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Mass Personalization in Industry: An Integrative Review

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Introdução
In the contemporary industrial landscape, the relentless pursuit of a competitive edge and the increasing demand from consumers for personalized products and services have shaped the way companies conceive and manufacture their products (Zhang, Ming, & Bao, 2022; Sajadieh, Son, & Noh, 2022). Industry 4.0 has brought promises of manufacturing flexibility, improved quality, and increased productivity. Amidst this revolution, Mass personalization emerges as a customer-centric production paradigm, seeking to balance cost, variety, and quantity (Sajadieh, Son, & Noh, 2022).
Problema de Pesquisa e Objetivo
Research on mass personalization in the industry has ranged from technical specifics to business process perspectives, characterizing the current state of the field as fragmented and heterogeneous, indicating the need for deeper insights into the topic. In this regard, this article aims to investigate the current landscape of mass personalization in the industry, exploring its challenges, technological advances, and implications for customer satisfaction and competitiveness in the global market through an integrative literature review.
Fundamentação Teórica
Industry 5.0 calls for increased interaction between humans and machines, ushering in a new era of personalization and complex problem-solving (Pereira & Dos Santos, 2023). Driven by the trend of individualization and enabled by heightened digitalization, mass personalization is becoming a reality. This new paradigm demands responsive and flexible manufacturing operations to produce customized products in dynamic batch sizes, economically and at scale (Qin & Lu, 2021).
Metodologia
The methodology employed in this study was an integrative literature review (Whittemore & Knafl, 2005; Torraco, 2005). This type of review differs from a narrative review as it follows a replicable, scientific, and transparent research process. An integrative review is a technique aimed at minimizing bias through exhaustive bibliographic searches of published studies, while explicitly detailing the reviewers' decisions, procedures, and conclusions (Tranfield, Denyer & Smart, 2003; Pereira & Cunha, 2020, 2021).
Análise dos Resultados
Utilizing the most suitable technologies for mass personalization remains the primary challenge in operationalizing it. However, there is a variety of studies indicating that the existing technological input has the potential to meet the requirements for personalization in the industry (Aheleroff, Zhong, & Xu, 2020). Mass personalization in industry, especially considering the context of Industry 4.0 and 5.0, has undergone a remarkable transition: from traditionally product-centric strategies to modern consumer-oriented approaches.
Conclusão
This article investigated the current landscape of mass personalization in industry by exploring its challenges, technological advances, and implications for customer satisfaction and competitiveness in the global market. It did so through an integrative literature review that categorized the studies analyzed into four main dimensions: enabling technologies for mass personalization, personalization strategies and models, frameworks and reference systems, and benefits and challenges of mass personalization in industry.
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Palavras Chave
Mass personalization, Industry 5.0, Integrative review

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MASS PERSONALIZATION IN INDUSTRY: AN INTEGRATIVE REVIEW

1. INTRODUCTION

In the contemporary industrial landscape, the relentless pursuit of a competitive edge and the increasing demand from consumers for personalized products and services have shaped the way companies conceive and manufacture their products (Zhang, Ming, & Bao, 2022; Sajadieh, Son, & Noh, 2022).

Industry 4.0 has brought promises of manufacturing flexibility, improved quality, and increased productivity. This revolution is characterized by the integration of smart objects that perceive, act, and behave within intelligent cyber-physical systems (CPS), enabling manufacturing ecosystems driven by self-configurable, self-monitoring, and self-repairing systems (Aheleroff, Zhong, & Xu, 2020). Amidst this revolution, mass personalization emerges as a customer-centric production paradigm, seeking to balance cost, variety, and quantity (Sajadieh, Son, & Noh, 2022).

However, the path to mass personalization is fraught with challenges. Adapting to this new paradigm requires complex and flexible production systems capable of responding rapidly to dynamic customer needs (Zhang, Ming, & Bao, 2022). Furthermore, integrating the customer into the production process, understanding and considering their requirements, and defining the level of involvement in product development are crucial and challenging steps.

Research on mass personalization in the industry has ranged from technical specifics to business process perspectives, characterizing the current state of the field as fragmented and heterogeneous, indicating the need for deeper insights into the topic.

In this regard, this article aims to investigate the current landscape of mass personalization in the industry, exploring its challenges, technological advances, and implications for customer satisfaction and competitiveness in the global market through an integrative literature review.

In addition to this introduction, the article consists of five sections: the next section addresses the theoretical framework of mass personalization; the third section describes the research methodology; the fourth section structures, presents, and discusses the results of the review. The final section provides concluding remarks, limitations, and recommendations for future work.

2. THEORETICAL FOUNDATION

Industry 5.0 calls for increased interaction between humans and machines, ushering in a new era of personalization and complex problem-solving (Pereira & Dos Santos, 2023). Driven by the trend of individualization and enabled by heightened digitalization, mass personalization is becoming a reality.

This new paradigm demands responsive and flexible manufacturing operations to produce customized products in dynamic batch sizes, economically and at scale (Qin & Lu, 2021). Manufacturing systems must timely respond to changes in demands, factory conditions, supply chains, and customer needs. Manufacturing systems need to be capable of self-optimizing manufacturing operations to achieve flexible, autonomous, and error-tolerant production within the context of mass personalization (Qin & Lu, 2021; Aheleroff, Mostashiri, Xu, & Zhong, 2021).

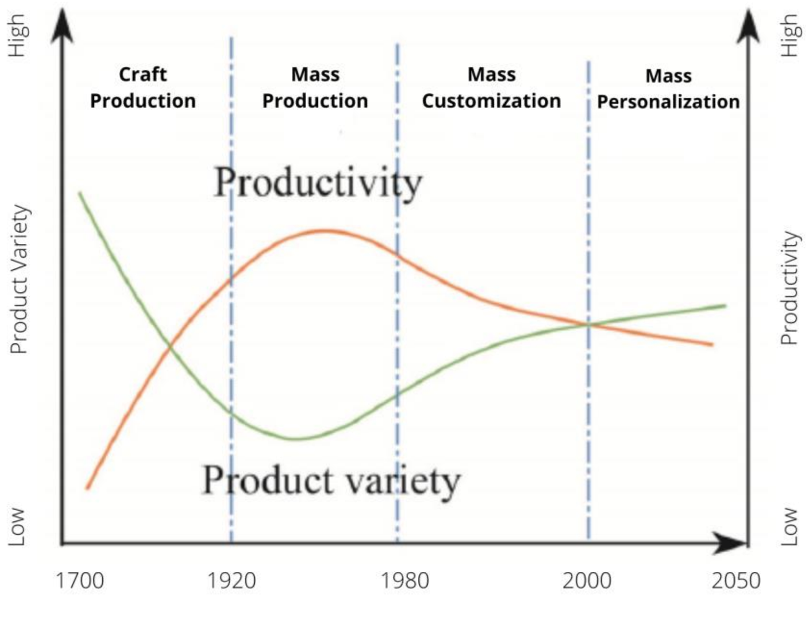
Several factors are facilitating this transformation in manufacturing, including: (1) the development of information technologies that enable greater interaction between customers and companies; (2) nearly universal internet availability; (3) customer willingness and readiness to be integrated into the co-design and co-creation of products; (4) modern manufacturing systems such as flexible and intelligent manufacturing; (5) mass personalization tools that help reduce cost and manufacturing cycle time; (6) the deployment of specific customer relationship management and retention software (Kumar, 2007).

Offering affordable and personalized products plays a significant role in customer satisfaction (Aheleroff, Zhong & Xu, 2020). Personalization allows companies to adopt a differentiation strategy to compete in added value rather than in price. While personalization itself is not a new concept, in recent years, additive manufacturing and collaborative robots (cobots) have enabled this process for a broader audience, offering a higher level of personalization at an affordable price that was not possible in the past (Torn & Vaneker, 2019).

Changes in societal needs, markets, and the emergence of new technological capabilities impose/facilitate changes in manufacturing development, which can be categorized into various paradigms (craft production, mass production, mass customization, and mass personalization; see Figure 01). This classification is based on the quantity of production and product variety (Sajadieh; Son; Noh, 2022; Zhang & Ming, 2022).

In the first Industrial Revolution (Industry 1.0), products were crafted based on user needs but at a high cost (craft production) and with a limited product range. It represented a paradigm shift from entirely manual production to machine-based production. With the advent of 'Industry 2.0' (mass production), it became possible to produce low-cost products using large-scale production systems. However, the variety of products offered was very limited. The 1920s marked the introduction of the first assembly line in the industry for producing Ford's Model T, which achieved significant success in the automotive industry. A famous quote by Henry Ford that characterizes the mass production model is, "Any customer can have a car painted any color that he wants so long as it is black" (Wang et al., 2017; Sajadieh, Son & Noh, 2022; Zhang & Ming, 2022).

Figure 01. Production Paradigms



Source: Wang et al. (2017)

Mass customization became possible with automation and the use of Information and Communication Technologies (ICTs), industrial robots, flexible manufacturing systems, computer-integrated manufacturing systems, Enterprise Resource Planning (ERP), enabling production flexibility, increased productivity, cost reduction, and the delivery of a wider variety of products. The current stage of the industry and the array of existing technologies have led to a new production paradigm (mass personalization), in which the industrial sector aligns with a market trend where customer demands and desires are converted into personalized products and services at an affordable cost, produced in less time, with a wide variety, and satisfactory quality (Wang et al., 2017; Sajadieh, Son, & Noh, 2022; Zhang & Ming, 2022).

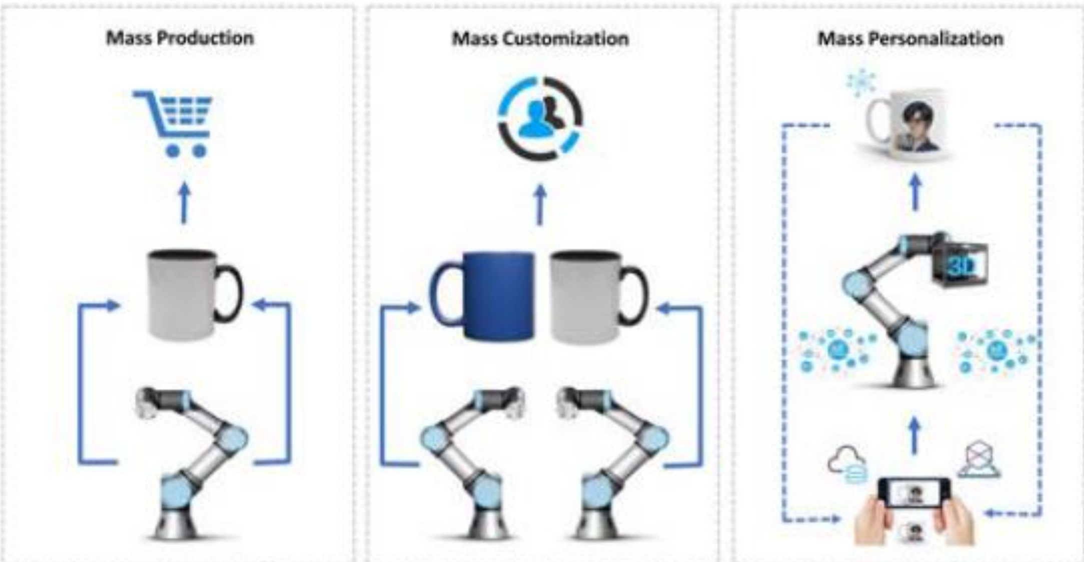
The challenges associated with each new paradigm were overcome by the new manufacturing system, which benefited from the application of advanced technologies at the time when the paradigm was introduced (Sajadieh, Son, & Noh, 2022).

The journey towards personalized products was initially hindered by the limitations of intelligent manufacturing automation technologies. However, technological advancements in the last decade in social communication, manufacturing (e.g., 3D printing), factory automation (e.g., robotics and artificial intelligence), and business systems automation (e.g., platforms) collectively provided the technical and commercial foundation for the production of personalized products (Aheleroff, Zhong & Xu, 2020). Fig. 02 illustrates the differences between mass production, mass customization, and mass personalization. Aheleroff et al. (2020) indicate that mass personalization can be achieved through a set of technologies, including Cloud, IoT, augmented and virtual reality, and additive manufacturing, through an iterative and incremental process, unlike customization and mass production, where products are predefined and made available for customers to purchase.

Mass customization and mass personalization are often considered synonymous. The main difference between the paradigms lies in the customer's involvement in the product development process.

In mass customization, customers have the opportunity to choose from affordable but limited product varieties. While mass customization has become a trend in maintaining mass production efficiency, there are some limitations due to the range of products and the lack of customer involvement to meet their expectations (Aheleroff et al., 2020).

Figure 02: Differences Between Manufacturing Paradigms



Source: Aheleroff, Zhong e Xu (2020)

Mass personalization, on the other hand, can be characterized by the use of flexible processes to produce individually varied and personalized products and services at the price of standardized, mass-produced alternatives. In other words, customers have the ability to alter both the product's structure and the design of its components (Katoozian & Zanjani, 2022).

The mass personalization process brings the customer into the production process. Customers are involved in the design process from the very beginning, culminating in a co-creation process where customer requirements and preferences are reflected in the product and service, enhancing customer satisfaction through an optimized experience (Zhang & Ming, 2022). Customers are no longer just buyers of products but key entities involved in the design of products and services. Due to customer involvement in the design process and the volatility of demand, mass personalization cannot solely rely on standardized items that need to be mass-produced and stored (Sajadieh, Son, Noh, 2022).

Instead, mass personalization can achieve its goals through an open-architecture product platform consisting of three categories of modules: common, customized, and personalized modules. Modularity is a key facilitator for achieving personalized production. While common modules can be mass-produced, customized modules can be subdivided based on usage frequency, and modules with higher usage rates can also be mass-produced. Modules with lower usage rates and personalized modules will be produced on-demand (Sajadieh, Son, & Noh, 2022). In addition to product and service modularity, decentralized manufacturing networks, cellular and flexible processes are other facilitators of mass personalization (Aheleroff, Zhong & Xu, 2020).

Personalization enables increased competitiveness and profitability for the company (Zhang & Ming, 2022). In this model, companies can enhance production capacity, reduce inventory, lower manufacturing costs, and improve the modular configuration of products compared to the traditional manufacturing model (Wang et al., 2017; Zhang & Ming, 2022).

Mass personalization adds more value for both producers and customers. By providing customers with personalized products, producers gain differentiation. Meanwhile, customers receive products with shorter lead times and high quality. Additionally, customers feel they are treated uniquely by the company. Customer active participation is a crucial factor in meeting user experience-related requirements because experience is influenced by a chain of human cognitive activities. Thus, customer active participation is important throughout the production process, directly affecting the final product offering in personalization (Wang et al., 2017).

Personalization allows companies to adopt a differentiation strategy to compete by delivering added value, providing a more personal customer experience, rather than competing on price (Torn & Vaneker, 2019). Mass personalization can be considered a data-driven manufacturing paradigm with a combination of distinct features and the value proposition of mass production (Aheleroff, Zhong & Xu, 2020).

3. METHODOLOGICAL PROCEDURES

The methodology employed in this study was an integrative literature review (Whittemore & Knafl, 2005; Torraco, 2005). This type of review differs from a narrative review as it follows a replicable, scientific, and transparent research process. An integrative review is a technique aimed at minimizing bias through exhaustive bibliographic searches of published studies, while explicitly detailing the reviewers' decisions, procedures, and conclusions (Tranfield, Denyer & Smart, 2003; Pereira & Cunha, 2020, 2021). Tranfield et al. (2003) propose three stages for a systematic literature review, such as integrative reviews: review planning, review conduct, and reporting and disseminating review results.

STAGE 1 - REVIEW PLANNING: The research began with identifying the need for the review and contextualizing the topic. The definition and contextualization of the topic help narrow and specify its content, avoiding ambiguities that could lead to a deviation from the research focus (Pereira & Cunha, 2020, 2021). In the final phase of stage 1, the review protocol was constructed. The protocol is a plan that contributes to the objectivity of the research through an explicit description of the steps followed.

STAGE 2 - REVIEW CONDUCT: In this stage, the following aspects were defined: search strategy; databases; temporal delimitation; languages of the articles; search terms; tools for data collection and organization; and inclusion and exclusion criteria.

The search strategy involved the use of the search string (("mass personali?ation" OR "mass industriali?ation") AND ("industry")) in the Scopus and Web of Science databases, filtering by title, abstract, and keywords. Articles and reviews in the English language were searched without temporal delimitation, resulting in a set of publications presented in Table 1.

Table 1. Articles Selected by Database

Database	**Number of Articles**
Scopus	48
Web of Science	(+) 71
Duplicates	(-) 39
Rejected	(-) 36
Total Selected Articles	**= 44**

Source: Research Authors (2023)

In the next phase (data selection), the metadata files from both searches were imported into the Zotero® bibliographic manager, where abstracts, keywords, and titles of publications were read, related studies were organized, and the studies that composed the portfolio were selected. This stage was completed by categorizing the selected studies.

STAGE 3 - REPORTING AND DISSEMINATION: The report was prepared based on the analysis and discussion of the results as presented below.

4. ANALYSIS AND DISCUSSION OF RESULTS

This section presents the results obtained from the analysis and synthesis of the selected articles, as shown in Table 1. The aim of the synthesis was to identify themes that could address the question "what is the current state of research in mass personalization in the industry." Data synthesis was operationalized with the assistance of thematic analysis proposed by Braun and Clarke (2006). This analysis allowed themes to be identified and coded throughout the process of reading and analyzing the articles (Pereira & Cunha, 2020, 2021), which will be discussed in the following subsections.

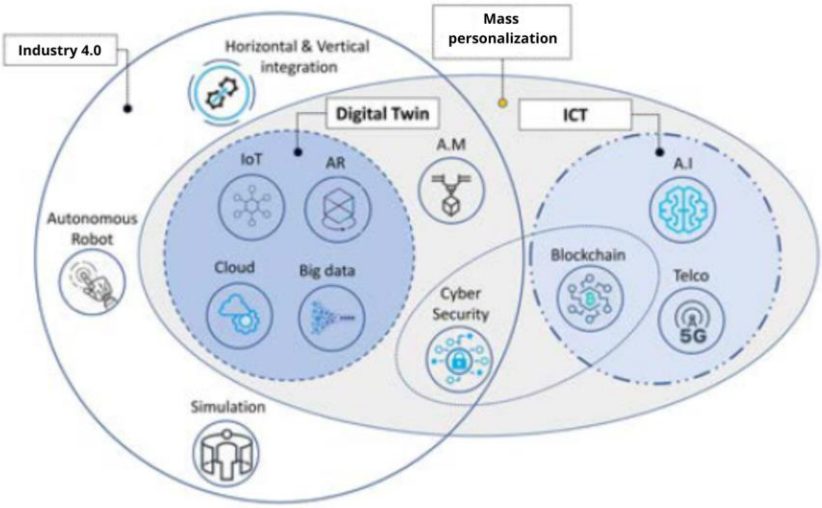
4.1 Technologies Enabling Mass Personalization

Utilizing the most suitable technologies for mass personalization remains the primary challenge in operationalizing it. However, there is a variety of studies indicating that the existing technological input has the potential to meet the requirements for personalization in the industry (Aheleroff, Zhong, & Xu, 2020).

Figure 03 illustrates some suggested/necessary technologies for a mass personalization process (Aheleroff, Zhong, & Xu, 2020). For instance, the fifth and sixth generations of digital cellular networks (5G/6G), Artificial Intelligence (AI), along with crucial Industry 4.0 and 5.0 technologies, can provide resource extraction and prediction based on historical customer data. Unlike conventional machining, casting, and forging processes, Additive Manufacturing (3D printing farms) will produce customized products from a digital file. Additionally, the Digital Twin has the potential to create a digital replica of desired features, appearances, and functionalities, along with processes and systems; in other words, the Digital Twin bridges the gap between customized design and manufacturing (Aheleroff, Zhong, & Xu, 2020). These technologies are considered essential for data collection, understanding individual customer needs, and producing on-demand at scale.

Aheleroff, Mostashiri, Xu, & Zhong (2021) further this point by providing examples and indicating the technologies that align with the personalization process. In a case study on implementing mass personalization in the manufacturing of facial masks, they suggest that the technologies that made the personalization process feasible included the Internet of Things, Additive Manufacturing, Big Data, Cloud Manufacturing, Digital Twins, and Blockchain.

Figure 03. Technologies Enabling Mass Personalization



Source: Aheleroff, Zhong, Xu (2020)

The same authors, in a general manner, indicate the technologies that would assist in personalization as follows:

Augmented Reality: Enables an intelligent customer experience by enhancing engagement and personalization while simultaneously reducing costs. It can influence a personalized experience. AI-driven, with other developing technologies such as IoT, Big Data, cloud computing, and computer vision, it adds significant value to visualize a customer's experience with a specific customized product before an actual product is manufactured.

Big data: Considering that individuals' characteristics and preferences vary, Big Data will enable the analysis of collected data, predict and respond to unexpressed individual needs, resulting in a dynamic response to mass personalization. Furthermore, it can enable going beyond the use of direct requirement collection for personalization and leverage the global network of connected things. Big Data and IoT together can empower a considerable volume of data for scalable personalization.

Blockchain: It provides a new way to securely and decentralized share data. This technology will enable the protection of customer data against deletion, tampering, and revision in different aspects of production that can play a crucial role in scalable personalization. Blockchain is a suitable technology for handling data privacy and traceability, complementing other technologies like IoT, Cyber-Physical Systems, and Big Data.

Cloud Manufacturing: It is a networked and decentralized manufacturing that promotes manufacturing into a highly collaborative, innovative, and service-oriented model. It empowers consumers to demand manufacturing resources like 3D printers, increasing the dynamism and agility as a service that adapts to accessible and scalable personalization.

Digital Twin: It can create a digital replica of desired characteristics, material, appearance, functionality, process, and system, extending to the digital replica of a customized product. The Digital Twin has a structure consisting of connected elements, meta-information, and semantics that converge to offer mass personalization. In this sense, the mutual flow of data between the physical, digital, and cyberspace is necessary to merge customer expectations, the digital model of customized products, and cloud-based manufacturing resources.

Internet of Things (IoT): Scalable personalization segmentation was not feasible before the evolution of IoT to meet the growing complexity and variety. IoT and personalization complement each other. The former deals with the power of the Internet and data processing from physical objects, and the latter involves individuals intentionally, enabling mass personalization. IoT encompasses all stages of mass personalization, from customer order placement and data collection to cloud manufacturing and delivery of a customized product.

These technologies enable the manufacturing industry to meet dynamic changes, reducing the time to market for products (Aheleroff, Zhong, & Xu, 2020).

Gu & Koren (2022) emphasize the essential technologies enabling mass personalization, including 3D printing, rapid prototyping, and direct digital manufacturing. Additive manufacturing technologies enable the production of unique personalized products on-demand. Additionally, cloud-based platforms and IoT allow for the storage and sharing of personalized products design data among different involved parties. To facilitate the development and production of personalized products, cyber-physical systems are crucial in integrating physical and digital resources.

The implementation of mass personalization requires the use of key technologies throughout the product lifecycle, from initial design to manufacturing and usage stages, culminating in end-of-life and post-usage phases. To effectively interact with customers, enable co-design, and facilitate personalized manufacturing, it's essential to incorporate the Internet of Things (IoT), Digital Twin (DT), and artificial intelligence. Furthermore, integrating Big Data, cloud and edge computing, additive manufacturing (3D printing), and mixed reality (MR) can yield significant benefits (Sajadieh, Son, & Noh, 2022).

Regarding enabling technologies, the reviewed articles primarily address well-established technologies, namely the Internet of Things (IoT), Big Data, and Artificial Intelligence (AI). However, considering Industry 5.0, it would necessitate exploring more sophisticated and emerging technologies such as quantum computing, biotechnology, nanotechnology, and smart materials. These innovative technologies have the potential to facilitate deeper levels of personalization (Aheleroff, Zhong, & Xu, 2020).

4.2. Personalization Strategies and Models

Mass personalization in industry, especially considering the context of Industry 4.0 and 5.0, has undergone a remarkable transition: from traditionally product-centric strategies to modern consumer-oriented approaches. This evolution leverages some technologies, mentioned in the previous subsection, such as cloud computing, the internet of things, and additive manufacturing (Aheleroff, Mostashiri, Xu, & Zhong, 2021).

These technologies are enabling the paradigm shift towards decentralized production processes, through modular simulation of manufacturing, product design, planning, engineering, production, and service processes, being intelligently, interdependently and simultaneously controlled (Sajadieh, Son, & Noh, 2022).

Personalization strategies in industry to be successful must consider customer demand attributes and the processes involved in their management. Customer demand ranges from meeting the functional product requirements to experiencing the product needs and ecological concerns (Zhang et al., 2019). To meet these demands, structured processes for monitoring, analyzing, optimizing and managing demand data are required. The text also underlines the construction of user ecosystems as a crucial step after data analysis and optimization, promoting a deeper understanding of customer needs and strengthening the relationship between company and consumer (Zhang et al., 2019).

In this perspective, Zhang & Ming (2023), propose the intelligent model system for mass personalization (MMP) that includes four dimensions: the industrial value chain, basic features, manufacturing process evolution and technology/intelligence methods. The first dimension addresses MMP implementation, highlighting four essential processes: customized demand, flexible production, customer experience and networked collaboration. Each process unfolds into specific tasks, from customer needs analysis to building networked collaboration platforms. The basic feature dimension encompasses key system elements at different evolution stages, including large-scale, customization, flexibility, experience, networked connectivity, community and intelligence. Each element plays a specific role in different MMP process phases, such as manufacturing, service and collaboration. The manufacturing process evolution dimension in MMP involves the transition from mass manufacturing mode, with large-scale production, to mass personalization mode, with customized and flexible production. This dimension entails the incorporation of intelligent elements, such as networked connectivity and advanced technologies. The last dimension of the intelligent system in MMP provides technology and methods for the system. Industrial intelligence is mainly reflected in the integration of computational intelligence, perceptual intelligence, cognitive intelligence and other methods and technologies into industrial activities.

Regarding personalization models, one of the most promising is the "Mass Personalization as a Service" (MPaaS). This model, as outlined by Aheleroff, Mostashiri, Xu, & Zhong (2021), leverages technologies such as the Internet of Things, Additive Manufacturing, Big Data, Cloud Manufacturing, Digital Twin, and Blockchain to meet unique and complex requirements at an unprecedented scale. The proposed MPaaS is driven by a sophisticated architecture and a suitable business model under the umbrella of Industry 4.0. It has great potential to maximize design and manufacturing resources via the Internet.

Also along this line of innovation, Zhang and Ming (2022) also introduced the idea of "Predictive Personalization with Digital Twins", which employs digital models to predict and optimize personalization needs. This approach, combined with the "Smart Mass Personalization with Big Data and AI" strategy proposed by Zhang et al. (2019), exemplifies how data analytics and artificial intelligence are being used to inform and enhance personalization decisions.

The field has also seen a growth in collaborative strategies. Tan et al. (2020) described "Collaborative Customization", a strategy that promotes co-creation between consumers and manufacturers, while Zhang et al. (2019) explored the benefits of "Hybrid Manufacturing", a technique that combines various production techniques to optimize personalized production. Another notable approach is "Mass Individualisation" (MI) presented by Sikhwal & Childs (2021), which integrates user-centered design with networked innovation, using open platforms and customizable modules.

4.3. Frameworks and Reference Systems

Mass personalization refers to companies' ability to provide personalized products or services to individual customers on a large scale (Maqueira, Novais & Bruque, 2021).

In this sense, industry's shift towards mass personalization requires complex and adaptable production systems. Besides being flexible, these systems must be able to quickly adjust to customers' dynamic needs.

In this context, companies need to be able to respond quickly and effectively to changes in demand, which can fluctuate rapidly and unpredictably (Maqueira, Novais & Bruque, 2021).

Gu & Koren (2022) advanced in this direction, proposing reconfigurable manufacturing system frameworks, emphasizing flexibility and scalability. To complement this approach, they also suggest systems with an integrated matrix and cell structure, which enables multiple production flows, allowing flexible routing for highly customized product manufacturing.

Zhang, Ming & Bao (2022), in turn, outline an intelligent flexible manufacturing system framework based on multiple interconnected modular production platforms. This system is structured with production platforms containing configurable virtual units, which in turn have flexible production lines. The main differential of this model is its ability to allow optimized layout and flexible allocation of manufacturing resources, all in response to customers' dynamic and customized demand.

In this scenario, modularity, interoperability and virtualization emerge as essential design principles. Smart factories, essential for mass personalization, are characterized by real-time data exchange, flexibility, transparency, optimized decision making, and crucially, the ability to create value from large data sets (Sajadieh et al., 2022).

Modularization, for example, is an approach used to efficiently organize complex design elements by breaking down a complex system into smaller, simpler segments known as modules (Hsiao et al., 2015).

Mass personalization is highly dependent on flexible production lines. In this sense, supply chains must also meet this requirement in order to adapt to changes in demand. By achieving supply chain flexibility, companies can better meet the demands of Mass Personalization, rapidly adjusting their production processes to customers' constantly changing needs. This can help companies improve their overall performance by reducing waste, increasing customer satisfaction, and enhancing efficiency (Maqueira, Novais & Bruque, 2021).

Thus, as industry moves towards more adaptable production models, the proposed frameworks and reference systems offer valuable insights into how this transition can be effectively managed. The combination of flexibility and scalability will be essential to meet the growing demands for mass personalization in industry.

4.4. Benefits and Challenges of Mass Personalization in Industry

Mass personalization brings several benefits, such as meeting customers' unique needs and preferences (Gu & Koren, 2022), higher productivity due to modular production, cost reduction through resource sharing between platforms (Zhang, Ming, & Bao, 2022). It also promotes sustainability through on-demand manufacturing, reducing waste. In addition, there is greater productivity gain due to more efficient use of resources (Gu & Koren, 2022).

Moreover, the value delivery of mass personalized products, as well as customized ones, is driven by the fit, style and functionality, or utility, perceived by customers, and the uniqueness of a product (Hentschke, Formoso, & Echeveste, 2020).

The operationalization of mass personalization, in turn, faces a range of major challenges. One of them has already been pointed out along the text which is the adequacy of technology to the personalization process. In addition, the manufacturer must create a design interface that is user friendly and provides support to customers in the design stage, conveniently demonstrating comprehensive and fascinating results. This interface is essential to ensure that the customer is integrated into the design and development process to achieve co-creation and value differentiation (Aheleroff, Zhong & Xu, 2020).

Moreover, companies must assess the projected manufacturing capability and find the ideal solution for the trade-off between quality, cost and delivery time. Product configuration, process and material selection, supply chain and manufacturing strategies are the main parameters to be outlined (Sajadieh, Son, & Noh, 2022). At this point it is important to emphasize that the high level of individualization in the product structure requires a flexible and reconfigurable supply network (Katoozian & Zanjani, 2022).

The integration of heterogeneous systems is cited as a technical challenge for mass personalization. Other challenges are the cost and complexity of large-scale implementation (Mourtzis et al., 2022).

For production personalization to happen, the customer needs to be integrated into the manufacturing process of that product. This step is one of the most challenging and essential in customization, as customer participation during co-production and co-creation processes directly influences service/product quality and behavioral outcomes, such as service usage, repeat purchase behavior, as well as company outcomes like efficiency, revenue and profits (Hsiao et al., 2015).

Customer integration requires the manufacturer to create a customer-friendly set of design frameworks to support them in conveniently creating designs. This adaptable design interface is essential to ensure customer integration in the design and development process, in order to achieve co-creation and value differentiation. In addition, it is necessary to assess the manufacturability of the design and find the optimal solution to balance quality, cost and lead time. Product configuration, process and material selection, and supply chain and manufacturing routes are also parameters to be considered (Sajadieh et al., 2022).

Additional gaps include the need for new business models (Aheleroff et al., 2021), as well as research on behavioral and human aspects, such as consumers' propensity for personalization (Mourtzis et al., 2022).

And also, issues of security and privacy (Gu & Koren, 2022; Zhang, Ming, & Bao, 2022), industry adoption of new technologies, and complexity of collaborative cyber-physical systems (Zhang, Ming, & Bao, 2022).

Importantly, it should be considered that to implement a mass personalization manufacturing model, companies need to meet real-time adjustment requirements according to customers' dynamic customized orders (Zhang, Ming, & Bao, 2022).

5. CONCLUDING REMARKS

As the paradigm of mass personalization continues to evolve and consolidate in industry, it becomes clear that companies are facing the pressing need to adapt to this transformation. This article investigated the current landscape of mass personalization in industry by exploring its challenges, technological advances, and implications for customer satisfaction and competitiveness in the global market. It did so through an integrative literature review that categorized the studies analyzed into four main dimensions: enabling technologies for mass personalization, personalization strategies and models, frameworks and reference systems, and benefits and challenges of mass personalization in industry. These categories provided valuable insights into the current state of the field and future directions that can be explored.

The growing importance of advanced technologies such as the Internet of Things (IoT), Big Data, Artificial Intelligence, Additive Manufacturing, Cloud Computing, Blockchain, Digital Twin, among others, in enabling mass personalization has been noted. These technologies allow collecting data, understanding individual customer needs, performing simulations, and producing on-demand. However, the Industry 5.0 vision points to the need to explore even more advanced technologies, such as quantum computing, biotechnology, nanotechnology, and smart materials, enabling deeper levels of personalization.

Personalization strategies and models, in turn, are evolving from product-focused models to consumer-centric approaches. Models such as "Predictive Personalization " and "Smart Mass Personalization" exemplify this shift, with the use of data analytics and AI to enhance personalization. Modular personalization, on-demand manufacturing, and consumer engagement are widely discussed approaches. The Industry 5.0 perspective indicates the emergence of more collaborative networked models, such as cognitive factories with cooperative cyber-physical systems, which have the potential to further expand the scope of customization.

New frameworks and reference systems emphasize principles such as modularity, interoperability and virtualization to make manufacturing systems more flexible and scalable, essential for mass personalization. Moreover, as the Industry 5.0 vision materializes, frameworks are expected to evolve to embrace networked collaboration, sustainability, radical personalization, and new technologies, providing solid guidance for the successful implementation of mass personalization in industry.

The benefits of mass personalization include consumer satisfaction and process efficiency, meeting unique customer needs, increased productivity, and reduced costs and waste. With Industry 5.0 becoming a reality, mass personalization is expected to achieve further gains in sustainability, productivity, and new business models that broadly materialize personalization across various industry sectors.

However, significant challenges and gaps have also been identified. Issues related to cost, system integration, and behavioral aspects were addressed, and the transition to Industry 5.0 would add further challenges in security, privacy, adoption of new technologies, and profound organizational changes.

Research still needs to explore business models, behavioral aspects, consumers' propensity for personalization, industry adoption of technologies, and system complexity.

Despite the challenges, the field has advanced with technological, strategic, and process innovations that make mass personalization increasingly feasible and beneficial. Further research is required in the pursuit of effective solutions to overcome these obstacles, aiming to improve its implementation.

Mass personalization is becoming an essential element for success in industry, requiring companies to adopt innovative approaches and advanced technologies. The transition to Industry 5.0 promises to open new frontiers and challenges for the field as organizations seek to meet consumers' ever-evolving demands and achieve a new level of excellence in mass personalization. Therefore, it is imperative that companies act promptly to develop the necessary capabilities and create real value for their customers and brands in this new industry paradigm.

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