Inventory Management in Mass Customization Operations: A Review**[[1]](#footnote-1)**

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First version: 5 September, 2017. Last revised: 22 March, 2018. Accepted: 16 May, 2018.

Accepted for publication in *IEEE Transactions on Engineering Management*.

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**Abstract:** Mass customization (MC), as an operations program to satisfy target consumers by offering personalized products or services, has attracted substantial attention from both the industry and academia. Under this program, one of the most important issues is an efficient management of the related inventories including the work-in-process inventories, standard items and the customized items, which can ultimately contribute to a profitable business for the companies who have launched MC. This paper therefore focuses on reviewing the mass customization based literature and identifying various methods to effectively manage inventory for MC schemes. In addition to regular inventory management, with the increasing emphasis on Corporate Social Responsibility (CSR), MC companies are required to devote more effort to the proper management of leftover and returned inventories under MC. This paper hence examines MC inventory management in both forward and reverse logistics. Findings from this review provide a guideline to operations managers on inventory management improvement in their MC operations. Future research opportunities related to MC inventory management are discussed.

**Key Words:** mass customization; inventory management; regular inventories; leftover inventories; consumer returns.

**Managerial Relevance Statement**

Nowadays, mass customization is an important operation in various industries. Motivated by the popularity and significance of inventory management in MC, this paper conducts a systematic literature review on the topic, with the objective of identifying specific methods to attain good performances of inventory management in MC operations, such as achieving a higher accuracy in demand forecasting and getting a higher salvage value of unsold leftovers and the items returned by the consumers. To the best of our knowledge, this paper is the first one which systematically reviews the MC inventory management literature. From the comprehensive and systematic review, managerial insights are generated which not only provide a guideline to operations managers on how to improve inventory management in their MC operations, but also inspire future research and innovation on MC operations.

**I. INTRODUCTION**

The market environment nowadays is widely acknowledged to be characterized by the diverse customer needs and preferences, as well as fierce competition. The involved firms are enforced to undergo changes from both strategical and operational levels in order to maintain and even extend their market share. These changes call for higher responsiveness to the consumer market, enhanced flexibility of adapting to the dynamic industrial environment as well as improving other competitive elements such as quality and price of products. As such, mass customization (MC) emerges, which is a term first coined by Davis [202] and then further developed by Pine [203]. According to Davis [202] and Pine [203], MC refers to a paradigm shift for the industrial companies to focus more on product variety and the customized consumer needs with affordable goods and services. More recently, MacCarthy et al. [84] define MC as the seller’s ability to quickly produce customized products to the segment consumers, with the cost and quality comparable to mass production. In this paper, similar to [84], we treat MC as an operations strategy which can satisfy the segmented market requirements[[2]](#footnote-2) with customized products or services in a cost-effective manner. MC helps a company to differentiate from the relevant competitors through adopting flexible processes [1][2]. For instance, Dell allows its consumers to flexibly select the memory size (e.g., from 512 MB to 2 GB), processor speed, hard disk size, software of their own computer system in the personal computer that they have purchased. Dell’s MC program is operationally efficient partially because of its close relationship with its suppliers such as Intel, Maxtor, and Selectron [3][4][5][6]. MC is in fact widely applied in various industries including big name companies like Dell, Hewlett-Packard, IBM, Cisco, BMW, Nike, Dorothy, Lego and Procter & Gamble. It is also especially popular in European countries and the US [7][8][9] in which consumers treasure uniqueness and are willing to pay a premium for customized products.

Offering a large variety of products under MC can bring challenges in areas such as the design process, configuration preparation, inventory management, and transportation management to MC operations. Among these challenges, inventory management is one of the most crucial issues that are emphasized by various prior studies on the MC program like [11], [12], and [14]. An efficient inventory management can undoubtedly yield a profitable business for the MC program while a failure in the inventory management not only will reduce the final profits of the involved players but also lead to some negative effects on the environment and affect social welfare. For instance, either a high percentage of consumer returns (e.g., because of poor quality) or a high level of unsold products (e.g., because of inaccurate demand forecasting) will lower the profitability of MC and make the environment suffer. Furthermore, considering the public emphasis on social responsibility and sustainability, these consumer returns and unsold inventories will damage the brand image and potentially reduce future market demand.

Therefore, motivated by the popularity and significance of inventory management in MC, this paper conducts a systematic literature review on the topic, with the objective of identifying specific methods to attain good performances of inventory management for the MC scheme, such as achieving a higher accuracy in demand forecasting and getting a higher salvage value of unsold leftovers and the items returned by the consumers. As a remark, all methods discussed in later sections are derived from the MC inventory management problems identified from the reviewed papers. Last but not least, future research areas are examined and proposed.

To the best of our knowledge, this paper is the first one which systematically reviews the MC inventory management literature (see Section II for other related reviews). From the comprehensive and systematic review, insights from this review will (i) provide a guideline to operations managers on how to improve inventory management in their MC operations, and (ii) inspire future research on MC inventory management.

The organization of this paper is listed as follows. Research gap and review methodology are introduced in Section II. Descriptive analysis, concerning the journal, the time of the selected publications as well as the most productive authors on mass customization inventory management, is reported in Section III. Section IV deeply explores the methods to improve the performance of the regular inventory management for the MC operations like market demand forecasting and production flexibility management. Then the ways to enhance the management of the leftover products are analyzed in Section V, with a major focus on enhancing the salvage value of unsold inventories and consumer returns. Section VI examines the cooperation issues between different parties related to MC inventory management. Section VII concludes the whole paper with a discussion on future research.

**II. RESEARCH GAP AND METHODOLOGY**

**A. Research Gap Identification**

Before reviewing relevant literature on MC operations, a deep searching process is conducted to examine whether there are any published similar review papers which also focus on inventory management in MC (including both the regular inventory management and the leftover management[[3]](#footnote-3)). By using the keyword of “mass customization review” (and its equivalent term “mass customisation review”), 8 review papers are found. Among them, Da Silveira et al. [15] conduct an MC review with the aim of investigating the enablers of the MC program and the corresponding impacts on the development of MC production systems, which is further extended by Fogliatto et al. [2]. Gunasekaran and Ngai [16] provide an overview of MC schemes to explore the concept and definition of MC, and classify the literature into the categories of competitiveness related issues, information technology applications, operations of MC and the corresponding implementation details. Their objective is to develop a framework for the development of MC. Drizo and Pegna [17] examine the research needs on the environmental impact assessment domain for MC programs by formulating a review focusing on the exploration of the MC technologies in rapid evolution (mainly rapid prototyping and rapid tooling). Zhao et al. [18] discuss the quality management methods in MC. Gosling and Naim [19] present a literature review on MC-related papers by categorizing them into the streams of lean and agile area, supply chain structures and MC strategy with the aim of introducing the development of MC supply chain. Yeung et al. [20] develop a comprehensive MC literature review with a special emphasis on the fashion industry. Most recently, Ferguson et al. [21] analyze the related papers under the category of MC development processes from marketing, engineering and distribution perspectives.

From our searching, although there are a few MC review papers in the literature, none of them are devoted specifically to examining MC inventory management. In addition, most of them were published before 2010 and thus the selected papers were not update-to-date. Consequently, there is a need to have a comprehensive and deep literature review covering both the recent and classical MC papers with a focal point on the inventory management. This paper aims at bridging this research gap.

**B. Research Methodology**

From the inventory perspective, we consider an MC supply chain consisting of various suppliers providing raw materials, manufacturers producing modules, components as well as both semi-finished and finished items, assemblers, retailers, and consumers (refer to Fig. I). Therefore, we develop the definition of MC inventory management as all activities related to the management of materials, modules, components, semi-finished items and finished products in MC, including the inventory stocking and inventory delivering actions. At the same time, given the uncertainty of market demand and the popularity of consumer returns policies in various MC programs, the management on unsold inventories and consumer returned products are also included in our review. Besides, notice that in Fig. I, in addition to the "Final MC products", the inventories of "Modules", "Components", "Semi-finished items", are also included in the section of "Retailers". The reason is that, in practice, some MC requirements passed by the consumers are simple and can easily be conducted by the retailers, like the requirement of adding some additional accessories or some personal printed messages on a given handbag. As a result, "Retailers" will have the "Modules", "Components", as well as "Semi-finished items". In fact, such MC cases are also observable in our real lives, and two representative instances are the MC programs in some electronic products (e.g. iPads in Apple) and the soccer jersey MC schemes in the fashion industry.



**Fig. I.** MC supply chain structure[[4]](#footnote-4).

Based on this definition, we search the related MC literature through Web of Science[[5]](#footnote-5) by combining the 1st keyword “mass customization” (or “mass customisation”) with the 2nd keyword “inventory”. Specifically, the 2nd keyword “inventory” is extended to include 15 specific sub-keywords, which are classified by three perspectives of inventory, i.e. the MC supply chain structure, the MC product proliferation, and the MC inventory with the participation of customers. The details are shown in Fig. II. First of all, based on the MC supply chain structure as shown in Fig. I, we divide MC inventory into five levels: material inventory, component or module inventory, semi-finished inventory (i.e., the basic items), final MC inventory and leftover inventory. Correspondingly, we have the sub-keywords such as "inventory level", "information management", "postponement", "product design", "product quality", "material management", "component management" and "consumer returns".[[6]](#footnote-6) Secondly, since MC firms respond to the stochastic MC market by proliferating various product variants, and the inventory management of MC will differ substantially under different modularity types or different points of customer involvement, the keywords related to product proliferation, e.g., "degree of customization", "product modularity", "product family", "product variant" and "product variety", are applied. These keywords are mainly for the middle stream of the MC channel, referring to the inventory management of the components, modules and semi-finished items. Thirdly, as a program of utilizing customer involvement to enhance the final performance, the participation of consumers also has a critical influence on MC inventory management, we thus contain the keywords like “consumer integration” and "process flexibility". Then, under these listed keywords, the searching process was conducted from May to July in 2017.

**Fig.II.** The specific searching keywords.

**Table I.** The specific number of papers selected under each searching stage

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **1st Keyword** | **2nd Keyword** | **Results in Web of Science** | **SCI journal papers searched from the hybrid keywords[[7]](#footnote-7)** | **After deleting the overlapped literature** | **After deep content analysis** |
| **Mass Customization/ Mass Customisation** | Material Management | 31 | 19 | 10 | 3 |
| Component Management | 67 | 28 | 16 | 7 |
| Product Design | 557 | 215 | 125 | 29 |
| Degree of Customization | 57 | 9 | 5 | 3 |
| Product Modularity | 108 | 28 | 18 | 10 |
| Product Family | 202 | 63 | 45 | 19 |
| Product Variant | 75 | 23 | 17 | 8 |
| Product Variety | 232 | 49 | 33 | 20 |
| Customer Integration | 82 | 22 | 19 | 15 |
| Process Flexibility | 65 | 34 | 30 | 21 |
| Inventory Level | 34 | 13 | 9 | 7 |
| Information Management | 139 | 44 | 40 | 34 |
| Product Quality | 118 | 19 | 15 | 6 |
| Postponement | 95 | 16 | 10 | 6 |
| Consumer Return | 3 | 2 | 2 | 2 |
| **Total** | | 1865 | 584 | 394 | 190 |

Notice that, throughout our searching process, we only keep those MC papers that contain the 1st keyword “mass customization” or “mass customisation” in their title, abstract, or list of keywords, which ensures MC is the major focus of the selected papers. Besides, we do not impose any constraints on publication year since the objective of this paper is to provide a comprehensive review on MC inventory management problems. The specific number of papers collected from each searching stage is shown in Table I, and the final selected literature under each keyword searching is provided in Table II in the Online Supplementary Appendix.

**III. DESCRIPTIVE STATISITCS AND ANALYSES**

Descriptive analyses on the published journals and years as well as the most productive authors are conducted in this section. As is exhibited in Table III, research on inventory management in MC programs is most widely published in well-established production engineering journals such as *IEEE Transactions on Engineering Management, International Journal of Computer Integrated Manufacturing*, *International Journal of Production Research,* and *Production Planning and Control.* This shows that MC is well-regarded as an important topic in the production engineering community[[8]](#footnote-8).

In the meantime, an increasing attention paid to MC inventory management can be identified from the time period of 1999-2001, as shown in Fig. III[[9]](#footnote-9) and it also presents a declining trend after the time period of 2008-2010. Furthermore, by referring to Fig. III again, it can also be observed that a large amount of MC papers have been published in the time periods of 2002-2004, 2005-2007, and 2008-2010, which is partially due to publications of the MC special issues in journals of *Production Planning and Control* (in 2004), *IEEE Transactions on Engineering Management* (in 2007) and *Journal of Intelligent Manufacturing* (in 2008). Fig. III therefore shows a complete cycle for the field of MC inventory management. It is interesting to note from Fig. III that MC inventory management has already reached the “mature” state and is well-established domain now. This also indicates the importance of this review paper as it helps to show the current state-of-the-art findings in this well-established area. Apart from this, the exploration on this domain can also help inspire innovative future research to further expand the field, which is one of the objectives of this review paper.

Then for the trend of research topics in different time periods, as we can see from Table V (see Online Supplementary Appendix), topics like “process flexibility” have been emphasized a lot in early days (especially during 1996-1998) since mass customization became gradually popular at that time and the revolution on the process was necessary so as to adjust to this new operations strategy. In recent years, however, the studies focus more on the domains like “product design” and “information management”, owing to the ever-changing consumer preferences and the entrance to big data era.

**Table III.** Distribution of MC inventory management papers by journals

|  |  |
| --- | --- |
| **Year of publication** | **No.** |
| ***Journals covering more than one related articles*** | |
| International Journal of Production Research | 25 |
| IEEE Transactions on Engineering Management | 15 |
| Production Planning and Control | 15 |
| International Journal of Computer Integrated Manufacturing | 13 |
| Computers in Industry | 11 |
| Journal of Intelligent Manufacturing | 11 |
| International Journal of Production Economics | 10 |
| Journal of Operations Management | 6 |
| International Journal of Advanced Manufacturing Technology | 6 |
| CIRP Annals-Manufacturing Technology | 4 |
| Computers and Industrial Engineering | 4 |
| Concurrent Engineering | 4 |
| Journal of Engineering Design | 4 |
| Production and Operations Management | 4 |
| Computer-Aided Design | 3 |
| Decision Support Systems | 3 |
| European Journal of Operational Research | 3 |
| IIE Transactions | 3 |
| Journal of Product Innovation Management | 3 |
| Journal of Systems Science and Systems Engineering | 3 |
| Management Science | 3 |
| Manufacturing and Service Operations Management | 3 |
| Technovation | 3 |
| Expert Systems with Applications | 2 |
| Journal of Construction Engineering and Management | 2 |
| Journal of Materials Processing Technology | 2 |
| Mathematical Problems in Engineering | 2 |
| ***Journals only covering one related paper*** | |
| Applied Mathematical Modelling, Automation in Construction, Engineering Applications of Artificial Intelligence, IEEE Internet Computing, IEEE Transactions on Automation Science and Engineering, IEEE Systems Journal, IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans, Industrial Management and Data Systems, Integrated Computer-Aided Engineering, International Journal of Clothing Science and Technology, International Journal of Computational Intelligence Systems, International Journal of Electronic Commerce, International Journal of Information Technology and Decision Making, International Journal of Technology Management, Journal of Industrial Ecology, Journal of Manufacturing Systems, Journal of Mechanical Science and Technology, Journal of the Operational Research Society, Omega, OR Spectrum, Robotics and Computer-Integrated Manufacturing, Simulation Modelling Practice and Theory, Transportation Research Part E | Total 23 |
| **Total** | **190** |

**Fig. III.** Distribution of MC inventory management papers across the time period.

**IV. REGULAR INVENTORY MANAGEMENT**

In MC operations, the supply chain players are required to prepare for both the stock-driven environment (i.e., inventory management for the standard products) and the order-driven environment (i.e., inventory management for those further-customized items)[[10]](#footnote-10). To achieve success in the MC program, regular inventory management like the planning on the raw materials and related technologies as well as equipment should always be well prepared. Therefore, from our review findings, several ways to guarantee the performance of the regular inventory management will be proposed in the following and a summary is provided in Table VI, referring to the collection of information for demand forecasting, and the management on production flexibility as well as quality management.

**A. Information Management for Forecasting**

The MC market, as a special market highly driven by consumer tastes, is closely related to the information collected from the market [55][56][172]. For instance, the collected information can be utilized to forecast the future demand and make decisions on inventory levels as well as specific features of the products. As a result, the collection and application of MC related information is widely analyzed in the literature, examples of which are [58], [59], [60], [61], [62], [63], [64], [174], [188] and [190]. Among them, Büyüközkan et al. [63] explore the information collection technologies or systems that could be applied in MC, while Comstock et al. [59] discuss the impacts of information management in the cooperation between adjacent MC supply chain members. Potter et al. [61] present the importance of information sharing in the MC program. To improve the performance of the forecasting system for MC, which can substantially influence the inventory management performance of MC, companies implementing MC are suggested to pay attention to the following measures, which are derived from the deep investigation on the selected MC papers.

*1) Purchasing and preference profile information:* MC providers can utilize data mining and collaborative filtering technologies, which can satisfy the requirement of an increasing size of the dataset for MC inventory management, to collect purchasing and preference profile information for inventory preparation of the basic items. For example, information like which model is most popular for a specific electronic (e.g., Apple) or automotive (e.g., BMW) product can be collected. Companies that apply these technologies include Amazon and Yahoo, which gather the purchasing and preference profile information from their individual members [65]. Besides, the finishing information system (FIS) introduced in [173], the association rule mining system (ARMS) [185] and the product definition patterns system [189] can also help.

*2) Unbiased market research information:* The benefits of collecting unbiased market information for product development and continuous improvement are proven by MC research such as [66], which can contribute to better knowledge about consumer needs and therefore a more suitable inventory plan. In practice, the collection of such kind of information for MC inventory management is emphasized by MC actors like Reflect, a subsidiary of Procter & Gamble that offers customized cosmetics.

*3) Personalized market information:* Given the large differentiation among different consumers, the inventory management stage of MC can substantially benefit from the visualization service[[11]](#footnote-11) provided to the consumers. For instance, by integrating the information collected from the 3D whole body scan technique into the MC manufacturing activities, or by combining the virtual fitting (i.e., mapping the MC product like a skirt over the 3D scanner) together with the real fitting (i.e., the subject tries the MC product), plenty of personalized information like the shape and size of a human body can be acquired easily. Then with this piece of accurate information, the inventory management for MC, such as the preparation of basic garment inventories for a special target consumer group, can be easily handled. The good performance of this technique is empirically proven by MC literature such as [67].

*4) Enterprise Resource Planning (ERP):* By fully integrating information technologies into corresponding business processes, the ERP system is a system which holds excellent information processing abilities. In an ERP system, all related data can be stored in a single database and be simultaneously shared among different entities in the system without any information delay or distortion [69]. This system can therefore support MC by feasibly translating the needs or preferences related information collected from consumers into detailed product specifications and effectively sharing among all relevant supply chain members like the material suppliers and the manufacturers for further inventory management, and the related MC works is [70].

*5) Radio Frequency Identification (RFID):* Aiming at realizing a high performance of the regular inventory management, RFID technology’s powerful ability of real-time data collection can be utilized in MC schemes to capture complete data, such as material delivery and consumptions. This can contribute to the timely control of real-time MC production decisions and the following executions. The application of this technology in MC is discussed by [71] and [72]. MC manufacturers like Keda are the typical users of RFID technologies. As a remark, the RFID technology is also known to be especially efficient and cited in the automobile or bicycle MC business [71].

*6) Special information management for small and medium enterprises (SMEs):* Apart from the above, there are some MC studies, such as [73], examining the participation of SMEs in the MC game. For these MC players, since the product and production related information is the core of MC, the internal industrialization of information processing should be emphasized when the companies manage the inventory of basic items and the customized ones, rather than merely following the traditional manner of information management[[12]](#footnote-12) [74].

**B. Modularity and Production Flexibility**

Consumers in the market are known to pursue a product or service that fits exactly to their needs and desires [75][76][77]. In the meantime, since personalization is the main difference between MC operations and the traditionally standardized and high-volume mass production operations, great attention should be paid to the target customers in all processing stages [78][79][80][81][82][182]. For example, according to [83] and [84], if the target customers participate in MC from the early design stage, the product can always be highly customized while the degree of customization can be largely decreased if one only considers the preferences of customers at the final stages like the assembly step. Empirical results in [85], [86], [87], [88], [89], [90], and [91] also have examined this kind of influence. They have explored this influence in various industries, such as the footwear industry [85], the natural gas industry [87], and the ski industry [88][89]. The success of customization, however, is mainly determined by the modularity[[13]](#footnote-13) in MC, the implementation of which substantially depends on the production flexibility in the regular inventory management process. Some typical examples to increase the performance of modularity and production flexibility management are then listed as follows.

*1) Flexible Manufacturing Systems (FMS):* This is a system made up of different program modules and can repeat the manufacturing sequences across different kinds of inventories prepared for the final MC products [83]. It is efficient in reducing the high inventory management costs induced by the high modularity in MC while still satisfying the consumer needs given a determined level of product modularity, which is emphasized by MC papers such as [37], [92], [93], [94], and [95]. In addition, one real case of FMS in MC is Levi Straus’ custom-fit jeans.

*2) Postponement:* Postponement is the action when the MC companies deliberately delay some MC processes like the production process and the design stage until the specific order is placed by the customer. It is beneficial for the inventory management of MC since the safety stock can then be more reasonably determined and the inventory planning process like modularity management also becomes less complex. Consequently, it is widely adopted in practice, e.g., Hewlett-Packard in the PC industry and Benetton in the fashion industry. Postponement is also commonly investigated by literature like [66], [96], [97], [98], [99], [175], [176] and [180]. However, owing to the delay, the postponement policy also requires a more reliable MC system. Then in order to successfully implement the postponement policy, some measures like Product Design Generator (PDG) can be utilized, which is an approach depending on the ability of the intelligent computers, e.g., the high processing speed. It can efficiently condense the whole design cycle time from several months to just a few minutes and thus flexibly adapt the inventory management of MC to the diverse changes from the market environment, and its unique efficiency is also empirically investigated in [100].

*3) Service-Oriented Architecture (SOA):* SOA is a technology known for its flexible and reliable communication platform. The SOA platform allows involved supply chain members (both internal and external) to freely share various sub-functions in a flexible and interactive way and provides a dynamic framework for product development and inventory management in MC operations. It can efficiently improve the modularity management of MC inventories since many MC actors have outsourced their production and manufacturing activities to third parties or purchase various MC components from different suppliers, which increase the interaction between internal and external networks (e.g., the inventory interaction between IBM and its external component suppliers). The application of this approach is specifically introduced by the selected papers such as [101].

**C. Quality Management**

As is shown by the MC literature like [93], [103] and [199], the quality of MC products has a substantial influence on the success of the MC program. For instance, MC providers can induce the customers to keep their products instead of returning them by controlling the quality of MC products, which can be managed in the regular inventory preparation and planning stage. Therefore, four methods to attain a better quality of MC items are proposed.

*1) Quality Function Deployment (QFD):* Under this approach, both the product characteristics and the criterion for quality control are demonstrated in an analytical function of consumer needs, which relies on the information extracted from consumers’ purchasing and preference profiles. The use of QFD can ensure an efficient integration of consumer needs into MC product development stages [104]. Another method is the Virtual Reality (VR) based technologies proposed in [10], which is efficient in transforming the specific voice of consumers into both functional and psychological requirements for developing the specific MC product. Both methods can substantially improve the overall quality of regular inventories since the quality requirements are specific and the quality criteria are also objective.

*2) Computer-Aided-Design (CAD):* This technique is composed of automatic made-to-measure processes and it can perform the MC function in a much more accurate and consistent manner. This technique can be employed in regular inventory management when the customization happens in the early stages of MC chains (mainly the production stage) [105]. For instance, the wydiwyg.co.uk website offers a simple and downloadable CAD design program to its MC customers, by which the customers can directly create their own designs without any extra help from a third party [106]. Then the final version of the MC product can exactly fit each customer’s requirement, which means quality consistency of the final products and also an obvious improvement in products’ quality management. Studies that investigate the utilization of this technique include [108], [109] and [169].

*3) Collaborative control approach*: Since it is difficult to have a direct inventory control (e.g., product quality) on the very complex and dynamic MC systems, increasing the cooperation between different subsystems that have close interactions with each other can contribute to a higher overall quality control level of the MC inventories [110]. For example, the principle component analysis based defects extracting scheme proposed in [107] can be adopted to establish a collaborative factory automation system, which can effectively help control the manufacturing process and consequently supervise the quality control of MC merchandise.

*4) Communication with target consumers:* Knowledge sharing about the basic or customized products with the consumers, for instance, via the decision support system introduced by Frutos et al. [112], the case-based reasoning technique proposed by Tseng et al. [113], the object constraint language exhibited by Felfernig [114], or the knowledge maintenance system in [94], is helpful to have effective communication with MC consumers, which can reduce potential conflicts like different understanding on the customization requirements. Therefore, this measure can substantially reduce mistakes in product preparation and inventory planning phases. In fact, these systems can also minimize the negative effects from a lack of sufficient MC experience, if any [115][116].

**TABLE VI.** Measures for regular inventory management in MC

|  |  |  |
| --- | --- | --- |
| **Methods** | | **Related references** |
| Information Management for Forecasting | Utilize the data mining and collaborative filtering technologies to collect purchasing and preference profile information | [65], [173], [185], [189] |
| Emphasize the collection of unbiased market research information | [66] |
| Introduce the visualization service to acquire personalized market information | [67] |
| Integrate the information management into all related MC processes, e.g., via Enterprise Resource Planning (ERP) | [69], [70] |
| Collect real-time data by adopting advanced technologies like Radio Frequency Identification (RFID) | [71], [72] |
| Eliminate geographic limitations when processing information, especially for small and medium enterprises (SMEs) | [73], [74] |
| Modularity and Production Flexibility | Adopt Flexible Manufacturing Systems (FMS) | [37], [83], [92], [93], [94], [95] |
| Implement the postponement strategy | [66], [96], [97], [98], [99],[100], [175], [176], [180] |
| Share relevant sub-functions through Service-Oriented Architecture (SOA) | [101] |
| Quality Management | Formulate customers’ needs by analytical functions via Quality Function Deployment (QFD) | [10], [104] |
| Use the Computer-Aided-Design (CAD) technique | [105], [106], [108], [109], [169] |
| Increase the cooperation between different subsystems by a collaborative control approach | [107], [110] |
| Communicate with target consumers | [94], [112], [113], [114], [115], [116] |

**V. LEFTOVER INVENTORY MANAGEMENT**

Given the uncertainty in market demand and the asymmetry information about consumer preference, it is impossible to make perfect market forecasting to support MC operations. Moreover, to better occupy the market and enhance the consumer loyalty, an increasing number of companies are devoting themselves to offering additional online services for their MC schemes (e.g., the apparel retailer Land’s End). In fact, the PC industry is reported as the most profitable industry under the web-related MC. In the literature, the Internet related MC program is also investigated by various papers like [56], [117], [118], [119], [120], [121], [122], [123], and [124]. For the MC firms, the multi-channel mode, which additionally includes the online interaction between the firms and consumers, can also result in a higher level of market demand uncertainty. As a consequence, unsold leftovers[[14]](#footnote-14) are inevitable in MC and should be addressed. Besides, in our daily lives, offering a return policy to customers for those unsatisfactory products, which can either be partial or full refund, has been commonly recognized as a competitive tool to win customer orders, especially for MC.[[15]](#footnote-15) Therefore, considering the market uncertainty and the existence of consumer returns policy, leftover management of unsold inventories and consumer returns are vital to the companies which offer MC, and thus the ways to raise the salvage value of these two kinds of leftover products will be discussed next. As a remark, Table VII is served as a summary of those proposed ways.

**A. Unsold Inventory Management**

The MC system is known to be made up of two different processing stages, referring to the initial phase for producing the basic items (semi-finished ones) and the final phase for conducting customize-to-order actions [125]. In this two-stage structure, in order to reduce the negative effect of under-supply, MC providers usually will keep an inventory service level of the semi-finished products that may be higher than the estimated demand in the primary stage. Such kind of special stock, which acts as a buffer between the “push line” and “pull line” in MC [171], can finally end up as excessive inventories at the end of the selling season. Consequently, unsold inventory management is influential in this case. For example, if the MC providers can optimize the reusability across those unsold modules or components, the total effort invested into the whole product life-cycle, like manufacturing facilities and material preparations, can also be saved to a large degree [126].

***Enhancement of Unsold Inventories’ Salvage Value***

For inventory management of the basic stock level, the major responsibility of MC provider is to determine the number of initial product variants and detailed product specifications. These small segments or product proliferation in the inventory management stage have effects on the cost and responsiveness the MC structures [131], and the complex MC system is therefore based on the balance between modularity and standardization. For instance, the whole production procedure can be broken down into several sub-modular processes and the customers can personalize their own products by changing some modules that are provided to them. This is also consistent with [78], which indicates that each individual MC product is the result of both customer specifications and parameters of its product modularity or family. Therefore, the salvage value of those un-customized products can be improved by the ways listed next.

*1) Reducing initial product variants:* As is proven by Jiang et al. [125], a superior MC program is always related to a lower level of product variants[[16]](#footnote-16). For example, the successful MC providers named Toyota and Volkswagen offer very limited choices on component modules to their customers. In fact, a limited range of component modules can also help MC companies increase the final salvage value of these leftover products since modularity can directly determine the degree to which the standard items can be separated or recombined into different components that can be further utilized for creating another new product. It thus can be a direct way to better manage the leftover inventories. Tools like the variety index (VI) method investigated in [196] can be a good reference. In practice, the best MC example to illustrate the excellent utilization of modularity is Lego’s toys whose various pieces or components can be easily combined together into kinds of shapes in the light of different customized preferences [4]. Besides, IBM also attains a high salvage value of leftovers by emphasizing the degree of modularity and produces their “new” product by containing several components from the “old” ones. Among the selected literature, papers such as [127], [132], [134], [135], [137], [138], [139], [141], [142], [143], [144], [145], [146], [147], [148], [149], [150] and [191] all deeply discuss the decision making on the product modularity and product variety of MC.

*2) Process or component standardization:* The standardization process is well known for its benefits of economy of scale [4][151][197] and the importance of the component standardization is examined in the MC literature like [152] and [154]. While in fact, pursuing a reasonable degree of component standardization across different product families in the inventory planning stage of those un-customized items can also enhance the salvage value of the leftover inventories for the MC channel. In addition, according to the Boeing Company, the parts or components of a finished plane can be classified into three categories: standardized, similar and special ones [155]. Among these three categories, those standardized parts or components can be directly re-used for the next designing and manufacturing process cycle. Then for those similar modules, modification is needed before re-using them. While for those special ones, they should be further designed before reuse, which reflects the highest degree of difficulties for other operations. Although other MC products may not be as complex as a plane, they are also made up of various parts. Consequently, choosing a reasonable degree of standardization can benefit every MC firm if they want to improve the salvage value of unsold inventories, which affect the “reusability” of the components in the reverse direction.

*3) Classification of semi-finished products and/or modules:* Considering the variety of semi-finished products and/or modules, a suitable classification of those leftover inventories before remanufacturing or reengineering is necessary. For instance, different product variants that belong to the same product family usually share a common structure and they can be selected for the same component of another product. Furthermore, basic items can also be divided into several groups of modules in terms of the characterized technologies or material properties, which is also an important origin of variety in MC products. Methods like the design structure matrix (DSM) in [128] and [130] can be a useful tool in this classification process, which is efficient in listing the relations between different components in the involved product.

***Cost Reduction of Unsold Inventories***

Apart from enhancing the salvage value of unsold inventories, MC companies can also improve the performance of the leftover inventory management process through inventory cost reduction. Two approaches are proposed in the following:

*1) Extensibility of the basic items:* It is a method to prepare the basic items with the emphasis on its structure rather than its function, and make the items to be “extendable” into a collection of different final MC products with little restriction. That is, multiple final MC products, which are presented in different formats, will share a common component in the first stage[[17]](#footnote-17), which directly combines the inventory prepared for different items into a relatively integrated one (i.e., inventory pooling/risk pooling). This can directly reduce the basic inventory service level and correspondingly release the heavy inventory costs by decreasing the number of final unsold leftovers. It is a kind of object-oriented system [156] and it can be especially efficient in industries like the computer and the fashion apparel.

*2) Warehouse sharing:* The warehouse storing leftover inventories can be shared among different unsold components or modules, or even together with the consumer returned items. The total costs of facility and the staff equipment can then be shared across different categories and this directly reduces the unit inventory cost for each leftover item. Besides, the MC companies can also share the stock space with another brand, which is common in practice, e.g., a UK-based company Argos has shared the same warehouse with Nestle UK for several years [157].

**B. Managing Consumer Returns**

Given the existence of consumer returns policy and the online platform, MC providers should have the capability to manage those collected items in order to achieve a sustainable development of MC programs. As a result, both the ways to raise the salvage value of consumer returns and the methods to reduce these returns are explored in the following.

***Enhancement of Consumer Returns’ Salvage Value***

The maximization of the profit derived from the remaining value of product returns can be realized by adopting modern information and manufacturing technologies, the details of which are presented as follows.

*1) Reconfiguration flexibility:* This is a term referring to the ability to reconfigure the consumer returns collected from the market, the degree of which is a function of the product specification that happens at an upstream level [158]. That is, if the producers of MC products can take advantage of their upstream supply, inventory planning, and production networks to design the customized items in a highly reconfigurable way, then the MC products will be more adaptable to the external changes as well as further remanufacturing or reengineering activities. As a result, consumer returns’ salvage value can be largely improved and finally the MC profits can also be lifted.

*2) New materials:* Additionally, the adoption of advanced technologies to create new materials is also beneficial in improving the salvage value of consumer returns, which is one of the decisions made when conducting the inventory management for MC. Nanotechnology, for instance, is a technology that can be utilized for creating new MC materials or MC products like smart polymers in materials and the nanochips as well as nanosensors in electronical items [105]. Undoubtedly, these new material technologies are useful in making MC products cleaner and achieving higher quality.

*3) Information sharing:* As is emphasized by the MC literature like [159], [160] and [161], the MC supply chain suffers a lot from the partial share of information between the relevant co-operators. Therefore, two directions of information sharing in MC will be discussed in the following as a measure to help enhance the salvage value of consumer returns.

a) From the downstream to the upstream: As is argued by MC papers like [66], information about future outputs of the corresponding process is exactly the input when planning the following manufacturing activities or other closely related MC steps. Consequently, sharing the knowledge of the future remanufacturing or reengineering options can be an efficient guidance to the designers of MC products, e.g. through the knowledge-intensive collaborative decision support system suggested by Zha et al. [186]. It also helps ensure a higher possibility that the leftover products can be further processed or remanufactured. By doing so, the salvage value of those used items is undoubtedly increased. Moreover, to improve information sharing, MC companies can also cooperate with cloud computing providers like IBM, Microsoft and Google [105][187].

b) From the upstream to the downstream: It is acknowledged that remanufacturing and reengineering activities are always constrained by the materials and modules of those finished products (e.g., the returned products collected from the market) as well as the limited availability of related information. Therefore, the reuse of information, which is suggested by [91] and [192], can also increase the salvage value of consumer returns. That is, the upstream MC members can utilize assistance tools, e.g., the ontology-based approach [153], the Product Data Management (PDM) method [68][72], the Generic Product Family (GPF) master model [163], or the binary tree algorithm [178], to share specific information of those used products like the materials and technical involvements invested with the downstream actors and thus substantially further simplify remanufacturing or recycling operations as well as reduce invested efforts.

***Cost Reduction of Consumer Returns***

Given the fierce competition in the market and government legislation, the term Extended Producer Responsibility (EPR)[[18]](#footnote-18) is widely introduced by various MC companies, e.g., the warranty and liability issue. One famous instance is Dell, an MC company from the computer industry, which accepts the warranty claim for the failing components [164]. The existence of this extended responsibility, however, can lead to plenty of additional inventory costs. Therefore, to release the heavy burden of the consumer returns, cooperation with powerful third party collectors such as the IBM's Global Asset Recovery Services is suggested, which not only can enhance the efficiency in collecting consumer returns but also substantially reduce the inventory management costs induced by these returned items [165]. Besides, this can also release MC companies from related opportunity costs, referring to the costs like the labour cost and transport cost resulted from tackling consumer returns, which can be utilized in other aspects [136].

**Table VII.** Measures for leftover management in MC

|  |  |  |
| --- | --- | --- |
| **Methods** | | **Related references** |
| ***Unsold Inventory management*** | | |
| Enhancement of Unsold Inventories’ Salvage Value | Reduce initial product variants | [4], [125], [127], [132], [134], [135], [137], [138], [139], [141], [142], [143], [144], [145], [146], [147], [148], [149], [150], [191], [196] |
| Pursue a reasonable degree of process or component standardization | [4], [151], [152], [154], [155], [197] |
| Classify semi-finished products and/or modules | [128], [130] |
| Cost reduction of Unsold Inventories | Emphasize the extensibility of the basic items | [156] |
| Warehouse sharing | [157] |
| ***Managing Consumer Returns*** | | |
| Enhancement of Consumer Returns’ Salvage Value | Enhance the reconfiguration flexibility of consumer returns | [158] |
| Adopt new materials | [105] |
| Information sharing | [66], [68], [72], [91], [105], [153], [159], [160], [161], [163], [178], [179], [186], [187], [192] |
| Cost Reduction of Consumer Returns | Cooperate with third party collectors | [136], [164] |

**VI. COOPERATION FOR INVENTORY MANAGEMENT**

Plenty of methods to improve the performance of regular inventory management and to enhance the salvage value of unused inventories as well as the consumer returns have been proposed in the previous sections. However, apart from product proliferation, the internal supply chain structure can also affect the eventual inventory performance of MC. That is, since the supply chain of MC contains different parties while each independent entity may have a totally different goal, constraints, and considerations, they may not cooperate in a way that is beneficial to the whole MC system. Consequently, integration or coordination of these members[[19]](#footnote-19) is crucial. This is also true for implementing those methods proposed above since a cooperative relationship ensures the consistency of information flow and reduces the conflicts and delays in implementing those measures. Related topics are studied by the literature like [57], [61], [91], [140], [161], [162], [163], [166], [167] and [168]. Two main measures are thus proposed below with a brief summary in Table VIII.

*1) Synchronized supply chain management:* Under this kind of MC network, strong business partnerships at all levels of MC are required, which start from the initial material preparation, manufacturing to the final market support. Given this requirement, highly shared databases and effective communication networks that can provide simultaneous information related to the customers and other technologies or resources are emphasized. For instance, simulation tools like Multi-Agent Systems proposed by Labarthe et al. [168] can be utilized to guide the design and inventory preparation process and the management of the interaction between different actors in the MC channel. Besides, intelligent technologies like the Integrated Vehicle Configuration System [13], the Intelligent Search Algorithm [29], RFID-enabled real-time manufacturing execution system [72], the Virtual supply network [102], the Web-based collaborative visualization [111] and the cloud manufacturing-based intelligent systems KAGFM [176] can also help achieve such integral cooperation. All of them can finally help raise the performance of inventory management.

*2) Supply chain coordination:* In addition to the synchronized supply chain management, the coordination with adjacent parties can be a method to prevent potential conflicts between various departments or participants in MC and to promote the execution of those introduced suggestions for MC inventory management. Notice that, in our paper, “coordination” refers to the optimization of the MC supply chain system, which can be achieved through various supply chain contracts. For instance, under the postponement strategy, Nike outsources the production of the shoes, which are for the MC program, to its partners in Asia through supply chain contracts instead of producing by itself [9]. In this case, the supplier’s heavy costs of fixed assets, material inventory as well as management of workers will not be considered by Nike when making orders. However, these elements will be extremely crucial when the supplier determines the final investment on this cooperation. Then given the different interests of the two parties, Nike and its supplier can cooperate by sharing the extra revenue or benefits from the cooperative relationship such as designing a revenue-sharing contract (interested readers can refer to [45] for more details), or by sharing the potential risks (e.g., a risk sharing contract[[20]](#footnote-20)), so as to motivate the adoption of an optimal inventory service level for the materials and components. Moreover, the MC channel can also be further improved by a buyback contract, under which the consumer returns and unsold inventories are emphasized. It can be applied to the automotive industry where large companies like BMW always offer contracts to other small and medium enterprises for purchasing related subcomponents or subsystems for further processing. Apart from the single coordination mechanisms, the hybrid contract can also be a solution to enhance the final performance of MC. One typical example is Hewlett-Packard which executes a hybrid contract with the combination of both a flexible-quantity contract and a fixed-quantity contract during the cooperation with its suppliers.

**Table VIII.** Measures for the inventory management cooperation between different parties in MC

|  |  |  |
| --- | --- | --- |
| **Methods** | | **Related references** |
| Synchronized supply chain management | Attain strong business partnerships at all MC levels and establish effective communication network, e.g., via Multi-Agent Systems or cloud manufacturing-based intelligent systems | [13], [29], [72], [102], [111], [168], [176] |
| Supply chain coordination | Coordinate adjacent parties by supply chain contracts like revenue sharing contracts, risk sharing contracts, and the hybrid ones | [45], [159] |

**VII. CONCLUSION**

**A. Summary and Concluding Remarks**

To adapt to the dynamic market and diverse consumer preferences, the MC program has been successfully launched in various industries all around the world. Under this program, the MC providers usually tend to offer a high product variety level and allow consumers to return the unsatisfactory products. However, although competing on the degree of customization is a common way to attract target customers, the final benefits of these competing MC providers can be reduced if the inventory planning process is not well managed, e.g., a low inventory service level of the basic products, poor information management of customer needs, or the over-customization on basic items. Besides, since environmental sustainability has also been increasingly emphasized by the consumer market, devoting more time and efforts to managing leftover inventories, including both unsold leftovers and consumer returns, is definitely beneficial to establish a good image of those involved MC companies. Therefore, based on a systematic review, this paper has proposed various methods to improve the performance of the regular inventory management process and to raise the salvage value of unused inventories as well as the consumer returned products for the MC operations. For instance, MC providers can utilize the quality control and flexibility management in the regular inventory management process to minify the probability of product failure in the future and use information sharing to enhance the salvage value of the used items collected from the consumers. Additionally, the company which offers MC services should also make a reasonable balance between the product variety level and the complexity level when making inventory plans so as to ensure the salvage value of unsold leftovers. Apart from the above, emphasizing the cooperation in the MC channel, like developing strong MC business partnerships under various intelligent technologies and coordinated relationships between adjacent parties, can also help improve the MC performance.

**B. Future Research Opportunities and Limitations**

After the comprehensive review of related papers, some topics are found to be under-explored in the MC inventory management literature and four promising future research directions are proposed below.

*1) Reconfiguration flexibility of leftover products:* Given the existence of consumer returns policies and demand uncertainty, the ability to maximize the remaining value of leftover inventories is vital for MC companies. For instance, as we mentioned above, the Boeing Company classifies the involved parts or components of their finished planes into standardized, similar and special ones [155], which hold totally different reconfiguration flexibility. To be specific, the standardized parts or components can be directly used for remanufacturing while those special ones reflect a highest difficulty level for reconfiguration and require further design before reuse. As a result, future studies can be conducted to deeply examine the measures to enhance the reconfiguration flexibility of leftover inventories, such as the tradeoff between customization (e.g.., initial product variants) and standardization (e.g., process or component standardization), and literature like [158] can be a good reference. This is especially important for the technology intensive companies like the airways and the electronic firms (e.g., Apple), the involved components of which are usually very complicated and expensive.

*2) Item extensibility:* This is a term describing the flexibility of extending one common basic item (i.e., a semi-finished one) into different formats of final MC products. It can directly influence the degree of common components sharing in the first inventory preparation stage (i.e., the push stage before specific MC orders are made by the consumers) as well as the inventory service level prepared for different basic items. Future research therefore can be executed to analyze the optimal extensibility degree of the basic items as well as related technologies that can be applied to raise this extensibility, which is almost absent in the reviewed papers (except [156]). The findings can correspondingly benefit the industries within which various components can be easily combined into different shapes or products, like the PC industry (e.g., Dell, Hewlett-Packard, IBM), and the toy industry (e.g., Lego).

*3) Risk management for small and medium enterprises (SMEs):* According to [73], the SMEs are typically more vulnerable to operational risks than larger companies. Then considering the popularity of SMEs’ participation in MC [74], structured low risk approaches for MC inventory management under the participation of SMEs (e.g., Crearmoda, MyCustomizer, ArtBag Design) are needed for future research, which can avoid supply disruptions and therefore ensure a success in MC.

*4) Coordination:* Considering the universality of double marginalization, exploring the coordination between different MC supply chain parties can contribute a lot to the execution of MC inventory management. One under-explored instance in MC inventory management is to design coordination mechanisms between the retailer and the related third party collectors for collecting and managing consumer returns, such as the quality and the reconfiguration flexibility of the collected returns. In addition, a noticeable absence on cost minimization coordination (e.g., costs on adoption of new raw material) is identified in the MC inventory management domain, which is also a potential future research direction for supply chain contracts design. The related implications can be a helpful guideline to the companies, which sell short life cycle products and outsource the production process to external suppliers, such as the fashion companies like Levi Straus.

*5) Correlation between different inventories:* In practice, since the leftover inventories like the unsold stock can tie up a huge amount of capital and prevent the companies from further re-investment, some MC actors may offer some additional discounts to their excess stock (e.g., through some Overstock Sale[[21]](#footnote-21) or through the brands’ outlet stores[[22]](#footnote-22)) so as to attract more customers and to minimize the leftover inventory costs. These discounts, however, may increase more consumer returns, which can be a result of impulse purchase or misfit. Consequently, it is also interesting to simultaneously explore the unsold inventory and consumer returns in MC and their correlations, and similar research is still absent in the extant literature so far.

Similar to other review papers, this paper has some limitations which call for readers’ attention and probable further examinations. First of all, since the searching process is mainly based on the selected keywords, which involve a certain degree of subjectivity, some MC papers may not be included in this review. Secondly, owing to the scope of this paper which focuses mainly on academic studies published in good journals, real-world industrial cases are not deeply analyzed in this paper. Further studies can hence be conducted to examine how MC cases in the real world operate and whether there are empirical evidences on their operations improvement in terms of inventory management with our proposed measures.

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**ONLINE SUPPLEMENTARY APPENDIX**

**Table II.** MC literature selected from each hybrid keyword listed in Section II.2.

|  |  |  |
| --- | --- | --- |
| **1st Keyword**  **2nd Keyword** | **“Mass Customization”** | **“Mass Customisation”** |
| Material Management (3) | Daaboul et al. [46], Spear [179], Huang et al. [200]; | Nil |
| Component Management (7) | Selladurai [4], Bruun et al. [128] Cho et al. [130], Tien [133], Fogliatto et al. [136], Blecker and Abdelkafi [154]; | Wang [107] |
| Product Design (29) | Yang and Li [35], Tu et al. [49], Aldanondo and Vareilles [51], Comstock et al. [59], Dai et al. [68], Sakao and Fargnoli [77], Tseng and Du [79], Krishnapillai and Zeid [81], Fogliatto and Da Silveira [87], Franke et al. [88], Franke et al. [89], Tuck et al. [93], Bare and Cox [100], Bateman and Cheng [106], Chen et al. [118], Helander and Jiao [119], Jiao and Tseng [138], Huang et al. [184], Zha et al. [186], Xu et al. [187], Yu and Wang [188], Yu et al. [189], Dean et al. [190], Blecker and Friedrich [191], Levandowski et al. [192]; | Doukas et al. [29], Büyüközkan et al. [63], McIntosh et al. [97], Qu et al. [194]; |
| Degree of Customization (3) | Liu et al., [45], Stump and Badurdeen [47]; | Wang [171], |
| Product Modularity (10) | Partanen and Haapasalo [24], Joneja and Lee [27], Zhang et al., [53], Duray et al. [83], Huang et al. [141], Mikkola [144], Li et al. [161], Ro et al., [164], Wang et al. [197], Zhang et al. [198]; | Nil |
| Product Family (19) | Cunha et al. [39], Yang et al. [41], Ben-Arieh et al. [43], Ismail et al. [73], Jiao et al. [78], Ong et al. [115], Jiao et al. [126], Jiao and Tseng [132], Jiao and Tseng [134], Du et al. [135], Rai and Allada [137], Jiao et al. [143], Chen and Wang [145], Moon et al. [150], Gu et al. [155], Jiao and Helander [163], Bonev et al. [195], Zhuo et al. [196]; | Cunha et al. [149]; |
| Product Variant (8) | Tu et al. [40], Dewan et al. [65], Mendelson and Parlaktürk [76], Tseng et al., [113], Jiang et al. [125], Cattani et al. [202]; | Matthews et al. [44], Su et al. [98]; |
| Product Variety (20) | Alptekinoğlu and Corbett [1], Daaboul et al. [7], Salvador and Forza [36], Zhang and Tseng [42], Tu et al. [50], McCarthy [80], Cavusoglu and Raghunathan [92], Kaplan and Haenlein [123], Salvador et al. [139], Jiao et al. [142], Forza and Salvador [146], Mendelson and Parlaktürk [147], Coronado et al., [152], Tseng and Chen [178], Jiao and Zhang [185], Alptekinoğlu and Corbett [193], Zhang et al. [201]; | Alford et al. [48], Kang and Hong [148], Scharf et al. [160]; |
| Customer Integration (15) | Kaplan et al. [6], Buffington [26], Piller et al. [66], Franke and Piller [75], Squire et al., [86], Merle et al., [90], Lai et al. [91], Frutos et al. [112], Ninan and Siddique [122], Frutos and Borenstein [156], Siddique and Ninan [169]; | Yeung and Choi [8], Carulli et al. [10], Piller and Müller [85], da Silveira [170]; |
| Process Flexibility (21) | Eastwood [5], Brabazon and MacCarthy [22], Rudberg and Wikner [23], Wikner et al. [25], Joneja and Lee [28], Barnett et al. [30], Zangiacomi et al. [31], Bock [32], Yao and Liu [34], Fulkerson [55], Potter et al. [61],Akkermans et al. [69], Shao [95], Karpowitz et al. [101], Bock [103], Tseng et al. [110], Rungtusanatham and Salvador [151], Brabazon et al. [158], Kim [166], Fogliatto et al. [183], Chen and Wang [182]; | Nil |
| Inventory Level (7) | Duray [12], Zhang and Efstathiou [14], Aigbedo [33], Aigbedo [38], Zhou et al. [175]; | Wong and Eyers [176], Calle et al. [177] |
| Information Management (34) | Rabinovich et al. [11], Helo et al. [13], Huang et al. [52], Dellaert and Dabholkar [56], Graessler [58], Frutos and Borenstein [60], Tien [62], Dietrich et al. [64], Daanen and Hong [67], Tu et al. [71], Zhong et al. [72], Svensson and Barfod [74], Trentin et al. [82], Dean et al. [94], Smirnov et al. [102], Tien [105], Siddique and Ninan [108], Chu et al. [111], Felfernig [114], Huang et al. [116], Baker et al. [117], Turowski [120], Ghiassi and Spera [121], Helms et al. [124], Tien [140], Yang et al. [153], Wang [162], Labarthe et al. [168], da Rocha et al. [172], Shin et al. [173]; | Giard and Mendy [57], Mason and Lalwani [157], Yao [159], Pan et al. [174]; |
| Product Quality (6) | Kuo [54], Zhao and Fan [70], Ni et al. [104], Rezapour et al. [199]; | Squire et al. [37], Vinodh et al. [109], |
| Postponement (6) | Shao and Ji [96], Liao et al. [99], Su et al. [131], Mikkola and Skjøtt-Larsen [167], Zhou et al. [180]; | MacCarthy [181] |
| Consumer Return (2) | Liu et al. [127], Choi et al. [129]; | Nil |

**Table IV.** Most productive authors in MC inventory management

(published in Web of Science listed journals only)

**Remarks:** From Table IV, it can be observed that authors like Jiao, J.X. (USA), Tseng, M.M. (Hong Kong) and Huang, G. (Hong Kong) have contributed a lot in MC inventory management research

|  |  |
| --- | --- |
| **Name (From)** | **No. of publication** |
| Jiao, J.X. (USA) | 13 |
| Tseng, M.M. (Hong Kong) | 9 |
| Huang, G. (Hong Kong) | 6 |
| Choi, T. M. (Hong Kong) | 4 |
| MacCarthy, B.L. (UK) | 4 |
| Forza, C., (Italy) | 4 |
| Salvador, F. (Spain) | 4 |
| Tien J. M. (USA) | 4 |
| Wang L.Y. (China) | 4 |
| Brabazon, P. G. (UK) | 3 |
| Borenstein, D. (Brazil) | 3 |
| Da Cunha, C. (France) | 3 |
| Da Silveira G. J. (Canada) | 3 |
| Franke, N. (Austria) | 3 |
| Frutos, J. D. (Brazil) | 3 |
| Ninan J. A. (USA) | 3 |
| Piller, F. T. (Germany) | 3 |
| Rungtusanatham M.J. (USA) | 3 |
| Siddique Z. (USA) | 3 |
| Zhang, M. (UK) | 3 |

**Table V.** The trend of research topics

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **1st Keyword** | **2nd Keyword** | **1996-1998** | **1999-2001** | **2002-2004** | **2005-2007** | **2008-2010** | **2011-2013** | **2014-2016** | **Total** |
| **Mass Customization/ Mass Customisation** | Material Management | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 3 |
| Component Management | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 7 |
| Product Design | 1 | 2 | 5 | 5 | 12 | 1 | 3 | 29 |
| Degree of Customization | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 3 |
| Product Modularity | 1 | 1 | 1 | 3 | 1 | 0 | 3 | 10 |
| Product Family | 1 | 2 | 4 | 6 | 5 | 0 | 1 | 19 |
| Product Variant | 0 | 0 | 1 | 3 | 4 | 0 | 0 | 8 |
| Product Variety | 0 | 1 | 5 | 7 | 5 | 1 | 1 | 20 |
| Customer Integration | 0 | 0 | 6 | 3 | 1 | 5 | 0 | 15 |
| Process Flexibility | 5 | 0 | 7 | 1 | 7 | 1 | 0 | 21 |
| Inventory Level | 0 | 0 | 1 | 2 | 1 | 2 | 1 | 7 |
| Information Management | 0 | 1 | 7 | 7 | 13 | 3 | 3 | 34 |
| Product Quality | 0 | 0 | 0 | 3 | 1 | 1 | 1 | 6 |
| Postponement | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 6 |
| Consumer Return | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| **Total** | | 8 | 7 | 40 | 42 | 52 | 23 | 18 | 190 |

1. This paper is partially supported by Research Grants Council (Hong Kong) – General Research Fund (Project account: PolyU 152294/16E). [↑](#footnote-ref-1)
2. Notice that, in this paper, the requirements from the customers or the market mainly refer to the combination of the revealed requirements and the expected requirements. For those exciting requirements, considering the difficulty to discover, they are not considered in this paper. [↑](#footnote-ref-2)
3. We define the regular inventory management as the management conducted to deal with MC related inventories that occur in the forward direction, i.e., from the upstream to the downstream. These inventories can either be work-in-process inventories or finished ones. At the same time, the leftover management refers to both the unsold leftovers and consumer returns. [↑](#footnote-ref-3)
4. Notice that, in our paper, the unsold inventories and consumer returned ones can occur at either tier under this MC supply chain structure (expect from the consumer level). [↑](#footnote-ref-4)
5. We choose Web of Science as the searching engine for this paper owing to the completeness of its SCI/SSCI database and its popularity in the academic domain. Note that we only examine SCI/SSCI journal publications in English. [↑](#footnote-ref-5)
6. These keywords are selected based on the classification of different inventories in the MC programs. In the meantime, “information” and “postponement”, as the two most crucial elements in MC schemes, are also included. [↑](#footnote-ref-6)
7. In this step, we only select those MC papers that contain the 1st keyword “mass customization” or “mass customisation” in their title, abstract, or list of keywords from the Web of Science results. Besides, the papers with a totally irrelevant topic to inventory management will also be directly excluded in this step. [↑](#footnote-ref-7)
8. For the most productive authors, refer to Table IV in the Online Supplementary Appendix. [↑](#footnote-ref-8)
9. Notice that, in our paper, MC papers published in year 2017 are not included since 2017 is not ended yet. [↑](#footnote-ref-9)
10. As a remark, in this paper, a standard item means the item that has not been further customized yet, which is deliberately postponed for production until further information about specific consumer needs is collected. It can be treated either as a component or a semi-finished product. For the customized item, it refers to the final product that is ready for sell. [↑](#footnote-ref-10)
11. This is a service to help make consumers clearer about the related MC process and the final result, and it is efficient in reducing the market demand uncertainty in MC programs [56] [68]. [↑](#footnote-ref-11)
12. Under the traditional information management, the related information is usually isolated by geographic limitations. [↑](#footnote-ref-12)
13. “Modularity” in our paper refers to the action to divide the production for MC products into different sub-elements (e.g., fundamental components or semi-finished items) before the final customization stage, which can be further manufactured. [↑](#footnote-ref-13)
14. Notice that the unsold leftovers in our paper refer to the leftovers resulted from all processing levels in the forward direction, which can be materials, components and modules, or semi-finished products. [↑](#footnote-ref-14)
15. The design and application of this policy are frequently explored in the MC literature such as [127] and [129]. [↑](#footnote-ref-15)
16. The variants of products can be measured by the number of different MC items that scheme can produce. [↑](#footnote-ref-16)
17. We treat the stage for preparing basic inventories as the first stage and the stage with further customization as the second stage. [↑](#footnote-ref-17)
18. It emphasizes the extended responsibility of the producer on the environmental performance of the product’s whole life cycle, especially the postconsumer stage like the take-back, repair and remanufacturing activities. [↑](#footnote-ref-18)
19. Although the term “integration” is mentioned in one of the previous MC review papers [19], no deep analysis is included in that paper. At the same time, no prior MC review papers have discussed supply chain coordination in MC. [↑](#footnote-ref-19)
20. The risks can be induced by the uncertain customer demand and preferences, the uncertain material and component supply, as well as other natural or man-made disasters and more information about MC related risks can be found in [159]. [↑](#footnote-ref-20)
21. For instance, the MC company Dell in the PC industry has its official online channel for selling the overstock products at retail prices lower than the regular season’s (see <https://www.dell.com/en-us/shop/electronic-and-accessory-deals/ar/8245>). [↑](#footnote-ref-21)
22. MC brands, like Adidas and Nike, all have their own outlet stores. [↑](#footnote-ref-22)