Business model innovation of 3D-printing garment enterprises in digital transformation: business model innovation canvas approach

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Abstract
Purpose – 3D printing has been warmly welcomed by clothing enterprises for its customization capacity in recent years. However, such clothing enterprises have to face the digital transformation challenges brought by 3D printing. Since the business model is a competitive weapon for modern enterprises, there is a research gap between business model innovation and digital transformation challenges for 3D-printing garment enterprises. The aim of the paper is to innovate a new business model for 3D-printing garment enterprises in digital transformation.

Design/methodology/approach – A business model innovation canvas (BMIC), a new method for business model innovation, is used to innovate a new 3D-printing clothing enterprises business model in the context of digital transformation. The business model canvas (BMC) method is adopted to illustrate the new business model. The business model ecosystem is used to design the operating architecture and mechanism of the new business model.

Findings – First, 3D-printing clothing enterprises are facing digital transformation, and they urgently need to innovate new business models. Second, mass customization and distributed manufacturing are important ways of solving the business model problems faced by 3D-printing clothing enterprises in the process of digital transformation. Third, BMIC has proven to be an effective tool for business model innovation.

Research limitations/implications – The new mass deep customization-distributed manufacturing (MDC-DM) business model is universal. As such, it can provide an important theoretical reference for other scholars to study similar problems. The digital transformation background is taken into account in the process of business model innovation. Therefore, this is the first hybrid research that has been focused on 3D printing, garment enterprises, digital transformation and business model innovation. On the other hand, business model innovation is a type of exploratory research, which means that the MDC-DM business model’s application effect cannot be immediately observed and requires further verification in the future.

Practical implications – The new business model MDC-DM is not only applicable to 3D-printing garment enterprises but also to some other enterprises that are either using or will use 3D printing to enhance their core competitiveness.

Originality/value – A new business model, MDC-DM, is created through BMIC, which allows 3D-printing garment enterprises to meet the challenges of digital transformation. In addition, the original canvas of the MDC-DM business model is designed using BMC. Moreover, the ecosystem of the MDC-DM business model is constructed, and its operation mechanisms are comprehensively designed.

Keywords Business model innovation canvas, Business model canvas, Garment, 3D printing, Mass deep customization, Distributed manufacturing, Business model ecosystem

Paper type Research paper

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Introduction

The personalized customization of clothing has become a mainstream trend (Sun and Zhang, 2021; Xu et al., 2021; Yu et al., 2020). Thus, greater customer participation in new product development in the era of Industry 4.0 is becoming increasingly important (Naeem and Di Maria, 2021). In this context, 3D-printing technology is being increasingly applied in the field of clothing (Gong and Kang, 2021; Khan et al., 2021; Perry, 2018). Compared to traditional manufacturing technologies, 3D printing has the advantages of a wide design range, high production flexibility and less labor input, but its principal characteristic is its personalized production capacity (Ngo et al., 2018; Thakar et al., 2022). JS shoes customizes 3D printed knitted shoes, Mon Purse produces customizable 3D printed handbags, the Adidas pop-up shop makes personalized merino sweaters using 3D printing, and Danit Peleg offers a customizable “Bomber jacket” (Kim et al., 2019). Obviously, 3D-printing technology has injected new vitality and provided a new direction for the development of garment enterprises (De Silva et al., 2020; Ertz et al., 2022).

However, these clothing enterprises must face the digital transformation that results from 3D printing (Jones et al., 2021; Savolainen and Collan, 2020). Digital transformation is upending businesses everywhere (Fernandez-Vidal et al., 2022; Matt et al., 2015a). 3D printing is simply a digital-based manufacturing technology, but it is one that is digitally changing the global business landscape (Öberg, 2019). Therefore, clothing enterprises using 3D-printing technology must face the development background of digital transformation (Caviggioli and Ughetto, 2019). On the other hand, 3D printing is also a disruptive technology (Garmulewicz et al., 2018; Rodriguez-Espindola et al., 2020). It has made a significant impact on the value proposition (Jin and Shin, 2021; Pisano et al., 2016; Todeschini et al., 2017), customer relationship (Arribas and Alfaro, 2018; Chaney et al., 2022; Rindfleisch and Im, 2019), key partners (KP) (Pal and Gander, 2018; Todeschini et al., 2017), value capture (Holzmann et al., 2020; Luximon and Luximon, 2021), value networks (Huynh, 2021; Rayna and Striukova, 2016), and value distribution (Rayna and Striukova, 2016) of the traditional business models used in garment enterprises (Jin et al., 2021a; Rayna and Striukova, 2014). Therefore, these garment enterprises adopting 3D-printing technology are facing a new problem in the context of digital transformation, which is the problem of business model innovation. Under this background, the business model innovation of 3D-printing clothing enterprises in the context of digital transformation represents an important gap to be researched.

Although the industrialization of 3D-printing technology occurs rapidly, it has only emerged in recent years, which leads to a lack of extant research on the business model innovation of 3D-printing garment enterprises (Azariadis and Papagiannis, 2010; Jia and Liu, 2007; Jin et al., 2021b; Lin, 2017). Our literature research on Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), The Engineering Index (EI), Scopus, China National Knowledge Infrastructure (CNKI) and other databases shows that previous scholars’ research on this issue has mainly emphasized the necessity of business model innovation in garment enterprises in the 3D-printing context. For example, Chang et al. (2016) believe that the use of technologies such as 3D-printing technology has narrowed the gap between production and consumption and is destroying the traditional value chain of the entire clothing industry. Therefore, it is urgent that garment enterprises innovate their business models. Tremblay and Yagoubi (2017) note that it is necessary to innovate the traditional business model of garment enterprises to fully transform the emerging technology of 3D printing into a force capable of driving the survival and development of the modern garment enterprises. Loetscher et al. (2017) point out in their article Changing fashion: The clothing and textile industry at the brink of radical transformation that garment enterprises are influenced by 3D printing, robots, etc. are on the brink of radical transformation, and this requires that they innovate their business model. Rindfleisch et al. (2019) think that garment stores can be transformed into clothing 3D-printing stations, which can save costs. Sun and
Zhao (2017) propose that within the garment industry, alternative business models are emerging to meet the increasingly diverse needs of consumers. Spahiu et al. (2020) conclude that 3D technology is being actively applied in the field of textile and garment manufacturing, and the business model of enterprises should follow these trends to distinguish and obtain competitive advantage. It is obvious that the above previous research has made great contributions to our understanding of business model innovation in 3D-printing clothing enterprises. However, there is a lack of specific business model innovation relating to 3D-printing clothing enterprises, let alone a specific new business model designed to address the issues of digital transformation. Therefore, we attempt to design a new business model that addresses digital transformation for 3D-printing clothing enterprises by adopting a business model innovation canvas (BMIC), which is a new method specifically designed for business model innovation and proposed by Professor Yuran Jin, in addition to the world-famous business model canvas (BMC) method. We also answer the following four questions in this paper:

**RQ1.** How can a new business model be innovated for 3D-printing clothing enterprises using the BMIC?

**RQ2.** What does such a new business model look like?

**RQ3.** What does the ecosystem of the new business model look like?

In theory, this study enriches the research work regarding subject integration between the subjects of 3D printing and business model innovation and has certain reference significance for promoting the theoretical development of 3D printing, business models and business model innovation. In practice, the research results not only impart direct guidance for garment enterprises adopting 3D-printing technology but also provide important guidance for clothing enterprises looking to adopt 3D-printing technology in the future. In addition, the research results from other manufacturing enterprises, ranging from jewelry, food, accessories, food, medical treatment, toys and others industries in the era of 3D printing, also have important reference significance and practical value for promoting business model innovation because the manufacturing characteristics of 3D-printing garment enterprises are similar to those of many other manufacturing enterprises.

The remainder of the paper is organized as follows. First, the previous related studies are reviewed and a theoretical framework for business model innovation in digital transformation is developed. After that, the methods and framework are introduced in Section 3. Then, the BMIC method is used to carry out business model innovation for 3D-printing garment enterprises. Here, the “Mass Deep Customization – distributed manufacturing (MDC-DM)” is designed, which is presented with a BMC. In addition, the ecosystem of the MDC-DM business model is constructed in Section 4. Finally, the discussion and conclusion are offered in Section 5.

**Literature review**

We have reviewed the literature regarding the main concepts used in this study and obtained the following results. The definition of these concepts is helpful for an in-depth understanding of the research background and the content of the article.

**Digital transformation and business model**

Digital transformation is the new stage reached following the digitization and digitalization stages (Verhoef et al., 2021). Most scholars define digital transformation as a way of rebuilding business models to better meet the needs of customers by applying new
technologies (Berman, 2012; Ziyadin et al., 2007). Bresciani et al. (2021) address the relationship between digitalization and business models, shedding light on how digital technologies can be used to foster successful business models. Andal-Ancion et al. (2003) claim that digital transformation is mainly related to the capacity to use new technologies to remain competitive in the Internet age, where services and products can be delivered either online or offline. Online service transformation is seen as a way to improve customizability and automation through standardization. Westerman et al. (2014) posit that digital transformation is “the use of technology to radically improve performance or reach of enterprises. Executives in all industries are using digital advances such as analytics, mobility, social media and smart embedded devices as well as improving their use of traditional technologies such as ERP to change customer relationships, internal processes and value propositions.” Value creation is seen as the outcome of digital transformation (Mergel et al., 2019). Steiber et al. (2021) research the innovation diffusion framework of digital transformation and expand the existing body of knowledge on what contributes to or hinders an industrial firm’s digital transformation by applying a validated framework based on innovation diffusion theories. Berman (2012) point out that digital transformation would result in a paradigm shift that is “characterized by hyperconnectedness and collaboration of consumers and organizations across the gamut of value chain activities: codesign, cocreation, coproduction, comarketing, codistribution and co-funding.” The above studies reveal the close relationship between digital transformation and business models, which promotes the innovation of business models.

Business model and business model innovation
The business model is an important weapon by which modern enterprises can compete (Bashir and Verma, 2017; Casadesus-Masanell and Ricart, 2010). Although academia has performed much research on this concept, as well as on the elements and value creation process of business models, it has not yet formed a unified concept. According to Timmers (1998), the business model refers to the basic logic behind enterprise value creation; that is, it refers to the means of providing products and services to customers and creating profit within a certain value chain or value network. Osterwalder and Pigneur (2013) posit that the business model describes the basic principles of how an enterprise creates, transmits and acquires value, and it includes nine modules: customer segmentation, value proposition, channel access, customer relationship, revenue source, core resources, key business, important cooperation and cost structure (CS). Abdelkafi and Täuscher (2016) claim that a business model is a feedback loop that creates value for customers, captures value and returns value to nature. The best business model is one that is mutually beneficial for both of the parties in a partnership rather than being a zero-sum game (Langley, 2022). The BMC approach is currently a globally recognized tool for presenting a business model (Osterwalder et al., 2011). This paper uses this method to visualize the innovative business model.

If one wants to develop a competitive business model, then business model innovation is necessary (Afuah, 2014; Chesbrough, 2010; Sjödin et al., 2020). Just as the theoretical research on business models is still in an immature stage, the research on business model innovation has not reached consensus in theoretical circles. Researchers have advanced a variety of conceptualizations from different perspectives, in different fields and based on different goals. Sosna et al. (2010) think that business model innovation is a strategic renewal mechanism by which an organization can face changes in their external environment. Sorescu (2017) proposes that business model innovation represents a change in the function of a company’s value creation, value possession or value delivery, which can have a significant impact on the company’s value proposition. Sjödin et al. (2020) argue that successful business model innovation is based on the continuous alignment of value creation...
and value capture. There are very few tools developed purely for business model innovation. The BMIC developed by Professor Yuran Jin from the University of Science and Technology Liaoning (Jin et al., 2022) has the advantages of strong maneuverability and high flexibility. This is a very popular method in the field of business model innovation in recent years. In this study, this method is used to carry out business model innovation research.

**Business ecosystem and business model ecosystem**

A business model ecosystem is a business ecosystem in which the business model operates and works as a value-adding mechanism (Lindgren, 2016). The business ecosystem is “an economic community supported by a foundation of interacting organizations and individuals – the organisms of the business world. The economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders” (Moore, 1993). Delong (2000) argues that a business ecology is a more productive set of processes for developing and commercializing new technologies, which is characterized by rapid prototyping (including 3D printing), short product-development cycles, early test marketing, options-based compensation, venture funding and early corporate independence. In this study, we will show the ecosystem of the new business model of 3D-printing clothing enterprises proposed in this paper.

**Mass customization**

Mass customization refers to the ability to provide customized products and services to each customer by leveraging a high degree of process flexibility and integration (Da Silveira et al., 2001). It is used to customize products for individual customers and produces those items using the principles of mass production (Partanen and Haapasalo, 2004). Mass customization refers to the automated manufacturing of purchased products (Kull, 2015). In contrast to traditional mass production, mass customization simultaneously enables economies of scale (mass efficiency) and strong customization characteristics, which is in line with the new production trend of the personalized era (Tseng and Jiao, 1998; Wu et al., 2020).

**Distributed manufacturing**

Distributed manufacturing is a paradigm suggesting that the geographical distribution of manufacturing systems adjacent to markets enables production on demand (Kumar et al., 2020). It is also known as distributed production, cloud production and local manufacturing and is a form of decentralized manufacturing in which enterprises use a geographically dispersed network of manufacturing facilities (coordinated through information technology). It can also refer to local manufacturing or to manufacturing that occurs directly in consumers’ homes (Matt et al., 2015b; Srai et al., 2016), such as the use of 3D printing to facilitate distributed manufacturing (Sedita et al., 2022). The features of distributed manufacturing include digitalization, personalization, localization, new enabling technologies and enhanced user and producer participation (Srai et al., 2016).

The above previous studies show digital transformation affects the business models of enterprises, so business models need to be innovated. In the process of innovation, relevant methods such as BMIC need to be combined (RQ1), and the new business models obtained after innovation also need to be presented in combination with relevant methods like BMC (QR2). Ultimately, the ecosystem of new business models needs to be characterized (RQ3). Therefore, we developed the research framework for business model innovation in digital transformation as shown in Figure 1. This framework clarifies the theoretical logic and defines the research path for the follow-up research of this paper.
Methods and research design

Business model innovation canvas (BMIC)- a new method for business model innovation

BMIC is a new method specifically designed for business model innovation and proposed by Yuran Jin in his doctoral thesis in 2018. BMIC was first published online in the European Journal of Innovation Management (EJIM) in 2021 in a paper entitled Business Model Innovation Canvas: A Visual Business Model Innovation Model (Jin et al., 2022). After the paper was first published, it attracts much attention from scholars all over the world and has been downloaded more than 4,000 times. Currently, this method has become a new tool for business model innovation worldwide, through which the users can systematize information and deliver an interesting output. The proposal of BMIC is the result of data mining and analysis of 13,670 business model innovation-related literature extracted from SCI and SSCI databases of Clarivate based on Ground Theory. Compared with the few current business model innovation methods in the world, BMIC gives 145 clear potential options for business model innovation, puts forward the concept of business model innovation hotspot for the first time and gives how to use these innovation options and innovation hotspots to carry out business model innovation. One more thing, BMIC is a new method specifically designed for business model innovation. For both theoretical researchers and practitioners of business model innovation, the emergence of BMIC is a new expansion in the field of business model innovation methodology.

BMIC can be used to effectively improve the efficiency and effectiveness of business model innovation. Using this method, researchers can innovate business models for enterprises without quantitative data as long as they reason and deduce various combinations of business model innovation directions. BMIC consists of three layers with seven modules, as shown in Figure 2. The first layer includes three modules: value drive, value goal and value proposition, which reflects the strategic consideration of business model innovation. The second layer contains two modules of value creation and value transmission, which reflect the innovation options of the core links of the business model. The third layer is composed of two modules, value capture and value evaluation, which reflect the evaluation considerations regarding the results of business model innovation (Jin et al., 2022). Each module contains different areas of concern, and potential innovation options are provided below each area.
<table>
<thead>
<tr>
<th>Value driven</th>
<th>Value goal</th>
<th>Value proposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>External power</td>
<td>Value of design</td>
<td>Value of innovation</td>
</tr>
<tr>
<td>Internal power</td>
<td>Value of patents</td>
<td>Value of technology</td>
</tr>
</tbody>
</table>

**Figure 2.**

**Business model innovation canvas (BMIC)**

**Implementation methods**
- Considering progressive, radical, destructive, or sustained innovation
- Considering path dependency and path dependence
- Considering the role of technology in the industry
- Considering the role of technology in the environment
- Considering the role of technology in the society
- Considering the role of technology in the organization
- Considering the role of technology in the ecosystem
- Considering the role of technology in the economy

**Value creation**
- Core competence: Considering the role of technology in the industry
- Knowledge resource: Considering the role of technology in the environment
- Knowledge management: Considering the role of technology in the organization
- Knowledge ecosystem: Considering the role of technology in the society
- Knowledge transfer: Considering the role of technology in the economy

**Value transmission**
- Distribution channel: Considering the role of technology in the industry
- Distribution management: Considering the role of technology in the environment
- Distribution strategy: Considering the role of technology in the organization
- Distribution ecosystem: Considering the role of technology in the society
- Distribution transfer: Considering the role of technology in the economy

**Cost structure**
- Consider the cost of production
- Consider the cost of distribution
- Consider the cost of marketing
- Consider the cost of sales

**Value creation**
- Value proposition: Considering the role of technology in the industry
- Value proposition: Considering the role of technology in the environment
- Value proposition: Considering the role of technology in the organization
- Value proposition: Considering the role of technology in the society
- Value proposition: Considering the role of technology in the economy

**Value transmission**
- Distribution channel: Considering the role of technology in the industry
- Distribution management: Considering the role of technology in the environment
- Distribution strategy: Considering the role of technology in the organization
- Distribution ecosystem: Considering the role of technology in the society
- Distribution transfer: Considering the role of technology in the economy

**Value proposition**
- Market positioning: Considering the role of technology in the industry
- Market positioning: Considering the role of technology in the environment
- Market positioning: Considering the role of technology in the organization
- Market positioning: Considering the role of technology in the society
- Market positioning: Considering the role of technology in the economy

**Customer**
- Considering customer satisfaction
- Considering customer loyalty
- Considering customer retention
- Considering customer satisfaction
- Considering customer loyalty

| Source(s): Author’s own work | 3D-printing garment enterprises |
For example, three domains, namely, external power, internal power and constraint resistance, are considered in the value drive module, which contains a total of 20 potential innovation options. A total of 145 potential innovation options can be considered in BMIC when carrying out business model innovation. The use process of BMIC is shown in Figure 3. It includes ① capturing innovation hotzones, ② finding potential innovation directions in these innovation hotzones, ③ innovating new business models by combining innovation directions and ④ reinnovating existing business models. Specifically, the business model innovation hotzones, which are fields with potential opportunities to innovate business models represented by ribbons, should be captured from BMIC first. In this process, enterprises need to combine their own internal and external environment to judge which of the 145 innovation options have the possibility of business model innovation. Every possible innovation option is a hotzone for business model innovation. After that, these innovation hotzones will be analyzed to find potential innovation directions. Then, these innovative directions will be combined comprehensively to deduce a new business model similar to business Models A, B and C in the figure. In the end, if necessary, there will be a new round of business model innovation (Jin et al., 2022).

Business model canvas (BMC)
A BMC is represented by a chart that illustrates the supplies, customers, infrastructure and finance of an enterprise, which drives enterprises to optimize their business activities (Barquet et al., 2011). Companies such as Ericsson and Deloitte have “described and controlled” business models using BMCs. BMCs are used to specify value propositions (VP), customer segments (CS), customer relationships (CR), channels (CH), key activities (KA), key resources (KR), KP, revenue streams (RS) and CS (Ladd, 2018; Osterwalder and Pigneur, 2013; Osterwalder et al., 2011, 2014), as shown in Figure 4.

A BMC is essentially different from a BMIC. Although a BMC can be used for business model innovation, its main function is to “describe and control” business models. The BMIC was meant for business model innovation, and its original design intention was to assist in the innovation of new business models. This can be seen from the obvious differences in canvas structure and content between the BMC and the BMIC. The nine modules of the BMC are used to describe the content of a business model, while the BMIC is used to describe the process and means of business model innovation.

Research design
This paper comprehensively adopts BMIC and BMC methods and explores their respective advantages in terms of business model innovation and business model display. First, the BMIC is used to innovate the business model of 3D-printing garment enterprises. By capturing innovation hotzones, identifying the innovation directions from those innovation hotspots and combining those innovation directions, a novel business model for clothing enterprises is finally innovated. After that, a BMC is used to illustrate this new business model. The 9 elements of the new business model are first analyzed. These elements are then combined to form a BMC. Finally, the means of operating the new business model is analyzed, including its ecosystem and the operation mechanism. Figure 5 shows our research design.

Innovating a new business model MDC-DM for 3D-printing garment enterprises
Identifying innovation hotzones and obtaining innovation directions
Corresponding to the BMIC indicators and framed within the current context of industrial development, we first identified the business model innovation hotzones for 3D-printing clothing enterprises. Then, we analyzed these hotzones and identified potential innovation
Figure 3. The application process of BMIC 3D-printing garment enterprises
Taking the value driven module and value goal module as examples, we show the process of analyzing the innovation hotzones and innovation directions in Tables 1 and 2. Through the above analysis, we obtained all the potential innovation directions from all 7 modules. After comprehensively analyzing these “innovation directions”, sixty “innovation directions” were finally obtained. We classified these directions according to the modules of
### Identifying hotzones → Analyzing hotzones → Getting the potential innovation directions

<table>
<thead>
<tr>
<th><strong>Considering the destructive potential and impact of emerging technologies</strong></th>
<th>3D printing, known as a disruptive technology, will subvert the traditional production mode of garment enterprises <em>(Kim et al., 2015)</em></th>
<th>1. It is necessary to innovate new business models</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Considering the dilemma of existing business models</strong></td>
<td>3D printing exerts a significant impact on the traditional business model of garment enterprises</td>
<td>2. It is necessary to innovate new business models</td>
</tr>
<tr>
<td><strong>Considering the environment of innovation-driven development</strong></td>
<td>Innovation-driven development has become a new driving force for global economic development, and the innovation environment has formed</td>
<td>3. It provides a context in which business model innovation is feasible</td>
</tr>
<tr>
<td><strong>Considering the market environment, including globalization, regionalization, and intellectualization</strong></td>
<td>The globalization of modern clothing has obvious characteristics <em>(Truett and Truett, 2017)</em>. Intellectualization has become a new trend <em>(Hong-Ying and Yu-Mei, 2016)</em></td>
<td>4. Integrating the global design elements and the participants into the global and industry chain. are integrated into the garment design system</td>
</tr>
<tr>
<td><strong>Considering technical maturity, technology transfer and technical services</strong></td>
<td>With the gradual maturity of 3D printing technology, it is being used to produce clothing</td>
<td>5. Promoting intellectualization, developing intelligent clothing etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. Carrying out technical services for customers, developing virtual reality optional clothes, customer customization and other services</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7. Using 3D printing equipment and skills to carry out technology transfer services, including design, OEM, ODM etc.</td>
</tr>
<tr>
<td><strong>Considering the attractiveness of regulations and policies</strong></td>
<td>The policy driving force is obvious under the positive influence of intelligent manufacturing, industrial 4.0 and other policies</td>
<td>8. Forming credible policies for developing business model innovation</td>
</tr>
<tr>
<td><strong>Considering the first-mover advantage</strong></td>
<td>Garment enterprises need to seriously consider the innovation of business model to obtain the first-mover advantage</td>
<td>9. Being proactive about innovation</td>
</tr>
<tr>
<td><strong>Considering whether there are new creative projects</strong></td>
<td>Using 3D printing technology to produce clothing has become a new creative project</td>
<td>10. It is necessary to innovate new business models</td>
</tr>
<tr>
<td><strong>Considering the lack of interaction</strong></td>
<td>Consumers, designers, garment manufacturers, raw material suppliers and middlemen lack the level of effective interaction to adapt to the changing trend in 3D printing</td>
<td>11. Through a variety of information platforms to achieve a full range of multiparty interaction from design to production, the Internet, WeChat, a variety of mobile terminals, etc., are considered</td>
</tr>
<tr>
<td><strong>Considering inertial barrier to thinking</strong></td>
<td>Business models need to eliminate traditional frame constraints</td>
<td>12. Abandoning traditional frame constraints</td>
</tr>
</tbody>
</table>

Table 1. The business model innovation hotzones and innovation directions of value driven module (continued)
the BMC, as shown in Table 3 and deduce new business models for 3D-printing garment enterprises to account for these directions.

**MDC-DM business model proposal based on combining innovation directions**
The following set of important guiding information can be extracted from the innovation directions presented in Table 3: [20] the conducting of deep customization or design for customers, [34] the development of personalized customized clothing products, [27] the carrying out of mass customization, [16] the acceleration of the business model response through distributed production, [29] the promotion of collaborative production through crowdsourcing and other forms and [57] the taking on of individual consumers, fashion lovers, fashion models and well-heeled consumers as the main consumers.

Summing up the above innovation directions in combination, we can conclude the following: (1) there are still some customers who are eager for “[20] deep customization or design” in the 3D-printing garment customization market, such as “[57] fashion lovers.” Therefore, the needs of these customers can be met by garment enterprises through the provisioning of more “[34] personalized garment customized products” to realize profitable development. This “[20] deep customization or design” actually provides customers with more customization space, which far exceeds the utility of the customization method that only involves the selection of modules. (2) The emergence of a large number of fully personalized 3D-printing garment orders leads to a sharp increase in the product varieties offered by garment enterprises because every product is unique (despite the reproduction of a single product). Therefore, 3D-printing garment enterprises must have the capacity for “[27] mass customization.” (3) Fully personalized garment customization forces garment enterprises to no longer be able to rely on large-scale production. To meet the customization needs of customers, garment enterprises require a large investment in 3D-printing equipment, which negatively affects the production cost, risk prevention and control of garment enterprises. “[16] Distributed production” and “[29] the promotion of collaborative production through crowdsourcing and other forms” can be used to solve these problems. By carrying out distributed production (crowdsourcing) with more partners, the investment burden of obtaining sufficient 3D printers in garment enterprises can be rapidly reduced, and customer needs can be more easily fed back locally. An important means of solving the problem of the mass customization of fully personalized 3D-printing clothing is the implementation of

<table>
<thead>
<tr>
<th>Identifying hotzones →</th>
<th>Analyzing hotzones →</th>
<th>Getting the potential innovation directions</th>
</tr>
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<tbody>
<tr>
<td>Considering selective attention</td>
<td>Under the background of 3D printing, the traditional customers, suppliers, and middlemen of garment enterprises will all change</td>
<td>13. Reexamining partners. Raw material suppliers, equipment suppliers and outsourced manufacturers of 3D printing join the enterprise network</td>
</tr>
<tr>
<td>Considering the insufficient allocation of social technology</td>
<td>The number of 3D printing factories and 3D printers is still small, and the performance of most 3D printers cannot meet the requirements of garment printing. (Lin, 2017; Vanderploeg et al., 2017)</td>
<td>14. Considering device sharing</td>
</tr>
</tbody>
</table>

Table 1. **Source(s):** Authors’ own work
Identifying hotzones → Analyzing hotzones → Getting the potential innovation directions

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Description</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>Considering an open innovation strategy</td>
<td>Enterprises can achieve a better financial return through Open Innovation (Aziz et al., 2017; Chesbrough, 2019; Lyu et al., 2019). Garment enterprises can make full use of external forces to realize both internal and external collaborative innovation (Giesen et al., 2010; Van Bommel, 2011)</td>
<td></td>
</tr>
<tr>
<td>Considering the method of system dynamics</td>
<td>System dynamics is the perspective used to study the business model (Cosenz and Noto, 2018; Kirkwood, 2013; Romero et al., 2015; Zhang et al., 2012). It has been used to verify the effectiveness of the existing model through simulation and to deduce the possible revenue change trend in the future.</td>
<td></td>
</tr>
<tr>
<td>Considering business modeling</td>
<td>Modeling the business can clearly show the business model composition and the relationship between the various components (Jacob et al., 2010; Oskam et al., 2018). The set of activities for cognitively manipulating the business model are used to evaluate alternative methods (Baloch et al., 2021; Bojovic et al., 2018). This is an important quantitative research method for studying business models (Cosenz et al., 2020)</td>
<td></td>
</tr>
<tr>
<td>Considering service-driven, user-driven and information-driven dynamics</td>
<td>Being able to provide the services required by customers is an important means for garment enterprises to attract consumers (Li et al., 2019; Wan et al., 2007). Carrying out production based on customer needs is the trend of the personalization era. Informatization has been the booster driving business transformation (Stanimirovic, 2015; Tang et al., 2022; Won and Park, 2020)</td>
<td></td>
</tr>
</tbody>
</table>

15. With the help of external research ability, promoting enterprises’ inner and external channels to expand the market together. Considering direct use (P&G mode), joint research and development (Intel mode), community support (IBM mode) or platform integration (Apple mode).

16. Using system dynamics to carry out simulation research on business model innovation.

17. Constructing the business model after innovation, and using system dynamics to carry out simulation research on this business model.

18. Service-driven is a reflection of focusing on the service needs of customers, such as convenience and diversification; User-driven is a reflection of the customized services offered to meet different customer groups; Information driven is a reflection of appropriately obtaining clothing element information, and it also includes garment production data as driven by order information etc.

(continued)
Identifying hotzones → Analyzing hotzones → Getting the potential Innovation directions

- Considering the cloud business model, agile business model and networked business model
  
  A cloud-based platform business processing model can meet the needs of the complex interactions between enterprises and customers, as well as those among enterprises (Labes et al., 2017; Wen and Zhou, 2016); an agile business model improves the response speed of enterprises and meets the heterogeneous needs of customers (Bock and Gerard, 2014; Ghezzi and Cavallo, 2020), which is obviously an important development trend within garment enterprises; and a networked business model is necessary for enterprises to create their value (Anwar and Ali Shah, 2020; Paiola et al., 2021; Zheng and Qing-Hua, 2012), which can extend the cooperative relationship and obtain relevant value-added. Distributed production and logistics outsourcing are important means of increasing the response speed of supply chain (Abbasi et al., 2021; Asamoah et al., 2021; Cohen and Lee, 2020; Shabbir et al., 2021).

- Considering a software-based mixed business model and a sponsor-based business model
  
  The mixed business model based on software emphasizes the driving role of “software as a service” in business model innovation (Ma, 2007); a sponsor-based business model can make firms monetize their offering via sponsors and invent new ways of generating revenues from either third parties (Clauß et al., 2020; DaSilva, 2020). Both of these business models can be used to improve the participation and satisfaction of garment enterprises’ customers.

19. Adopting cloud service platform
20. Accelerating the response speed of business model through distributed production and logistics outsourcing
21. Extending network of business model through distributed manufacturing
22. Considering the pull function of 3D printing garment design software, developing and applying APP software operation chain
23. Attracting sponsors to invest capital

Source(s): Authors’ own work
<table>
<thead>
<tr>
<th>S/N</th>
<th>Innovation directions</th>
<th>Canvas module</th>
<th>S/N</th>
<th>Innovation directions</th>
<th>Canvas module</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Developing smart clothing, such as temperature somatosensory clothing and Internet of things smart clothing</td>
<td>Value propositions</td>
<td>31</td>
<td>Providing a 3D-printing clothing change style service</td>
<td>Value Propositions</td>
</tr>
<tr>
<td>2</td>
<td>Enabling virtual reality for selecting and trying on clothes</td>
<td>Customer relationships</td>
<td>32</td>
<td>Providing recycling services for 3D-printing clothing (process it into new consumables for use or sale)</td>
<td>Value Propositions</td>
</tr>
<tr>
<td>3</td>
<td>Developing 3D printing clothing design, OEM and ODM services</td>
<td>Revenue streams</td>
<td>33</td>
<td>Providing 3D-printing clothing product conversion service</td>
<td>Value Propositions</td>
</tr>
<tr>
<td>4</td>
<td>Providing OEM services for other productions suitable for 3D printing besides clothing</td>
<td>Revenue streams</td>
<td>34</td>
<td>Developing personalized customized clothing products</td>
<td>Value Propositions</td>
</tr>
<tr>
<td>5</td>
<td>Establishing information platforms such as Internet, WeChat, various mobile terminals etc.</td>
<td>Key resources</td>
<td>35</td>
<td>Producing ornaments of 3D-printing clothing</td>
<td>Value Propositions</td>
</tr>
<tr>
<td>6</td>
<td>Producing integrated clothing products, such as various ornaments</td>
<td>Value propositions</td>
<td>36</td>
<td>Adopting skimming prices or a combination of skimming prices and satisfactory prices</td>
<td>Customer Relationships</td>
</tr>
<tr>
<td>7</td>
<td>Considering device sharing</td>
<td>Customer relationships</td>
<td>37</td>
<td>Implanting social media sites, Weibo, WeChat, blogs, forums, podcasts and other social media</td>
<td>Customer Relationships</td>
</tr>
<tr>
<td>8</td>
<td>Optimizing the supply chain and logistics network</td>
<td>Channels</td>
<td>38</td>
<td>Carrying out production outsourcing, service outsourcing, R&amp;D outsourcing, logistics outsourcing etc.</td>
<td>Key Activities</td>
</tr>
<tr>
<td>9</td>
<td>Expanding the market through both internal and external channels</td>
<td>Channels</td>
<td>39</td>
<td>Introducing the Internet community</td>
<td>Customer Relationships</td>
</tr>
<tr>
<td>10</td>
<td>Using system dynamics to study business model innovation</td>
<td>Key activities</td>
<td>40</td>
<td>Building B2C and B2B2C models</td>
<td>Key Activities</td>
</tr>
<tr>
<td>11</td>
<td>Building a business model and conducting simulation analysis</td>
<td>Key activities</td>
<td>41</td>
<td>Building an online and offline collaborative operation</td>
<td>Key Activities</td>
</tr>
<tr>
<td>12</td>
<td>Service-driven. Convenience, diversification etc.</td>
<td>Customer relationships</td>
<td>42</td>
<td>Carrying out convenient payments such as mobile banking, Alipay, WeChat Pay etc.</td>
<td>Customer Relationships</td>
</tr>
<tr>
<td>13</td>
<td>User-driven. Meeting the customized services of different customer groups</td>
<td>Customer relationships</td>
<td>43</td>
<td>Integrating into the Internet</td>
<td>Customer Relationships</td>
</tr>
</tbody>
</table>

Table 3. Innovation direction and its module attribute in business model canvas (continued)
<table>
<thead>
<tr>
<th>S/N</th>
<th>Innovation directions</th>
<th>Canvas module</th>
<th>S/N</th>
<th>Innovation directions</th>
<th>Canvas module</th>
</tr>
</thead>
<tbody>
<tr>
<td>[14]</td>
<td>Information driven. International fashion week, store sales and other clothing element information drive clothing design, and order information drives clothing production</td>
<td>Customer relationships</td>
<td>[44]</td>
<td>Implanting style design, fabric selection, 3D size measurement, presale VR try-on virtual experience, etc. in the early stage of production</td>
<td>Customer Relationships</td>
</tr>
<tr>
<td>[15]</td>
<td>Adopting a cloud service platform</td>
<td>Key resources</td>
<td>[45]</td>
<td>Interacting with remote media</td>
<td>Customer Relationships</td>
</tr>
<tr>
<td>[17]</td>
<td>Implementing the modular production of 3D printing clothing</td>
<td>Key activities</td>
<td>[47]</td>
<td>Developing a new partnership among 3D printing raw material suppliers, equipment suppliers, outsourcing manufacturers etc.</td>
<td>Key Partnerships</td>
</tr>
<tr>
<td>[18]</td>
<td>Value creation between consumers and enterprises</td>
<td>Customer relationships</td>
<td>[48]</td>
<td>Capitalizing on the digital model of clothing and accessory products</td>
<td>Revenue Streams</td>
</tr>
<tr>
<td>[19]</td>
<td>Value creation between consumers and consumers</td>
<td>Customer relationships</td>
<td>[49]</td>
<td>Realizing information sharing</td>
<td>Key Activities</td>
</tr>
<tr>
<td>[20]</td>
<td>Carrying out deep customization or design for customers</td>
<td>Value propositions</td>
<td>[50]</td>
<td>Developing 3D printing clothing games</td>
<td>Customer Relationships</td>
</tr>
<tr>
<td>[21]</td>
<td>Working with virtual operators to achieve advertising placement and obtain user data (demand preferences, three-dimensional body size obtained through mobile phone lens scanning, etc.)</td>
<td>Customer relationships revenue streams</td>
<td>[51]</td>
<td>Providing free service. Earning value-added fees, advertising fees, production costs or obtain data models through consumer information</td>
<td>Value Propositions Revenue Streams</td>
</tr>
<tr>
<td>[22]</td>
<td>Increasing customer participation and considering printing production in public service centers</td>
<td>Customer Relationships</td>
<td>[52]</td>
<td>Removing or reducing the sales agency link of the traditional garment industry</td>
<td>Channels</td>
</tr>
<tr>
<td>[23]</td>
<td>Establishing a platform for collaborative innovation</td>
<td>Key resources</td>
<td>[53]</td>
<td>Adding the sales channel of experience store</td>
<td>Channels</td>
</tr>
<tr>
<td>[24]</td>
<td>Providing clothing change service after sale</td>
<td>Customer relationships</td>
<td>[54]</td>
<td>Establishing designer resource database to realize collaborative design</td>
<td>Key Activities</td>
</tr>
<tr>
<td>[25]</td>
<td>Changing or inserting a new scheme according to the actual situation in production</td>
<td>Customer relationships</td>
<td>[55]</td>
<td>Carrying out “precustimized scale production”</td>
<td>Key Activities</td>
</tr>
<tr>
<td>[26]</td>
<td>Carrying out niche customization</td>
<td>Key activities</td>
<td>[56]</td>
<td>Obtaining income from patent transfer</td>
<td>Revenue Streams</td>
</tr>
</tbody>
</table>

Table 3. (continued)
Based on the above analysis of the extracted innovation direction combinations, we present the mass deep customization – distributed manufacturing (MDC-DM) business model.

**Design concept behind the MDC-DM business model**

The most important feature of 3D-printing clothing is deep customization. If a 3D clothing company takes this feature as a future development direction, all of its customers’ 3D-printing clothing needs become different. In this context, if the enterprise hopes to adopt a centralized production business model to achieve this kind of deep customization in response to increasing mass demands and due to the fact that the production efficiency of 3D printing is still not comparable to that of traditional large-scale manufacturing, clothing enterprises need to concentrate on obtaining a large number of 3D printers to improve their rapid response abilities, which obviously increases the fixed asset investment and capital risk faced by clothing enterprises. In this content, distributed manufacturing has more advantages. Distributed manufacturing involves more direct feedback. When enterprises are unable to focus on the production of large-scale customized 3D-printing tasks, the business can be quickly dispersed to the 3D-printing subfactories (or their experience stores) in other areas, to allied factories (or their experience stores) or to other 3D-printing clothing enterprises through direct outsourcing. Another advantage of this dynamic is that localized production that is distributed in various places can be used to produce the supply near to the demand, thus reducing logistics costs and better meeting the rapid response needs of customers.

In terms of deep customization, the MDC-DM business model mainly provides services such as customized garment schemes, customer participation in clothing design and the accurate selection of parameters for customizing a 3D printable garment. As shown in Table 4, the deep customization inherent in the MDC-DM business model is that not all garment elements can be customized. 3D-printing garment enterprises are usually unable to meet the extremely special production requirements of “any color”, “any material” and “any precision” that are demanded by consumers. The first reason for this limitation is that some special needs cannot be met by the large-scale procurement of raw materials, which leads to a...
large increase in the raw material procurement costs for 3D-printing garment enterprises. Another reason is that there may be no suppliers of very special materials or hard to produce colors available. The third reason is that the production accuracy of 3D printers is limited and 3D-printing clothing products with any accuracy cannot be ensured. In addition, due to the different body types of different customers, the MDC-DM business model cannot be applied to the preproduction of parts and is the model provides no inventory of goods or clothing parts. 3D-printing garment enterprises must meet the customization cycle requirements of customers by applying measures such as rapid production and agile logistics.

The presentation of MDC-DM business model
Under the background of digital transformation, according to the generation process and main concept of the MDC-DM business model, to clearly reveal the whole-canvas landscape of this new business model, we apply the BMC method to conduct the following analysis in accordance with its 9 elements.

Value propositions. The main products aimed for through use of the MDC-DM business model are completely customized 3D-printing clothing and 3D printed garment accessories. The main available services are as follows: ① free 3D shape measurement, websites, Applications, etc.; ② digital size scanning and deep-style design; ③ 3D printed garment modification services. Clothing companies can customize parts of clothes for 3D printing for customers and then make modifications locally; and ④ recycling and transformation services for 3D-printing clothing. Some 3D printed garments can be recycled to provide new raw materials. Therefore, clothing enterprises can provision recycling services for 3D-printing clothing. In addition, garment enterprises can also provide modification services for 3D-printed clothes that customers have already purchased, such as updating sizes of the different parts for the 3D-printing clothing. The final available serves is the ability to ⑤ be an original equipment manufacturer (OEM) or original design manufacturer (ODM). On the one hand, 3D-printing clothing enterprises can provide 3D-printing production for external enterprises. On the other hand, because the enterprise has developed the R&D and design ability required to produce high-end 3D-printing clothing, it can also carry out ODM R&D and production services for 3D-printing clothing.

Customer relationship. To enhance CR and improve customer stickiness, 3D-printing garment enterprises adopting the MDC-DM business model can usually benefit from the following measures: ① Providing interactive body measurement and style design for 3D printed garments is an important service. Consumers can scan their digital body data through their own mobile phone cameras, portable scanners, or via the professional equipment provided in physical stores. In addition, based on the rapid development of 4G and 5G mobile communication networks, 3D-printing garment enterprises can fully leverage

<table>
<thead>
<tr>
<th>Type</th>
<th>Garment Size</th>
<th>According to Figure Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Size</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Accuracy</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Color</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Style</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Fabric</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Table 4. The mass customization example of 3D-printing garment

Source(s): Author’s own work
remote media to enable video live scanning (mainly photographic 3D scanning, that is, the
scanning of images first followed by the generation of digital models through software). In
this process, the user only needs to turn on the video live broadcast and then professional
equipment that is set up in various places (3D-printing enterprises, experience stores, etc.)
scans the video and, in combination with the environmental parameters, obtain the user’s
body data. ② Before purchase, 3D-printing clothing may be tried on by consumers through
digital means such as “virtual reality” or “scene simulation,” which improves customer
perception and satisfaction. ③ Full use should be made of the digital information gained from
experience stores and other channels to improve the customization quality of 3D-printing
clothing and enhance consumer loyalty. ④ Value is created for customers and the relationship
between the garment industry and consumers is strengthened. ⑤ Potential users are
developed through virtual operators. The forms of cooperation here include distributing
advertisements through virtual operators, obtaining user preference data from virtual
operators and so on. ⑥ Online services are introduced. Clothing module collections are
provided to buyers through digital technology. ⑦ Digital online communities are formed to
enhance customer communication. ⑧ A skimming pricing priority strategy can be adopted
to generate higher profits. ⑨ The influence of brands that use digital apps, blogs, forums,
podcasts and so on should be expanded. ⑩ Convenient payment methods, such as digital
mobile banking, should be enabled. ⑪ Full use should be made of the Internet to link
customers and enterprises. ⑫ The sharing of devices can be considered to be a means of
attracting consumers through the equipment sharing mode; that is, 3D-printing garment
enterprises can provide consumers with free digital scanning, free printing and other
services, but charges for raw material procurement, design, logistics and other links still need
to be applied. ⑬ The selection of a clothing model, clothing fabric and clothing color, as well
as consumer measurements, should occur prior to production. ⑭ Digital games should be
developed for 3D the printed garment process to make shopping more interesting for
consumers.

Channels. In the new model, clothing enterprises can use the coordinated operation of
internal and external channels to develop the market. However, there is no doubt that the
middle seller link is reduced in this case because 3D-printing clothing is basically customized,
and its sales are no longer as simple as traditional product sales. An experience shop is a more
suitable organization. The experience store can be self-operated, outsourced, or jointly
operated in conjunction with other enterprises. In addition, to provide customers with virtual
options and trial assembly (through digital virtual reality (VR), radio frequency identification
(RFID), Internet of Things (IoT) machinery, digital projection technology, etc.), some
experience stores also need to produce clothing through 3D printing, forming a compound
experience store for both production and sales. In addition, some mathematical models can be
constructed for optimizing costs. Moreover, clothing enterprises can adopt third-party
logistics services to improve the professionalism of logistics services and the level of
customer satisfaction.

Customer segments. Garment enterprises adopting the MDC-DM business model provide
customers with a “high degree of freedom” regarding garment customization products and
services. It mainly meets the needs of those consumers who have a high demand for
personalized clothing (such as fashion lovers) and are willing to deeply participate in the
process of personalized customization.

Key activities. “Mass distributed production” is the key aspect of the MDC-DM business
model. Figure 6 shows the specific distributed manufacturing network structure. This
distributed production can take place in a company’s headquarter factory, company branch
plant, company experience store, partner’s factory, or partner’s experience store. The core
factory may not be involved in manufacturing at all, as shown in the dotted box in Figure 6.
The other two KA are the deep customization design of 3D-printing clothing” and the
collection of digital customer 3D measurement data. Among them, the collection of digital customer 3D measurement data, as an initiative through which to improve CR, has been described in the “Customer Relations” module. The deep customization design of 3D-printing clothing is also an important activity. Even if 3D-printing garment enterprises obtain the digital measurements of their consumers, it does not necessarily entail a successful sale because obtaining the data is just the beginning of the sales process. If 3D-printing clothing enterprises cannot develop satisfactory fashion designs for customers, the process is reduced to becoming only a failed sales experience in the end and might reduce customer stickiness. In addition, enterprises can also consider the following measures:

① Promoting online and offline collaboration capacity, which is an important measure of digital transformation that was proposed by Westerman et al. (2014), Berman (2012) and so on. Specifically, this measure means that enterprises can build network platforms and experience stores in conjunction with one another.

② Outsourcing logistics, R&D, etc., to achieve enterprise operation
objectives. ③ Conducting business model innovation and optimization by applying a system dynamics model, establishing a model and simulation analysis for that business model and optimizing the supply chain production network. ④ Establishing a designer resource pool and reserve talent. The final measure involves ⑤ organizing enterprise unions and realizing collaborative innovation.

**Key resources.** Clothing enterprises adopting the MDC-DM business model should possess certain important resources, including the following: ① A distributed manufacturing network. Branch factories need to purchase 3D printers with good performance for garment production. The core factories and the experience stores need to purchase 3D garment printers according to their situations. Regardless of whether the core enterprise carries out production or not, from the group level, 3D printers are still necessary core resources. ② Senior 3D-printing garment designers who should have the ability to design 3D-printing clothing need to be established. ③ Workshops for 3D printing runs need to be developed. ④ A cloud platform is needed to enable digital information exchange among different agents. ⑤ Collaborative innovation platform are needed to integrate all the participants in the clothing manufacturing supply chain. ⑥ Digital information platforms such as the Internet and various mobile terminals need to be leveraged to improve the communication ability between enterprises and consumers, and more channels need to be developed for clothing enterprises. ⑦ Application software needs to be designed for customizing 3D-printing clothing for customers. Finally, the ⑧ raw materials for the production of 3D-printing clothing need to be procured.

**Key partners.** The most important partner for the 3D-printing garment enterprise is the third-party 3D-printing manufacturer, or clothing service provider in the business model. The reason for this is that enterprises adopting the MDC-DM business model can better realize distributed manufacturing by cooperating with these third-party enterprises. In addition, 3D-printing garment enterprises also maintain close contact with the suppliers of 3D-printing equipment, 3D-printing raw materials, 3D-printing software and so on. In addition, from the development trend in recent years, it can be seen that logistics enterprises are also important partners in meeting the needs of “multi variety and small batch” production. In addition, the experience store of the cooperative enterprise is a very important node for 3D-printing clothing enterprises, so it is undoubtedly also a key partner.

**Cost structure.** The purchase of 3D printers, 3D-printing software, raw and auxiliary materials for 3D printing, 3D-printing recycling equipment and so on incurs costs. On the other hand, R&D, marketing, digital copyright, logistics, platform development and maintenance, cooperation with partners and so on also incurs costs. In addition, labor costs also represent a major cost. In the process of 3D-printing garment recycling, there recycling costs also occur. In addition, due to the adoption of distributed manufacturing, business cooperation costs are generated together.

**Revenue streams.** 3D-printing garment enterprises adopting the MDC-DM business model can mainly realize income through the sales of completely customized garments, digital models of 3D-printing clothing and recycled waste products. In addition, advertisements through cloud platforms and applications, patent transfers, OEM or ODM services, etc., can also be used to increase the level of income for clothing enterprises.

Based on the above analysis, we finally obtain the canvas landscape of the MDC-DM business model, as shown in Figure 7.

**The operation of MDC-DM business model**
The business model ecosystem can fully reflect the operation mechanism between the external environment and internal structure of the business model (Delong, 2000; Lindgren, 2016). To systematically reflect the MDC-DM business model of 3D-printing garment
enterprises, based on the theoretical framework for business model innovation in digital transformation and the basic architecture of the supply chain, including logistics, information flow, capital flow and design flow and combined with the MDC-DM BMC, we construct the MDC-DM business model ecosystem of 3D-printing garment enterprises, as displayed in Figure 8.

**Basic operating process.** The social participants in the entire business model ecosystem include the 3D-printing garment production enterprises, 3D printing raw and auxiliary material suppliers, logistics enterprises, 3D-printing garment experience stores, consumers, online communities, independent designers, etc. These subjects work together to promote the orderly operation of the business model. The specific operating process is as follows:

In terms of order fulfillment, under the background of digital transformation, the MDC-DM business model places more emphasis on the customization process of the 3D-printing clothing model based on digitalization, as shown in Figure 9. It is mainly generated by the following three channels: (1) consumers design their own clothing models and then submit them to the core enterprise through an Internet cloud platform. Next, the garment enterprise divides the received garment models into two types. The first type represents those garment models that do not need to be redesigned. At this time, the core enterprise schedules production tasks. The second channel is the need of the garment model needs to be redesigned. At this time, the redesign process will have already begun. The designer communicates with the customer for garment design, and then the core enterprise arranges the production of the garment. (2) The second channel is that consumers provide 3D mannequins through self-service scanning, such as that conducted with their own mobile phone’s convenient equipment or simple 3D human body scanning equipment, the body shape data are submitted to the core enterprises through the Internet cloud platform, and then

<table>
<thead>
<tr>
<th>Key Partners (KP)</th>
<th>Key Activities (KA)</th>
<th>Value Propositions (VP)</th>
<th>Customer Relationships (CR)</th>
<th>Customer Segments (CS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D printing equipment suppliers</td>
<td>Mass customization of 3D printing garments</td>
<td>The completely customized 3D printing garments</td>
<td>Help consumers choose and try on clothing in advance through digital “virtual fitting” or “Simulation”</td>
<td>Fashion lovers</td>
</tr>
<tr>
<td>3D printing software suppliers</td>
<td>Organize core competencies, union enterprises and experience stores to carry out distributed</td>
<td>Service driven, information-driven</td>
<td>Highly personalized consumers</td>
<td></td>
</tr>
<tr>
<td>3D printing raw material suppliers</td>
<td>3D printing garment deep customization</td>
<td>Value creation between consumers and companies</td>
<td>Consumers willing to deeply participate in Personalized Customization</td>
<td></td>
</tr>
<tr>
<td>3D printing garment manufacturers</td>
<td>Collection of digital customer 3D body data</td>
<td>OEM and ODM service for 3D printing garments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Third party 3D printing experience stores</td>
<td>RED outsourcing, logistics outsourcing, etc.</td>
<td>Recycle waste for 3D printing garments</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Establish online-offline collaborative operation</td>
<td>3D printing garment product development and services</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>System dynamics research business model</td>
<td>3D printing garment product development and services</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Business model establishment and simulation analysis</td>
<td>3D printing garment product development and services</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Modelling and optimizing supply chain and product models</td>
<td>3D printing garment product development and services</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Build designer reputation</td>
<td>3D printing garment product development and services</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Study and judge the viability of new business model</td>
<td>3D printing garment product development and services</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Source(s):** Author's own work

![Figure 7](source_url) **Canvas of MDC-DM business model**
the design and production processes can commence. (3) The third channel is that of “picture modeling” and “conceptual modeling.” The process of picture modeling is one in which consumers provide two-dimensional pictures containing three-dimensional information to garment enterprises either online or offline, and then designers convert these pictures into three-dimensional data, establish a 3D human body model following customer communication and then engage in the garment design process and the print production process. The process of conceptual modeling is one in which consumers only provide ideas, concepts, etc., and then designers carry out the actual design of 3D mannequins and clothing according to these conceptual elements, finally entering the process of clothing printing production after the design is approved by consumers. Regardless of which of the above channels is selected, when scheduling production, core enterprises must optimize the scheduling of distributed production planning according to customer demand, demand time, clothing quality requirements, etc., the geographical layout of their own factories, experience stores and cooperative enterprises, printing capacity, equipment accuracy, production cycle, etc. and the cooperative willingness and cost of cooperative enterprises, etc. Finally, it assigns production tasks to itself, the distributed factories, the experience stores and so on.

In terms of supplier management, this business model ecosystem lists out suppliers according to the type of raw materials used. These raw materials are the main materials currently used in 3D garment printing. If these suppliers want to become suppliers of 3D-printing garment enterprises, they must possess the basic ability to provide these raw materials or other relevant raw materials.
In terms of waste material, core enterprises and their own distributed factories and experience stores can carry out 3D garment recycling business. On the one hand, the raw materials generated after treatment can be used by the production department, while on the other hand, they can also be externally sold to obtain profits. Whether a partner ends up carrying out the business has nothing to do with the core enterprise because the income of the outsourcing enterprise is not related to the core enterprise. They only represent the outsourcing and contracting relationship of 3D-printing clothing. Therefore, the recycling business of partners is not reflected in this ecosystem. In addition, garment enterprises may also carry out conversion services for products to make up for consumer expenses for...
purchasing new goods and encourage consumer secondary consumption regarding the recycled products.

**Information flow based on cloud platform.** Through the cloud platform, the participants in the business model realize the information sharing and collaborative innovation needed for producing 3D-printing clothing. Both self-operated distributed factories and union enterprise distributed factories can realize business communication through cloud platforms to promote information sharing and collaborative innovation. 3D-printing raw material suppliers provide timely feedback on new material information to promote the research and development of new products. At the same time, the participants in a collaborative innovation platform also drive demand for new material development among raw material suppliers. The fashion elements and customer demand information captured by the social independent designers, relevant online communities and experience stores of 3D-printing clothing, as well as the clothing design information fed back by consumers through apps and other channels can be shared in the cloud platform to achieve collaborative innovation. In addition, through the cloud platform, customers can also access printing progress information and logistics information regarding their products at any time.

**Capital flow based on convenient payment.** At the payment level, PayPal, Alipay, WeChat, Visa, Union Pay card payment and cash payment are all payment methods used in the process of selling or recycling 3D-printing clothing. Among them, some new media payment methods can be prioritized to increase the opportunities for consumers to contact enterprises and, in turn, increase customer stickiness.

**Logistics based on outsourcing services.** It is difficult for garment enterprises to realize self-logistics for 3D-printing garment customized products due to their multivariety and small batch attributes. Outsourcing is the main means of improving logistics efficiency and reducing logistics costs (Chu et al., 2019). Therefore, the final 3D-printing garment products can be delivered to customers through logistics outsourcing enterprises. Considering that consumers who purchase customized products generally have higher service requirements and expect high added value from 3D-printing clothing products, high-speed rail or even air transportation can be used for logistical transportation.

**Discussion**

From the above research, we obtain three new findings and discuss the theoretical and practical implications of this study, particularly its management implications, as follows.

**New findings**

Our first finding is that 3D-printing clothing enterprises are facing digital transformation and urgently need innovative business models. At the same time, mass deep customization and distributed manufacturing are important ways of solving the business model problems faced by 3D-printing clothing enterprises in the process of digital transformation. Although many scholars have studied digital transformation (Berman, 2012; Bresciani et al., 2021; Mergel et al., 2019), business model innovation (Afuah, 2014; Chesbrough, 2010; Jin et al., 2022; Sjödin et al., 2020), the business model of clothing enterprises (Gray et al., 2022; Jin et al., 2021b; Pal and Gander, 2018), mass customization (Da Silveira et al., 2001; Tseng and Jiao, 1998; Wu et al., 2020) and distributed manufacturing (Matt et al., 2015b; Sedita et al., 2022; Srai et al., 2016), no scholar has paid attention to the business model innovation of 3D-printing clothing enterprises under the background of digital transformation, let alone carried out mass customization and distributed manufacturing research on this issue.

The second new finding is that a new business model, Mass Deep Customization-Distributed Manufacturing (MDC-DM), has been innovated using BMIC for 3D-printing
garment enterprises in the context of digital transformation for the first time. Compared with
the previous research on the business model of clothing enterprises (Gray et al., 2022; Jin et al.,
2021a; Pal and Gander, 2018; Sawatenarakul and Roopsing, 2021), the MDC-DM business
model obviously differs in terms of VP, CS, CR, channels, KA, KR, KP, RS and CS. The nine
modules of the MDC-DM business model have been analyzed, and its canvas was presented
using the BMC. The ecosystem of the MDC-DM business model was constructed, and its
operation mechanisms, including basic operating processes (order fulfillment, supplier
management, waste material, etc.), information flow based on cloud platforms, capital flow
based on convenient payments, logistics based on outsourcing services and so on were
comprehensively designed.

Another finding is that BMIC, as a new method of business model innovation proposed by
Professor Yuran Jin, has been demonstrated to be an effective tool for business model innovation.
Through the BMIC method, we find a large number of business model innovation hotzones for
3D-printing clothing enterprises. From these innovation hotzones, we have excavated 60 business
model innovation directions suitable for 3D-printing clothing enterprises. Through the
combination of these innovation directions, we have succeeded in innovating a new business
model in the context of digital transformation for 3D-printing clothing enterprises.

**Theoretical and practical implications**

Important extant studies, such as Andal-Ancion et al. (2003), Osterwalder et al. (2011),
Westerman et al. (2014), Matt et al. (2015a), Öberg (2019), Spahiu et al. (2020), Tang et al. (2022)
and so on, have laid an important research foundation for this study and have provided much
enlightenment. Based on previous research, a theoretical framework for business model
innovation in digital transformation is developed for the first time in this paper. And just with
this theoretical framework, a new business model for 3D-printing clothing enterprises, MDC-
DM, is innovated successfully, which shows the framework has positive theoretical
significance. Scholars can use this theoretical framework to develop other new business
models of 3D-printing clothing enterprises. At the same time, the MDC-DM business model is
also not a specific model designed for a particular enterprise. Rather, it has a certain degree of
universality. It can provide an important theoretical reference for other scholars faced with
similar problems. In addition, the background of digital transformation is taken into account
in the process of business model innovation. This is the first hybrid research conducted on 3D
printing, garment enterprises, digital transformation and business model innovation. In
previous research, some scholars have studied 3D printing, some scholars have studied
digital transformation, and some scholars have studied business model innovation, but there
is a lack of research that couples these four focuses together. We have completed such an
innovative study and filled this gap. Moreover, the business model ecosystem we present for
3D-printing clothing enterprises comprehensively introduces the business operation
environment and mechanism that are faced by 3D-printing clothing enterprises, which
also enriches the research on the business model ecosystem.

There are three values in practice. On the one hand, the MDC-DM business model
proposed in this paper can provide new ideas for the development of 3D-printing clothing
enterprises and promote their competitiveness. On the other hand, for clothing enterprises
that are likely to use 3D printing in the future, the MDC-DM business model can provide an
effective path for business development. Finally, the business model innovation studied in
this paper takes garment enterprises as the starting point, but these problems are some
common problems faced by manufacturing enterprises in the era of 3D printing on many
levels. Therefore, some other types of enterprises that are using or considering using 3D-
printing technology can also learn from this study to promote their business model
innovation.
Management enlightenments
In the process of proposing and designing the MDC-DM business model, we obtained three management insights, as follows:

First, the external market environment exerts a robust impact on the implementation of the MDC-DM business model. The customization scale of consumers directly determines the feasibility and necessity of distributed production. Without scale, the existence of this business model is greatly reduced. Therefore, guiding and creating demand is a strategic task for 3D-printing garment enterprises.

Second, in the process of mass deep customization-distributed manufacturing, the requirement for the 3D-printing production capacity of garment enterprises is not high because the production order is completed through the cooperation of many partners. Even if garment enterprises do not have strong 3D-printing production capacity, they can still realize this business model through distributed production.

The third insight is that 3D-printing garment enterprises need to pay attention to partnership management. Because distributed manufacturing needs to be carried out jointly with partners and the coordination and sharing of information, funds, equipment and materials are involved in this process, 3D-printing clothing enterprises must attach great importance to the selection and management of partners to promote the successful implementation of the new business model.

Conclusions
To meet the development trend of customization, 3D printing has been adopted by many clothing enterprises. Throughout this process, 3D-printing clothing enterprises must face digital transformation. Business model innovation has become an important choice through which clothing enterprises can achieve development in this context. The purpose of this study is to explore the business model innovation of 3D-printing clothing enterprises under the background of digital transformation. Through the above research, we have answered questions about how to innovate a business model, what the new business model is and the ecosystem of the new business model. A new business model, the MDC-DM model, has been innovated for 3D-printing garment enterprises in the context of digital transformation using the BMIC method for the first time. Moreover, the ecosystem of the MDC-DM business model was constructed, and its operation mechanisms were comprehensively designed. Our analysis shows that the MDC-DM model has good theoretical and practical significance. In particular, this is the first hybrid research regarding 3D printing, garment enterprises, digital transformation and business model innovation. We have completed this innovative study and filled this gap in the literature. Moreover, research on business model ecosystems has also been enriched in this study.

Business model innovation is a type of exploratory research, and the new business models obtained through innovation require a period of reform in practice. For this reason, it is difficult to directly verify the effectiveness of the new business model proposed in this paper in the short-term. However, it is necessary to demonstrate the competitive advantages of the new business model. For this reason, in follow-up research, we will attempt to conduct a system dynamics simulation study on the new business models proposed in this paper and reveal the operation trend and competitive evolution of the new business model according to different scenarios to provide decision support for 3D printing-related enterprises.

References


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