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A Bibliometric Analysis Approach to Review Mass Customization Scientific Production

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Abstract. Mass customization is an important manufacturing concept aimed at integrating product varieties to provide customized services and products based on individual needs. This concept has emerged in the 1980s as demand for product variety increased, and the research in this area has been present for the last three decades. This article aims to study the scientific production around mass customization through metadata analysis of all articles indexed in the bibliographic database Web of Science. The science mapping and bibliometric analysis was conducted using the "bibliometrix" R Package. Also, a graphical analysis of the bibliographic data was performed using VOSviewer software. This study identified the most relevant sources, authors, and countries active and influential through a five-stage workflow consisting of study design, data collection, data analysis, data visualization, and data interpretation. Keyword analysis revealed the related emerging research topics. Co-citation and co-occurrence analysis was performed to underline research streams.

Keywords: bibliometric analysis, bibliometrix, mass customization.

1 Introduction

In the last few decades, the manufacturing sector has been undergoing constant changes and technological advancement, keeping manufacturing companies in a continuous state of disruption [1]. Individual needs and customer requirements have become a priority for companies to gain a competitive advantage [2]. Mass customization concept has emerged in the 1980s as demand for product variety increased [3], and it has been identified as a competitive strategy by an increasing number of companies [4]. This is an important manufacturing concept aimed at integrating product varieties to provide customized services and products based on individual needs. Research in this area has been present for the last three decades.

Many authors have used bibliometric analysis to identify aspects of science that receive the most contributions from authors, journals, organizations, and countries, and the collaborative networks among them [5], [7]–[11]. Bibliometric studies have become an emergent discipline, given the importance posed on the assessment of scientific production. The bibliometric studies help researchers understand and analyze the research structure, the extent of the topic, emergent trends, and its evolution over time [5], [6]. The objective of this bibliometric analyzes is to analyze the

scientific production around mass customization through bibliographic data analysis of all articles indexed in the Web of Science containing "mass customization" in the title or authors keywords with the aim identify the most relevant sources, authors, countries active and influential in this field with the emergent trends and evolution over time. This study is targeted to a broad and diverse audience from various research fields like engineering, operations research, management science, business economics, etc. The science mapping and bibliometric analysis was conducted using "bibliometrix" R Package tool [12] while the graphical analysis of the bibliographic data was done using VOSviewer software [13].

The paper's remainder is structured as follows. Section 2 describes the research workflow. Section 3 presents research results and findings, followed by a conclusion with limitations and suggestions for further research in Section 4.

2 Research Workflow

This research is conducted following a standard workflow consisting of five stages [14]:

(1) Study design - In the first stage, the research objective was identified and based on that the study design was structured. The objective was to review mass customization scientific production and its intellectual and conceptual structure; (2) Data collection - In the second stage, bibliographic data were retrieved from the online bibliographic database Clarivate Analytics Web of Science. The search was restricted to Web of Science as it is the most important database of scientific articles whose metrics are widely used in academic assessment. After that, data converting and loading was performed to adjust it into a suitable format for the "bibliometrix" tool. All indexed articles that contain "mass customization" in the title or authors keywords were included. Only publications in English were included and all document types except articles were excluded. The following search string were used: *((TI=(mass customization OR mass-customization OR mass customisation OR mass-customisation)) OR (AK=(mass customization OR mass-customization OR mass customisation OR mass-customisation)))) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article)*; (3) Data analysis – In the third stage, descriptive analysis and network extraction were performed using the "bibliometrix" R package tool for quantitative research in bibliometrics and scientometrics [12]. Firstly, annual scientific production, the most productive countries and authors, and co-authorship among countries were analyzed. After that, the most relevant publishing sources and highly cited articles, and keyword occurrences were analyzed; (4) Data visualization – In the fourth stage, a visual analysis of the bibliographic data was done using VOSviewer software [13], specifically co-citation and keyword co-occurrences analysis; (5) Interpretation – In the fifth stage, the findings were described.

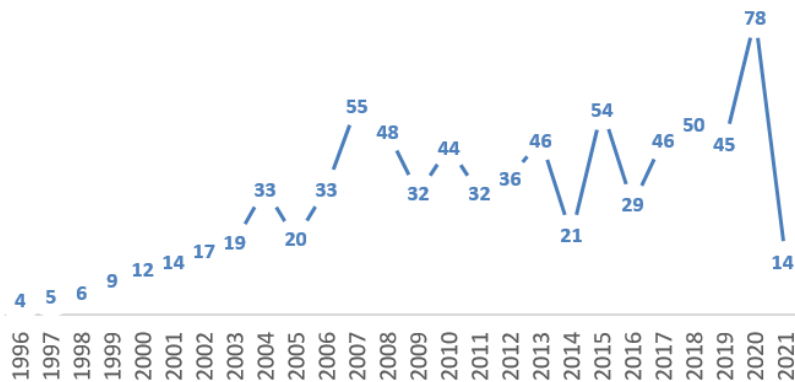
3 Research Results and Description of Findings

The final sample consisted of 802 articles published in 268 sources (journals and conference proceedings) during the timespan 1996:2021. These articles were (co)authored by 1630 people, out of which there were 97 single-authored documents and 705 multi-authored documents, with the average number of authors per document 2.03. Articles are concentrated around main research areas: engineering, operations research management sciences, computer sciences, and business economics. Web of Sciences assigns indexed articles to one or more research areas. The 802 articles in our sample were assigned to 53 research areas. The top five research areas are shown in Table 1.

Table 1. Top five research areas assigned to articles in the sample

Research Areas	# Articles	% of 801
Engineering	478	59.601 %
Operations Research Management Science	252	31.421 %
Computer Science	198	24.688 %
Business Economics	182	22.693 %
Automation Control Systems	42	5.237 %

Fig. 1 graphically represents the tendencies in publications on mass customization from 1996 to April 2021. When analyzing the annual scientific production, it could be seen that the number of articles published per year had a stable growth from 1996 to 2004. Multiple periods were identified until 2019 with different and decreasing growth rates. The decreasing growth rate could signalize that research in this field is consolidating. From 2019 to 2020, the number of articles published grew rapidly again. It must be noted that Fig. 1 doesn't present all data for 2021 but only until May of that year.

**Fig. 1** Number of articles published per year

3.1 Most Productive Countries and Authors

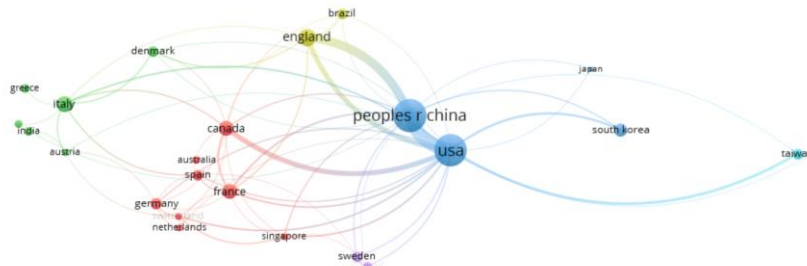
Table 2 shows the top ten most productive countries with the total citations (TC) per country and average citations per article (AC). It could be observed that China is the country whose authors have published most articles, and the USA is second. When analyzing the number of total citations per country, the situation is reversed, with an average citation of 18.09 per article for the USA and 13.94 for China. It is important to highlight that England has the highest average citations per article (23.67) among the leading countries, which can be used as a proxy for scientific importance or article quality. When analyzing the funding sources in articles, it was identified that the National Natural Science Foundation of China NSFC is the funding agency with the highest occurrence in articles (76 articles). It could be noted that China is highly influential and dedicated to research in this field. Table 3 shows the most productive authors in mass customization research. This classification is based on the number of publications and the author's h-index, which is calculated for this bibliographic collection. When comparing the number of articles produced with the production year start and the h-index for this bibliographic collection, it could be seen that Zhang M and Huang GQ are the two most influential authors. Forza C is the most productive author with 21 articles. According to co-authorship analysis among countries (Fig.2), the most intensive collaboration exists among the USA, China, and England.

Table 2. Top ten most productive countries

Country	# Arti- cles	TC	AC	Country	# Arti- cles	TC	AC
China	259	1715	13.94	South Korea	40	130	6.19
USA	191	1495	18.01	Canada	34	238	11.90
England	57	497	23.67	Brazil	33	92	5.41
France	43	408	19.43	Denmark	29	211	17.58
Italy	43	282	11.28	Germany	27	88	5.87

Table 3. Top ten most productive authors

Authors	No. of Articles	H-index	Total Citations	Production year start
Forza C	21	10	249	2002
Jiao JX	17	1	16	1997
Trentin A	17	11	256	2007
Tseng MM	17	2	6	1997
Zhang M	14	8	337	2005
Huang GQ	11	4	339	2007
Salvador F	11	2	27	2002
Hvam L	10	6	86	2007
Liu WH	9	6	75	2013

**Fig. 2** Co-authorship analysis among countries (source: extracted from VOSviewer software)

3.2 Most Relevant Sources

In Table 4, the top ten most relevant journals publishing articles related to mass customization are presented. The most relevant source is the International Journal of Production Research, with 60 articles published. This is a prominent journal that publishes leading research on manufacturing and production engineering, followed by the Journal of Intelligent Manufacturing, with 34 articles published, representing a unique international journal for developers of intelligent manufacturing systems. The International Journal of Production Economics, with 32 articles published, focuses on topics treating the interface between engineering and management. When analyzing the article annual occurrences growth, the International Journal of Production Economics is on the rise in previous years, as opposed to the International Journal of Production Research and the Journal of Intelligent Manufacturing, which are declining since 2010. When comparing

the average citation per article, h-index for this bibliographic collection, and the number of articles published, the International Journal of Production Economics is the most influential.

Table 4. Top ten most relevant sources

Sources	# Ar- ticles	Impact factor	H-in- dex	TC
International Journal of Production Research	60	4.577	15	581
Journal of Intelligent Manufacturing	34	4.311	13	369
International Journal of Production Economics	32	5.134	12	419
International Journal of Advanced Manufacturing Technology	28	2.633	5	82
Production Planning and Control	27	3.605	8	132
International Journal of Computer Integrated Manufacturing	20	2.861	7	114
Computers in Industry	19	3.954	7	184
IEEE Transactions on Engineering Management	18	2.784	5	118
International Journal of Operations and Production Management	18	4.619	7	231
Computers and Industrial Engineering	17	4.135	6	97

3.3 Most Influential Articles

H-index for this bibliographic collection consisting of 802 articles related to mass customization is 68, with a total of times cited 21,795. Table 5 shows the most influential articles in mass customization research from 1996 to April 2021. This table was constructed based on the number of total citations per article. Among the ten most cited articles in this research area, there is just one article published in a journal from the ten most productive journals (Table 4). Although the most productive journals are mainly in industrial engineering, production, operational, and manufacturing research, among the ten most influential articles are the ones that are mostly published in journals oriented towards management sciences.

3.4 Main Keywords and Keyword Co-occurrences

This section provides an overview of both main keywords (measured by the keyword frequency) and keyword co-occurrences. Keyword analysis helps identify research trends [15]. Table 6 shows the ten most used keywords and keyword-plus (automatically generated from the titles) in the mass customization articles. It could be identified that multiple periods exist with distinct growth rates for "mass customization" word occurrences when we observed word growth through annual occurrences. When analyzing other main keywords through annual occurrences, more or less the flat growth rate could be identified.

Table 5. Top 10 highly cited articles

Author (year)	Title	Source	TC	AC
De Silveira et al. (2001)	Mass customization: Literature review and research directions	International Journal of Production Economics	629	29.95
Von Hippel and Katz (2002)	Shifting innovation to users via toolkits	Management Science	488	24.40
Feitzinger and Lee (1997)	Mass customization at Hewlett-Packard: The power of postponement	Harvard Business Review	442	17.68
Schafer et al. (2001)	E-commerce recommendation applications	Data Mining and Knowledge Discovery	421	20.05
Huffman and Kahn (1998)	Variety for sale: Mass customization or mass confusion?	Journal of Retailing	406	16.92
Von Hippel (1998)	Economics of product development by users: The impact of "sticky" local information	Management Science	403	16.79
Duray et al. (2000)	Approaches to mass customization: configurations and empirical validation	Journal of Operations Management	382	17.36
Gilmore and Pine (1997)	The four faces of mass customization	Harvard Business Review	346	13.84
Franke et al. (2010)	The "I Designed It Myself" Effect in Mass Customization	Management Science	307	25.58
Zhong et al. (2013)	RFID-enabled real-time manufacturing execution system for mass-customization production	Robotics and Computer Integrated Manufacturing	261	29

Table 5. Main keywords

Author keywords	Occurrences	Keyword-plus	Occurrences
mass customization	297	design	121
mass customisation	90	mass customization	75
product configuration	19	impact	57
3d printing	15	management	55
additive manufacturing	15	model	49
mass production	14	performance	38
supply chain management	14	systems	36
modularity	12	variety	35
product design	10	product	29
product platform	10	system	28

In Fig. 3 keyword co-occurrences are presented through seven separated clusters identified through Vosviewer. Cluster nodes are connected with the links. The red cluster includes "mass customization" as the dominant keyword and "design", "modularity", "system", "variety", "optimization" "product configuration" as other most important keywords, including many other keywords like "product family", "product family design", "product platform", "platform design", "family design", etc. In the second, green, cluster, the most important keywords are "model", "product", "innovation", "quality", including other keywords like "information", "choice", "customer", "satisfaction", and others. The blue cluster includes "impact", "performance" and "integration" and "strategy" as most important keywords, followed by "manufacturing practices", "quality management", "customer", "capability", "perspective", etc. "Mass customisation," "management", "postponement", "strategy" are the main keywords in the yellow cluster. The purple cluster consisted of the following main keywords: "supply chain," "customization", "mass production", "complexity" and "big data". Other words in this cluster are "sustainability", "industry 4.0", "internet of things", etc. The sixth (light blue) cluster contains "product development", "technology", "3d printing", "additive manufacturing", "flexibility", etc., and the seventh (orange) cluster included keywords like: "logistics service supply chain", "allocation" and "scheduling."

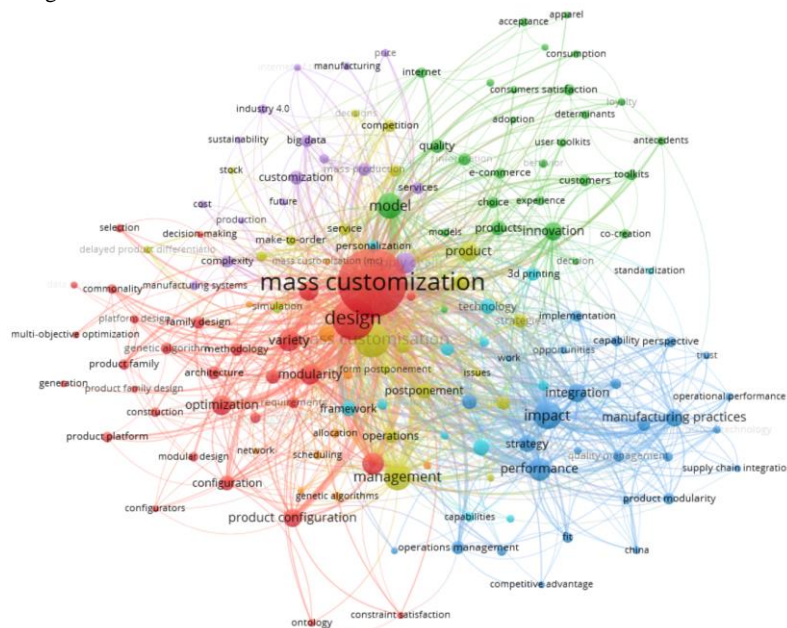


Fig. 3 Keywords Co-occurrences (source: extracted from VOSviewer software)

3.5 Co-citation Analysis

VOSviewer software was used to conduct co-citations analyses. Fig. 4 shows that five clusters were identified concerning co-citation analysis based on cited sources. Three clusters in which the highest co-citation intensity was identified were furthered analyzed. The red cluster includes the following main sources: International Journal of Production Research, International Journal of Production Economics, Journal of Intelligent Manufacturing, Computers in Industry, etc. As it could be seen, this cluster covers almost all journals from the list of most productive journals

4 Conclusion

Accumulation of papers, analysis of bibliographic data to determine the structure of research, and tendencies in the evolution of a particular topic, are becoming more complicated as the production of articles grows. Thus, the knowledge base is increasingly difficult to analyze objectively. Bibliometric analysis is becoming very valuable and helpful in conducting objective and reproducible science mapping and research structure analysis in all research areas. Using the "bibliometrix" R Package tool and VOSviewer software, the bibliometric analysis of the bibliographic data was performed on a sample of 802 articles related to mass customization published between 1996 to April 2021. The mass customization literature comprises research predominantly in industrial engineering, engineering manufacturing, and operations research, with the International Journal of Production Economics as the journal with the highest impact and increasing productivity in this topic. Annual scientific production had a stable growth from 1996 to 2004. After that, the decreasing growth rate could signalize that research is consolidating. Though, it must be noted that the number of articles published grew rapidly again in 2020. We identified a high concentration of articles in the most productive countries (the USA and China), whose authors collaborate intensively on this topic. The extensive amount and variety of data allowed us to identify the keyword occurrence and co-citations networks and reveal the related emerging research topics and research streams.

The limitations of this research should be also highlighted. Namely, this research is strictly limited to bibliographic data and analysis that could be extracted using the "bibliometrix" R Package tool and VOSviewer software. The content analyzes of the articles from the sample was not performed. Findings presented in this study can assist future research in this or related research areas in order to overcome these limitations. Future research could answer some of the following questions: Is there an evolution of the mass customization tendency through the years for the research areas? Are there any particular types of products or industries for which mass customization is especially relevant or especially successful? Are there any marked differences between articles from the different "journal clusters"?

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