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Apparel Mass Customization Digital Natives: New Insights into Development and Technology Implementation

Moudi Almousa[1]

[1] King Saud University, Riyadh, Saudi Arabia

Correspondence: Moudi Almousa, King Saud University, Riyadh, Saudi Arabia.

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Abstract

Despite advancements in manufacturing and information technologies along with innovative operating models and engineering designs, apparel mass customization (MC) has mostly not lived up to its expectations. The main goal of this study is to explore digital native apparel MC companies and establish relevant insights concerning development and technology implementation. The study starts by facilitating a comprehensive literature review to explore apparel MC and related technologies, combined with exploring its implementation in different successful digital native cases. Following a descriptive-analytical approach, this paper offered insights into current technology implementation and utilization in the apparel MC industry, and then classifies their practices from low to high technology adoption. Moreover, by exploring real world cases, the paper developed insights on technology application of MC, which can guide strategic directions in order to accelerate a successful implementation of MC in the apparel industry.

Keywords: apparel mass customization, technology, online customization, digital native startups

1. Introduction

Mass customization reflects a production strategy that integrates the flexibility and embodiment of custom-made goods with the minimal unit costs obtained from mass production. The coining of MC took place in 1970 in a book by Toffler titled 'Future Shock' (Yeung, Choi, & Chiu, 2010). However, the emergence of the term was introduced nearly three decades ago by Davis (1987), due to increasing consumer demand for item variety. Tseng and Jiao (2001) defined the term as producing products and services to address consumer needs, while almost achieving mass manufacturing efficiency. From a similar perspective, Kaplan and Haenlein (2006) referred to the concept as a scheme that adds value by promoting interactions between firms and clients during the fabrication and assembly phases to develop customized goods with similar prices and manufacturing expenses as mass-produced items. At that juncture, MC entails maximum responsiveness, moderate expenses, and meeting the requirements of all consumers.

Since its inception, MC has gained a lot of prominence due to technological advancement and increasing consumer demand. One of the main benefits of MC is that it promotes customer satisfaction. Yeung, Choi and Chiu (2010) argued that MC enables companies to deliver appropriate responses to the changing needs of consumers. Similarly, Aichner and Gruber (2017) highlighted the necessity of high-quality products in attaining consumer satisfaction. However, the authors pointed out that these products are insufficient despite their necessity. On the contrary, Liu, Shah and Babakus (2012) claimed that the positive association between MC and customer satisfaction only prevails when consumer demands demonstrate high uncertainty degrees. Another advantage of MC is that it leads to decreased customer churn, allowing companies to retain more customers due to the perceived value acquired from MC. According to Pędzik et al. (2020), MC significantly improves customer satisfaction and increases consumer retention.

Despite the various advantages associated with MC, the concept has multiple limitations that are necessary to address. Firstly, it faces the shortcoming of attaining low-cost operations without causing employee confusion as each product has different requirements in terms of design, material, fit preferences, and body measurements. Simon et al. (2018) stated that MC faces the challenge of smaller profits than traditional production forms. Also, it is difficult for MC to attain low-cost operations, since the process often requires more experts' involvement, causing additional costs. Secondly, MC faces challenges from dealing with item returns, since products are often customized for a specific client, making it hard to resell products. From a distinct perspective, Schmidt et al. (2015)

claimed that MC, through the industry 4.0 framework, may decrease product returns by manufacturing goods that meet clients' various needs. Therefore, the benefits of MC outweigh the shortcomings, making it a vital factor, especially in the fashion industry.

Apparel MC has become a popular strategy in the apparel industry, where more digital native startups are adopting such a model. Despite the increasing discussion in the academic literature regarding apparel MC, there were imbalances between theoretical and empirical research, where the investigation of technology implementation practices among companies is scarce and yet to be explored. MC model development, theoretical frameworks, and consumer behavior dominated most previous research. To address this gap, an extensive exploration of online apparel MC firms' was conducted, focusing on technology adoption practices as enablers and establishing relevant insights concerning development. Afterward, it classifies selected cases according to the level of technology adoption. The article achieves this aim by facilitating a comprehensive literature review in apparel and textiles, marketing, and computer science journals on the state of the apparel MC, manufacturing, and digital technologies as enablers of MC in the context of the online apparel industry. The article's next section reviews the vital technologies relevant to the apparel MC system. Afterward, the paper evaluates technology adoption among different real-world cases and establishes additional insights into the industry. A detailed conclusion highlights the key findings and future research directions.

2. Literature Review

2.1 Apparel Mass Customization

Apparel MC reflects the production of personalized styles by considering the particular tastes of consumers at the appropriate period and cost (Dissanayake, 2019). From a similar perspective, Barkova (2018) identified MC as the personalization of the interactions between buyers and manufacturers, and the prerequisites for integrating it into the fashion industry have ripened. The author further stated that MC had facilitated the separation of competition between firms by brand owners, growth of consumer needs, and extensive demand volatility from the prerequisites. According to Lim, Istook and Cassill (2009), the processing of MC in the apparel sector occurs via computer technology, and it comes in three varieties: individualization, fit, and design. The authors also claimed that the future of apparel MC is bright and relevant companies will have to establish and maintain strategies revolving around new product development. In a different study, Yeung, Choi and Chiu (2010) argued that despite the prominence of MC in the fashion industry, its integration by apparel firms has been minimal. Moreover, the authors argued that most apparel MC initiatives mainly focus on reducing costs rather than fulfilling the diversified needs of consumers.

The changing environment of the fashion industry has impacted apparel MC by encouraging the prominence of the customer-driven culture. In such a setting, clothing companies need to consider clients' diverse needs, highlighting the significance of consumer perspectives. Liu, Chow and Zhao (2020) claimed that MC attracts customers' attention, enhances satisfaction, and advances their purchasing intentions. More importantly, the authors insisted that numerous companies have applied MC as a strategy for attracting customers to their brick-and-mortar in addition to e-commerce stores. This changing trend has significantly affected consumers' perspectives, since the situation overwhelms them with numerous offerings and many unmet requirements. A study on consumer behaviors is vital in explaining this concept. For example, Lee and Chang (2011) claimed that the perceived usefulness of online MC positively affected the attitudes of consumers towards the process. Other determinant factors identified were perceived enjoyment and supposed control of online MC. A separate study spearheaded by Ribeiro, Duarte and Miguel (2017) revealed that situational traits include the need for unique items, touch, simplicity, reality, and apparel involvement. These arguments imply that the changes in the fashion industry have impacted consumer behaviors and attitudes, leading to the establishment of diverse perspectives toward MC.

Since the apparel MC process requires direct consumer involvement in the product development to customize it according to the desired design and fit, the product must be personalized at the most effective point in the supply chain. According to Fogliatto et al. (2012), MC processes can be broken down into four stages: order elicitation, designing, manufacturing, and supply chain coordination, as illustrated in Figure 1.

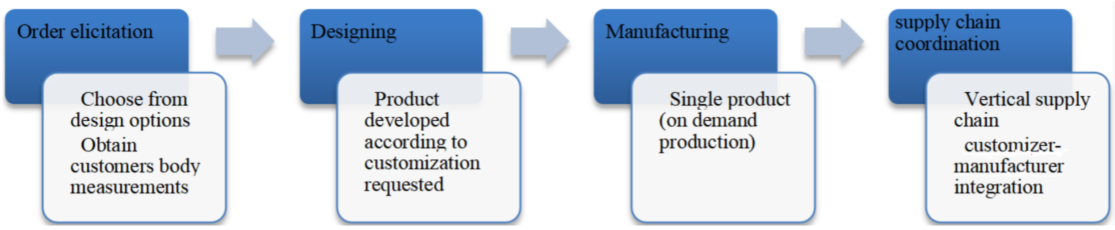

Figure 1. MC process

2.2 Points of Customization

Apparel MC literature has defined five points of customization including: post-production, fabrication, fit, feature, and design (Senanayake et al., 2010). Though, three primary points of MC are discussed, as they are the most currently practiced in the fashion industry. The first category is fit customization, which entails the production of fitting clothes based on a client's body measurements. The availability of individual body measurements is vital to producing well-fitting garments. According to Yeung et al. (2010), it remains clear that fit is the most critical issue in MC in the fashion industry. The fit classification falls in the dimensional customization category, whereby the delivery of good fitting products remains possible, since they rely on actual consumer body measurements. It can be obtained either digitally through the use of 3D body-scanners, as evident at Unspun. Other companies such as iTailor and Sumissura require consumers to input measurement information into the website. The second category is style customization, which enables customers to select from design options to create personalized products. The third category is fabrication customization, where consumers are offered material and color choices to select from. The combination of the three points of customization has an impact in both pre-production and assembly processes. The reviewed companies are mostly operating at this level of MC, with varying approaches offered to deliver style and fabrication customization.

According to Lim, Istook and Cassill (2009), numerous consumers aim to personalize their products based on design and fit. Therefore, the changing nature of customer interests makes it challenging for MC to fulfill the needs of both the producers and clients. This argument implies that achieving the balance between design and fit is vital since it will increase the level of customization, leading to enhanced consumer satisfaction

3. Essential Technologies in the Apparel Customization System

3.1 CAD

stands for computer-aided design and is structured as developing computer models according to geometric outlines. The computer-aided designs are normally portrayed as 2D flat shapes or 3D models characterized by a computer model (Gao et al., 2015). CAD proposals are necessary for fast product promotion. Designers, engineers and pattern designers can solidify their strategies virtually under any condition. This technique is more efficient than prototyping a product in reality and fine-tuning material entities. Moreover, computers can be incorporated into various fashion design procedures. The first place would be during the illustration stages when designers draft their initial fashion design concepts. During this stage, designers usually use graphic design programs such as Photoshop and illustrator. The CAD fashion design software is critical in the fashion industry, since it enables designers to access information down to a granular level (Pasricha & Greeninger, 2018). It helps them remain competitive in modern business by eliminating as many variables as possible. Furthermore, it is important to eradicate difficult labor to stay efficient in business. Therefore, automation plays an important role in the fashion industry. Hence, automated machines, such as automatic cutting machines, laser cutting machines and high-ply automatic cutting machines, infer the required procedure to implement the provided designs and mock-ups from the CAD software model automatically. Software, such as SMART mark, prevents designers from using excess material and enables them to utilize their entire fabric.

3.2 3D Scanning Technology

3D scanning is another technology implemented in the apparel industry that has brought various benefits. According to Weller, Kleer and Piller (2015), 3D scanners allow the production and customization of small quantities of goods at a fair price. Furthermore, 3D scanners assist retailers in inventing and delivering merchandise in small amounts in real-time, as well as shorter periods of design and personalization and reduced production lead-time. During the past few years, 3D body scanners have developed and have become affordable, more accurate and easy to use. Most online MC retailers require consumers to know their measurements and submit them to MC orders, which can be challenging to some consumers and prone to errors. Therefore, the wrong information will lead to ill-fitted garments and contribute to consumers' dissatisfaction. In this case, a 3D body scanning mechanism can collect more accurate body information for the manufacturer and the consumer. However, 3D body scanning equipment is relatively expensive.

3.3 Virtual Try-on System

Another technology in MC is the virtual try-on system, where customers have the ability to fit a selected garment on a virtual model. In addition to testing garment fit, the technology enables users to coordinate apparel products, visualize selected design options using 360^o rotation (Lee, 2010). In the context of the apparel industry, researchers have investigated the application of this technology in online apparel shopping. Consumers have the ability to virtually try-on selected clothing either using non-personalized (Kim et al., 2006, Fiore et al., 2005) or personalized (Kim & Forsythe, 2008, 2009) virtual try-on models. The technology uses real-time image processing with augmented reality, enabling consumers to try-on clothing before making a purchase decision. A more advanced alternative is using a 3D scanner to construct the consumer's own avatar. Some MC firms are utilizing this technology through smart phone applications, where a consumer can scan their own body to visualize selected clothing before making a purchase decision.

3.4 RFID and Big Data

RFID, also known as radio frequency identification, is a different technology used by MC firms in the fashion industry with the development of mobile technologies, cloud computing, enterprise systems, and business analytics have advanced how fashion retailers run their businesses (Zhong et al., 2017). RFIDs allow MC firms to physically link their merchandise to databases with abundant information on customizable features. Most retailers in the fashion industry are now using the big data technologies. The development of cell phone technologies, product tracking technologies, cloud computing, and business apps have restructured how fashion retailers conduct their businesses.

Additionally, consumer feedback on social media platforms such as Instagram, Facebook, and tweeter, among others which are examples of big data, can affect fashion retailers' beliefs about forthcoming brands (Liu, Shin, & Burns, 2021). In the production sector, manufacturers need big data to boost production and operations management, such as RFID and cloud service. Nevertheless, the cloud service can also be seen as data storage that presents important information, for instance, in a dynamic workload scheduling complication, cloud computing services can assist with orchestrating tasks from various departments. Additionally, big data can improve the predictive capabilities of our systems by utilizing past data points of interventions. Also, wireless sensor networks can be incorporated in gathering important information far and wide (Horita et al., 2015). RFIDs and other technologies are extensively observed in MC systems. For instance, an RFID-based distributed control system for MC manufacturing and a circulated information system can be used in conjunction to build a MC manufacturing process in an insecurely joined shop-floor control surrounding.

3.5 The Flexible Manufacturing System

The flexible manufacturing system used in the fashion industry is vital in the MC process. The manufacturing and distribution systems are supposed to coordinate the supply and restructuring of materials and conduct all the processing activities in the most suitable location. This technology presents products by combining push and pulls techniques to attain a flexible processing system (Esmaeilian, Behdad, & Wang, 2016). In the MC sector, the flexible logistics system can quickly adjust to the changes in the market for new products and product features. For this to happen, a company needs to establish reprogrammable, reconfigurable, and modular production systems that can run economically. The nimble processing system facilitates the completion of production at affordable prices by incorporating the efficient implementation of a malleable workforce and virtual alliances. Multiple studies have been conducted concerning the technology, with one by Karaköse and Yetiş (2017) stating that an integrated vehicle configuration system can manage the customer order processing according to the information received from various sectors in MC. Also, the model can improve communication between different shareholders involved in the order fulfillment procedure.

3.6 Artificial Intelligence

Artificial intelligence (AI) is related to the machines' ability to understand and use human language then continue to function unaided. The system works by merging large datasets with intelligent, iterative processing algorithms, which allows AI to learn from repeated features and patterns in the data (Honavar, 2017). The application of AI in the apparel MC has the ability to revolutionize the industry by increasing the customer experience through size and design predictions and enable firms to gain better insights into behaviors of their consumers to better meet their demands, forecast trends more accurately, drive corporate decisions, create customer value, and create an efficient on-demand inventory system (Kohler, 2018).

Apparel firms with MC operating models implemented AI technology either built in house such as Red Thread and Knot Standard or outsources to B2B technology startups. An example of a firm that uses the B2B model is Xometry, an on-demand production marketplace that connects consumers with manufacturing solutions by using artificial intelligence algorithms (Okwudire & Madhyastha, 2021). It permits customers to compare goods from various producers and retailers for on-demand ordering and have the products delivered within hours or days. More importantly, True Fit uses the B2B model by giving size recommendations to customers through machine learning (ML). The basis of the firm's recommendations is the world's biggest fashion data platform, whereby ML algorithms connect shoppers with their unique preferences. This venture of using ML for size recommendations has allowed True Fit to partner with establishments like the Very Group.

4. Method

This research reviews academic journals and books that address apparel MC and related technologies and industry publications discussing industry practices linked to apparel customization as well as related companies' websites to study their profiles, business models, and customization processes. The selection criteria for the discussed cases in this research include digital native brands that are direct to consumer MC apparel startups that have operated successfully for five years or more.

After identifying and discussing enabling technologies of apparel MC, this paper then reviewed some cases according to the mentioned above selection criteria. The author then compares the use of advanced technology throughout the customization process (see Table 1), and then classifies companies according to their level of technology adoption from low adoption to high adoption (see Figure 2).

Digital-native startups in the apparel industry

The digital disruption took a toll on all industries and specifically apparel. The apparel industry is shifting from product centric to consumer centric, where consumer experiential value of both personalized products and services provided by retailers along with the convenience of online shopping are major drivers. Apparel retailers are adjusting their strategy to match their paradigm with the disruption in consumer demand by shortening product development lead-time and more flexibility in design and quality. As a result, fast fashion retailers have become a trend in order to capitalize on new fashion before their competitors. With increasing consumer awareness for environmental sustainability, the apparel market is starting to shift to a new sustainable paradigm. Guided by the industry 4.0 framework and changing consumer demand, the fashion industry started shifting towards more size-inclusive and sustainable practices (Choi & Chiu, 2010). During the past decade, the industry has witnessed a growing number of digital-native custom-made clothing startups. The following section will present and discuss technology adoption along the customization process for the six selected cases.

4.1 Indochino

In 2015, a Vancouver-based Indochino was established as an online MC startup specialized in men's suits, where it has grown its customized offerings into menswear essentials. The company adapted an Omni channel strategy with revenue reaching nine-figure since 2019. Consumers can choose a clothing item, and then customize style from design options using the same material with limited color options. They can then either input their own body measurements guided by an instructional video or have their measurements taken at one of fifty showrooms across North America and recently expanding into Australia. The lead-time for their products is between 4–6 weeks as they outsource production in China.

4.2 Unspun

The company was founded in 2015 with a vision of sustainability and efficiency specialized in custom-designed jeans. The firm was established first in San Francisco and recently opened another location in Hong Kong supported by $12.4 million in funding over 8 rounds. They offer wide jeans selections for both men and women. Upon jeans style selection, consumers are offered to choose from available color options and can customize their jeans in three style points namely waist height, stitch color, and cuff length. Customers can have their body measurements taken either in store or remotely with the help of fit experts. Customers can also use the TrueDepth camera system on their smartphones to 3D scan their bodies capturing 30,000 data points in body measurements, where data is extracted through custom software. In November 2021, Unspun introduced a patented technology for a 3D topographical weaving machine that can produce a seamless pair of jeans in just 10 minutes. Vega ™, the 3D weaving technology was introduced in June 2023 to set up the first micro factory in California, aiming to introduce the technology to other retailers and manufacturers to advance custom fit apparel manufacturing worldwide. With a vision of sustainability, unlike the other discussed cases in this study, the company started with custom-fit manufacturing moving to a longer-term goal of supply chain adoption at a scale through brand partnerships with other manufacturers and retailers Although the company was established with automation in mined, no visualization tool is offered for the customized jeans, where consumers rely on 2D photos offered for the original style. The lead-time is three weeks, where they partnered with a local factory for jeans production keeping their supply chain local.

4.3 eShakti

New York based eShakti, which was established in 2008 is one of few online firms specializing in women's customized clothing. It offers three brands including eShakti original), Zapelle (contemporary), Wayward Fancies (Boho) and Newbury Street (High Street Fashion). It started with the original brand offering women's dresses before expanding its offerings recently to the three new brands. Consumers can choose an item from available online designs, where they have the choice of either submitting bespoke measurements using a tape measure or selecting from standard sizes. The firm's website uses a 3D full-figured model design tool enabling consumers to visualize their options as they are offered limited design options for the neckline, sleeves, and hem length of their apparel with very limited selection of colors. The company utilizes consumer feed back into their database to improve their pattern making technology. The product lead-time is 2–3 weeks as their production partner is located in India with company offices nearby making logistics more efficient.

4.4 Hockerty

Hockerty is one of the earliest ecommerce startups founded in 2008 specialized in customized menswear and based in Zurich, Switzerland. During 2013, the company launched a separate ecommerce website for customized women's wear called Sumissura. It offers a wide section of menswear essentials as well as a wide selection of suits. Consumers can customize fabric, style, and fit, where a 2-D for front and back visualization tool is offered with a full-figured model to view the selected material and style options before making a purchase decision. The last step in the customization process, consumers are required to input their measurements using a tape measure. Although they outsource the production to China and Vietnam, where they have their logistic centers, they manage to keep the lead-time to an average of 3 weeks.

4.5 Knot Standard

The company was launched officially in 2012 using a different approach in transforming the virtual customization experience into a physical space. They started as a digital-first brand then launched their first brick and mortar showroom in their first year in New York followed by nine more locations since then across the United States. Unlike the cases discussed earlier, Knot Standard is targeting the higher end menswear market reflected in their clubhouse-inspired showrooms equipped with a digital style wall to personalize the entire showroom for each customer with the help of a style advisor. This wall of screens is logged into the customer profile that includes customization preferences as well as purchase history enabling the system to suggest pairings for items in their current wardrobe. In addition, it has more than 200 commands to illustrate all style and fabric customization options. After selecting the style, consumer measurements can be obtained either by a 3D scanner or manually, where it is then saved into their system enabling convenient online future orders. Coupled with more than $25 million in venture capital funding at the initial phase and a similar amount at the second expansion phase, Knot Standard were able to target the higher end suit market by investing heavily in both technology and state of the art technology showrooms to provide a unique customization experience for its customers.

4.6 Red Thread

The brand was launched in 2018 in the United States as a customized women's wear direct-to-consumer brand. It raised $1.2 million in capital from independent angel investors with the aim of improving the apparel industry's sizing problem. The company developed a patent-pending technology for a proprietary algorithm for translating measurements that are captured through a cell phone camera into a custom fit pattern. During the past few years they managed to have a 50% repeat purchase rate and 8% returns with 68% gross margins. Consumers can order their custom clothing in three steps, where they can choose an item from the available styles, then they are asked a few fit related questions, followed by body scan through their mobile scanning technology that generates a 3D model with 15 key measurements that can be extracted automatically. With investing 60% of the funding in technology research and developments along with a small production workshop close by, they are able to produce a custom-fit garment in 1–2 weeks.

Table 1. Company profile for selected cases.

Company	Total funding (M)	Funding rounds	Patents	Registered Trademarks	IT spending	No. of employees
Indochino	$91.5	7	1	2	9.9 K	500–1000
Unspun, Inc.	$26.4	8	2	3	N/A	10–49
eShakti	$33.3	7	1	3	N/A	101–250
Hockerty	Unfunded	0	0	1	N/A	10–49
Knot Standard	$25.4	9	3	1	$80.8K	50–100
RedThread	$1.3	7	2	4	$66K	50–100

Source: IPqwery, Cruchbase, Aberdeen, and Trade journals.

The selected six company profiles are illustrated in Table 1, where five of the six companies have received between 7 to 9 rounds of funding. While five of the discussed cases have registered patents, the newly established three companies namely; Unspun, Inc., Knot standard, and Red Thread have managed to develop between 2–3 registered patents, as they focus more in digitizing both the product development and manufacturing processes. According to the OECD business size classification two are categorized in the small sized, three in the medium sized, and one in the large sized enterprises. A comparison was conducted between the use of advanced technology throughout the customization process (see Table 2), and then classification of companies according to their level of technology adoption from low adoption to high adoption (see Figure 2). Although some Automation technologies such as VTO and 3D body scanning have been the focus of apparel and computer science researchers for more than a decade, the industry implementation is rather limited. Only half of the studied cases have adopted 3D scanning technology to obtain consumer body measurements, while none have adopted VTO as an advanced visualization tool enabling consumers to visualize their customized garments on their own 3D scanned image. Five companies are utilizing AI and accumulating big data in order to improve the company algorithm in pattern making and fit as well as improving consumer satisfaction.

Table 2. Comparison of technology adoption among digital-native apparel MC startups

Criteria	Measurements			Visualization tool			Process		AI	Other
Company	COM	MAL	3D scan	2D	3D	VTO	CAD	Own Software		
Indochino	✓	✓		✓			✓		✓	
Unspun		✓	✓	✓				✓	✓	
eShakti	✓				✓		✓		✓	
Hockerty	✓			✓			✓			
Knot Standard	✓	✓	✓		✓			✓	✓	Digital wall
RedThread	✓		✓	✓				✓	✓	

Note. COM = Consumer obtained measurements, MAL = Measure at location, VTO = Virtual try on.

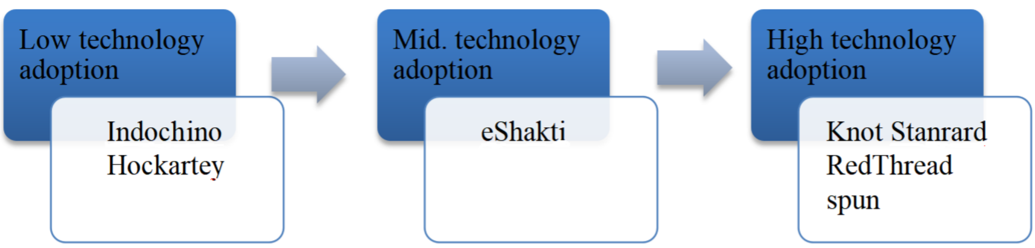

Figure 2. Classification of selected companies according to their level of technology adoption.

5. Discussion

The study's primary purpose revolves around exploring and analyzing the apparel MC industry and establishing relevant insights concerning execution and technology implementation. Despite advancements in manufacturing and information technologies, along with innovative operating models and engineering designs, apparel MC has mostly not lived up to its expectations. It is apparent that the rapidly evolving consumer demand along with digitization, technological innovations, and sustainability are transforming the apparel industry. MC in the apparel industry has become a growing trend among both fashion startups and apparel retail firms. This study's holistic analysis demonstrates that, apart from consumer demand and sustainability, manufacturing technology is a requirement for the success of MC implementation.

This paper has identified technology adoption practices among selected digital native apparel MC companies, and then classified them according to level of technology adoption practices from high technology adapters to low technology adapters. First, from the cases explored, it is apparent that the digital mindset is as pivotal as the business model mindset. The high technology adapters such as Knot Standard, Unspun, and RedThread have adopted both mindsets, which allowed them to take a leap and position their brands as leaders in their niche markets. A common factor among high technology adapters is relying to secure funds through crowd funding or venture capital funding, which allows them to invest heavily in research and development in technology implantation.

Second, while some of the covered cases outsource their production to other countries, such as Indochino and eShakti to India and Hockerty to China, other smaller high technology adapters, such as Unspun and RedThered, are following a vertical integration supply chain strategy by either keeping production in house or collaborating with local factories. An interesting new business model is starting to be adopted by the late market entrants, such as Unspun and RedThread, where they are deploying the technology to set up micro factories that are close to consumers for a more agile and flexible production model, fulfilling shorter lead times to meet consumer demand as-well-as company vision for sustainability. Third, overtime, the digital native start ups can accumulate data related to consumers' body measurements, fit, fabric preferences, shopping behavior, and consumer demographic data. The utilization for such big data through AI can improve the company's algorithms in pattern making and fit, as well as improving consumer satisfaction.

Although some Automation technologies such as VTO and 3D body scanning have been the focus of apparel and computer science researchers for more than a decade, the industry implementation is rather limited. This might be due to the immaturity of the technologies, and that firms are underutilizing these technologies because of lack in knowledge of such methods and their benefits (Heim, 2022). In addition, consumers' are unwilling to adapt to new technologies, as the case in Knot Standard, where they explored this option along with automated measurements. According to the company president and co-founder, Matt Muller, that consumers did not like their virtual mannequins and preferred to view clothes on models, while only 15% of their customers used the online automated sizing service by capturing a few photos via a webcam. It is still unclear from a consumer perspective the acceptance of this technology in real time experiences. Earlier studies that were conducted in laboratory-controlled environments show that technology does not lead to greater influence on consumer behavior (Merle & Shin, 2012) and they prefer to try on actual garments rather than using VTO or augmented reality (Shin & Baytar, 2014). More studies are needed to understand consumers' opinions regarding the technology in real experiences, confidence in the technology, and whether they prefer more real time experiential shopping in the context of apparel MC.

Although the focus of this study is technology implementation among apparel MC firms, the discussed results can be adopted by other MC industries. Since the level of customization in the apparel industry is rather complicated, which involves design and fit customization, other industries that have similar or lower level of customization can evaluate their relevant technology implementation practices and business models to be competitive in the market.

5.1 Research Implications

The results generated via this literature review and insights from the industry provide a new interpretation of the apparel MC industry. The use of the scientific literature as well as current practices advancements as an analytical tool shed light on the digital native apparel MC industry practices and identify potential gaps between academia and industry. It is evident from reviewed cases that successful implementation of apparel MC from consumers' perspectives is as pivotal as enabling technologies, which are the core for academic research. The conceptualization of apparel MC and the attitudes customers have toward it will enable businesses to assess how they deal with the changes in the apparel industry and develop more positive perceptions toward the concept, in addition to aligning its implementation for a more successful product development approach.

Furthermore, the research facilitated the understanding of the relevant technologies to apparel MC, which was vital in understanding the main purpose played by every technique. This factor will enable firms to assess their current technologies and improve or change them based on their goals. This situation can help SMEs select a business model that represents and helps them achieve their various goals. Also, examining the study insights was beneficial as it can help SMEs understand the steps they should take to improve their competitiveness in the fashion sector. Such implications can be applied to other MC industries in improving the adoption of relevant technologies and evaluation of business models.

5.2 Future Research Directions

From the review of the apparel MC literature and further insights discussed with firms' cases, it remains clear that additional and more comprehensive research into the topic is necessary. As MC is a consumer centric model, consumers' attitudes and preferences regarding technology application in MC current practices represent a potential area of investigation. Future researchers should examine technologies relevant to apparel MC by evaluating consumer acceptance and possible improvement of the customization experiences. Finally, future research should focus on a critical comparison of the operational models to identify their benefits and shortcomings, which will allow the development of deeper debates concerning the models most suitable for small, medium, and large companies. Such an evaluation will ensure that companies master the business models most compatible with their businesses, given their size.

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