. Next, we would discuss five cases of MC in the fashion industry. The five case studies, including Levi's, GS Company, Brooks Brothers, Lands' End, and Nike, illustrate how those companies implement MC in the traditional and innovative ways. Nine MC examples in fashion would also be discussed briefly in this section. All information is collected from primary (interviews and field visits) and secondary data (from published works and the internet) sources. By investigating the above factors in each company, we would then classify the "traditional" and "innovative" MCs.

4.1 Traditional Mass Customization

For traditional MC, it relies on a high degree of manual procedures during the MC process in order to provide a wide range of products to satisfy individual customers. Technology may be less useful in this kind of MC. In the following, Levi's and GS Company are regarded as examples of the traditional MC.

4.1.1 Levi's

In 1994, Levi's introduced "Personal Pair" (PP) program for women to customize their own jeans (Hill 1998). For creating this program, Levi's increased the number of sizes by two orders of magnitude from about 40 to over 4,000 (Pine 1998). The lead time was around 3 weeks (McCann 1996). Jeans under PP just costed customers about $10 more than a pair of off-the-rack jeans (Cuneo 1995). Owing to the success of PP, Levi's then expanded this program for both women and men later, and renamed the program as "Original spin" (Hill 1998). More options were available to the customers (Corcoran 2004). However, these two MC programs were considered as cumbersome, customer-annoying and obsolete in certain extent since customers should visit the store, be measured, and try on several pairs of stock jeans (Zeleny 1996). Later on, Levi's stopped this program. Although Levi's was trying to set up the body scanning in 2005, such data were only used to match customers with the best-fitting jeans in stocks, instead of custom-making any product (Ammenheuser 2008).

Technology. A degree of manual procedure was utilized in Levi's MC. In the PP, customers had to visit the stores for buying customized products, instead of online ordering. In the stores, women would use a kiosk computer system with the help of a trained sales associate to design (i.e., co-design) a pair of jeans (Hill 1998;

Carr et al. 2002). Manual measurement was necessary in this program. The sales associates would take four measurements (i.e., waist, inseam, hips, and rise) from each customer and then enter those data manually into the kiosk (Pine 1996). Next, computers would suggest which of the four prototype jeans would fit best from 400 prototype pairs that were stocked at the kiosk (Ederer 1995; Business Wire 2000). Customers should try on the physical prototypes and then modify the fit based on their preferences (Lee and Chen 2000). In addition, customers were able to decide the color/finish and style of leg cut (Carr et al. 2002). Finally, sales associates would enter the information into the computer and the order would be transmitted by email through modem from the kiosk to Custom Clothing Technology Corp., the software provider of PP, where it would be logged in and transmitted daily to Levi's factory for production (Hawley et al. 1997). In the factory, a pattern would be generated and cut using laser technology. The sewing team would then construct the jeans (Ederer 1995). To facilitate the repurchase, a bar-code label was sewn into the labeling of each personalized pair jeans (Ederer 1995). Simultaneously, those jeans could be tracked through the factory and sent to the correct customers (McCann 1996). Besides, Levi's invested heavily in data warehouses and decision-support technology for the MC program in order to enhance the collection of point of sales (POS) data (Hill 1998).

Supplier Relationship. Levis' did not outsource its own production for MC, but set up own factory in Tennessee (Berman 2002; Carr et al. 2002). Each pair was individually cut, hand-sewn, inspected, and packed for shipment in this factory.

Customer Involvement. According to the classification scheme in Duray (2002), customers were involved in the assembly stage in Levi's MC programs. In PP, customers had five options on colors/finishes and two more on leg cut - boot-cut and tapered legs (Carr et al. 2002). Levi's provided more choices in the "Original Spin". Customers could choose among classic, low cut, or relaxed style, 18 colors and finishes, and leg or fly preference. Fit customization was also allowed. All in all, customers could create own jeans by assembling those components.

4.1.2 GS Company (http://www.blablabra.com/)[1]

Godsend Trading Company (GS) is one of the companies which exercise MC in Hong Kong (in the context of B2B). This company engages in lingerie business. In Hong Kong, GS targets at the young market with the line called "Bla Bla Bra." Apart from trading and retailing, GS also manufactures lingerie with private labels for oversea markets. MP, (craft) customization, and MC are also used in this company. For MC, this company sends lingerie designs to customers and allows them to modify designs, for example, changing the style of shoulder straps or accessories.

[1]This company case is based on a personal interview with the company. We are grateful for the information provided by GS.

Technology. GS depends on hand-drawing (no CAD/CAM) for lingerie designs. Physical prototype will be sent to customers for previewing the customized products. Owing to a lack of technological support, virtual prototype cannot be provided. Digitalized information is limited. GS mostly uses technology for communication, instead of the automation of MC process. The order information is entered manually. GS simply transfers data and information by email. Email and face to face discussions are the most important communication means. There is no system linking GS with manufacturers or customers. GS also uses bar-code to track the products. To conclude, email, internet, database (for storing customers' information) and bar-coding are the technologies that GS mostly used.

Supplier relationship. GS outsources most of the production processes, including fabrication, dyeing, finishing. However, long term partnership with suppliers is absent because GS is cost-oriented in supplier selection. No information would be shared between GS and suppliers.

Customer involvement. Apart from craft customization, GS sends its own lingerie designs to customers and allows them to modify designs, like changing the style of shoulder straps or accessories (a kind of MC). Customers can change the components from the given material lists. Therefore, customers are involved in design, fabrication, and assembly stages according to Duray (2002). As GS markets the young lingerie market with the brand called "Bla Bla Bra," it exploits the POS data in order to develop MC and MP.

Modularity. Product modularity and process modularity are employed in GS. The products of GS employ modularized design. Although some technical problems may hinder component sharing (e.g., narrow shoulder straps can't support the bras with large cup size), GS commented that most of the components (like shoulder straps, laces, and accessories) could be shared across the products actually. For the process modularity, the production processes in GS can be rearranged and added easily for changing production needs.

4.2 Innovative Mass Customization

To compare with the traditional MC, some manual operations are replaced by automation in the innovative MC. The contribution of automation is based on partnership, extensive use of technology, modularity, and of course, customer involvement so as to deliver more variety of products to fulfill customers' needs. The idea conforms to Silveira et al. (2001): "MC as a system that uses information technology, flexible processes, and organizational structures to deliver a wide range of products and services that meet specific needs of individual customers, at a cost near that of mass-produced items." The case studies of Brooks Brothers, Lands' End, and Nike show that they pursue MC in an innovative way.

4.2.1 Brooks Brothers

In Brooks Brothers (BB)' MC program, customers can customize their own products (e.g., suit) based on individual fit and preferences (Rabon 2000) both online and in stores. In the beginning, BB had started from the traditional MC that heavily relied on manual operation. As time goes by, the degree of automation in the MC process is enhanced.

Technology. In the initial stage, BB focused on manual process as stores were required to fill out and mail to Pietrafesa Corporation (a Liverpool, NY based manufacturer of private label suits for many leading retail chains) the order forms with alteration information for MC (Rabon 2000). Eventually, data transmission could be done by an automatic computer system which is called "eMeasure." eMeasure has evolved into a kiosk system that allows customers to create and visualize the products. Sales associates assist customers during the process. They validate and enter the measurement information into the system. Following that, the system will suggest try-on prototype from the store's inventory. The orders will be finally sent to Pietrafesa Corp. automatically. The manufacturing process starts when Pietrafesa imports BB's orders from an internet site. After the customers' data have been collected, patterns and markers will be created by Pietrafesa Corp. based on Gerber technology's AccuMark Made to Measure (MTM) system (Stacy 1999) and Pietrafesa Corp. would assign work-in-process number and then allocate or order the necessary fabric. Patterns will be cut from the special ordered fabrics when the fabrics have been sent from suppliers. Simultaneously, the order information is uploaded to Pietrafesa's mainframe. The stock tickets, labels, production coupons, style file, bill of materials, costing information and sales order would automatically be generated. Apart from Gerber's AccuMark system, BB also added cutters, a UPS system, and Made-to-Measure (MTM) software for developing MC (Chelan 2007). The MTM system is a software that allows automatic modification of patterns according to customer's measurement. In other words, a pre-existing set of patterns with standardized alternation can be used. In order to have precise measurement data, BB employed a 3D body scanning tool called "Digital Tailoring" (2008), currently available in its flagship store in New York. The scanning process takes about 12 seconds with the use of white light-based scan (Haisley 2002). More than 200,000 data points will be captured and then created a 3D map of the body. In order to accommodate the individual customers tastes, sales associates can make some adjustments in the program accordingly. The measurement data will be transmitted to factory electronically in order to create patterns in a timely manner. In particular, such data will be stored in the database on a company's server for sharing and facilitating re-ordering processes. Moreover, online ordering of customized product is allowed in BB. With the advanced configurator, customers can create their own products step by step and can preview them virtually.

Supplier relationship. BB's MC relies on long term partnership with Pietrafesa Corp. and Gerber Technology (Rabon 2000; Chelan 2007, Stacy 1999). Essentially, suppliers are long-term partners with BB and Pietrafesa Corp. as the system is integrated between suppliers and them (Stacy 1999).

Customer involvement. Customers can create their own products, such as suits, dress shirts, and dress pants, from the given options. In BB's MC, customers pick up modules, for example, collar style, cuff style, pocket, and fabric types, to build products. For providing best-fit products, customers can enter their own measurement data onto the web site or visit the stores for body scanning. In other words, customers are involved in assembly stage for MC.

Modularity. For obtaining flexibility, process modularity is applied in BB. BB designs the program to be modular, which means the ordering process can be resequenced (Haisley 2002), e.g., customers can pick fabric first and then be scanned, or vice versa.

4.2.2 Lands' End

Lands' End (LE) offers shirts and pants (e.g., Chino, Jeans, and Corduroy) which can be customized in LE's website. Fit customization is also given. In order to implement successful MC, automation is found in LE. Ives and Piccoli (2003) reported that 40% of all jeans and chinos sold on the website are custom made in LE case. Essentially, a low return rate of customized products is reported.

Technology. LE provides fit customization with algorithms provided by Archetype solutions, Inc (ASI). As LE gathers the orders entered onto the web site, they will send the information to ASI electronically. Next, ASI software will process those data automatically (Drickhamer 2002). According to the customer's measurement data (weight and body size) and the answers of self-assessment questions (individual fit preferences), an electronic pattern would then be generated with the use of algorithms. After that, the pattern is drafted with the use of Gerber's PDF 2000 and made to measure programs and Nester software (Ives and Piccoli 2003). Software coders have automated all of these decisions. After that, the patterns would be transmitted to a contract factory in Mexico for production, where ASI has already installed its systems (McElwain 2001). Single-ply cutter would be used for cutting patterns (i.e., cutting one layer fabric each time). In the MC program of LE, modular manufacturing is employed (Drickhamer 2002). Bar-code would also be used for tracking products as well.

Supplier relationship. LE partners with ASI to develop MC. ASI can be regarded as a high-tech middleman that uses its MC system to link up retailers and manufacturers/contractors (McElwain 2001). For creating customized products, ASI pattern makers would develop base patterns, including allowances for the various styling alternatives, for each clothing line beforehand (Ives and Piccoli 2003). ASI also partners with the right manufacturers for developing MC (McElwain 2001).

Customer involvement. LE gives ability to customers to select colour, fabric, design, and also fit (Ives and Piccoli 2003) on the basics, instead of the fashionable items (Corcoran 2004). As customers pick up modules to build their own customized products, LE involves customers only in the assembly stage.

Modularity. Corcoran (2004) claimed that LE uses modular manufacturing techniques in MC. LE has modular lines to assemble each item, so the garment products are bundled and moved around the factory together.

4.2.3 Nike

Nike runs its famous MC program, which is known as NIKEiD. This program is popular as Nike's webpage showed that NIKEiD business has grown more than tripled since 2004. More than three million unique visitors are visiting www.Nikeid.com every month. Apart from running shoes, apparels (e.g., performance apparel and graphic tees) and gears (e.g., watches and bags) from two Nike's sub-brands (Nike Sportwear and Nike Pro) can be customized. Customers are able to order customized products online. In addition, design studios are also available in different countries (e.g., UK, USA, and China) so that customers can visit them and thereby design their own products. Besides NIKEiD program, Nike also provides Niketeam.com for providing customizing services on team uniforms and related gears. (PR Newswire 2001).

Technology. To facilitate online ordering, Nike has an advanced web-based configuration system and in-house developed and off-the-shelf software. This configurator and software help to transmit the designs automatically to manufacturing systems at Nike factories (Wilson 1999). In addition, customers are able to track the production status online. It implies that Nike's configuration system is actually linked with the manufacturing partners system. In the Nike design studio, trained sales associates also use this configurator (i.e., laptops are available to access Nike's website) to help customers to design and order customized products. Nike provides a virtual prototype to customers instantly. Nike develops MC using advanced technology. Recently, Nike is working with AKQA (a global interactive marketing agency) to let customers take pictures on their phones and then use multimedia messaging service (MMS) to send them to Nike Photo iD. Next, customers can enter unique design codes at nikeid.com to customize and buy them. In fact, the use of color re-cognition to create the service is claimed to be a world first technological application. As the visibility of information is important in MC, Nike has an ERP system for sharing information with its SC partners (Koch 2004). This application of ERP system is also integrated with supply chain planning software and CRM software. In such a way, Nike can share information up and down the SC with different parties effectively.

Supplier relationship. Nike outsources a large part of production, assembly, finishing, sales and distribution, and packaging to contractors, with only design and marketing kept in Nike (Password and Profile 2005). Although most of the tasks are outsourced, Nike believes in partnership. As mentioned before, Nike's configuration system is linked with their manufacturing partners. Thus, it is believed that Nike's MC program is based on partnership with suppliers. From Nike's webpage, it shows that Nike's business is built upon strong alliance with the SC partners.

Table 2 Traditional MC vs. innovative MC

	Traditional MC	Innovative MC
Supplier relationship	No partnership	Long term partnership
Technology	Limited use, relies on documentation. It results in a low degree of automation in MC process.	Extensive use of technology/advanced technology. It results automation in MC process.
Modularity[a]	Yes	Yes

[a]Here, we mainly focus on whether the company adopts product modularity. Modularity is essential for MC regardless of its innovativeness.

Customer involvement. Nike involves customers in the assembly stage. It is simply because Nike offers opportunity for customers to design own customized products from re-configurating components among the predetermined options, such as fabric color, sleeve style, embellishment, trim style, pants style, logos, and so on. However, fit customization is not provided. It means that customers should select from the standard sizing. In Nike's design studio, co-design is available. Customers can enjoy a 45 min private design section with the help of NIKEiD trained design consultants. The design consultants facilitate customers to design the products.

4.3 Comparison Between Traditional and Innovative Mass Customization

After we have defined the traditional MC and the innovative MC and reviewed some cases, we compare the features of the traditional MC and the innovative MC and summarize the key aspects in Table 2.

After we have described the above MC example cases, we further compare technology, supplier relationship, customer involvement and modularity of each company as follows (see Table 3).

According to our comparison, we then position MC of each company from the most traditional to the most innovative ones as shown in Fig. 1.

4.4 Remarks: New Models

Zafu (http://www.zafu.com/). Although Zafu.com does not allow customers to design their own jeans, it provides an innovative matching service for jeans. Zafu asks women shoppers 11 questions about their preference and then creates a body profile. This profile will be used to find out the best-fit jeans for customers from the database of hundreds of styles. Zafu would then link the customers to a retailer to purchase. Meanwhile, Zafu gets the commissions between 5 and 20% of each sale. Most important, customized jeans, like Indi Jeans, would also be featured in Zafu.

Table 3 Comparison in MC cases covered

Criteria/ examples	Supplier relationship	Level of customer involvement	Modularity	Technology			
				Measurement	Online ordering	Prototype (final customized product)	Information sharing
Levi's	Own factory	Assembly	Yes	Manual	No	Physical	Email
GS	Outsource No Partnership	Design, fabrication and assembly	Yes	No	No	Physical	Email
Nike	Outsource, Partnership	Assembly	Yes	Standard sizes	Yes	Virtual	ERP
BB	Outsource, Partnership	Assembly	Yes	Body scanning	Yes	Physical and virtual	E-measure
LE	Outsource, Partnership	Assembly	Yes	Algorithm calculation	Yes	No	ASI software
JCP	Outsource, Partnership	Assembly	Yes	Algorithm calculation	Yes	No	ASI software
QVC	Outsource, Partnership	Assembly	Yes	Algorithm calculation	Yes	No	ASI software

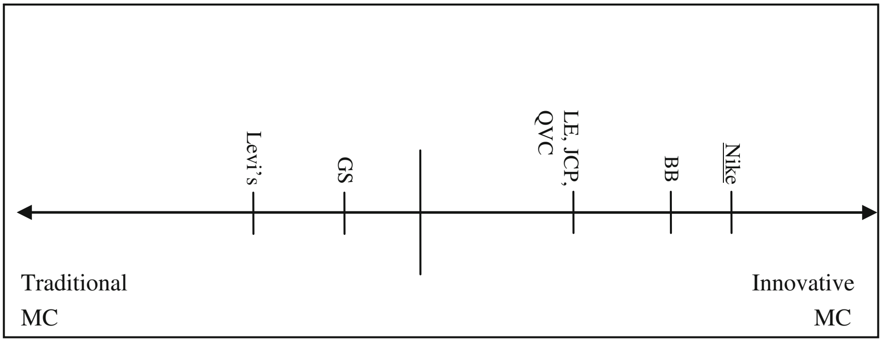

Fig. 1 Positioning of MC examples

My virtual model (MVM). My virtual model (MVM) is considered to help MC potentially (Guay 2003). MVM allows shoppers to create their own 3D virtual model to try on garments. On one hand, each customer can enter personal information, such as body measurements, heights, and weights so as to develop a personal avatar to try on the garment before she/he purchases (Nantel 2004). On the other hand, MVM produces 3D garments based on manufacturer's patterns and specification. In other words, customers can try on garments in a virtual world, instead of in-store fitting. Companies, like Lands' End, adidas, H&M are now employing MVM in their own websites for online shopping.

5 Recommendations and Conclusion

As a result of market turbulence and changing consumer behavior, MC has become a growing trend in the fashion industry. Good MC operations require the support of the whole related supply chain. From our analysis, apart from modularity and customer involvement, technology is a prerequisite for successful MC implementation. Technology, (for instance, configurators, CAD/CAM, Internet, body scanning, and product data management), helps coordination, communication, and information transfer in the MC program. In the fashion industry, MC focuses on dimensional and modular customization. However, most fashion companies have engaged in MC only in a limited extent. Most important, they usually aim at cost reduction, but not fulfilling customers' needs. Several published works in the literature have classified MC with different dimensions, such as customer involvement, modularity, processes, and technology. In order to measure MC performance, a time-based performance measure is one of the benchmarks (Loker and Oh 2002, Chandra and Grabis 2004c).

In this chapter, we have identified the traditional and innovative MCs with respect to supplier relationship, modularity, customer involvement, and technology. These four factors determine the degree of automation in the MC process. We have then revealed some MC practices and classified those cases into either the traditional MC or the innovative MC according to the degree of automation in the MC process. For implementing successful MC, we have the following recommendations:

1. Bar-coding system is employed in either the traditional MC or the innovative MC in the fashion industry. Companies mainly utilize this system for tracking products and storing (limited amount of) customer data. We suggest that MC companies in fashion invest in radio frequency identification (RFID) in order to improve the efficiency during the customization process. RFID helps to track the materials and products in an efficient way. For example, Dell, a pioneer in MC, tracks the processes using RFID and this tracking through the assembly line is linked to customer service systems and order website for tracing orders (Kumar and Craig 2007). Moreover, RFID is able to store a larger amount of customer data, when compared with bar-code. Schenk and Seelmann-Eggebert (2003) also manifested that RFID can contain information about customized working steps and specifications together with delivery date and distribution information. Documentation can also be reduced. It allows the ease of reordering customized products at the same time. In the reality, Ford Motor Co. employs RFID in MC. They use RFID transporters on every vehicle. Such transporters send query to database to find the correct paint code. After that, the system routes the information to a robot and selects the correct paint and sprays the vehicle. In this manner, vehicles can receive the right paint and features automatically on the basis of customers' orders (Greengard 2004). The above successful implementations of RFID are good evidence to support RFID's application for MC in the fashion industry.

2. With the advent of intelligent clothing, MC is not limited only to preference, fit, and design (see Sect. 2.1) but can be extended to functionality in the fashion industry. On one side, smart wearable electronic device (also known as e-apparel) gives a new direction in MC (Langenhove and Hertleer 2004). This type of wearable electronics allows the addition of some electronic components to increase the functionality of garments. For instance, Gap has offered a hooded jacket with built-in FM radio (Langenhove and Hertleer 2004). As the e-clothing is getting its popularity, functionality may emerge as one major issue in MC in the future. Customers can therefore customize the use of technology in their own clothes. On the other side, intelligent clothing is derived from smart materials and textiles. Langenhove and Hertleer (2004) identified that smart textiles are able to sense stimuli from the environment, to reach them and adapt to them by integration of functionalities in the textile structure. Smart textiles include, for example, shape memory materials (materials return to a pre-set shape with the right stimulus), phase change materials (a kind of latent heat-storage materials), thermochromic dyes (color changes with a change in temperature), and photochromic dyes (color changes after activation in visible light and invisible light) (Tang and Stylios 2006). With the use of smart textiles and materials, satisfaction of the changing customers' needs can be achieved to a certain extent; say, garment color changes with customers' moods. It appears to be similar to the MC objective – meeting specific customers' needs with a wide range of products. However, MC is still considered as a vital strategy and will not be replaced by smart technologies. The main reason is that customers can gain unique experience, like knowledge gained from design and configuration processes. Essentially, MC allows customers to satisfy themselves by designing/configuring their own products according their own preferences (i.e., an active way). It is different from smart textiles which accommodate customers' needs by reacting with stimulus (i.e., a passive way). However, if the smart technologies can be combined into MC, MC will become even more interesting (e.g., fit of garment changes with the body shape). We reckon that intelligent clothing (e-clothing or smart textiles) should be regarded as an extension of MC, instead of a replacement.
3. As we mentioned earlier in Sect. 2.2, MC generates outsourcing opportunities. The internet technologies have given possibility of crowdsourcing (Hintikka 2008). Crowdsourcing is an example in the market ideology of web 2.0 (Scholz 2008). Scholz (2008) stated that "Web 2.0 provides continually-updated service that gets better the more people use it, consuming and remixing data from multiple sources, including individual users, while providing their own data and services in a form that allows remixing by others, creating network effects through an architecture of participation, and delivering rich user experiences." For crowdsourcing, it utilizes the talent of the crowd as the job traditionally performed by employees can be outsourced to general public now (Scholz 2008). Innovative MC companies, like Zazzle, Café Press, and Nike, are adopting crowdsourcing principle as they allow customers submit and store the designs in database for selling. In this manner, it provides another way for company to gather customer information and feedback. Customer preferences can be

collected for developing MC program and the related products (Helms et al. 2008). At the same time, customer involvement can be enhanced because of customer participation in content contribution, and thereby, collaboration can be derived. In particular, crowdsourcing leads to a higher level of responsiveness and flexibility as companies focus on their own core competencies. It is one innovative feature of MC.

4. The present configurators, in both the traditional and innovative MCs, seldom give opportunity to customers to verify their own preferences. It has strong product orientation as it only provides components or modules and lets customers choose among them (Blecker et al. 2004). However, most customers are not well-equipped with product knowledge. It is especially true and important for performance and sportswear clothing (e.g., Nike and Beyond Clothing). Customized products may somehow not meet the customers' real expectations. Blecker et al. (2004) noted that "the language in which customers identify and understand their needs is completely different from the language used by engineers and product centered toolkits consisting of modules and components." Customers may find it hard to understand the product specific terms. For example, customers want to stretch easily with an MC product. In product specific term, it means using spandex while most customers do not fully understand its meaning. In order to exactly meet customer's needs, we should start from understanding customers' implicit needs. The system should investigate the customer needs, like asking open ended questions, and then match with the product components so as to create a customized product. To deal with this issue, Blecker et al. (2004) suggested a customer-oriented advisory system that guides customers with their profiles and requirements during the MC process. However, such an advisory system is still rare in practice especially in the fashion industry.
5. Implementing MC would imply changes in the organization (e.g., organizational structure and SC). As mentioned before, a change can be costly and time-consuming. A required big change may lead to employee resistance towards MC. One proposal which reduces the resistance is to implement MC program gradually. In addition, top management's support is important. As MC aims at satisfying customers, MC is regarded as a continual program as customer needs always change. Top management should create a culture that encourages employees to increase their capabilities and skill continually (Pine et al. 1993). Moreover, a diversity of employee capabilities is needed to deal with a greater product variety. In short, a robust change management program is needed for a fashion company to successfully implement MC.

For future studies, it will be interesting to explore how new technologies can further enhance the implementation and applications of MC. Moreover, an exploration on the degree of modularity adoption in both the traditional MC and the innovative MC is another promising extension of this paper.

Acknowledgements This research is partially supported by RGC(HK)-GRF under grant number of PolyU5145/06E.

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