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MAPPING THE PATH OF INDUSTRY 4.0: ANALYSIS USING BIBLIOMETRIC ANALYSIS

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ABSTRACT

The bibliometric is a research area that examines literature's most recent trends in a given field as well as provides directions and inspirations to conduct future research. It provides an overview of the research topic and its overall structure. The purpose of this article is to use bibliometrics' methodology and instruments to examine and critically appraise the literature on Industry 4.0. This study contributes to the field of Industry 4.0 research by providing a quick reference guide for academics and marketers interested in understanding how scientific research has addressed Industry 4.0 over time. The study identifies the main authors, journals, countries, and articles in this field of research, and then lays out the structure of Industry 4.0 research across time., integrating the key streams by using citation-based networks. This study summarises the most recent advancements in the discipline, intending to assist practitioners, policymakers, educators, and researchers in the future. The remaining of this paper is organized as follows: The study's objectives are outlined in the second section. The procedure of collection of data and the methods utilized are described in the third section. In Section 4, a detailed and exhaustive bibliometric study is carried out. The findings are summarised in section five of the paper.

Keywords: *Bibliometrics' Methodology, Scientific Research, Collection of Data, Bibliometric Study.*

Introduction

Industrial revolutions have shaped humanity's progress as a society. In the first three industrial revolutions, the process moved from mechanisation and the steam engine to power, assembly line production, and automation. To fully comprehend the notion of Industry 4.0, it is indispensable to first comprehend the previous industrial revolutions that ensued before the Fourth industrial revolution. The very First Industrial Revolution, which spanned from 1780 to 1820, was the most momentous economic, social, and technological revolution in the history of mankind. It revolutionized industries by employing steam as a source of energy. During this period, humanity's rural economic structure transitioned from agricultural production to manufacturing and industrial production. Machine inventions, energy generating alternatives, like steam for industrialized production, and the structures of labour unions, such as factory workers, were all key influences. Since that time, society has evolved and changed from surviving to developing (Narvaez Rojas et al., 2021). During 1870 and 1914, The Second Industrial Revolution occurred in the first globalization era. Electricity and assembly lines were utilized in mass production during the second industrial revolution. The expansion of land transportation and airplane journeys, as well as the introduction of cinema and communication networks, all contributed to its growth. Serialized processes, based on these new models, significantly reduced production time and costs but it also increased unemployment as employees were replaced by machinery. In 1970, the Third Industrial Revolution began. The United States, Japan, and the European Union were its leaders. Industry automation was its key feature. Information technology and computers were integrated into production during the third industrial revolution. (Muhuri et al., 2019). The cornerstone for this industrial revolution was the employment of microchips and integrated electronic components to replace conventional storage and communication techniques. The fourth industrial revolution is approaching, and It is expected to usher us into the next manufacturing echelon., in which machines will reshape how they communicate

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and carry out distinct functions. (Muhuri et al., 2019). The term "Industry 4.0" was originated by (Kagermann et al., 2011). A wide range of new factory technologies has been established during the Fourth Industrial Revolution, based on information systems and sensors, to adapt and develop tailored client services. The breakneck pace of disruptive developments in cyber-physical systems, Smart industry, robotics, neural networks, deep learning, big data, and the Internet of Things (IoT) characterized Industry 4.0., Fig. 1 depicts the transition that takes place.

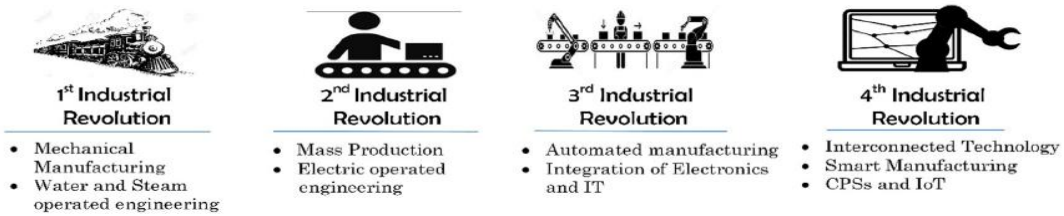

Figure 1: Stages of Industrial Revolution

Source: (Muhuri et al., 2019)

Objectives

The main intent of the research is to describe the current status of research on Industry 4.0, with the questions that follow defining the scope of the study:

- RQ1) How research on Industry 4.0 has evolved, and What are the latest research trends and themes in this field?
- RQ2) In terms of chronology, publications, authors, and countries, what are the current publishing trends in Industry 4.0?
- RQ3) Which studies have had the most impact in this field?

Data Collection and Methodology

The most widely used method for a thorough understanding of the structure of a research subject is bibliometrics (Li et al., 2017). Scopus is a database owned by Elsevier, which is the largest database in the world for published articles and citations, was used to extract data relevant to this study in March 2022. The papers were searched using the search query "Industry 4.0" in title, abstract, or keywords. The final data set for this research included a total of 1023 articles. R software Biblioshiny and VOS Viewer were utilized to conduct the analysis. The distance between things can be used to explain the relatedness of items in VOS Viewer. The closer two objects are, the more related they are (van Eck & Waltman, 2010). It is based on the “visualization of similarities”(VOS). The current study employs techniques such as citation network analysis and publishing patterns. (Paul & Benito, 2018). For the bibliometric study in this paper, a variety of performance indicators were extracted i.e., Total Papers (TP), which refers to the total publications published by the source., whereas the total citations received by a publication is referred to as Total Citations (TC).

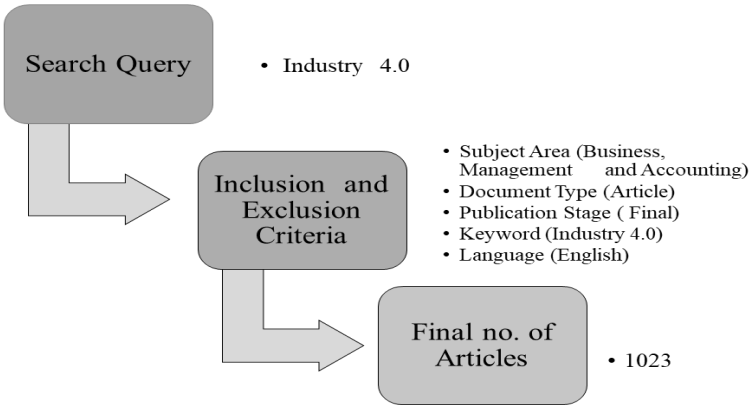

Figure 2: Search Query, Inclusion and Exclusion Criteria

Bibliometric Analysis

The bibliometrics findings for several performance metrics, for instance, research progression highly prolific and cited authors, top journals, country-wise analyses, and highly important publications on "Industry 4.0" are shown in this section.

Research Progression

Industry 4.0 since its inception has attracted a lot of attention. Fig. 3 indicates the total publications in Scopus on the theme “Industry 4.0”. The first Industry 4.0 articles appeared in Scopus in the year 2015, with three papers. Later, it increased at an exponential rate and attained a maximum of 332 papers in 2020. The first study on Industry 4.0 was only released in 2015, indicating that it is a relatively new phenomenon. Scopus has accumulated 1023 papers on this topic within seven years.

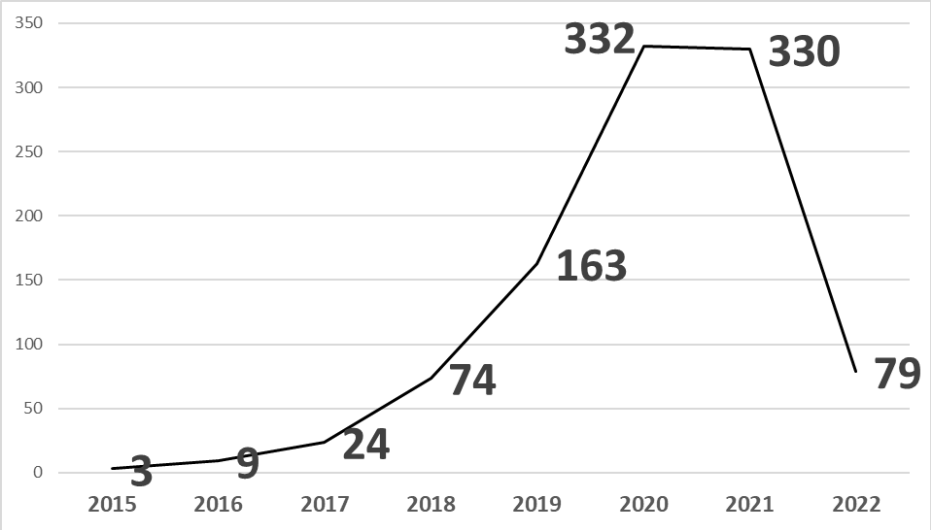

Figure 3: Total Publication in Scopus

Highly Productive and Influential Authors

Authors who are most productive for Scopus are extricated and Sorted by the number of articles published. If two or more authors have the same number of publications, the ranking is determined by the TC. Table 2 displays the list of the top ten most prolific authors. Müller Jm, Voigt K-I, and Kumar A are the highest contributors in the database with 9 publications each in Scopus.

Table 1: Top 10 Most Productive Authors, TP = Total Publications, TC = Total Citations

Scopus			
Rank	**Authors**	**TP**	**TC**
1	Müller Jm	9	990
2	Voigt K-I	9	929
3	Kumar A	9	184
4	Tortorella Gl	8	507
5	Orzes G	8	334
6	Garza-Reyes Ja	8	311
7	Chen Y	8	82
8	Frank Ag	7	1475
9	Pellerin R	7	567
10	Kumar M	7	80

To compile a list of the authors who have had the most impact, the authors were ranked according to the total number of citations obtained across all papers and are listed in Table 2. Frank Ag is the most influential author with 1475 Citations, followed by Ayala Nf with 1442 citations and Li L with 1433 Citations. Müller Jm, who produce the maximum number of articles with 9 publications, is at the Seventh position in this list of the most influential author with 990 citations in the Scopus.

Table 2: Most Influential Authors, TP = Total Production, TC = Total Citation

Scopus			
Rank	**Authors**	**TP**	**TC**
1	Frank Ag	7	1475
2	Ayala Nf	6	1442
3	Li L	5	1433
4	Dalenogare Ls	2	1092
5	Xu Ld	2	1064
6	Xu El	1	1036
7	Müller Jm	9	990
8	Voigt K-I	9	929
9	Dolgui A	5	755
10	Ivanov D	4	753

Top Journals

In this section, the study compiled the top ten journals in the burgeoning field of Industry 4.0. A journal is a periodic publication (monthly, annually, etc.) to promote and monitor the growth of the discipline. Table 3 summarizes the findings. The Total Publication and Total Citation of the top 10 Scopus journals are shown in this table. The total number of publications is used to sort the list. In Scopus, Technological Forecasting and Social Change have the highest publication 99, followed by the International Journal of Production Research with 57 publications and it has also received a maximum citation count of 4811.

Table 3: Top Journals

Scopus		
Journal	**TP**	**TC**
Technological Forecasting and Social Change	99	3345
International Journal of Production Research	57	4811
Journal Of Manufacturing Technology Management	46	1320
Journal Of Cleaner Production	44	1085
International Journal of Production Economics	42	2627
Production Planning and Control	25	1113
IEEE Engineering Management Review	21	287
Management And Production Engineering Review	20	317
Systems Research and Behavioural Science	19	264
Benchmarking	16	315

Country-wise Analysis

In terms of the number of papers published, the top ten most productive countries in Scopus are given in this section. Table 4 shows the ranking of the countries sorted by Total Publication, also taking into consideration Total Citation. In Scopus, Italy comes first in the list with 310 publications, followed by India, China, and Brazil with 275, 211, and 198 publications, respectively. Interestingly, Germany is the most cited country with the number of citations of 2370, after that Brazil and the USA with 2111 and 1755 citation counts each.

Table 4: Top Countries working on Industry 4.0

Scopus			
Rank	**Countries**	**TP**	**TC**
1	Italy	310	1598
2	India	275	1232
3	China	211	1217
4	Brazil	198	2111
5	UK	189	1478
6	Germany	184	2370
7	USA	140	1755
8	France	102	1005
9	Poland	94	443
10	Malaysia	91	64

Top 10 Highly Influential Papers

The most cited papers in Scopus are listed in this section. Table 5 shows the ten most influential papers in Scopus, as measured by the number of citations. The citations a document has gained over time are determined by the citation count. A document that is cited more frequently is considered more influential (Tsay, 2009). To figure out the articles with the largest influence on Industry 4.0, the network of citations of 1023 articles was analyzed using R software Biblioshiny. The names of the authors, journal, and year of publication are also included in this table. The paper by Xu Ld, (2018) in 2018 has received the highest citation count of 1036. It is preceded by Kang Hs, (2016) with 670 citations. There were six publications in the top ten most influential papers in 2018, with a total citation count of 3035. There are two papers in 2019, with a total of 1068 citations. Researchers are working in this sector to produce a smart and intelligent industry in the future, as evidenced by the trend.

Table 5: Highly Cited Paper

Rank	Author and Year	Journal	Title	TC
1	Xu Ld, (2018)	International Journal of Production Research	"Industry 4.0: state of the art and future trends"	1036
2	Kang Hs, (2016)	International Journal of Precision Engineering and Manufacturing-Green Technology	"Smart Manufacturing: Past Research, Present Findings, and Future Directions"	670
3	Frank Ag, (2019)	International Journal of Production Economics	"Industry 4.0 technologies: implementation patterns in manufacturing companies"	614
4	Dalenogare Ls, (2018)	International Journal of Production Economics	"The expected contribution of Industry 4.0 technologies for industrial performance"	478
5	Ivanov D, (2019)	International Journal of Production Research	"The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics"	454
6	Ghobakhloo M, (2018)	Journal of Manufacturing Technology Management	"The future of manufacturing industry: a strategic roadmap toward Industry 4.0"	412
7	Moeuf A, (2018)	International Journal of Production Research	"The industrial management of SMEs in the era of Industry 4.0"	389
8	Müller Jm, (2018)	Technological Forecasting and Social Change	"Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0"	376
9	Sanders A, (2016)	Journal of Industrial Engineering and Management	"Industry 4.0 Implies Lean Manufacturing: Research Activities in Industry 4.0 Function as Enablers for Lean Manufacturing"	367
10	Li L, (2018)	Technological Forecasting and Social Change	China's manufacturing locus in 2025: With a comparison of "Made-in-China 2025" and "Industry 4.0"	344

Topmost Keywords in Scopus

The author's keywords represent the themes of research articles (Goyal & Kumar, 2021). The study utilized the VOS viewer in this section which extensively used information visualization software for selecting the authors' most important keywords in their papers. There were 3114 keywords found in total from 1023 papers. 'Industry 4.0' is the most frequently used keyword. The other most frequently used keywords are sustainable development, automation, smart factory, smart manufacturing, digital transformation, big data, etc. The network of the most popular keywords indexed in Scopus is depicted in Figure 4.

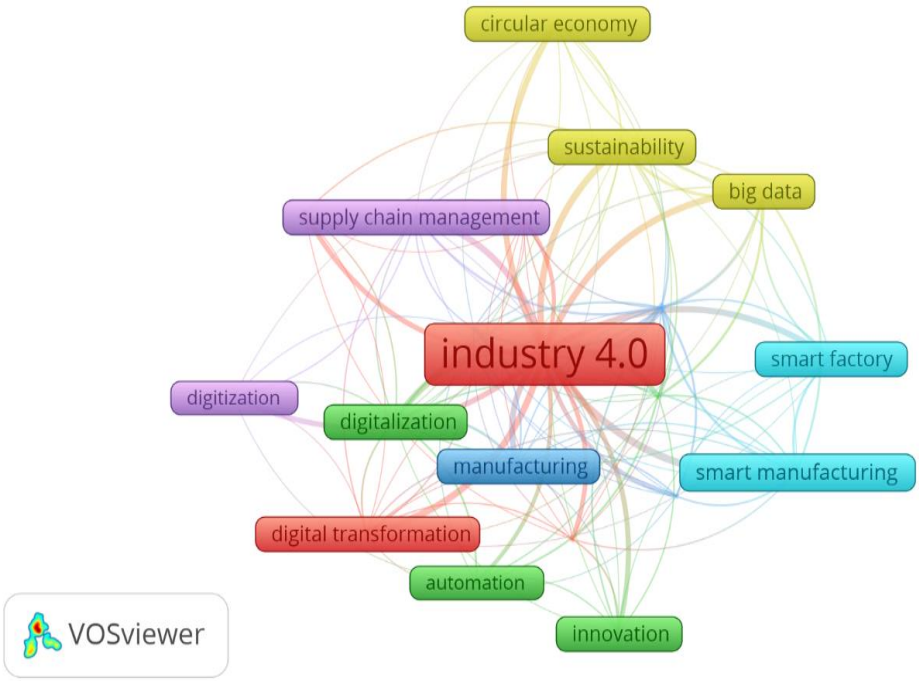

Figure 4: Most Popular Keywords in Scopus

Discussion and Conclusion

This study derived valuable insights on Industry 4.0 by meticulously reviewing the available literature. It contributes to Industry 4.0 research by analyzing the changing literature in terms of different themes and trends, thus presenting the state of scholarly effort from its inception to the present. A comprehensive bibliometric evaluation in the rapidly growing arena of "Industry 4.0" has been done in this research. The bibliometric analysis aided in the discovery of the structures and trends in this field. Scopus database is used for the bibliometric analysis. Müller Jm is the most productive author, according to the results. The most productive journal is Technological Forecasting and Social Change. Italy and India are the most productive country on the theme of Industry 4.0. This is an important study that will allow the scholarly community to investigate the publication hierarchy in this field. Finally, there are a few drawbacks to this study. First, despite our best efforts to ensure that the search words reflect the vast span of the field, there may be some studies that are absent due to the lack of any related terms in the parameters for the search. In addition, rather than focusing on a specific aspect, the study examines a general idea.

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