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Mapping the Scientific Research on Mass Customization Domain: A Critical Review and Bibliometric Analysis

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Abstract: Researchers of the Mass Customization domain face not only challenges of proper and timeless identification of latest practical trends, but also difficulties in rational analyses on the numerous existing scientific studies in this field as well as a need for a comprehensive and multidimensional state-of-the-art overview of the Mass Customization research domain in the last three decades. Therefore, the present research article aims to provide a critical standpoint and reveal the main research directions and content at systemic, bibliometric and historical research levels in the period of 1990–2020. Four types of bibliometric clustering techniques and a visualization of results in a format of two-dimensional maps by the VOSviewer software were applied in the analysis on 1783 scientific papers from the Clarivate Analytics Web of Science Core Collection. The analysis reveals six historical periods in the Mass Customization research domain, from which, in the last three decades, three are identified as influencing modern Mass Customization research areas and objects. Results confirmed a shift from a stand-alone scientific approach to the customization of tangible products in the manufacturing field and their risk management, to a hybrid scientific approach with a focus on the customization of non-tangible products and personalized customer behavior in online environments.

Keywords: Mass Customization; mass personalization; digitalization; risk management; bibliometric; Web of Science

1. Introduction

Mass Customization (further MC) is primarily recognized as a differentiation strategy in the manufacturing and retail spheres that provides a wide range of customized products or services as well as co-design or other value co-creation options, which are attainable for large market segments by keeping operational costs near to a mass production level. Otherwise, in late 2000s and mostly in the whole of the past decade, an intensive application of combined technology and management solutions, digital society and business transformations have shifted the orientation of the concept more towards intangible products' management, customer involvement and mutual value creation via platforms and tools in an online environment (Baranauskas 2020; Raišienė and Baranauskas 2018). Furthermore, these practical tendencies do not only illustrate different MC domain transformation periods, but also undoubtedly appear as the root cause for three theoretical research subdomain

areas, their topics and gaps. In 2000–2010, MC researchers focused on a detailed examination of a multidimensional implementation process within different types of organizations and combined subdomains of MC, influenced by organizational operational activities and specifics as well as the rise of online environments (Rungtusanatham and Salvador 2008; Morelli and Nielsen 2010; Piller et al. 2014). From 2010 up until now, the focus has been switched to a synergy of interrelated scientific domains, which together with trends of globalization, digitalization and sustainability have become the main drivers in MC research and resulted in a number of new concept versions like Smart Customization, Agile Mass Customization (further Agile MC) and Electronic (customer and data driven) Mass Customization and Personalisation (e-MCP) (Medini et al. 2015; Hora et al. 2016; Hu et al. 2011; Grosso and Forza 2019; Zhang et al. 2019). These areas and periods replaced research gaps or in some cases overlaped with the first decade's (approx. from 1987 to the beginning of 2000s) research interests in the traditional MC, including such topics as a transition from Mass Production, and an analysis of technological, economic, market specific trends and critical success factors for MC implementation in the manufacturing field (Pin et al. 1993; Gilmore et al. 1997; Schubert and Ginsburg 2000; McCarthy 2004).

Accordingly, this particular study has both theoretical and practical contributions to the MC field by assisting researchers of the MC domain with a comprehensive and multidimensional state-of-the-art overview of the MC research domain in the last three decades. The main scientific contribution of the research is exceeding the boundaries of content and methodology since, in other state-of-the-art MC-based research papers, limitations are followed rather than overcome. Another factor contributing to the scientific field is a systemized and coherent evaluation of key scientific research areas and content within MC research studies in the past three decades. Furthermore, the practical contribution is revealed by an identification of the most recent research gap and future research directions, which should be more focused on various combinations of Digitalization and Personalization sub-domains, mostly supporting a practical application of modern MC concept versions.

The main research question is how content and scientific discourse of the MC research domain have changed within the period of 1990–2020. From the methodological perspective, the research is based on a systemic analysis of the main theoretical perspectives and the context of the MC research area. Furthermore, a bibliometric analysis allows investigating and disclosing the main research outcomes, current research streams and tendencies in the selected research field.

The paper is composed of six key parts. The first part introduces the topic, the second one covers the theoretical background regarding the MC concept, the third one presents materials and methods, the fourth analyzes results and research findings, the fifth section provides a discussion of the research results, and the sixth one concludes the findings.

2. Theoretical Background

2.1. Retrospective Changes of the Mass Customization Research Area

Retrospectively, the general idea of the MC concept was described by Alvin Toffler in the works "Future shock" (1971) and "The Third Wave" (1980) while the term MC was first suggested 33 years ago by Stanley M. Davis. Later on, it was popularized and developed for practical application in business by B. J. Pine (1993), which was mostly influenced by the practices of such companies as Toyota and Dell (Piller et al. 2005; Anišić et al. 2013; Brandão et al. 2017). Numerous transformations of background and content features have been identified in the evolution of the MC concept, starting from 1850, but key semantic features have remained throughout the whole period of its usage: an orientation to specific needs and an involvement of a target mass audience; harmonization of diversity, costs, and quality features and risks; a competitive advantage via combined management and the application of technological methods and risk management. A historical transition of the MC concept and its background transformations are illustrated in Figure 1.

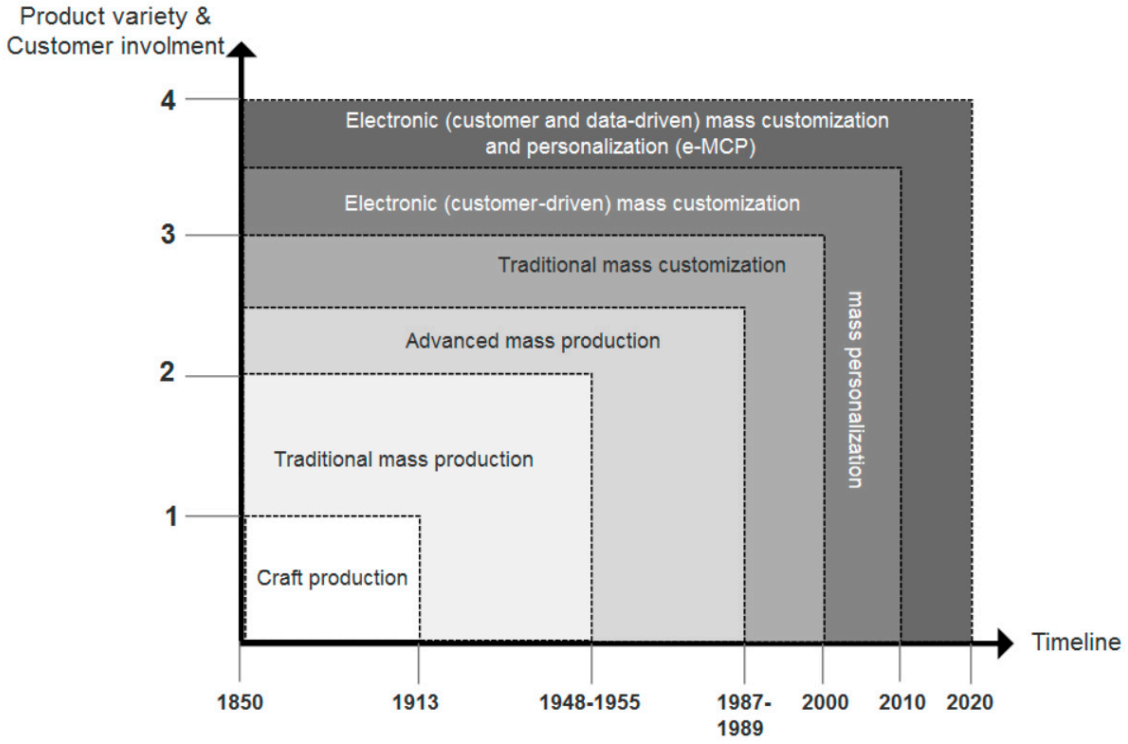

Figure 1. Historical background and evolution of the Mass Customization concept. Source: Composed by the authors according to Anišić et al. (2013); Kanama (2018); Zhang et al. (2019).

The main transformation stages of MC are based on two criteria: (a) a timeline of history including six key dates, or a time period that marks the main transformations in the context of the MC concept, and (b) a combined product variety and a customer involvement indication in a four-level scale based on the modified Gilmore and Pine II (1997) model of four types of MC.

In accordance with the above defined criteria, six historical stages have been identified. The first is a craft production stage known as a large scale (mass) production prototype, where a process features low volume manufacturing by hand with or without machine toolkit usage. Its origins date back to 1850 and are closely related to the Second Industrial revolution and the Art and Crafts movement of around 1913 (Kanama 2018). It also stands for the transition from the traditional business and risk management model of "pull" principles to the new model of "push" and sequential production techniques (Orošnjak et al. 2017). The second period, from 1948 to 1955, shows a transition from traditional mass production to an advanced (flexible) mass production. The third period, 1987–1989, illustrates the origin of the term MC and its practical transition to a new multidimensional and combined business and manufacturing strategy. Retrospectively, and from the content point of view, the main evolution of the MC concept can be split into three main periods and sub-stages including the traditional MC from the 1990s, its transformation to the electronic or customer-driven MC and Mass Personalisation (further MP) concepts from late 2000s, while in the last decade the transition of the concept to a combined version with Personalization (named as Mass Customization and Personalization (MCP)) and digitalization domains (named as E-MC) is identified (Pollard et al. 2016; Xu et al. 2016; Zhang et al. 2019). This assumption about the development of the MC concept is related to the direction and content of the scientific research in the MC domain as well. Otherwise, the following analysis on the most cited scientific journals and publications of the MC research domain in the period of 1990–2020 also indicates a strong legacy and vitality of the traditional MC concept version over the whole investigation period.

2.2. Literature on Methods Applied in Systemic MC Research

The analysis of prevailing studies suggests that there is a need to apply a methodological triangulation as a relevant and valid methodology for a more comprehensive state-of-the-art analysis of the MC field. Da Silveira et al. (2001) conducted a literature review and disclosed research directions of MC in the selected 10-year period. Moreover, the study focused on the development of a comprehensive and structured framework of the MC domain as well as success factors and enablers of MC systems in practice. Fürstner et al. (2009) presented insights and an analysis of a relevant MC status in practice and science, where a literature review was used only to support the author's findings and proposals of the knowledge support system methodology. Later, this scientific discourse was acquired by Ferguson et al. (2010). Here, the state-of-the-art analysis logic was applied to determine and highlight specific future research areas in MC, which refer to the paradigm across the marketing, engineering and distribution domains in the context of practical MC application metrics and barriers. Fogliatto et al. (2012) continued studies in the MC domain and, after a decade, presented an updated review of the literature, where the MC was investigated from both scientific and industrial perspectives. However, the scholar adopted a view of operational and concept application methods. Furthermore, Anišić et al. (2009, 2013) investigated the status and trends of MC and MP strategies at research institutions at the scientific activity as well as practical implementation levels. However, these studies were focused on Central and Southeast Europe. Sandrin et al. (2014) conducted a wide scientific literature review by considering the EBSCOhost, Web of Science, JSTOR and Wiley databases. The research focused on MC organizational antecedents. The latest research was carried out by Chatzopoulos (2017), where an application of web analytics was examined to focus on the usage of five specific terms in practice in the MC and interdisciplinary domains in the period of 2012–2016. Brandão et al. (2017) mapped the most relevant scientific works within last two decades in the field of MC and Personal Fabrication, but only in relation to production and design control.

This particular study aims to provide a comprehensive and an extended state-of-the-art analysis, shaped around the MC scientific domain and indicating not only historical changes of the concept or a relation to other scientific domains, but also presenting key points of scientific research in this field in the period of 1990–2020 including leading countries and researchers, publications, dynamics of research interests and analysis objects. This study evaluates the largest scope of scientific papers in terms of quantity as well as a wide period of time, 1990–2020, as compared to the previous state-of-the-art analyses in the MC domain. Additionally, this study covers results not limited to any specific region or scientific domain, while other preceding studies considered certain areas as the focus for investigation.

3. Materials and Methods

The data for this particular research paper was retrieved on May, 2020, from Clarivate Analytics Web of Science (WoS) Core Collection. Thus, the scientific integrity of the data source is assured (Bužavaitė et al. 2019; Meng et al. 2020). The database was selected due to its popularity and efficient selection possibilities. The search defined the timeline from 1990 to 2020, and keywords selected for the analysis were "mass customization" and "mass customisation". The search was conducted using the WoS field tag "Topic", keywords were observed in the title, abstract, author keywords, and Keywords Plus. Notably, the search resulted in 1783 scientific papers. The data was extracted to Tab-delimited format (Unicode Transformation Format– 8-bit for Windows applications (Win, UTF-8)) for convenient management in VOSviewer. With the data results set up, the analysis was conducted by applying a graphical visualization with the VOSviewer version 1.6.15 (www.vosviewer.com) software.

This study adopted the approach of analyzing a large number of papers, which is common in other scientific studies, investigating various issues (Kokol et al. 2018; Meng et al. 2020). Moreover, the above presented analysis has disclosed the evolving interest in customization and the contribution of scholars from various fields. The investigation of interdisciplinary fields is more common by adopting data mining methods (Stepanić et al. 2017; Dinçer et al. 2020; Qi et al. 2020). For instance, these methods were adopted by the scholars investigating social media websites or industry 4.0 issues when big

data sets were analysed (Pejic-Bach et al. 2020). The selection of mixed research methods, such as an interdisciplinary and literature review, and text mining with a bibliometric analysis using data and characterization logic, are also applicable in different studies of management science (Kostoff 2012, 2013; Youngblood and Lahti 2018). In general, the interdisciplinary mapping method is useful for identifying layers of the analysed concept as well as for a visualization of relationships between different approaches to MC among authors, a support of historical assumptions about the development of fields, and positioning the research in relation to previous works of MC (Aboelela et al. 2007; Brandão et al. 2017; Youngblood and Lahti 2018).

The popularity of bibliometric analysis as an alternative approach has been recently increasing among scholars investigating interdisciplinary fields. This type of bibliometric analysis discloses the latest trends and provides a systematic overview of the overall developments in a specific field of research (Wang et al. 2014). Moreover, it allows the analysis of a large scope of scientific literature, so scholars obtain a facilitation to identify relevant research trends and patterns at different levels, for instance, at the author, scientific journal or country level (Nunen et al. 2018). The usage of a wide range of bibliometric indicators and analysis types allows a significant reduction in the researcher bias, effort and time required for a traditional systematic literature review and mapping (Blanco-Mesa et al. 2016; Radhakrishnan et al. 2017). Moreover, it is agreed that bibliometric networks provide meaningful cumulative knowledge by holistically mapping the main trends in a selected scientific field as well as supporting the results of traditional user-driven data categorization methods and processes (Blanco-Mesa et al. 2016; Radhakrishnan et al. 2017).

In this paper, four types of bibliometric clustering techniques were applied: bibliographic coupling (of publications), co-citation analysis (of journals and authors), co-occurrence (of keywords) and co-authorship (of countries). Finally, a synthesis of results and final results presentation were conducted using the VOSviewer software. Moreover, the data was reorganized using MS Office Excel 2016 software. The outcome of the analysis is a construction of visual bibliometric data networks in the format of two-dimensional maps.

4. Research Results and Analysis

4.1. Dynamics of Scientific Publications

The historical development of the MC research domain during the period of 1990–2020 can be measured and evaluated by the number of scientific papers as well. An article was selected as a document type, and English was selected as a research language. It is important to note that the publication dynamics in 1990–1996 appear to have been very limited since, for example, only seven articles were published within 1992–1995 (Figure 2).

The analysis reveals the following tendencies:

(a) A steadily increasing number of scientific articles from 1992 until 2007;
(b) A fluctuating number of articles from 2007 until 2017.

In spite of the historical dynamics in the field of MC research, it is relevant to analyze the most cited and influential publications. The 15 most cited publications in the MC domain are listed in Table 1.

In the last two decades, the selection of topics in the research field illustrates that the scientific literature on the MC domain is rather prolific and addresses the research subject from numerous points of view, including general product engineering and manufacturing processes, business operations and strategic management, as well as the specifics of customization processes and the usage of tools. Moreover, it also reflects significant changes of organization practices in this period, which influence a transition of the concept towards becoming a stand-alone multidisciplinary business operations management concept. Furthermore, a strong focus on applying combined management and Information and Communication Technologies (ICT), customer centric approaches, Big Data and Big Data Analytics

(BDA) development, and value co-creation in digital platforms, should be outlined as currently trending in this research domain (Hora et al. 2016; Risdiyono et al. 2016; Tiihonen and Felfernig 2017; Zhang et al. 2019).

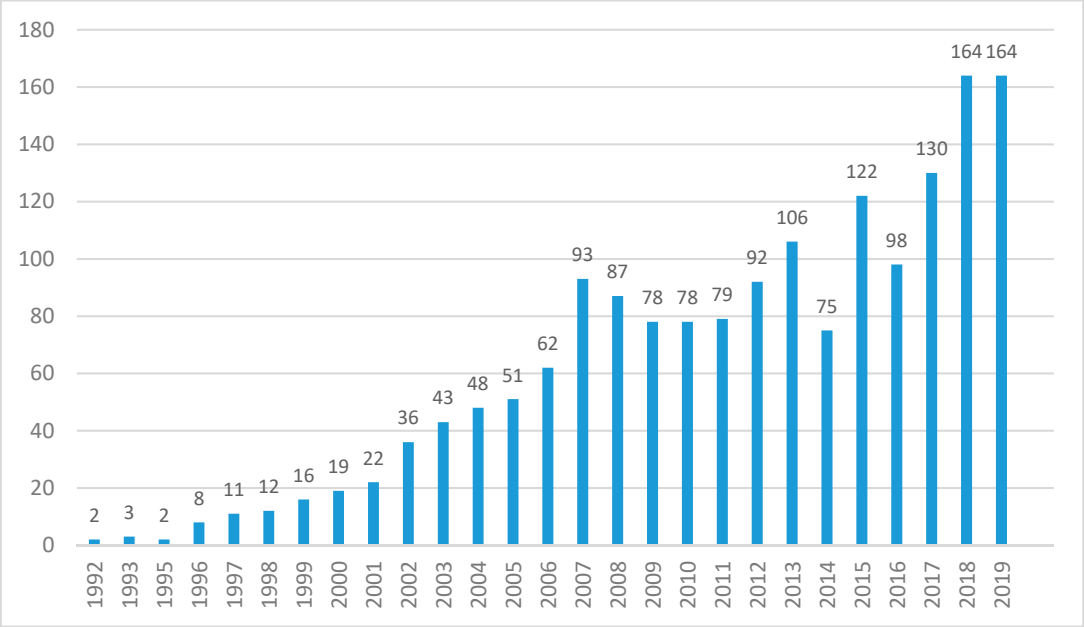

Figure 2. Dynamics of scientific investigations in domain of Mass Customization (1992–2019). Source: Composed by the authors using Web of Science Clarivate Analytics (WoS).

Table 1. The 15 most cited publications in the MC domain in 1990–2020.

Author and Publication Year (Sorted by Date)	Title of Publication	Total and Average Citations per Year
Franke et al. (2010)	The "I Designed It Myself" Effect in Mass Customization	281/25.55
Hu et al. (2011)	Assembly system design and operations for product variety	253/25.30
Berman (2012)	3-D printing: The new industrial revolution	804/89.33
Fogliatto et al. (2012)	The mass customization decade: An updated review of the literature	269/29.89
Zhong et al. (2013)	RFID-enabled real-time manufacturing execution system for mass-customization production	242/30.25
Huang et al. (2013)	Impact of Rapid Organism Identification via Matrix-Assisted Laser Desorption/Ionization Time-of-Flight Combined With Antimicrobial Stewardship Team Intervention in Adult Patients With Bacteremia and Candidemia	294/36.75
Schubert et al. (2014)	Innovations in 3D printing: a 3D overview from optics to organs	233/33.29
Weller et al. (2015)	Economic implications of 3D printing: Market structure models in light of additive manufacturing revisited	208/33.29

Table 1. *Cont.*

Author and Publication Year (Sorted by Date)	Title of Publication	Total and Average Citations per Year
Marcel Bogers and Bilberg (2015)	Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing	98/19.60
Wu et al. (2016)	A critical review of the use of 3-D printing in the construction industry	142/28.40
Tao et al. (2017)	Advanced manufacturing systems: socialization characteristics and trends	137/34.25
Attaran (2017)	The rise of 3-D printing: The advantages of additive manufacturing over traditional manufacturing	148/37
Zhong et al. (2017)	Intelligent Manufacturing in the Context of Industry 4.0: A Review	322/80.5
Yin et al. (2017)	The evolution of production systems from Industry 2.0 through Industry 4.0	75/25
Ngo et al. (2018)	Additive manufacturing (3D printing): A review of materials, methods, applications and challenges	626/208.67

Source: Composed by the authors using a search engine and metadata of WoS.

4.2. Bibliographic Coupling of Publications

Bibliographic coupling is a method for the visualization of bibliometric networks, which represents data with an overlap in reference lists of publications. To explain, the number of overlaps indicates the ratio of relation strength among publications, where a higher ratio means more bonds in reference lists. This allows the visualization of actual referencing connections among separate studies; therefore, the VOSviewer software has been selected as the main work tool, as it offers a detailed visualization of the bibliographic publication coupling option with specific characters to illustrate relatedness level. In detail, a circle character indicates a specific publication while its size represents the number (frequency) of overlapped citations. Lines and the distance between circles are important characters too, as they show how related and similar pairs of publications are at this point. Colour marking stands for clusters of publications (Van Eck and Waltman 2014).

Seven predominating clusters were identified by defining a threshold of 50 citations, as per Figure 3. The red color cluster is predominated by Salvador et al. 2009 (citations n = 269) and Simpson T.W. (citations n = 349). The green color cluster is predominated by von Hippel E. (citations n = 458). The blue color cluster is predominated by Fixon S. K. (citations n = 253). The dark khaki color cluster is led by Kotha, S. (citations n = 288). The purple color cluster is led by Berman B. (citations n = 748). The light blue color cluster in the upper left corner is led by the most cited author Akkermans H.A. (citations n = 246). The light brown cluster is led by Elmaraghy H. (citations n = 206). Moreover, highly influential and closely related, but keeping clear boundaries, the four clusters (red, green, blue and khaki color) confirm that the MC domain had clear thematic boundaries in the first two decades. It is undoubtedly important to outline that a less influential and cross mixed part of the figure stands for the domain transition to an interdisciplinary approach and, later, to practical outcomes, which came into clear recognition in the past decade.

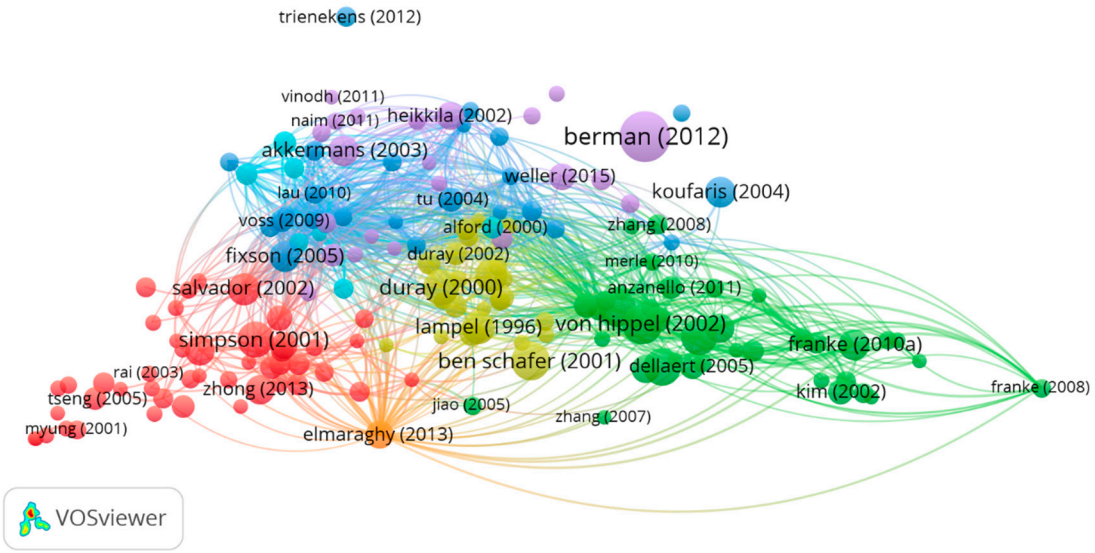

Figure 3. Bibliographic coupling of Mass Customization publications in 1990–2020. Source: Composed by the authors using VosViewer software.

4.3. Bibliographic Coupling of Publications

An important feature of nodes in bibliometric networks is an evaluation of a citation relation by applying an analysis of the most cited and influential scientific journals as well as a co-citation analysis of scientific journals and authors. The analysis reveals a level of a relatedness of selected scientific journals based on the number of citations in journals by which two selected journals are co-cited. The same logic is applied to a co-citation analysis of researchers, meaning that the relatedness of research relies on counting their co-citation by a third researcher. The VOSviewer software tool was used with specific characters and logic to illustrate a relatedness level, as defined in Section 4.2. Accordingly, the top ten most cited journals of the MC research domain are presented in Table 2.

Table 2. Top 10 most cited scientific journals of the Mass Customization research domain in 1990–2020.

Journal Title	TP	% of Total Number	IF2019	CPP2019
International Journal of Production Research	135	7.57	4.577	19.5
International Journal of Production Economics	65	3.65	5.134	30
International Journal of Advanced Manufacturing Technology	64	3.59	2.633	15
Journal of Intelligent Manufacturing	58	3.25	4.311	18.7
Production Planning Control	45	2.52	3.605	20
International Journal of Computer Integrated Manufacturing	40	2.24	2.861	14
Computers in Industry	38	2.13	3.954	23
International Journal of Operations Production Management	35	1.95	4.619	41.8
Computers Industrial Engineering	26	1.455	4.135	13
IEEE Transactions on Engineering Management	26	1.455	2.784	31.9

Source: Composed by the authors using a search engine and metadata of WoS. TP: total number of articles; IF2019: journal impact factor in 2019; CPP2019: citations per paper (TC2019/TP), where TC2019 is the total citations received since publication until the end of 2019 (Hu 2012).

The results show that the International Journal of Production Research (IF2019 = 4.577) published the majority of articles (135 articles, 7.57% of 1783), followed by the International Journal of Production

Economics (IF2019 = 5.134) with 65 articles and the International Journal of Advanced Manufacturing Technology (IF2019 = 2.6.33) with 64 articles. It should also be noted that six out of seven of the most cited scientific journals belong to the engineering, manufacturing and computer science fields. This situation confirms that customization research topics in the overall MC research domain are strongly related to a still vital legacy and an interest in tangible products. The co-citation analysis of journals demonstrates five clusters in total, where not only product manufacturing and operations management hold predominant positions, but also journals oriented to end-user studies are distinguished, as per Figure 4. It should be specified that the results were presented by following a benchmark of at least 50 citations, using specific characters and logic to illustrate a relatedness level, elaborated in the paper above.

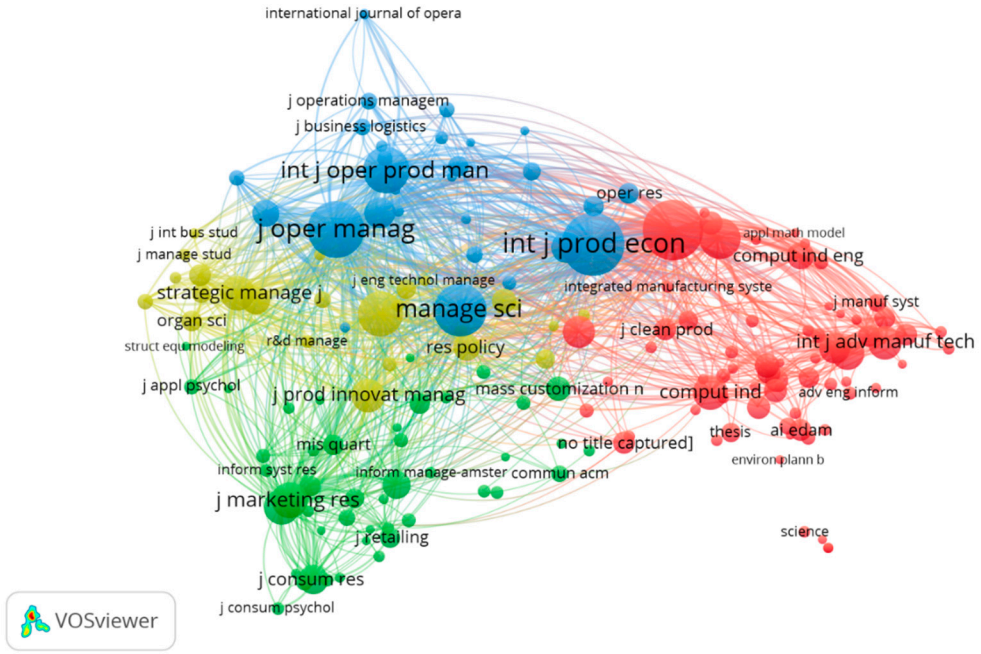

Figure 4. Co-citation of scientific journals in 1990–2020. Source: Composed by the authors using the VosViewer software.

The analysis of the co-citation of scientific journals led to four clusters. The biggest cluster in red color is predominated by the International Journal of Production Economics (total link strength n = 88,825). The green cluster is led by the Journal of Marketing Research (total link strength n = 34,766). The blue color cluster is led by the International Journal of Production Economics (total link strength n = 93,691), the Journal of Operational Management (total link strength n = 106,710). The khaki color cluster is predominated by the Harvard Business Review (total link strength n = 46,129). The nodes and edges of the red cluster confirm the above defined transition period of the MC research domain in the past decade as well as an increased concept focus on modelling end-user behavior and their experience management, and an overall combined methods application in customization processes. Supplementary results came from the author co-citation analysis, as per Figure 5. It should be specified that results were presented by following a benchmark of at least 20 citations, using specific characters and logic to illustrate a relatedness level, elaborated in the paper above.

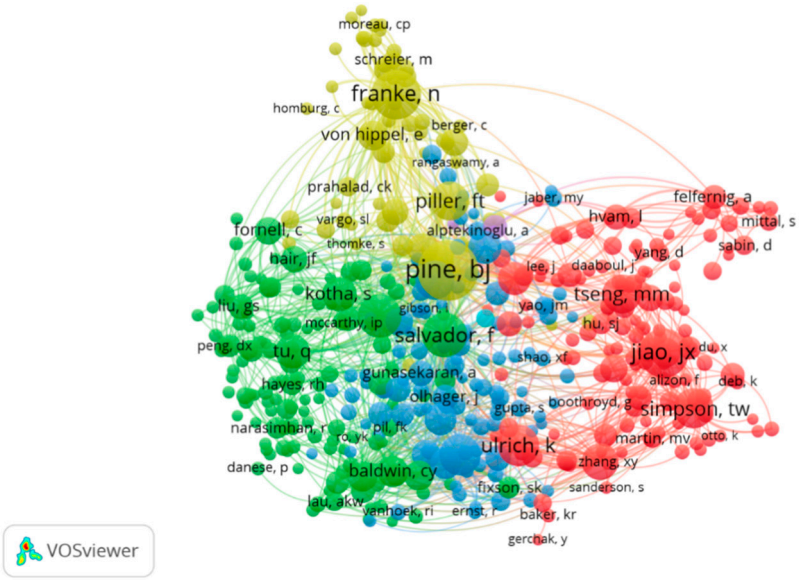

Figure 5. Co-Citation of Mass Customization researchers in 1990–2020. Source: Composed by the authors using VosViewer software.

A bibliometric map of an existing influence level and connections among studies of the MC research domain in past three decades was observed, as per Figure 5. In total, five closely related central themes and clusters are highlighted. On the right side, the red color cluster represents Ulrich, K. (with 402 links and 252 citations), Jiao, J.X. (with 390 links and 356 citations), Tseng, M.M. (with 384 links and 258 citations) and Simpson, T.W. (with 334 links and 244 citations) as the most influential authors. In the middle part, the blue color cluster represents Lee H.L (with 392 links and 249 citations) as the most influential author. In the left part, the green color cluster represents Salvador et al. 2009 (with 428 links and 304 citations), Kotha, S. (with 384 links and 178 citations), Baldwin, C.Y. (with 386 links and 147 citations), Tu, Q. (with 388 links and 174 citations) and Fornell, C. (with 326 links and 112 citations) as the leading authors. In the top-center part, the khaki color cluster represents Pine, BJ. (with 437 links and 543 citations), Piller, F.T. (with 411 links and 222 citations), Franke, N. (with 354 links and 366 citations) and Von Hippel, E. (with 319 links and 132 citations) as the leading authors. In the top-middle part, the purple color cluster represents Trentin, A. (with 319 links and 87 citations) as the leading authors. Clear and intensive links are visible between the green and blue color clusters, which indicates that representatives of these clusters have quite common investigations, research methodologies and methods.

4.4. The Co-Authorship Analysis of Countries

Bibliometric networks based on the co-authorship at the level of countries are studied extensively in different scientific fields, however, with relatively little attention to the visualization part (Van Eck and Waltman 2014). This type of visual bibliometric network is used to identify leading countries in a specific research area and assess their collaboration trends that are based on a number of publications, which researchers from certain countries have authored jointly (Van Eck and Waltman 2014). It should be specified that results were presented by following a benchmark of at least 11 citations, and using specific characters and logic to illustrate a relatedness level, elaborated in the paper above.

There are five predominate clusters identified, as per Figure 6. In the middle-bottom part, the cluster in red has the People's Republic of China (with 39 links; total link strength n = 243,530) as the leading country. In the middle-top part, the green color cluster has the USA (with 39 links; total link strength n = 243,530) as the leading country. In the right part, the blue color cluster has England (with 39 links; total link strength n = 121,523) as the leading country. In the left part, the khaki color has Germany (with 39 links; total link strength n = 56,074) and Canada (with 39 links; total link

strength n = 68,669) as the leading countries. In the middle and right parts, the purple color cluster identifies a relation between two countries, Brazil (with 39 links; total link strength n = 31,690) and Japan (with 39 links; total link strength n = 12,661). Moreover, similar tendencies are identified by analyzing numbers of the most productive countries regarding the MC research domain in 1990–2020, as per Table 3.

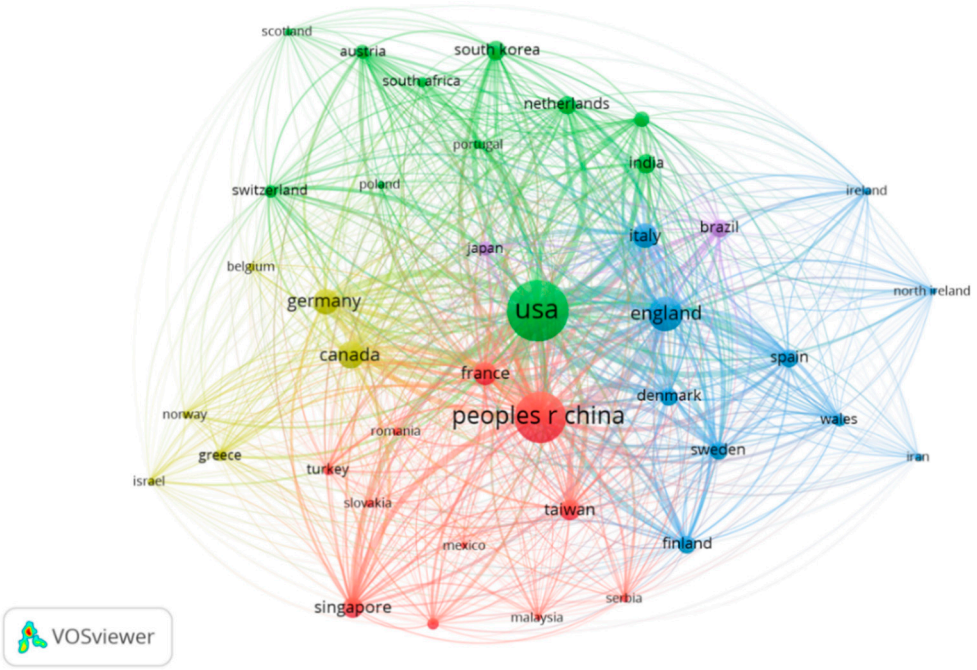

Figure 6. Co-Authorship of Mass Customization researchers at the country level (1990–2020). Source: Composed by the authors using VosViewer software.

Table 3. The top 10 productive countries regarding the Mass Customization research domain in 1990–2020.

Countries/Territories	TP	% of Total Number	CPP2019
USA	540	29.687	39
People's Republic of China	371	20.396	18
England	171	9.401	24
Canada	99	5.443	30
Germany	93	5.113	24
Italy	91	5.003	25
France	81	4.453	22
Singapore	63	3.463	33
Taiwan	62	3.408	18
South Korea	58	3.189	13

Source: Composed by the authors using a search engine and metadata of WoS. TP: total number of articles; IF2019: journal impact factor in 2019; CPP2019: citations per paper (TC2019/TP), where TC2019 is the total citations received since publication until the end of 2019 (Hu 2012).

There are three top countries, which together generate near to 60% of total publications in this research domain: the USA, the People's Republic of China and England, as per Table 3. In addition, the researchers from these countries mostly focused on a practical application of customization across a broad range of tangible products like automotive, food and clothing, and industries. From a geographic perspective, two main groups of the most productive countries can be identified: four countries from Europe and four countries from Asia. External factors of global market dynamics, new automation tendencies of services and product lines, and the infusion of digitalization in recent decades, are worth mentioning as substantial development factors, which extend the map of researchers to non-industrial

countries. In detail, MC primary is accepted as a modern business model, a process and risk management version for customer and data driven small and medium service-based organizations by covering their highly heterogeneous demand patterns from customers, and an approach to the value co-creation process (Elgammal et al. 2017; Zhang et al. 2019). The listed factors do not only illustrate new development of the concept, but also influence its organizational frameworks, its practical operating logic, the application format of mass service or product systems and processes, as well as stimulating new forms of innovation in the Customization field (Ferguson et al. 2010). Therefore, the pre-dominance of five clusters in researchers' countries should not lead to the misleading interpretation that Customization does not work and is not compatible with any modern technology application, customer experience management or intangible goods (Piller et al. 2005; Trentin et al. 2013).

4.5. The Co-Occurrence of Keywords

The analysis of keyword co-occurrence is based on a data mining procedure by extracting keywords from a title, an abstract of a publication, or from an author-supplied keyword list. A visualization of the results of an analysis depends on the number of times that a keyword or a pair of keywords co-occurs in multiple sources and a weight of the link connecting a keyword or a pair of keywords. In general, keyword co-occurrence networks (KCNs) are relevant for a researcher as an existing knowledge mapping tool as well as for understanding a holistic view and development of a specific research domain in a selected period (Van Eck and Waltman 2014; Radhakrishnan et al. 2017). It should be specified that results were presented by following a benchmark of at least five keyword occurrences, using specific characters and logic to illustrate a relatedness level, elaborated in the paper above.

It should be noted that general noun phrases such as literature review, survey, etc., were extracted from the keyword analysis. In total, there were 11 clusters identified. The biggest clusters reveal the following results:

- For the biggest cluster in red, the most influential keyword is customization (total link strength 113);
- For the yellow cluster, located in the left part, the most influential keyword is modularity (total link strength 101);
- For the purple cluster, located in the right part, the most influential keywords are additive manufacturing (total link strength 67).

A variety and quantity of keywords in the bibliometric network above confirm the existence of a multidimensional approach to the MC domain and its relevance in different scientific fields. Considering development in MC scientific research, it should be noted that MC was widely discussed as a part of process management, marketing, engineering and other related scientific domains until the end of the 2000s. Only in the decade of the 2010s, after receiving a practical approval as an efficient e-business approach and strategy of supply chain and process management, did it become a separate research area (Piller et al. 2005). There is a need to mention the studies of Da Silveira et al. (2001) as they proposed a dual definition model of a visionary and practical MC as well as its later development by Kaplan and Haenlein (2006) (Brandão et al. 2017). Together with the definition, Da Silveira et al. (2001) noticed that this concept would never be appropriate enough for a practical adaptation for all types of products and all kinds of consumers. These closely interconnected theoretical and practical interpretations, as with application and adaptation abilities in different practical areas, might be the key reasons why the concept still does not have any coherent and universal framework for assessment or implementation as well as any commonly agreed position regarding the semantical meaning on a scientific level, as illustrated in Figure 7. On the other hand, this situation explains the long-lasting vitality and relevance of the MC topic, as researchers influenced by dynamic changes in the society and business environment constantly seek for new formats to explain a variety of MC outcomes or obstacles. The concept is addressed from different points of view in practice and is frequently understood under definitions of typologies, models, evaluations and deployment frameworks as a management concept, a paradigm, a stand-alone business model, an operations or manufacturing

strategy, or a product development approach (Medini et al. 2015; Elgammal et al. 2017; Ezzat et al. 2019; Zhang et al. 2019). Although in rare cases MC is defined on behalf of the term Mass and its content, according to McCarthy (2004), the term Mass signifies an important feature, which clearly indicates that the concept excludes low volumes of bespoke products or services, and this is proven by two of the three predominant keyword clusters in Figure 7. This position is also supported by Joergensen et al. (2014) by stating that MC is a general, strategic level change model, while MP is the most relevant towards individual customers or small groups of customers as it generates requirements for a service or product. This is a questionable position, taking into evaluation recent trends in MC, where a tendency of E-MC, Smart Customization or Agile MC application is identified and, respectively, partly indicated in Figure 7 (Xu et al. 2016; Zhang et al. 2019).

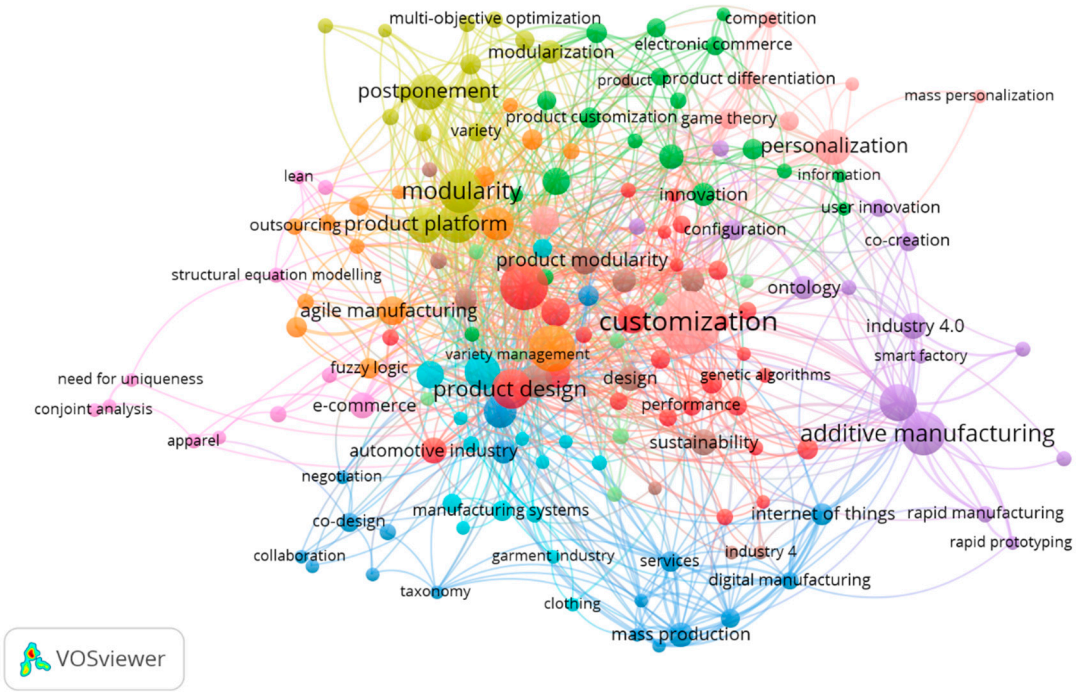

Figure 7. Co-occurrence of author's keywords in the Mass Customization domain (1990–2020). Source: Composed by the authors using VosViewer software.

4.6. Summary of the Main Research Streams in the Mass Customization Domain in 1990–2020

Before the beginning of 2000, the meaning and role of the MC concept were mostly influenced by internal risk factors coming from product manufacturing processes and their features of standardization, modularity and made-to-order, as well as from issues of supply chain and communication network management, and difficulties in terms of long-term strategic management and planning. A wide range and complexity of risks were not only the key reasons for a low practical adoption level of customization, especially in service-oriented organizations, but also triggered a parallel development of scientific methodologies and methods of agile manufacturing, lean production, six sigma and more, which conflicted or diverted the attention away from the MC concept.

In general, findings on MC revealed that studies in 1990–2020 have mainly focused on three subdomain areas:

1. The focus on major external factors (technological, economic, market specific) and their trends, which naturally influence a shift from Mass Production to MC. The analyses mainly include the topics of internal Customization features and risk factors as a critical source of success for a new business strategy or model transformation, the integration and assessment of an organizational structure, and the capabilities of processes to change. Despite the focus on current features

and principles the shift presents, it also draws back to the origins of MC with a historical and semantical evaluation (Morelli and Nielsen 2010; Piller et al. 2014; Brandão et al. 2017).

2. The focus on the implementation process and elements in MC. The scientific works from this particular category are oriented to multidimensional and combined subdomains, including separate enablers–elements of the MC system, for instance, supply or value chain management, employee training, marketing and MP processes, overall operational performance, resource management, etc. It also analyzes possible links among these enablers–elements, and maps coherent frameworks in detail in order to outline leading factors towards a successful implementation of MC in the context of organizational activities and the online environment. Retrospectively, it is claimed that the most intensive research period of first and second subdomains were two decades from the middle of the 2000s to the 2010s (Morelli and Nielsen 2010; Stojanova et al. 2013; Piller et al. 2014; Brandão et al. 2017).
3. The focus on the dynamic demand side and influence of interrelated scientific domains, crossing information and computer technology management, marketing, environmental, and social dimensions. In detail, from the middle of the 2010s, the MC concept has been recognized in new combinations of globalization, digitalization, networking, and short product life cycles, and has usually been named E-MC. Accordingly, this synergy became one of the main drivers towards value and competitiveness in both organizational practice and overall economy levels, although relatively little attention has been paid to this subdomain on a scientific level. Publications of recent years, more specifically in last 7 years, appear to interpret the object of MC as a multidimensional management paradigm based on a combination with the MP concept, user and data driven technologies' application, Big Data sources, e-commerce and e-business, environmental impact via sustainability feature, etc. (Medini et al. 2015; Brandão et al. 2017; Tiihonen and Felfernig 2017; Zhang et al. 2019).

In the last decade, a recognition of an extended concept meaning and scientific studies can be explained as a transition from a standard understanding of a stand-alone business/manufacturing/operations strategy or a concept oriented narrowly to a technological-instrumental approach, to a widespread e-business philosophy and a value driver of economics with a concentrated focus on synergy, digitization and sustainability features. Paradoxically, during this time, the well recognized terms MC, Individualization, Modularization or MP were transformed into buzzwords such as Mass Customerization, Smart Customization, Agile MC, Sustainable MC, but they still stand for the creation of new possibilities to set up highly contextualized, cost efficient, globally available customized goods or service solutions for local markets or microsegments of customers (Pourabdollahian et al. 2014; Xu et al. 2016; Chatzopoulos 2017; Tiihonen and Felfernig 2017; Grosso and Forza 2019).

5. Discussion

Over the last 30 years, the number of scientific articles covering the interdisciplinary MC research domain has increased enormously both in quantity and in the range of topics. In general, MC as a research domain has a rich historical background, which is amply evident from six long-term transformation periods. The origins of the idea and the scientific term MC extend back to 1987 and mark the beginning of the three main historical development periods. Accordingly, the systemic and bibliometric analysis on the MC research domain in 1990–2020 supports the above defined findings by showing that there are three MC sub-domains identified throughout the scientific research. It should be noted that three key semantic features remained throughout all transformations: an orientation to individual demands and an end-user involvement in the customization process, a harmonization of diversity, costs, and quality features and risks, and an aim of competitive advantage by applying combined customization and risk management methods. From the practical perspective, this is confirmed by the latest modern e-MCP version, which is adapted to a clear demand of a combined version of online customized products and personalized service types, rapid response times to requests sent, and a constant communication and support model need.

The historical business environment evolution and significant changes of end-users draw researchers from five different scientific domains, including traditional, manufacturing and engineering-based semantical and practical interpretations, as well as a modern version with a lead from combined business operations management, marketing and information technology domains. This situation confirms the continuity of the fragmentation of the concept and challenges the idea of there being one coherent framework. It should be added that the original approach and interpretation of the MC concept still has a high scientific research interest, which is confirmed by pre-dominant clusters of co-citation of scientific journals as well as the most cited scientific journals and most cited publications of MC in 1990–2020. Moreover, the topics of the most cited publications show tendencies of the research discourse towards a practical transition and issues of intelligent and additive manufacturing–production systems or an application of innovative technical solutions such as, for instance, 3D printing.

The results of the four types of bibliometric clustering analysis in 1783 scientific articles from 1990–2020 add new findings and provide a holistic view of the MC research domain:

- Scientific publications and interest in the Customization topic has two periods: a stable growth until 2007 and dynamic development after 2007, where a high intensity of publications was reached in 2017–2019. Even though the quantity of publications significantly increased from 2007, 14 out of the 15 most influential publications were published during the first period, and the most co-cited author remained Pin et al. (1993) with 437 links and 543 citations.
- The most cited publication is Fisher, M.L. (1997) *What Is the Right Supply Chain for Your Product?* with a total of 1312 citations per analysis period. The author presents the influence of a new technology application at the operational and product levels. The second one by citing rate is Berman (2012) article 3-*D printing: The new industrial revolution* with a total of 804 citations per analysis period, where an application of new technological innovation is evaluated in the MC context. It is worth mentioning that the most cited journal is the International Journal of Production Research with a total of 135 citations and a 7.57% citation rate while the most co-cited journal was the Journal of Operational Management.
- The co-authorship analysis illustrates that the leading countries in the scientific research of the MC domain are the USA (with 39 links; total link strength n = 243,530) and the People's Republic of China (with 39 links; total link strength n = 243,530). Researchers from England (with 39 links; total link strength n = 121,523), Germany (with 39 links; total link strength n = 56,074), and Canada (with 39 links; total link strength n = 68,669) have a significant influence in this field.
- The co-occurrence of keywords analysis shows that the most influential keyword pair is the concept title MC. It also confirmed a dynamic and a multidisciplinary background in the MC domain. In general, the most influential keywords can be divided into two main groups as being oriented to a standard technological-instrumental approach to MC or to a modern and extended concept meaning with a high focus on end-user and digital solutions.

6. Conclusions

The complex and dynamic business environment and its risks, technological innovations and digitalization have stimulated significant changes in past three decades not only in the practical attitude and organizational frameworks of MC, but have also influenced the continuous development of the concept at a theoretical level. A historical and systemic analysis reveals three main periods in each decade and, respectively, three research sub-domains, which marks a transition of the concept towards a stand-alone, multidimensional and interdisciplinary business operations concept. The analysis confirms that the modern MC has increased focus to non-tangible products, end-user behavior, sustainability and an application of combined Digitalisation and Personalisation methods in customization processes. The results of bibliometric analysis indicate a long-lasting vitality and relevance of traditional MC research topics, and note last 5 years as the most intensive research period.

The main scientific contributions rely on an extension of preceding MC state-of-the-art research in the sense of a selected methodological triangulation approach, the largest research scope both in time scale and quantity, as well as following the theoretical outcomes of the research. The research confirmed assumptions regarding the historical development of the concept and its content, where the three main historical development periods and the research interests within them can be identified as follows: the period of 1987–2000 stands for an evolution and a rise of the traditional MC concept, where the dominant research focus is on the manufacturing and engineering domains, a shift from Mass Production to MC and the influence of external technological, economic, market specific factors. The period from approximately the 2000s to the 2010s marks an increased focus on the MC implementation process and elements in it, while studies in the decade of the 2010s have illustrated a semantical and content transition from a traditional technological-instrumental approach to a modern e-business philosophy and operations approach. Research has focused on the dynamic demand side and the influence of interrelated engineering, information and computer technology management, marketing and social science scientific domains. It was confirmed by the variety and quantity of keywords in the bibliometric network analysis.

Considering the practical implications of the research, it should be outlined that the results of scientific publication dynamics, the most cited publications, as well as bibliometric networks in the co-authorship and co-occurrence of keywords, confirm both the diverse nature of the concept and a necessity of continuous studies in the field of practical MC application. Modern e-MCP concept versions support current global economic and business trends, which demand that organizations use agile, smart innovations and a customer-oriented business model with a broadly segmented market, omni-channel retail and sustainable development strategy focused on daily operational activities. An alignment and a continuous adoption of new digital solutions or sources for making proper decisions on the customization and management of personalized customer experience are undoubtedly required as well.

The conducted research has limitations that should be taken into consideration. The analyzed data was extracted only from the WoS database. This database features constantly update, therefore, a constant self-follow up of the latest data in WoS, as well as a comparative analysis with data from another well recognized database, for instance, Scopus, are required. The study analyzes the whole period of the MC research with limited attention to the dynamics within and among separate periods of the MC research domain. The bibliometric analysis has limitations in the visualization of the massive and heterogeneous scope of the topic by eliminating parts of important data, which are under a threshold indicator (minimal number) and not well applicable in a niche field with quite sparse networks (Van Eck and Waltman 2014). There are also certain software limitations that do not offer any option to connect and get metadata via Crossref Application Programming Interface (API) or support interactive querying for other scientific sources that are important to mention. Therefore, future investigations should consider other techniques and approaches, for instance, a bibliometric analysis combined with a content analysis.

Further studies on the MC research domain should focus on a more detailed investigation over the content and major differences among last three transformation periods, presented in Figure 1. Besides, a recommendation would be to examine recent practical trends and new research sub-domains of Digitalization and MP, their combinations, interpretations and incorporations into the concept, to a deeper extent in terms of online customization frameworks and end-user behavior modelling methods in customization processes or platforms. An argument over the preceding recommendation is that recent practical trends illustrate an extended approach to the MC research domain as an interdisciplinary business operations concept, which is widely applied in digital platforms and service-oriented organizations.

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