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Challenges and critical successful factors for apparel mass customization operations: recent development and case study

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Abstract
Mass customization (MC), which is popular in the fashion industry, is proposed to provide customers with products with a high degree of adaptation and a price comparable to a mass product. Both the manufacturer and customers can benefit from it. However, how to properly apply the MC strategy when facing challenges in the real world needs more exploration. In this paper, we first review the related operations research literature. Then, we conduct a real case study of a fashion company adopting MC in China. We highlight the challenges and critical successful factors for implementing apparel MC. We identify important technologies in fashion MC systems. We also propose future research opportunities on MC operations in the fashion industry.

Keywords Mass customization · Literature review · Case study · Personalization · Fashion industry

1 Introduction

In 1970, Toffler creatively proposed an innovative idea which can meet the specified requirements of customers with cost close to that of standardized production in "Future Shock". A few years later, Davis (1997) named the proposed production mode as mass customization (MC) in "Future Perfect". This is deemed to be the creation of the idea of MC. Mass production means lower cost and huge production volume, whereas customization implies a higher degree of fitness and suitable. To reconcile the extremes of the different sides, MC is proposed to provide the customer with a product with a high degree of adaptation and a price comparable to a mass product.

The nation's largest living generation in US—millennials—is driving demand for customized products. Personalizers, as the YouGov survey calls them, tend to be millennials

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(40%), highly educated (30%) and have $1000 or more in monthly disposable income (31%) (industry week). When it comes to smartphones, tablets, notebooks and cameras, 86% of those we surveyed found customization appealing. Digital is changing the economics of manufacturing, and of course fashion industry. A Deloitte report noted half of consumers are interested in customized products and would be willing to pay more and wait longer if they could have an active role in design (Forbes.com), flexible models, analytics, automation, and adaptive supply chains are opening new doors to personalized manufacturing. According to an April 2018 YouGov survey, 26% of US consumers have personalized a product. Apparel and footwear (29%) as well as food and beverages (29%) were the most common categories for buying personalized items (emarketer.com). Nowadays, we are witnessing, across a wide range of domains, MC is no longer a fantasy, and it has become a reality that can be found in lots of industries especially in fashion. Quite a lot of companies apply MC as a strategy to attract customers either in bricks and mortar store or in online store. There are a number of well-known real-world examples, such as General Motors, Ford, and Toyota in automobile industry, and Nike iD, mi adidas, Puma, Lands' End, Louis Vuitton, Burberry and Brooks Brother in fashion industry including luxury brands and sport wear brands, as well as Proctor and Gamble in fast moving consumer goods (Selladurai 2004; Yeung et al. 2010; Liu et al. 2012). Nevertheless, not all MC stories had a happy ending. Many companies implementing MC failed such like Levi's (Yeung et al. 2010) while some others are still successful like National Bicycles Industrial Company of Japan, Hewlett-Packard, Motorola, Benetton, Chryslers, and Dell (Daaboul et al. 2012). Table 1 lists some well-known MC examples in various industries.

Table 1 Examples of MC programs

Industry	Company	Name of MC program	Product
Footwear	Nike	Nike ID	Shoes
	adidas	mi adidas	Shoes
	Puma	Mogolian shoes BBQ	Shoes
	Vans	–	Shoes
Apparel	Levi's	Original spin	Jeans
	Lands' End	–	Shirts
	JC Penney	–	Trousers
	Brooks Brother	–	Shirts
	North Face	–	Fleece jacket
	Ralph Lauren	Create your own	Polo shirt
Luxury	Louis Vuitton	Mon monogram	Handbag
	Bulgari	Design Your Love	Jewelry
	Cartier	Customise your watch	Watch
	Burberry	Burberry Bespoke	Trench coat
Automobile	BMW	Build your own	Car
	Audi	Customise your Audi	Car
Computer	Hewlett-Packard	–	Computer
	Dell	–	Computer
Electrical equipment	Haier	COSMOPlat	Household Electric Appliances

Both MC product and MC service, are necessary to identify opportunities for customization that create value for the customer, and achieve a manageable cost for the producer even though an MC system would increase the manufacturing complexity. Broekhuizen and Alsem (2002) present factors fostering the introduction and the development of MC may be divided into internal (which relates to the company's characteristics) and external (which includes the customer, the product, the market and the trade). Chandra and Grabis (2004) classify factors that determine the emergence and the development of MC, i.e., the customer's tendency to bear additional costs and involvement in MC process, as well as the willingness for the longer production and delivery time of MC product; susceptibility of the product and processes to customization; competitive market characterized by a high variability of customer requirements; the readiness of companies operating on the analyzed market to adapt new solutions and undertake competitive struggle, as well as to share knowledge inside own chains of creating value. Fogliatto et al. (2012) identify six success factors of MC, including customer's demand, markets, value chain, technology, Customizable offer, and knowledge. In general, modularization and standardization of product platforms, production postponement strategies, and customer interaction are regarded to the key success factors.

We aim to address the following research questions in this paper: (1) What are the present main research domains in the literature of MC in the fashion industry and what are the related research findings? (2) How does a fashion manufacturer apply MC and what are the challenges in practice? (3) What are the important technologies in the fashion MC system? (4) What are the future research opportunities for applying MC in fashion industry? To achieve these, we firstly review the related literature and discuss the application of MC in the literature. Afterwards, we proceed to conduct a case study on Kurtsmart Co., Ltd. (KM) to investigate the implementation of fashion MC in real practice. We choose KM as the real case study as it is one of the largest fashion manufacturers adopting MC in China. The in-depth analysis of KM's practice could draw a vivid picture of fashion MC adoption. We would like to know how to determine the best MC strategy or even if such a strategy should be adopted. The solutions for the most challenging problems can be found to be a guidance for other companies as well.

To the best of our knowledge, this is the first paper in the literature that focuses on systematically revealing recent challenges and critical successful factors for apparel mass customization operations from the manufacturer's perspective, consumer's perspective and the supply chain's perspective. Moreover, this paper includes a real MC operations case study in the fashion industry and the practical challenges of apparel MC systems are examined.

The rest of the paper is as follows. We conduct the comprehensive literature review in Sect. 2. Section 3 presents the insights derived from the case study on KM. We then discuss the key factors influencing fashion MC implementation in Sect. 4. Finally, we conclude the paper with the future research opportunities in Sect. 5.

2 Literature review

Being a new frontier in business competition for both manufacturing and service industries, MC can benefit both the manufacturers and the consumers. In the following, we review the MC-related literature from the perspectives of different supply chain members, namely: the manufacturer, the consumer, and the MC supply chain.

2.1 MC from the manufacturer's perspective

In this sector, we focus on the various MC strategies adopted by the manufacturer, including the settings of MC, MC production process and the required technology.

2.1.1 Modularity

Modularity refers to the modules that the product is decomposed to and reassembled as the final product according to the customers personalized requirements. Product variations in most industries tend to be numerous and firms often find themselves difficult to determine the products' variety and hence modularity level. It is the common cognition in theoretical literature that modularity is the most crucial factor among the other factors in MC production (Modraka et al. 2014; Liu et al. 2012). Based on the study of Chinese manufacturers, Wang et al. (2014, 2016) empirically explore the relationships among innovation, standardization (which related to modularity), MC capability, and delivery speed. The results show that these factors have strong relationships. Modularity has positive effects on innovation, and innovation positively affects MC capability individually and interactively with modularity. It is indicated from empirical case that modularity or modularization related to production is the key factor in MC.

Modularity is deemed to have influences on the products and process management. A large number of works have examined the modularity of products. Tu et al. (2004) study the relationship between product modularity and MC capability, and proposed a direct relationship between them. Antonio et al. (2007) propose a relationship between modularity and competitiveness. Ahmad et al. (2010) improve this result, and Inter-functional design coordination was found mediating the relationship between modularity and MC capability and is critical in fostering plant competitiveness. Poulin and Montreu (2013) propose a simulation-based methodology to configure a MC network, which focuses on the approach to create product models that include personalization details, the generation of demand profiles, and the creation of generic process routings for MC products. Wang et al. (2014) examine the effects of modularity in building MC capability, and finds that modularity mediates effects of customization knowledge utilization and business process improvement. Suginouchi et al. (2018) propose a decision making method to prepare modulus satisfying customers' demands by estimating their needs and establishing a production schedule with small tardiness.

It is observed that some of the MC programs in industry suddenly stopped or suspend. The main reason for the failure of majority mass customized applications and projects is an increasing overall complexity of the system while relevant solutions for the overall production complexity reduction are still missing (Bednar and Modrak 2014). Modraka et al. (2014) investigate the influence of modularity level on complexity of assembly processes, in the way of considering the base components and optional number of the complementary components. High level of customer requirements means higher modularity level, and the production environment will change rapidly, both of them induce complexity. Bednar and Modrak (2014) present the view that variety could induce complexities in assembly operations capability, and the impact of assembly variety on performance is also been examined. Zhang et al. (2017) investigate the effects of MC and product modularity on supply chain quality integration by conducting empirical research of global manufacturers, the results show that MC and product modularity improve internal quality integration directly, and product modularity also improves internal quality integration indirectly through MC. Usually, it is hard in MC to identify which features are essential, dispensable, highly required by other features, or highly in compatible with the remaining features. Heradio et al. (2016) propose an algorithm that takes into account of a sensitivity parameter to efficiently compute the measures using binary decision diagram

Refer to the process modularity, Modraka and Soltysova (2018) analyse the relationship between product modularity and process modularity, the results show that management of process architecture in MC might not be conducted in isolation from management of product development, and indicate that the impact of process modularity on effectiveness can be almost predicted based upon experience with traditional mass production.

2.1.2 Process/framework

Realization of MC requires not only the integration of the design process from an organizational perspective, but also the provision of the necessary contextual framework and the system integration architecture for product development (Tseng et al. 1996). Feitzinger et al. (1997) highlight that research and development must redesign the product so that it can be customized at the most efficient point in the supply network. MC processes can be divided into four stages, order elicitation, design, manufacturing, and supply chain coordination (Fogliatto et al. 2012). Ferguson et al. (2014) review references within the process frameworks of MC and to highlight opportunities for future development in MC, i.e. the customer's needs and preference assessment tools, approaches for requirement specification and conceptual design, insights from methodologies focused on the development of durable MC goods and enhancements in information mapping and handling.

Fang et al. (2016) examine the effects of organizational learning on process technology and operations performance in MC empirically, the results show that team and systems orientation learning can increase process automation and operations performance, learning orientation does not affect process technology and operations performance. Zhang et al. (2014) propose that organizational flatness is antecedence to MC capability and the supply chain planning and corporation coordination mediates the relationship between organizational flatness and MC capability. Ellena et al. (2018) propose a design framework for the custom-fit bicycle helmet models.

2.1.3 Technology

Apart from modularity and customer involvement, technology is a prerequisite for successful MC implementation. Been introduced for several decades, the paradigm of MC has largely not lived up to its promise, due to the technology of both production and information. Technology, (for instance, configurators, CAD/CAM, Internet, body scanning, and product data management), helps coordination, communication, and information transfer in the MC program (Yeung et al. 2010). Although MC is not a new concept, recent technological advances in several areas have made it more feasible, including the development of online marketplaces, mobile devices and platforms, virtual reality, CAD, RFID and 3D scanning system, body modeling, digital pattern design. RFID-enabled real-time manufacturing execution system for MC production is proposed in Zhong et al. (2013), which are deployed systematically on the shop-floor to track and trace manufacturing objects and collect real-time production data.

2.1.3.1 CAD In the literature, CAD is cited as a fundamental design technology for MC implementation (Ninan and Siddique 2006; Nielsen and Cox 2008; Ulrich et al. 2003; Yang et al. 2007). Bonev et al. (2015) create a consistent and formal approach for the design and MC of entire product families, which can make decision about a preferred solution (communication, synthesis and documentation) explicit and transparent.

Due to limited production speeds and other technological bottlenecks, 3D production is mainly applicable to small production volumes, customized products and/or high-value products (Berman 2012; Hopkinson et al. 2006). The integration of 3D laser scan with CAD systems received great attention in the MC literature in the past decade (Apeagyei and Otieno 2007; Au and Ma 2010; Daanen and Hong 2008; Fiore et al. 2003; Istook and Hwang 2001; Jensen et al. 2007; Luximon et al. 2005; Nielsen and Cox 2008), mainly on the clothing, garment, and shoes industries for virtual design and/or fit testing. Satam et al. (2011) study the economic factors leading to MC, and propose a new CAD system of 2D and 3D computer-aided garment intelligent design systems. Tao et al. (2018) propose a 3D garment collaborative design process with normalized sensory evaluation on garment fitting effects in a virtual environment, and integrates the interactions between the designer and the specific consumer and the communications of the concerned actors are enhanced.

2.1.3.2 3D printing Researchers has drawn attention to the large amount of application of 3D printing in industry, and the benefits of 3D printing have been explored in the literature. Gandhi et al. (2014) imply that 3D printing enables small quantities of customized goods to be produced at relatively low costs. Parker (2016) discuss the possible application of 3D printing in fashion. 3D printers could allow retailers to create and deliver products in small quantities in real time, Attaran (2017) state that 3D printing enables MC at low cost, shorter design and personalization time, as well as shorter manufacturing lead time.

In the last decades bulky and costly 3D body scanners evolved to inexpensive, accurate, and easy-to-use devices (Daanen and Psikuta 2018). In the online MC programs, customer should know the measurements of herself to submit the fit options of MC orders. However, not all the customers know exactly how to measure human body and hence the inaccurate data will lead to physical fitting impossible and of course many unsatisfied customers. 3D body scanning technology can make a more precise body data for both manufacturer and consumer, nevertheless, the cost is much higher and the device is usually not portable and online customers cannot experience it. Recently, research efforts have put a lot on the 2D–3D data transformation, i.e. use a 2D photo copy of customer to derive the real measurements data of the human body.

Many researchers propose reconstructive modeling methods, which uses less information to generate more information of the real body shape data. For example, Hilton et al. (2000) generate whole-body modeling of people from multi-view images, Wang et al. (2003) create a virtual human modeling from photographs for garment industry, and Anguelov et al. (2005) use partial scans to estimate the data. Hasler et al. (2009) and Guan et al. (2010) introduce a method for estimating the real body data by scanning a dressed human body.

Customer's cross-sectional 3D shape based on size features extracted from the customer's photos is predicted in Zhu et al. (2013), and 30 subjects with varied body shapes including male and female have been recruited to verify the model customization method. Ludwig et al. (2015) present an algorithm for morphing shape reducing the complex 3D shape and material morph into multiple simpler 2D morphs. Later on, Zhu and Mok (2015) present an intelligent two-phase method to customize 3D digital human body models based on two orthogonal-view photos of the customers, so as to create human body models for individual customers with precise body measurements and realistic appearance, which makes the measurement process more convenient for customers.

2.1.3.3 Virtual try-on system Yang et al. (2014) propose a virtual try-on system in augmented reality using RGB-D cameras for footwear personalization, the users can virtually try on 3D shoe models in a live video stream in the system. Virtual fitting which relates to uncertainty and cognitive dissonance can provide more information about the product than an e-catalog, therefore, virtual fitting can reduce the perceived risk. Consequently, Beck and Crié (2018) examine the presence of a VFR on a website, and argues that virtual fitting increases perceptual specific curiosity about the product and increase the online purchase intention.

Peng et al. (2011) identify four types of IT that potentially support MC capability, including product configurator IT, new product development IT, manufacturing IT, and supplier collaboration IT. Zawadzki and Żywicki (2016) try to explore the smart product design and production control for effective MC in the industry 4.0 concept, finds that the system must be capable of processing large amounts of data, which will be subjected to analysis, and make decisions related to the material flow. Zhang et al. (2015) examine the relationship between absorptive capacity and MC capability, and the results show that absorptive capacity significantly improves MCC, plus, knowledge sourced from customers and suppliers enhances MCC directly and indirectly. From a contingent configurational perspective, Sandrin et al. (2018) find empirical evidence to leverage high-involvement human-resource-management practices to develop MC capability, including push power, information, rewards, and knowledge down to the lowest level of an organization.

2.1.3.4 RFID The advance of mobile technologies, product tracking technologies (e.g., radio frequency identification, RFID), cloud computing, social media tools, enterprise systems, and business analytics applications have changed the way that fashion retailers operate. Big data is commonly used to describe the case when the amount of data is so massive that it is impossible for existing computing devices to effectively manipulate (Choi 2018). Retailers, not only fashion retailers, are now operating in the big data era. The advance of mobile technologies (Xu et al. 2014), product tracking technologies (e.g., RFID) (Basole and Nowak 2018), cloud computing (Nohadani et al. 2016), social media tools (Colicev et al. 2016), enterprise systems (Duan and Xu 2016), and business analytics applications (Cao et al. 2015) have revolutionized the way fashion retailers operate. Comments from consumers on the social media platforms (Facebook, YouTube, Twitter, Weibo, Wechat, etc.), which form a set of ''big data" would affect the fashion retailers regarding their beliefs towards the future demand (Choi 2018). Regarding to the production, manufacturer also need big data to support the production and operations management (Chan and Bennett Moses 2016) such as RFID and cloud service (Choi et al. 2017). The cloud service can be considered as a data warehouse which provides a useful source of data (Chaudhuri et al. 2011; Xu et al. 2009). Zhang et al. (2013) consider a dynamic workload scheduling problem with the help of big data stored in distributed cloud services. Wireless sensor networks (e.g., RFID) can be used to collect useful data ubiquitously (Gaukler 2011).

As applied in MC systems, RFID, cloud, and other technologies are widely observed (Wahlster 2014). For example, Liu et al. 2004 propose an RFID-Based Distributed Control System for Mass Customization Manufacturing. Chen et al. (2008) propose a manufacturing control framework based on RFID technology and a distributed information system to construct a mass-customization production process in a loosely coupled shop-floor control environment. Tu et al. (2009) create an agent-based control framework for mass customization manufacturing with UHF RFID technology. Duo to the inefficient scheduling caused by paper-based identification and manual data collection, Zhong et al. (2013) propose an RFID-enabled real-time manufacturing execution system. RFID devices are deployed systematically on the shop-floor to track and trace manufacturing objects and collect real-time production data. Apparel enterprises are transformed into the intelligent enterprises which can proactively perceive and respond the personalized demands of the large quantity of consumers, and realize MC by the social manufacture cloud service platform (Shang et al. 2013). Xu et al. (2016) propose a novel integrated solution to realize effective MC for customer-oriented product design in an intelligent computerized manner based on big data mining, in the system, manufacturing enterprises can adjust product design schemes keenly adapting with the specific requirements of a certain group of customers.

2.1.3.5 Flexible manufacturing and logistic system There is no doubt that the flexible logistic is important in the MC process. Manufacturing and distribution functions must coordinate both the supply and the redesign of materials and situate all manufacturing processes in the most efficient locations (Feitzinger et al. 1997). MC products are delivered through combining push and pull strategies to achieve a flexible manufacturing system. DeVor and Graves (1997) identify the main strategic dimensions of agile manufacturing as value-based strategies. In MC, the flexible logistics system can respond quickly to market changes related to customer demands for new products and product features (Da Silveira et al. 2001). Achieving this goal requires the establishing of reprogrammable, reconfigurable and continuously changeable production systems which can operate economically (Jagdev and Browne 1998). The agile manufacturing system allows customization to be completed without the associated higher costs, through an efficient use of flexible work force and virtual alliances (Hormozi 2001). Researchers have done lots of works within this domain. For instance, Helo et al. (2010) propose an integrated vehicle configuration system to facilitate customer order processing based on information from multiple domains in MC, and the model can enhance communications between different stakeholders involved in the order fulfillment process. Shang et al. (2013) investigate a social manufacturing cloud service platform for the MC in apparel industry. Liu et al. (2013) study the order allocation research of a logistics service supply chain in offering MC logistics services.

Table 2 summarizes the literature reviewed above.

2.2 MC from the consumer's perspective

Many companies launch MC projects in online stores, where the customers can design their own products by fulfilling the individual requirements, then the manufacturer can produce to order. MC application attracts the customer's attention, enhance the satisfaction and increase the intention of purchase. Coletti and Aichner (2011) conduct a survey to explore the customers' perceptions to MC. The results show that most of the customers are willing to possess personalized products, and price, time, and brand are the main reasons that have influence on consumer's MC decision. Moreover, as is showing in the survey that at least half of brand loyalty can be broken by MC companies provided price and quality remain the same. Park and Yoo (2018) investigate how benefits, attachment, attitudes, and loyalty intentions differed as a function of involvement and fashion innovativeness by conducting an online survey participated by 290

Table 2 MC-related literature from the manufacturer's perspective

Paper	Methodology	Aspects of MC	Details
Modraka et al. (2014)	Analytical	Modularity	Approach to create modules
Liu et al. (2012)	Analytical	Modularity	Optimal decisions of price, return policy and modularity level
Wang et al. (2014)	Empirical	Modularity	Effects of modularity in building MC capability
Wang et al. (2016)	Empirical	Modularity	Relationships among innovation, standardization, MC capability, and delivery speed
Tu et al. (2004)	Analytical	Modularity	Relationship between product modularity and MC capability
Antonio et al. (2007)	Analytical	Modularity	Relationship between modularity and competitiveness
Ahmad et al. (2010)	Analytical	Modularity	Modularity's influence on MC capability and plant competitiveness
Poulin and Montreu (2013)	Analytical	Modularity	Approach to create product models
Suginouchi et al. (2018)	Analytical	Modularity	A decision-making method to prepare modulus
Bednar and Modrak (2014)	Analytical	Modularity	Complexity measurement and management within assembly processes in MC productions
Zhang et al. (2017)	Empirical	Modularity	Effects of MC and product modularity on supply chain quality integration
Heradio et al. (2016)	Analytical	Modularity	Algorithm with a sensitivity parameter to efficiently compute the measures
Modraka and Soltysova (2018)	Analytical	Modularity	Relationship between product modularity and process modularity
Fogliatto et al. (2012)	Review	Process	MC processes
Fang et al. (2016)	Empirical	Process	Effects of organizational learning on process technology and operations performance in MC
Zhang et al. (2014)	Empirical	Process	Organizational flatness with MC capability
Ellena et al. (2018)	Analytical	Process	Framework design
Peng et al. (2011)	Empirical	Technology	IT types that potentially support MC
Zawadzki and Żywicki (2016)	Analytical	Technology	Smart product design and production control for effective MC in the industry 4.0 concept
Zhang et al. (2015)	Empirical	Technology	Relationship between absorptive capacity and MC capability
Sandrin et al. (2018)	Empirical	Technology	ERP, high-involvement HRM practices to develop MC

female online shoppers in South Korea. The results show that the perceived benefits associated with a customized product can lead to greater emotional attachment to that product, a more positive attitude toward the customization program, and ultimately high loyalty intentions.

At present, the application of MC has been attributed to the two factors of preference that is fit achieved (as high as possible) and design effort (as low as possible). Franke et al. (2010) induce the factor of the awareness of being the creator of the product design, and the result shows that self-designed products generate a significantly higher willingness for customers to pay. Moreover, this effect is mediated by feelings of accomplishment and moderated by the outcome of the process as well as the individual's perceived contribution to the self-design process. Collected information from 438 e-commerce customers in Bangkok, Tangchaiburana et al. (2017) investigate the elements of the MC website that influence the customer's participation in design process. The research shows that customization had a significance effects on customers' needs to design clothing types and to create co-design tools. Considering that providing efficient customization is not sufficient to assess the value of MC, Merle et al. (2010) evaluate the perceived value of the MC product and MC experience for individual consumers, the empirical findings show that MC value from a consumer viewpoint is polymorphous, and the value derived from the experience of co-design can have a positive influence on the overall value of MC. Supported by empirical evidence, Trentin et al. (2014) argue that two benefits (hedonic and creative-achievement benefits) increase as a sales configurator deploys, to a greater extent of the capabilities of focused navigation, flexible navigation, user-friendly product space description, easy comparison and benefit–cost communication. Kwon et al. (2017) propose from empirical evidence that a successful online consumer-customized experience can definitely increase a consumer's preference fit. Furthermore, it allows the customer to embed their sense of self and of course themselves into the customized products during the customization.

Puligadda et al. (2010) examine the role of idiosyncratic attribute evaluation in MC by conducting experiments, the results from three experiments show that offering greater variety in idiosyncratically evaluated attribute options could increase the consumers' satisfaction. As consumer narcissism is considered, Bellis et al. (2016) show that the uniqueness of MC products depends on consumer narcissism, consumers those are higher in trait narcissism should configure more unique products, and state narcissism can be primed via marketing communications to influence product uniqueness. Product customization potentially yields an increase in customers' perceived product value and, thus, higher willingness to pay (Franke and Piller 2004; Franke et al. 2009). Therefore, firms can charge a price premium.

Social technologies empower customers to broadcast their creations with friends and strangers online. As MC programs are becoming ever more common among luxury brands, like Louis Vuitton and Burberry, Yoo and Park (2016) seek to identify and examine the dimensions of consumers' perceived value in MC through a survey of female online shoppers in South Korea. The result reveals that hedonic, utilitarian, creative achievement (which is consistent with Franke et al. 2010), and social value influenced satisfaction with the customization, which in turn influenced brand loyalty. Moreover, the relationships between consumer value and satisfaction differed depending on the consumer's past loyalty and need for uniqueness.

Table 3 summarizes the related literature reviewed in this sub-section.

Table 3 MC-related literature from the consumer's perspective

Paper	Approach	Industry	Aspects explored
Coletti and Aichner (2011)	Empirical	–	Willingness of customers to compromise on the issue of suitability
Park and Yoo (2018)	Empirical	Fashion	Benefits, attachment, attitudes, and loyalty intentions
Franke et al. (2010)	Empirical	T shirt, scarf, cell phone	Awareness of being the product design creator
Kwon et al. (2017)	Empirical	–	Customer's sense mixed to MC process
Tangchaiburana et al. (2017)	Empirical	Garment	Elements of the MC website
Merle et al. (2010)	Empirical	Shoes	Perceived value of the MC product and MC experience for individual consumers
Trentin et al. (2014)	Empirical	–	Hedonic and creative-achievement benefits
Puligadda et al. (2010)	Empirical	–	Variety in idiosyncratically evaluated attribute options
Bellis et al. (2016)	Empirical	Car configuration	Consumer narcissism
Yoo and Park (2016)	Empirical	Luxury	Consumer perceived value, satisfaction, and loyalty
Franke and Piller (2004)	Empirical	–	Willingness to pay for product created by customer himself
Franke et al. (2009)	Empirical	–	Willingness to pay, purchase intention, and attitude toward the product than standard products

2.3 MC from the supply chain's perspective

As one of the core features is modular, another core feature of MC is postponement, which is defined as "an organizational practice of delaying the timing of the ending production or service processes, considering customers specific needs or requirements, allowing end products to assume their specific functionalities, features and identities" (Lee 1998).

2.3.1 Empirical research

In the perspective of MC supply chain, related works are both from empirical and analytical perspectives. Hong et al. (2010) suggest that lean practices can reasonably predict MC performance, E-commerce and e-procurement are reasonable predictors of MC performance in product manufacturers, while ERP is not. Qualitative study is explored in Brunø et al. (2013) to explore the links between MC and sustainability, and concluded that MC is either sustainable or unsustainable, but has indeed the potential to contribute to sustainability. Compared MC with generative customization relative to a consumer's ability and willingness to be involved in the conceptualization and fulfillment process, Buffington (2011) show that a crucial difference between MC and generative customization is the degree of elasticity regarding consumer involvement and sacrifice, and the degree to which a consumer's involvement can be virtually simulated alternatively in a generative design process. Companies need new supply chain management methods to convert materials into individually customized products (Smith et al. 2013), where more work is needed on integrated with mass production volume, cost, and efficiency, i.e. 'design-to-order', 'shared custom-module', 'just-in-time' and 'supplier'. Zhang et al. (2014) examine the effects of organizational flatness, coordination, and product modularity on MC capability, and results show that product modularity, cross-functional coordination and supply chain coordination contribute to MC capability development. Employed a stated preference survey and model, Yao and Xu (2018) provide a production selection strategy in dynamic environment and find out the most beneficial production strategy. Huang et al. (2010) investigate the role of organizational structure in facilitating the development of MC capability in various manufacturing settings, including flatness, centralization, and employee multi-functionality by empirical research, the results show that a positive relationship exists between the organic organizational structure and MC capability, and is moderated by mass customizer's type (full MC or partial MC). Liao et al. (2013) analyze the factors that influence Chinese automotive suppliers' MC capabilities, and suggest that the MC capability of a firm can be achieved by systematically coordinating suppliers, implementing modularity-based manufacturing practices, and postponing key production steps that determine specialized product features and performance. Theurer et al. (2014) examine the lean control for MC companies, induces workload control that integrates customer enquiry management, including a due-date setting rule, with order release control, the results show that workload control can reduce the percentage of tardy jobs and thus reduce and stabilize workloads. Liu and Deitz (2011) indicate that MC capabilities are driven by customer-focused product design and reduced supplier lead times, and these factors are driven by management's emphasis on supply chain planning. As uncertainty coherently, Liu et al. (2010) explore the influence of uncertainty on MC, and identified that individual demand and supply uncertainty management mechanisms that are likely to help a company achieve MC ability through reducing demand and supply uncertainties or their effect.

2.3.2 Analytical research

Loginova and Wang (2013) develop MC in an endogenous-timing game with vertical differentiation, the results show that MC by one or both firms occurs only if the quality difference is sufficiently large. Although the firm with higher quality is more likely to apply MC, in some circumstances the low quality firm can obtain an advantage by becoming the first and only firm to adopt MC. Xiao et al. (2016) develop game-theoretic models to explore the quoted delivery leadtime, price, and channel structure decisions for a make-to-order duopoly system under three game scenarios, the results show that decentralization of the supply chain increases quoted leadtime, and both manufacturers may choose different channel structures under symmetric duopoly. Hsu et al. (2014) propose a theory of competition and customization. When firms allocate their production to both custom-made and standardized products, the fraction of sales from the former will increase in the face of increased competition. Uncertainties are considered more in MC literature. Liu et al. (2015) establish a multi-objective program scheduling model of logistics service supply chain that considers the uncertainty of operation time for functional logistics service providers in an MC service environment. Lalmazloumian et al. (2016) create a robust optimization model for agile and build-to-order supply chain planning where uncertainties are considered.

Analyzing and processing information of customer preference, product features and cost, Xu et al. (2017) derive an MC decision support model to obtain the optimized production solution with genetic algorithm. Chod et al. (2010) investigate the value of flexibility in an MC system, including the procurement, assembly, and product pricing, finds that the effects of demand variability and correlation depend critically on the commonality structure the entire product line, and the degree of commonality between two products affects their optimal prices. Other works study the related problems in MC supply chain. Chiu and Choi (2016) review the works on supply chain risk analysis with mean–variance models. Feng et al. (2013) study the coordinated contract decisions in a MC manufacturing supply chain. In MC, the customers are expected to have a longer waiting time for the product, since the product is only produced until the order is placed. However, the long waiting time truly affect the customer's willing to MC products. Su et al. (2010) discuss the impact of delayed differentiation in MC system and find that it offers the potential of reducing the customer's waiting time. Under some conditions delayed differentiation results not only in shorter customer waiting time but also lower cost.

Guo et al. (2018) provide a comprehensive literature review on inventory management in MC operations. Mass customization has the potential to improve preference alignment regarding a specific purchased product, but at the risk of increasing brand dilution. In case of that, Çil and Pangburn (2017) suggest that the firm can offer reduced prices to consumers with extreme preferences, with a higher fixed price being offered to those consumers having more central preferences. Liu et al. (2015) employ a multi-objective programming approach to explore the problem and suggest that the logistics service integrator must clearly know what the optimization goal when making the optimal scheduling decision. Paul et al. (2015) study the inventory planning problem for a modular product family through the multi-product newsvendor model with budget constraints. Liu et al. (2017) build a time scheduling analytical model to study the problem of logistics service supply chain based on the time windows of the functional logistics service provider's operation and customer requirement.

2.3.3 Return and sustainability

Although majority of the MC programs do not offer return policy for customers, since the product is personalized for individuals and cannot be sold to others. To attract the potential customers and enhance demand, some brands allow customers to return the MC fashion product for a full refund minus a service charge, Choi (2013) examine the optimal return service charging policy for a fashion MC Program into two cases, risk-neutral and risk-averse MC companies, respectively. The results show that the level of risk aversion affects the optimal return service charge policy. Liu and Yao (2018) propose a resource evaluation method from a dynamic and integration process-oriented perspective in service MC, and examine the impacts of service firm's strategic renewals, as well as the operational decisions.

Piller and Blazek (2014) state three major strategic capabilities of MC, i.e. solution space development, robust process design, and choice navigation. Value of MC can be achieved via design of features, fit and comfort (e.g. 3D scanning), functionality which related to technical attributes of an offering (e.g. speed, power, and memory), as well as form and visual aspects (style, aesthetic design, color, style, and flavors). MC has become a major trend in the consumer goods markets, however, it is still unclear if MC goods have a positive impact on the environment due to the many influencing factors in comparison to mass produced goods. In order to draw the shape of the sustainable mass customized enterprise, Medini et al. (2012) provide insights on crossings between MC and sustainability, that sustainability enablers have impact on MC, and the link between customer involvement and design for sustainability becomes stronger when it comes to sustainable mass customized enterprise. Piller and Blazek (2014) examine the core capabilities of sustainable MC, states that configuration systems are playing a crucial role in meeting the particular demands of each individual customer and addresses the fundamental capabilities of sustainable MC are solution space development, the design of robust processes, and choice navigation. Trentin et al. (2015) empirically investigate the interconnectedness of MC and green management on the level of their enabling capabilities by case study, the results show that overlaps and path dependences exit between MC capabilities and green-management capabilities.

Guo et al. (2017) take a comprehensive consideration of consumer returns and salvage value together to study quick response MC supply chains. The authors apply game theory to study the coordination challenges. Choi and Guo (2018) use the newsvendor model to explore the value of quick response supply in fashion MC systems with consumer returns. They show that consumer returns can enhance the value of quick response supply to the fashion supplier, and quick response supply is also found to be helpful in reducing the environmental cost.

Tables 4 and 5 list the MC-related literature from the supply chain's perspective with empirical and analytical approaches, respectively.

2.4 MC in the fashion industry

To deal with the challenges of shortened product life cycle, while considering various trends and changing consumers' tastes and demands, MC is employed very common in fashion industry, and several works studies MC in fashion industry and luxury, where most of the research works put effects on the empirical studies.

Table 4 MC-related literature from the supply chain's perspective

Paper	Approach	Aspects of MC
Hong et al. (2014)	Empirical	Lean practices with MC performance
Brunø et al. (2013)	Empirical	Links between MC and sustainability
Buffington (2011)	Empirical	Difference between MC and generative customization
Zhang et al. (2014)	Empirical	Effects of organizational flatness, coordination, and product modularity on MC capability
Yao and Xu (2018)	Empirical	Production selection strategy in dynamic environment
Huang et al. (2010)	Empirical	Role of organizational structure in facilitating the development of MC capability
Liao et al. (2013)	Empirical	Factors that influence Chinese automotive suppliers' MC capabilities
Theurer et al. (2014)	Empirical	Lean control for MC companies
Liu and Deitz (2011)	Empirical	MC capabilities driven by customer-focused product design and reduced supplier lead times
Liu et al. (2010)	Empirical	Influence of uncertainty on MC
Piller and Blazek (2014)	Review	Core capabilities of sustainable MC
Medini et al. (2012)	Review	Links between customer involvement and design for sustainability
Trentin et al. (2015)	Empirical	Interconnectedness of MC and green management
Loginova and Wang (2013)	Analytical	Product vertical differentiation
Xiao et al. (2016)	Analytical	Quoted delivery leadtime, price, and channel structure decisions for a make-to-order duopoly system under three game scenarios
Hsu et al. (2014)	Analytical	A theory of competition and customization
Liu et al. (2015)	Analytical	A multi-objective program scheduling model of logistics service supply chain
Xu et al. (2017)	Analytical	MC decision support model to obtain the optimized production solution
Chod et al. (2010)	Analytical	Value of flexibility in MC
Feng et al. (2013)	Analytical	Coordinated contract decisions in MC manufacturing
Su et al. (2010)	Analytical	Impact of delayed differentiation in MC system
Choi (2013)	Analytical	Return service charging policy for risk neutral and risk averse manufacturer
Liu and Yao (2018)	Analytical	A resource evaluation method from a dynamic and integration process-oriented in service MC
Piller and Blazek (2014)	Analytical	Core capabilities of sustainable MC
Çil and Pangburn (2017)	Analytical	Portfolio design and pricing models

Table 5 MC-related literature from the supply chain's perspective with analytical approach

Paper	Objective	Channel agent(s) involved	Period	Decision variable(s)	Objective function	Key parameters	Risk concern?
Loginova and Wang (2013)	Profit maximization	2M	Double	Product variety, price	Profit	Product variety, quality	Risk neutral manufacturer
Xiao et al. (2016)	Profit maximization	2M, 2R	Double	Delivery lead time, price	Profit	Lead time, price, production cost	Risk neutral manufacturer, Risk neutral retailer
Hsu et al. (2014)	Profit maximization	Multiple M	Multiple	Customization scope, price	Profit	Price, cost	Risk neutral manufacturer
Liu et al. (2015)	Total expected time minimization	1M, multiple R	Double	Expected time	Cost, time, satisfaction	Service cost, punishment cost, expected time	Risk neutral manufacturer, Risk neutral retailer
Xu et al. (2017)	Profit maximization	1M	Single	Price, quantity	Profit	Customer preference, product features, cost	Risk neutral manufacturer
Chod et al. (2010)	Profit maximization	1M	Double	Component quantity,	Profit	Component quantity, component inventory	Risk neutral manufacturer
Feng et al. (2013)	Profit maximization	1M, multiple R	Double	Spot sales, production quantity,	Profit	Price, production cost,	Risk neutral manufacturer, Risk neutral retailer
Su et al. (2010)	Utility maximization	1M	Double	Waiting time, cost	Utility of waiting time and cost	Waiting time, cost	Risk neutral manufacturer

M manufacturer, *R* retailer

Design, fabrication, fit, feature, and postproduction, as defined as the critical points of apparel MC programs in Senanayake and Little (2010), it is suggested that the success and the capability of apparel MC depend on how effectively a company can combine the defined points of customization and their extent of customization in pre-production, production and post-production of the apparel product. Satam et al. (2011) study the economic factors leading to MC and propose a new CAD system of 2D and 3D computer-aided garment intelligent design systems ways to facilitate the design personalization in the entire process of apparel MC, thus provides a versatile selection of styles and fits for apparel production processes, and the efficiency of MC can be improved in the apparel industry.

Mpampa et al. (2010) derive a methodology for the development of sizing systems for garments MC system to control MC degree and the corresponding number of garment sizes, and to reach a balance between the number of sizes and the percentage satisfaction of consumers. The proposed methodology has been successfully applied for MC of male shirts, coats and trousers with respect to in Greece. Zhang and Luximon (2013) design a shoe-last for MC footwear. Mok et al. (2016) create a fashion skirt design MC system using evolutionary algorithms and fuzzy set theory. Pan (2016) propose a smart system model to improve customer choice, and the model is tested by a British small and medium enterprise ethical and sustainable fashion designer/retailer. The author finds that it can increase and improve customer choice while reducing environmental waste significantly.

The well-established retailers Land's End, and Brooks Brothers once implemented MC for men's shirts for several years. However both brands do not offer online MC right now. The possible reason is that men's shirt is a basic item and customers can find thousands kinds of ready-to-wear shirts (different fabric, different pattern, different design, etc.) in the existing market, they do not have the patience to wait for a longer time (most of the programs need 3 or 4 weeks to deliver the MC product) to get an MC shirt. Another reason is that, although the price of the MC product is higher than the normal product, most of the companies do not earn more money from the program. Despite the fact that MC companies can learn more about their customers from customers reaction in the MC program, which will be beneficial to the product development in the future. For other similar companies doing MC for gentleman shirts under the made-to-measure schemes, we find that there are several firms still providing MC products, such as Ownonly and Tailorism. However, to the best of our knowledge, KC company should be one of the biggest companies which launch production under made-to-measure schemes. The reason explaining why there are very few companies applying MC is that the MC program needs a total transformation of the business operations system, which will cost a lot of money to develop. Moreover, this system is also difficult and time consuming for the managers and especially for the workers on the assembling line to accept (Table 6).

3 Industrial case: Kutesmart Co., Ltd

3.1 Company background

Founded in 1995, Kutesmart Co., Ltd. (hereafter referred as KM) is one of the largest MC apparel manufacturers in China. Targeting young professional working class of age between 28 and 38, the product categories of KM include menswear and ladies' wear in four main series, namely: formal business, casual business, dress, and mix & match. As of 2018, KM has more than 3000 employees and operates three manufacturing plants for production of

Table 6 MC-related literature under the context of the fashion industry

Paper	Approach	Product category	Aspects of MC
Senanayake and Little (2010)	Empirical	Garment	Success and the capability of apparel MC
Satam et al. (2011)	Empirical	Garment	CAD system
Mpampa et al. (2010)	Analytical	Garment	Sizing systems
Zhang and Luximon (2013)	Analytical	Footwear	Shoe-last system
Mok et al. (2016)	Analytical	Fashion skirt	MC system
Pan (2016)	Empirical	Fashion outlet	MC system

suits, shirts and casual pants, respectively. KM produces over one million customized apparels annually and customers cover a wide range of industries such as finance, media, sports, fashion models, internet industry.

KM started as a traditional apparel manufacturer that provided original equipment manufacturing (OEM) and original design manufacturing (ODM). In light of the vicious price competition and excess inventory issues, the company began to explore the possibility to transform its business model to apparel customization in 2003. A new company was established in 2007 based on the original one. At the beginning, the company observed many drawbacks in traditional customization such as low efficiency, high cost relative to mass production and the dependence on worker's measuring skill and sewing technology. In order to solve these problems, the company began to consider to use MC as a means to make personalized clothes. After more than 10 years' research and development, hundreds of millions of funds have been invested and the company has successfully developed a MC system that had become a case example in China. Moreover, it also provides consultation and personalized customization services for dozens of corporations from different industries, including clothing, shoes and hats, electronic products, motorcycles, bicycles, and cosmetics.

Being one of the largest MC apparel manufacturers in China, KM produces over 4000 customized apparels daily through 308 production processes with the production lead time from seven to ten working days after order receipt. The production efficiency of KM is higher than the average in the industry. Upon receipt of the customer's personalized needs, its MC system starts to provide a complete solution for the whole process of clothing customization. The system is more suitable for small batch production, e.g. shorter delivery time, more timely replenishment, more stable quality and stronger technological satisfaction.

KM accepts orders from both the apparel enterprises and individual end consumers. For corporate clients, KM provides a complete supply chain solution from design, material purchasing, production, logistics, to customer services. Currently, KM has developed a mobile application (APP) *Cotte Yolan* with which individual end consumers can place orders for customized formal menswear. The following sub-section presents the MC process for orders from individual end consumers.

3.2 The MC process in KM

Body measurements are essential information for apparel customization. To order for a personalized men's suit for the first time, a customer must register in KM's mobile APP and schedule appointments for body data measurement. KM provides two alternatives for body data collection, namely: a customer can either go to the designated brick-and-mortar stores of KM, or he can make a reservation for door-to-door body measurement service online or by phone. The customer can also choose whether to be measured by 3D scanning or by hand. In either way, the responsible measurement staff will help the customer to collect body measurements and input into the information system of KM. The body measurements are saved under the customer's personal profile in KM's system and can be extracted for future use whenever the customer login the system.

With the body measurements available in KM's system, the customer can design his desirable suits using KM's mobile APP. Apart from the suit style, a customer can also decide on his favorite pattern version, fabric, color, embroidery personalization, buttons, pockets and other details. The number of options available for customization exceed 100. Based on the chosen options, a 3D virtue model is displayed for the customer to review and finalize his design. After the customer has confirmed his design and placed the order through the mobile APP, the order details are saved and transmitted to the company's factory order platform for further process.

Based on the order details received, the manufacturing execution system of KM compiles the customer's body measurements into from its intelligent database, and then automatically generates the personalized pattern version for the customer. The database covers millions of different type's body data, and it makes the accurate personalized suit pattern than the experienced craftsman. When the order data enters the system which contains process database, style database and raw material database, the C2M system decomposes the task at the production node. And then it transforms the order information into production task by way of pushing instruction, and then decomposes and pushes it to each workstation.

When the pattern is confirmed, the system will cut the parts of all the customization details of the suit and arrange the order sequence automatically in the system. First, the work needs to observe the orders in real time and check more than 50 customized details in each order. Different from the traditional production process, each part is attached with an RFID card in the whole process of production, in which records the personalization details of this clothing part. The RFID card records all of the data, and it's the electronic identity card of the suit parts, with the required material, it is automatically transferred to the corresponding work station using the hanging system. And then the personalized suit is produced. In each working station, it has a dedicated terminal device to download and read order information from the Internet cloud. The worker should scan the RFID card first to check the personalization information, and then act accordingly. In each work position, the worker has different kinds of sewing thread or buttons with him in order to fulfill the different personalization requirements. This is different from the traditional factory, where the worker only has one kind sewing thread because the products are all the same. However, in this production process, the workers have different threads to match the different fabrics of the personalized suits. It is noted that each worker can only see the data required in his own duties, and the irrelevant data is automatically concealed by the system.

Finishing the product, the workers will double check the product. The total inspect includes 25 processes. The inspector will examine the details of the order according to the data set after scanning the RFID card, to check whether the size and data are correct. Normally the personalized apparels are delivered within seven to ten working days.

Through the intelligent logistics system, intelligent reclaiming system, intelligent cutting system, etc., the production line of personalized products is realized. Based on the technology of internet of things, the data of multiple information systems are shared and transmitted. It enables multiple production units and enterprises from upstream and

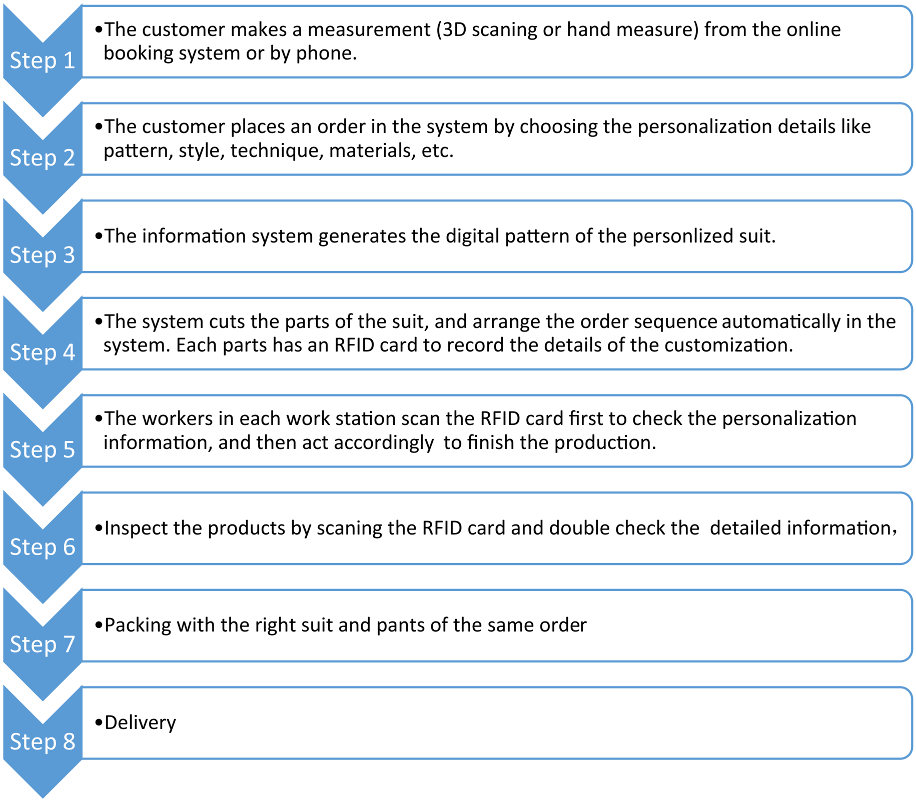

Fig. 1 The apparel MC process of KM

downstream to transfer and share data through information systems, and realizes the collaborative production of the entire industrial chain (Fig. 1).

3.3 Technology adopted in MC system

With the integration of traditional clothing production and modern information technology, KM constructs an apparel MC platform using 3D scanning system, CAD system, big data, RFID, and intelligent production system. It has made the full customization of clothing which is personalized, differentiated, and digitized to be feasible.

3.3.1 3D scanning

The company employs 3D scanning system for customers' body measurements. It helps the system to extract the body data and enhances the efficiency and accuracy for the measurements process. In traditional, when a customer wants to make a personalized suit, the craftsman will help the customer to measure his body, and it is always operated by hand. Thus, it highly depends on the craftsman's measuring skill. Most of the time it is also subjectively, due to the craftsman's working habit is different. However, adopt with 3D scanning system, 22 body data of 19 body parts is obtained by the system objectively and it is not affected by human. Moreover, the data is collected by the machine very fast, just within 2 s, compared with more than 10 min of the hand measuring. In the current system, the customer should wear tight clothes to be scanned, which makes the process inconveniently.

3.3.2 CAD

Customer's order is made by himself in APP and sometimes, the order is a bit weird contrast to the normal products. For example, some of the customers make the suit with different fabrics of the front part and back part or choose different buttons for the suit. Mostly, that kind of design is not allowed in mass production, but in this system, the customer can design his suit whatever he wants to show.

Pattern making is a crucial process in garment production, and it is related to the final performance of the whole garment. In the traditional fashion customization, an experienced can only make two sets of suit patterns without rest. In order to achieve the efficiency of industrialization and meet the needs of MC, it is impossible to use the traditional pattern making method, which is time-consuming and effortless. In KM, the pattern of the personalized suit is automatically generated by the CAD system, and double checked by the experienced pattern makers, if not perfect then amend it.

After the completion of the pattern matching, the data system will automatically transmit the information to the fabric department. According to the length and width of the fabric, the most economical cutting arrangement method of the suit for the fabric is calculated. According to the fabric requirements of each piece of clothing displayed on the system, the worker only needs to put the reserved fabric on the cutting bed. After the confirmation, the fabric will be automatically tailored by laser positioning. After the cutting, the workers put the fabric and lining on the top of the work station, and the RFID labels attached to the customer information will be hanging together.

The CAD patterning and cutting machine not only make it possible for the computer to make pattern automatically, the efficiency is also greatly improved, and the accuracy can be compared with those old tailors who has decades of experiences.

3.3.3 Big data and information system

Generating the pattern of the suit automatically by industrial intelligent manufacturing process and big data system, is the crucial part to accomplish MC of clothing.

In early days, when the customer placed an order in the stores, when the staff found from the system that the fabric is sufficient, but after the order is placed, the staff may find that the fabric is not enough, because the same fabric is booking in the other stores at the same time. This means that the customers should amend his order otherwise he cannot get his suits on time. The system cannot handle the conflict orders, therefore, the complaints from the customers come. In the producing process, the company had tried to use paper or cloth to record the customers' data information, however it always makes the workers confused and lead to reproduction.

After exploration for years, KM has built the data base concluding the pattern, style, technique and material bills. Currently, the system can help the customers to make their own orders by millions of modeling combination, thus, to fulfill the personalized demands. The pattern data base can generate the pattern of the suit automatically according to the body data of the customer, no matter the figure of the customer is normal or abnormal. For those whose figure is not normal, for example, too fat in belly or too strong in arms, they cannot find suitable suit in the department stores, however, in KM, they can make their personalized suit without paying too expensively. Usually in mass production, the product can only have limited sizes (e.g. S, M, L), but in database, a suit can have more than 9000 models, from 1.3 to 2.5 m, fat to thin, the system can generate all kinds of figures. If the customers do not want to spend too much time on the choices, the system, which constitutes of more than 20 subsystems, can also help them to manage all of the materials in an integrated way, i.e. match the fabric, buttons, lines, threads and so on.

To the company, the cost is also reduced. The pattern maker plays a crucial role in suit producing no matter in customization or mass production, and the payment is much high especially for those has decades of experiences. Nevertheless, under the MC system of KM, the pattern maker just works as the inspector. The experts' experiences have been transferred into the data base, and the data base is growing time to time. The number of the pattern maker could be highly reduced and thus the cost is cut rapidly. Moreover, the speed for the process is speed up, and at present, the company can produce 4000 suits every day.

The core technology is big data, which drives the pipeline with data and makes the personalized products. The data base can monitor the working efficiency and skill evaluation of each worker in each work station and match the suitable work process and push to him. The intelligent system makes the workers working more efficiently, the total production efficiency is increasingly higher. For the workers, owning to the more and more suitable works for him, he can earn more money than before. For the company, the reproduction rate is very low as well. When the equipment is damaged, the system can get the signal automatically, and determine the compatibility of equipment according to the repair time, number of times and other data. Orders, materials, garments and other data interact with each other to ensure the continuous supply of materials. The system will calculate how to match or cut the materials will be the most reasonable and economically. Therefore, the inventory is almost zero, and the total production cost is reduced as well.

Through application of the big data system, the company does not have human resources office and finance office, and the production is automatically continued. The staffs' job is monitoring the system in real time (for example, the revenue, the stage of certain order, the performance of certain staff, etc.) and all of the data can be extracted whenever it is needed.

3.3.4 RFID technology

In the very beginning, the company did not use RFID card for information transmission and tracking, just using handwriting in paper or fabric. However, in the real production, the paper will be tear up or the words will be indistinct after several production process. Sometimes it will lead to the production mistake. Therefore, the company used RFID quickly.

The application of RFID technology plays an important role in the distribution of work flow in KM. It can be seen as a form of data flow. After the customer's body data collection is completed, it will be transmitted to the company's data platform, and the RFID card maker inputs the full data into this tag. Thereafter, the tag, like an ID card, will follow the corresponding garment pieces throughout the whole production process. The workers in each process get a piece of clothing, they should first swipe the card in the system, complete the work such as cutting, button nailing, embroidery and other specific operations according to the translated code. And the small screen in front of them is used to show the translated code implies what instructions each garment should carry out.

3.4 Supply chain management

3.4.1 Changes for cooperation with suppliers

The relationships with suppliers have been changing since KM transformed to apparel MC, and the changes can be classified into three phases. In the first phase, the company bought materials from the suppliers. And so, the demand forecasting was needed in this period. The company forecast the materials demand based on the historical data which might deviate significantly from the actual demand. Such situation lasted for about 8 years, and KM had to dedicate a large amount of cash flow for excessive material inventory. After years of operations, the accuracy of the company's forecasting had been improved, and the relationship between KM and its suppliers was transited to the second phase. In this phase, KM and its suppliers had come up with an agreement to better manage the material inventory. To be specific, the suppliers shipped the materials in the warehouse of KM according to the company's forecast, but KM were allowed to pay the suppliers based on the actual amount that had been used. Recently, KM's relationship with its suppliers had shifted to the third phase, a new platform for material management has been constructed with which KM can reach minimum cost in the industry. In this platform, KM assembles a large amount of the fashion materials suppliers, including different kinds of fabrics and materials (like wool, button, lining, lace, and etc.) from different countries in the world. And, all of the materials are open to other companies in the platform. The other companies can find the materials they required from this platform and do not need to looking for materials overseas. Nowadays, this platform has become profitable.

The system can automatically manage the stock of raw materials. When an end consumer orders from KM's mobile APP, the material that needs to be consumed will be recorded in stock in real time. Once the stock of a certain type of raw material is lower than the pre-set threshold, the system will automatically order from the supplier. By applying MC, the supply chain of KM has been changed. KM does not need retailers or wholesalers to reach end consumers and its supply chain could also accommodate customer-to-manufacturer (C2M) business mode.

3.4.2 Benefits of MC

KM has benefited a lot from its MC system. Firstly, the approach of MC has brought about good financial performance. Whereas the production cost is 10% higher than traditional customization, the profit margin is doubled the traditional mass production company. Secondly, MC has also shrunk the production lead time of KM significantly from 3 months to 10 days. Thirdly, owing to the make-to-order nature of MC, the inventory of KM has been reduced to zero. Inventory management has always been a challenge to fashion companies adopting mass production as the inventory (holding and stock-out) cost can constitute 30–50% of the cost on average and be a fatal problem. Having zero inventory level has improved the cash flow and financial performance of KM. Fourthly, the fitting and product quality of customized apparel are enhanced under the MC system of KM. The experiences of measuring staff and pattern craftsman play crucial roles in tradition garment customization. The uncertainties caused by human experience could affect the fitting accuracy and outfit of the tailor-made apparels greatly. By contrast, under the MC system of KM, body measurement and pattern making are undertaken objectively with minimal bias (Table 7).

Table 7 Production improvements experienced by KM after MC adoption

	Before (mass production)	Present (MC)
Production cost	100	110
Design cost	100	5
Production lead time	More than 12 days	Less than 7 days
Product inventory	100	0
Material inventory	100	0

3.4.3 Customer involvement

In the MC system of KM, when an end customer makes an order through the company's mobile APP, he has to specify his design options. The options were originally created by the company, and the modularity level related to the options is higher compared with the mass-produced garment. As a result, the availability of a wide range of customized options makes customers happy and enhances customer satisfaction. Additionally, some of the customers, who are creative and have good taste of fashion, can produce some good options. By saving these creative options into the system, on the one hand, KM can expand the database and makes it more attractive to other end consumers. On the other hand, customers who had their design options kept in KM's database could feel that they had become a designer and this makes the consuming experience much more memorable, and in turn their satisfaction level with KM is increased.

3.5 Challenges and future direction for KM

To KM, the key challenge to MC adoption is the difficulty to change its employees' mindsets to adapt to the MC approach. Factory workers are familiar with the conventional way of mass garment production under which the manufacturing process and design of individual garments are nearly the same. Proficient workers in general could simply work by instinct. Thus, it could be imagined the workers' reluctance to accept the MC approach. Especially, when the workers have to swipe the RFID tags and check the design details, and even change the threads for each piece of clothing, they consider the work too complex than before and they do not like to change. Besides, the wages of factory workers of KM are paid piecemeal. At the very beginning of MC adoption, factory workers were slow in production and stagnation in output lowered their wages and in turn affected their working enthusiasm. The managerial staff do not like MC as well, because their job functions and work procedures have been changed. To resolve employees' negative responses to MC implementation, KM has been providing various training workshops and discussions regularly to better equip its employees to adapt to the MC business model.

In the future, KM intends to export its experience in apparel MC and provide solutions for enterprises in different industries. Since its MC system started to work, KM had already planned to extend to e-commerce with some large-scale platforms like other clothing companies had been doing. However, the company found that the operation logic of the existing e-commerce platforms did not support mass customization while it was infeasible for those platforms to develop a portal specifically for it. As a result, the company has devoted to developing the MC system by itself. With the success in its MC system, KM decided to build an intelligent ecosystem, in which a large number of enterprises can be cooperate in the ecosystem and customers can buy personalized products from different companies in different industries. As of now, more than 60 traditional manufacturing enterprises from local and Germany, across a wide range of industries such as chemical, bicycle, furniture, textile and other industries, have established a cooperative relationship with KM.

4 Antecedents for successful apparel MC

On the basis of the case study of KM and the review of MC-related literature, a number of factors are identified that are critical to successful implementation of apparel MC, namely: data-driven production process, integrated data infrastructure, supporting technology, consumer involvement, and relationship with other supply chain agents. We discuss these factors one by one in details as follows.

4.1 Data-driven production process

As remarked by KM, production of customized apparels in massive volume efficiently within a short period of lead time is a fundamental challenge to its adoption of apparel MC. Unlike the conventional mode for mass production under which apparels are relatively homogenous for the same batch of orders, MC targets at manufacturing of a large quantity of customized apparels that are different from each other in many aspects from the fabrics and materials required, fitting to design details. This increases tremendous complexity in the manufacturing process, which is acknowledged in the literature (e.g. Bednar and Modrak 2014; Modraka et al. 2014). A primary obstacle to apparel MC is how to automate the pattern making process for large amount of customized apparels. Efficient pipeline management in the factory floor is another hurdle for apparel MC. In particular, factory workers are accustomed to standardized sewing procedures under the convention mass production mode and their ability to work according to ever-changing sewing procedures for different customized apparels determines the productivity of the MC system. To respond to these challenges, KM re-engineered its manufacturing process to be completely data-driven. The processes of pattern making and fabric cutting are undertaken automatically upon receipt of customer orders. The detailed garment sewing procedures for individual customized apparels are stored in RFID tags to guide factory workers and ensure customers' specified design requirements are fulfilled. KM's data-driven production approach illustrate the upcoming trend of the use of cloud services and big data in production and operations management (e.g. Chan and Bennett Moses 2016; Choi et al. 2017).

4.1.1 Integrated data infrastructure

A well-developed integrated data infrastructure across different production units is a prerequisite to make data-driven production process feasible. From the above case study, KM has put heavy investments in the development of different databases for suit patterns, styles, techniques, and clothing materials. It also took years for the company to modify the databases and establish data retrieval and compilation during different phases of the MC manufacturing process. As commented by Zawadzki and Żywicki (2016), an effective MC system should be capable of processing huge volume of data for analysis and decision making. The integrated data infrastructure can streamline data exchange cross the MC system and accelerate the manufacturing process. With all possible data available, the MC system can also increase modularity level and offer more variety and possibility for MC.

4.2 Facilitated technology

The case of KM has demonstrated application of a wide variety of technology in apparel MC such as 3D scanning system for body measurement detection, CAD system for automated pattern creation, and RFID technology for MC requirement and order tracking. In fact, cost reduction, shorten design and personalization time are some of the merits of the integrated use of 3D scanning and CAD systems (e.g. Apeagyei and Otieno 2007; Satam et al. 2011; Tao et al. 2018). The fitting of a customized apparel is large attributed to accurate body measurements and in turn precise pattern making. For traditional apparel customization, obtaining accurate body measurements depends on the experience and the skill of the tailor. The process of pattern making is also time-consuming and do not facilitate repetition to other styles. Now with the assistance of 3D scanning system, collection of customers' body measurements can be done within a short period of time. Since measurements are collected by standardized procedures, measurement error can be controlled at the minimal level. Besides, data are stored digitally in the system. This can expedite data transfer to other systems like the CAD system for pattern making. The measurement data can also be retrieved easily for repeated use and encourage customers' patronage. On the other hand, RFID technology supports real-time efficient product and procedure tracking (Chan and Bennett Moses 2016). It also serves as an assistance and monitoring tool to guide factory workers to compliant with the design requirements of customized apparels, which enhance the productivity of the apparel MC system.

4.3 Consumer involvement

A number of literatures advocate the positive effect of consumers' co-design experience on purchase willingness and perceived value of customized products (e.g. Franke et al. 2010; Merle et al. 2010; Kwon et al. 2017). Accordingly, a high level of consumer involvement is a definite asset of an apparel MC program. For the case of KM, the mobile APP *Cotte Yolan* offers a new channel for the company to reach potential end consumers directly. Through the mobile APP, individual end consumers can decide on their preferred design details of the customized apparels. Involving customers directly in the design process can enhance their purchase experience with KM. Their designs are stored in the company's information systems and could provide useful information for the company for fashion trend forecast and more style design variety.

4.4 Relationship with supply chain agents

Through its case KM has shared the continuous change of relationships with its suppliers during different phases of apparel MC implementation. Whereas apparel MC results in better demand forecast and minimum inventory for materials, KM also has to obtain cooperation from its suppliers to enjoy cost saving and effective inventory management brought by MC adoption. Specifically, KM has come to an agreement with its supplier to have flexible materials inventory management. In the literature, a number of works examine optimal pricing and production policies in MC supply chains (e.g. Liu et al. 2012; Choi et al. 2013) while few are devoted to supply chain coordination of make-to-order systems (e.g. Sahin and Robinson 2005; Feng et al. 2013). Whereas contractual agreements ensure profitability, maintenance of good and long-term relationships with suppliers could definitely improve the performance of an apparel MC systems. As demonstrated by the case of KM, collaboration with suppliers plays a significant role in the smooth transformation of the company's business model from traditional mass production to apparel MC.

5 Conclusion, insights and future research directions

5.1 Summary and managerial insights

With the comprehensive literature review and the case study on KM, we have identified different types of MC implemented in fashion industry. Integrating with the literature review and the findings of the case study on KM, we have identified a list of key factors that affecting the success of MC in fashion industry, including the important technology and the operation managerial strategies.

The managerial insights for answering the research questions proposed at the beginning are summarized as the conclusion for this paper.

1. The present main research domains in the literature of MC in the fashion industry and what are the related research findings. The research works fall to several aspects, including the modularity, process and technology in MC, consumers behavior research, MC supply chain management, and MC application in fashion.
2. MC application for fashion manufacturer and the challenges in practice.

   Management of process architecture in MC might not be conducted in isolation from management of product development (this is consistent with what we find in CY company's case study that production of MC will bring big change to management architecture)
3. The important technologies in the fashion MC system. Big data technology seems to be the most important technology in the production system and order system. Big data analysis system helps the company to learn the customers' habits and extract the useful data to facilitate the MC production system.

5.2 Limitations and future research opportunities

Though the study provides comprehensive implications for MC application in fashion industry, the paper suffers some limitations. First, our case study only focuses on a single MC fashion company, and the results of the case study may lack generalizability. Due to the resource limitations, we only can concentrate on a limited number of informants for the interview. Besides, personal bias may avoidably occur during the process of selecting paper and conducting the case study.

According to the findings derived from literature review and case study, future research directions are summarized as follows. (1) New technologies adopted in fashion MC. As we can observe from industry, technology is developing intensively fast, and new technologies are continuously been employed. Not only include the production technology like 3D printing, internet of things like big data, but also include the try on technologies like virtual try on mirror etc. (2) Consumers behavior in MC. In the literature, we find near all the works are empirical research. In the future, the more analytical works are needed. (3) The MC operations management. Most of the MC works focused on the supply chain management and the production process. However, as changed by the production process, the operations consequently change a bit or even turn to another way, which requires more attention.

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