European Economic Letters
ISSN 2323-5233
Vol 14, Issue 3 (2024)
http://eelet.org.uk

Unveiling the Past and Anticipating the Future: A Bibliometric Analysis of Technological Innovations in Industry 5.0 and Their Applications

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Abstract
This study aims to 1) Execute a bibliometric analysis focusing on the realm of Industry 5.0 and its associated technological advancements, 2) Explore the domains in which these technologies are frequently employed, 3) To discern and delve into both the precedent and emergent research themes that define the evolving sphere of Industry 5.0. The data was gathered using the Web of Science database, and analysis was performed using VOSviewer software. The findings, based on the data gathered from 899 articles, indicate that there is a need for more research in the domain of Industry 5.0. Through a retrospective analysis, this research paper identifies research themes spanning four distinct eras: 2015-2019, 2020-2021, 2022, and Upcoming themes. This paper attempts to identify and discuss these upcoming research themes that define the evolving sphere of Industry 5.0.

Keywords - Industry 5.0; Cobots; Digital twins; Internet of things; Artificial intelligence; Cloud computing; Edge computing; Machine learning; VOSviewer; Bibliometric Study

Introduction

The term 'Industry 5.0' was introduced on December 1st, 2015, in an article published by Michael Rada. 'Industry 5.0' refers to the fifth industrial revolution. It represents the balanced integration of advanced technology with humanity, focusing not just on technological enhancement but also on the enrichment and improvement of the planet and humanity (Aslam, et al., 2020).
The technologies associated with Industry 4.0, such as Artificial Intelligence, have raised questions among researchers regarding their impact on the society and planet, particularly in the absence of a human element. These concerns about Industry 4.0 have brought Industry 5.0 into the spotlight. Authors describe Industry 5.0 as a means to continue building technology without compromising sustainable innovation and a human-friendly future (Özdemir & Hekim, 2018).
(OZKESER, 2018) emphasizes that consumers do not resist technology; rather, they desire the ability to customize products to their individual needs and preferences. This level of personalization is possible with Industry 5.0, which successfully merges human touch with technology. Industry 5.0 introduces technological advances but maintains a focus on their role in improving human life, rather than removing the human element from manufacturing and operations.(Demir, et al., 2019)study the area of human-robot coworking under Industry 5.0.

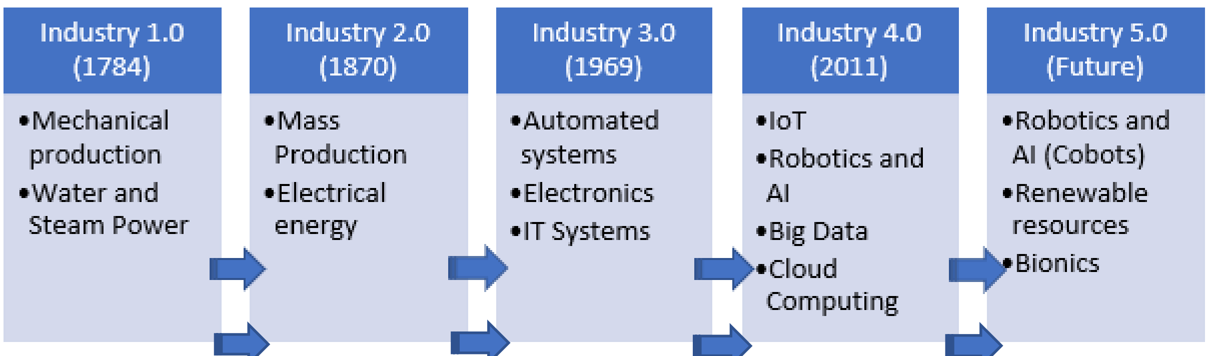

Fig 1 – From Steam to AI: The Evolution of Industry from 1.0 to 5.0
Source – Adapted from (Demir, et al., 2019)

Fig 1 shows the progression of Industrial Revolutions from 1.0 to the Emergence of 5.0. Industry 5.0 aims to establish a balance between industry, innovation, and society. The study (Nahavandi, 2019) explores the concept of Industry 5.0. The author envisions Industry 5.0 leading to a blend of environmental management and AI, resulting in actionable technological solutions. While Industry 4.0 technologies were based on removing human workers from processes, Industry 5.0 aims to address this issue. Specifically, Industry 5.0 aims to automate the repetitive tasks in manufacturing processes, leaving the creative roles to humans.(Paschek, et al., 2019) attempt to analyze the impact of the new industrial revolution, i.e., Industry 5.0, on business. An absolute innovation management framework was developed in the study (Aslam, et al., 2020). However, the limitation of this research lies in the fact that the framework has not been empirically tested and verified. (Frederico, 2021) conducted a systematic literature review to explore the relationship between Industry 5.0 and supply chain management. The author suggests that literature in this field is scarce. The study found that Industry 5.0 aims at mass personalisation and intends to use innovative technologies to facilitate a sustainable society. In Industry 5.0, technology is not developed for its own sake, but for the improvement in the lifestyle of people; it does not exclude humanity (Skobelev & Borovik, 2017). (Xu, et al., 2021) discuss the differences between Industry 4.0 and Industry 5.0 in depth. The authors describe how Industry 4.0 is primarily driven by technological developments like digitization or AI technology. However, Industry 5.0 is gaining acceptance now because of its value-centric and human-centric approach towards society. It achieves this by considering not only the growth of the industry but also the industry workers. Industry 5.0 is expected to prioritize societal and planetary aspirations over jobs. The authors posit that what society is observing is a Socio-Technical Revolution. The technological landscape of Industry 5.0 comprises the following:

- Technologies that coalesce the potencies of both humans and machines.
- Recyclable and ecological technologies and smart materials
- Digital Twins
- Artificial intelligence leading to actionable intelligence
- Technologies based on the advancement and use of Renewable energy, energy efficiency
- Data analysis technologies capable of handling data and system interoperability.
- Collaborative robots or Cobots
- Cloud computing
- Internet of Things

Literature Review

Industry 5.0

“Humans should never be subservient to machines and automation, but machines and automation should be subservient to humans” – Howard Rosenbrock, 1990 (Lu, et al., 2022).

Now, perhaps more than at any other time, the society today is understanding the essential role of human wellbeing (Aceta, et al., 2022). During the fourth industrial revolution, technological innovation and the establishment of mass production systems focused solely on fast production and better efficiency, even at the cost of the diminishing human way of life (Lu, et al., 2022). (Aslam, et al., 2020) describe in their paper how technological innovations are directly related to the progress and advancement of developing countries, but there is still a struggle to innovate in ways that are functional and serviceable. The solution to this predicament is to innovate human-centered technology that is sustainable and implementable. (Coronado, et al., 2022) discuss the role of robotics in Industry 5.0 in their study. The authors outline the differences between Industry 4.0 and 5.0, explaining that robotics needs to focus on the wellbeing of humanity, unlike Industry 4.0, which centered around increasing productivity at all costs. However, the authors point out that both Industry 4.0 and 5.0 can coexist. (Demir, et al., 2019)discuss potential issues with human-robot coworking, or cobots. The significant issues they raise include determining how much decision-making power should be given to cobots, how negative media views affect people's decisions to work with cobots, how the real-life use of cobots could lead to unprecedented psychological effects on humans, the social status of cobots in professional environments, and identifying separate job descriptions for cobots and humans. The authors conclude their study by stating that whether positive or negative, the effect of cobots on human lives will be significant. (Du, et al., 2022) highlight that edge computing and machine learning are the key upcoming technologies of Industry 5.0. However, the potential applications of Industry 5.0 are not limited to technology use in industries. (Ali, et al., 2021)identify the critical factors affecting the adoption of cloud computing in government organizations. The authors found that the factors positively influencing the likelihood of this technology's acceptance include “compatibility, complexity, cost, security concerns, expected benefits and organization size”. (Wang, et al., 2019) on the other hand, study the role that government can play in effectively integrating cloud computing through regulations and support. (Joseph & Ezhilmaran, 2018) study how Cloud computing's secure user authentication with finger vein recognition and the efficient fuzzy classification algorithm for finger vein images make it an attractive solution for securing data while reducing environmental impact and optimizing resource utilization. (ElFar, et al., 2021) explore the potential role of Industry 5.0 in the study of algae for clean bioenergy generation. (Fatima, et al., 2022) discuss how the fourth industrial revolution has transformed the warehousing sector by introducing Internet of

Things (IoT), machine learning, and data mining. The authors point out that the purpose of the 4th industrial revolution is to ensure that machines can handle all the work, including controlling each other, with the goal of minimizing human involvement. In contrast, Industry 5.0 focuses on the use of technology under human supervision, promoting the completion of skilled work by humans. (Dong, et al., 2017)study the impact of perceived psychological factors on the perceived usefulness of IoT by consumers. The psychological factors that make an impact include perceived ease of use, intelligence, convenience, and privacy risk. (Fedorov, et al., 2021) in their paper, introduce the basics of a new technology to facilitate the implementation of Industry 5.0. This technology is based on neuro-digital ecosystems.

Bibliometric study

A bibliometric study is performed to analyze large amounts of scientific data. Nowadays, it is an increasingly popular method due to the advent of new technologies and software (Donthu, et al., 2021). Scholars undertake bibliometric studies for various purposes such as examining collaborations among authors, analyzing past research conducted by others, or investigating probable future trends for upcoming research. (Donthu, et al., 2021) in their study illustrate the different techniques in bibliometric analysis. The techniques used in bibliometric analysis, as depicted in Fig 2.

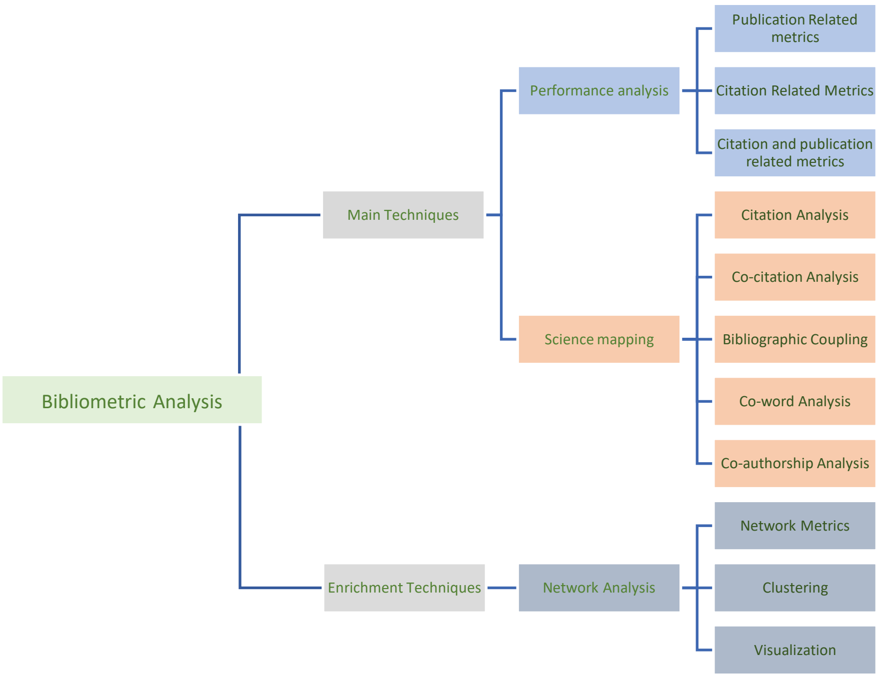

Fig 2 – Bibliometric Analysis

Source – Adapted from (Donthu, et al., 2021)

(Bhatt, et al., 2020) describe in their study that bibliometric analysis is applied to a large number of scholarly articles to understand patterns of keywords, themes, collaborations among authors, and so on. They also discuss various software applications widely used for conducting a bibliometric analysis, such as BibExcel, CiteSpace, Gephi, and VOSviewer. In this study, VOSviewer has been used to conduct the analysis, and Web of Science has been employed to gather the scientific data from scholarly articles.

Objective of the study

Industry 5.0 was introduced in 2015 and since then, humanity has witnessed a rapid increase in research in this area. The objectives of this study are to:

- Execute a bibliometric analysis focusing on the realm of Industry 5.0 and its associated technological advancements
- Explore the domains in which these technologies are frequently employed.
- To discern and delve into both the precedent and emergent research themes that define the evolving sphere of Industry 5.0.

Methodology

Bibliometric Analysis

Bibliometric analysis has become exceedingly popular in recent years, and one of the key reasons is the easy accessibility of software tools like VOSviewer and others, coupled with the availability of databases such as Scopus and Web of Science (Donthu, et al., 2021).

(Fairthorne, 1969) defined Bibliometric Analysis as “Quantitative treatment of the properties of recorded discourse and behaviour appertaining to it”. (Broadus, 1987) in his paper refers to many definitions of bibliometrics (bibliometric analysis) put forward by different authors. He concluded by defining bibliometrics as “A clearly delineated body of research involving physical t/nits of publications, bibliographic citations, and surrogates for them. The measurement of these items is called, logically, "bibliometrics."”
(Donthu, et al., 2021) discussed in their paper how bibliometric analysis has experienced a surge in research in recent years, despite the term 'bibliometrics' being mentioned in papers since the 1950s.

Bibliometric analysis steps
(Romanelli, et al., 2021) & (Donthu, et al., 2021) describe the different steps of the bibliometric analysis. Referencing these studies following are the steps that will be followed in this paper:

1) **Outline the aims for the study** – defining the aims for carrying out the bibliometric analysis lays the groundwork for deciding what will be the first step in carrying out the study in that particular topic (Donthu, et al., 2021)
2) **Identify the bibliometric analysis techniques that will be used –** different methods to perform bibliometric analysis are :

- Citation analysis
- Co-citation analysis
- Bibliographic coupling
- Co-occurrence analysis
- Co-authorship analysis

3) **Ascertain relevant database for articles –** in this study the database Web of Science is being used to look for relevant research articles for the bibliometric analysis
4) Defining the keywords to search for appropriate papers
5) Defining other parameters such as timespan for selecting papers, type of sources(for ex., journals, magazines, news), etc
6) **Performance Analysis –** this step in the bibliometric analysis can be done with the help of tools available with Web of science database.
7) **Complete bibliometric analysis (science mapping)** – many softwares are now available for carrying out the bibliometric analysis. VOSviewer is one such software which is very popular for this type of study. The same software will be used for conducting bibliometric analysis on the data gathered from Web of Science database Convey the findings.

Limitations and Scope for future research
The last step for the study will be to put forth the limitations in carrying out the research and proposing further questions that can enhance and draw attention towards scope for further research in the area of Industry 5.0.

Data collection and implementation
Bibliometric analysis can be done with multiple techniques as explained by (Donthu, et al., 2021). Studies choose either all or one of these techniques to complete their study. In this paper techniques from following two categories will be used:

Performance analysis

Science mapping

Data Collection
The data used for the bibliometric analysis in this study has been sourced from the Web of Science database. The keywords employed to locate the pertinent data, based on a literature review, are as follows: Industry 5.0, Digital Twins, Cloud Computing, Cobots, Internet of Things, Artificial Intelligence, and Industrial Revolution 5.0. Given the limited research in the area of Industry 5.0, papers spanning the time frame from 2002 to 2022 were selected, with a maximum of 150 papers chosen from each of these constituents. Papers from both Industry 5.0 and Industrial Revolution 5.0 were merged, and any duplicates were excluded. As Industry 5.0 is a relatively new research topic, a larger quantity of papers from this subject was permitted, aiming to cover as much research as possible. The breakdown of topics and the corresponding number of papers for each are presented in Table 1.

Table 1 - topics and number of papers per topic

Topic	Number of papers
Industry 5.0	153
Digital Twins	150
Cobots	148

Artificial Intelligence	150
Internet of things	150
Cloud computing	149

A total of 899 papers (excluding repeated papers in different topics) were analysed for this study.

Implementation

Performance Analysis

Performance analysis quantifies the attributes like authors, countries, journals, publications etc., for the purpose of the study (Heradio, et al., 2015) (Donthu, et al., 2021). For ex., total number of publications, total number of authors, total number of citations etc. These are widely accepted indicators in bibliometric analysis (Xu & Xu, 2022).
For this study, a total of 899 papers, spanning a 20-year period from 2002 to 2022, were considered. It was observed that the number of publications concerning the Industrial Revolution 5.0 has been rapidly increasing, as illustrated in Fig 3.

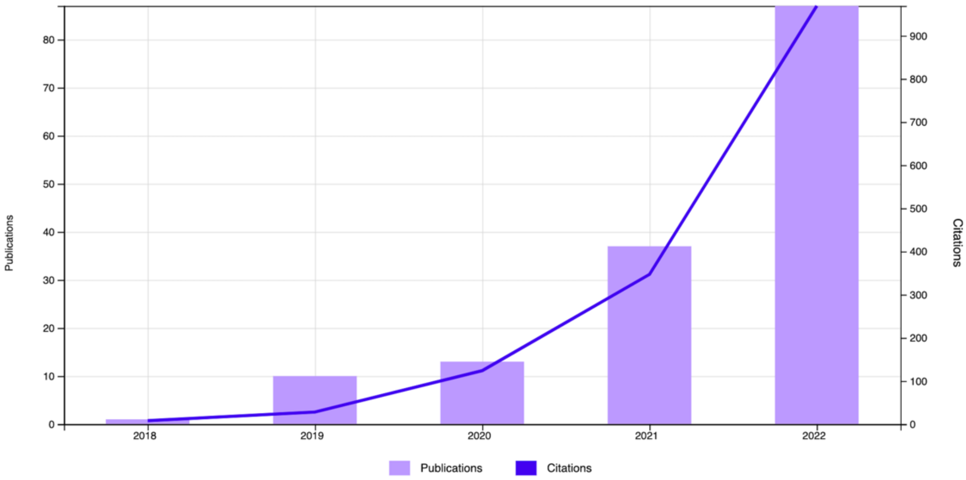

Fig 3 - Number of publications and citations per year for industry 5.0

Source –created by WoS (Web of Science)
The period from 2002 to 2022 has seen a significant rise in the number of publications and citations per year in the field of Industry 5.0 and its associated technologies. This trend underscores the escalating interest and ongoing advancements in this area of study. This rapid increase in publications and citations is vividly demonstrated in Fig 4.

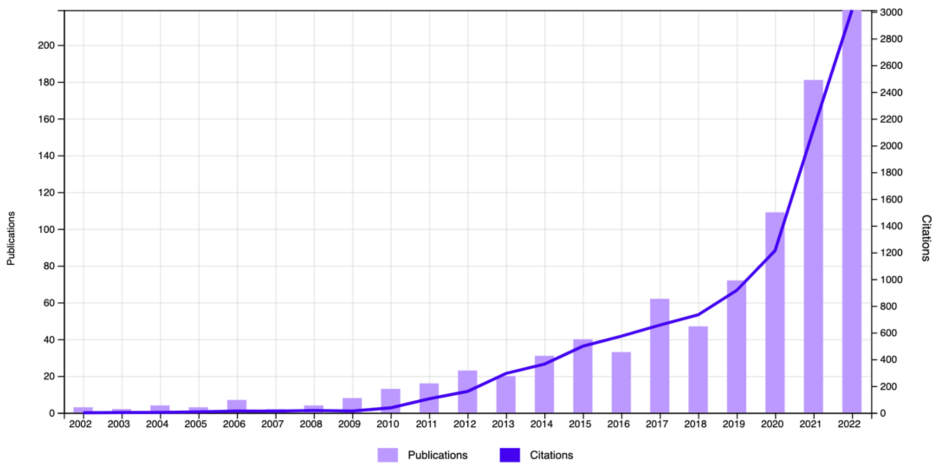

Fig 4 – Publications and citations per year

Source –created by WoS (Web of Science)

The number of citations associated with each area of research is another aspect of interest. This information can be visualized effectively using the bar chart presented in Fig 5.

European Economic Letters
ISSN 2323-5233
Vol 14, Issue 3 (2024)
http://eelet.org.uk

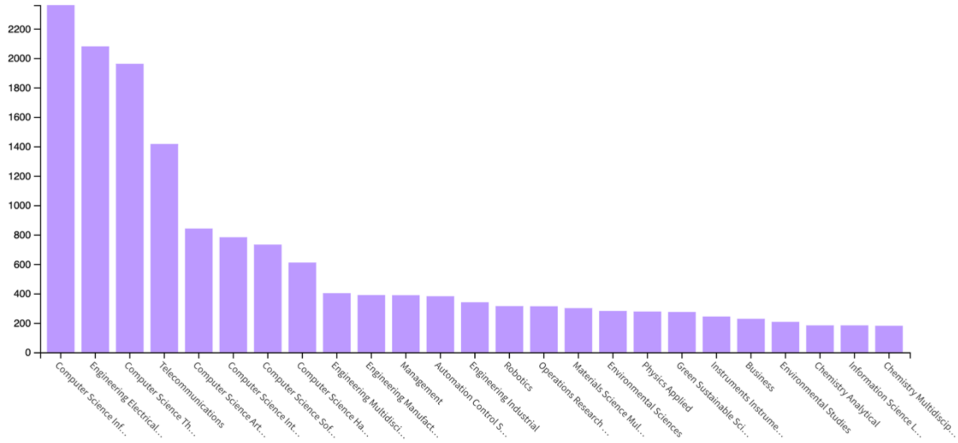

Fig 5 – Citations per year

Source – Created by WoS (Web of Science)

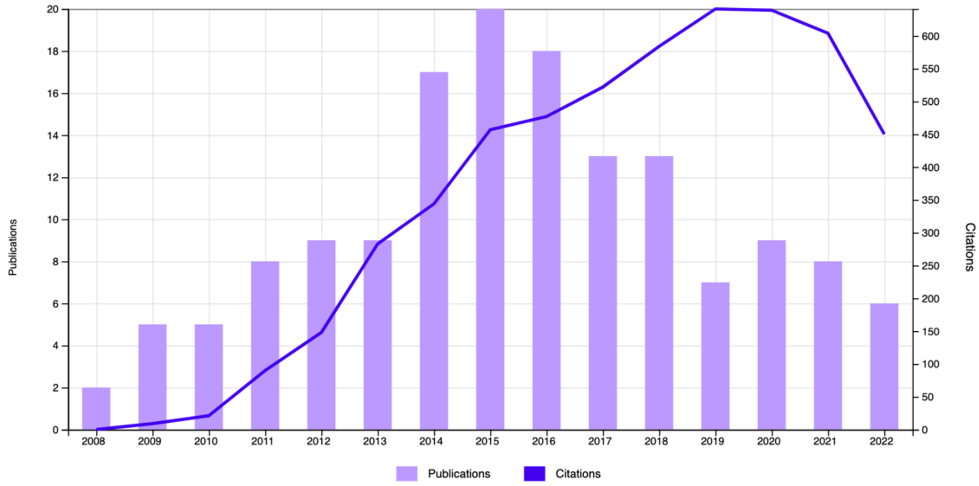

Fig 6 – Citations and publications for cloud computing

Source – Created by WoS (Web of Science)

A total of 2,791 authors contributed to the 899 papers that form the corpus of this study. For reference to the top 10 most-cited authors, please see Table 2. Domains of research with the most publications can be found in Table 3. As demonstrated in Table 3, Robotics and Artificial Intelligence are the only two technological innovations associated with Industry 5.0 that appear predominantly in the most-published domains. This indicates that further research is necessary in the area of Industry 5.0. Figure 6 illustrates a gradual decline in research concerning Cloud Computing. This occurs despite various researchers suggesting that Cloud Computing represents the future of Industry 5.0 (Ruparelia, 2016).

Table 2 - list of top 10 most cited authors

Author	Citations
Colgate JE	7
Carayannis EG	6
Faccio M	5
Li WD	5
Liu Y	5
Wang LH	5

Wang Y	5
Burdet E	4
Cohen Y	4
Cruz-villar CA	4

Table 3 - domains of research with most publications

Technology	Number of publications
Engineering Electrical Electronic	170
Computer Science Information Systems	149
Computer Science Theory Methods	121
Computer Science Artificial Intelligence	115
Automation Control Systems	93
Computer Science Interdisciplinary Applications	83
Telecommunications	83
Engineering Manufacturing	69
Engineering Multidisciplinary	59
Robotics	57

Science mapping

Science mapping serves as a tool to elucidate the relationships between the constituents that performance analysis quantifies and explains. It is the subsequent step in bibliometric analysis, following performance analysis. According to (Donthu, et al., 2021), five analysis techniques are instrumental in performing science mapping:

1. Citation analysis
2. Co-citation Analysis
3. Bibliographic coupling
4. Co-occurrence analysis
5. Co-authorship analysis

In the context of this study, all the aforementioned analyses have been carried out, with details provided further in this section.

Citation analysis

Citation analysis is a highly favoured technique in bibliometric analysis (Zafrunnisha, 2022). (Smith, 1981) discusses citation analysis and asserts that the rise in its usage can be attributed to the increasing number of new techniques and measures. Novel tools have been facilitating the growing number of bibliometric analyses. This technique can be employed to determine the most significant publications, authors, and countries in a domain and to comprehend the impact they have made by counting the number of times a publication, author, or country has been cited (Donthu, et al., 2021).

As per (Smith, 1981) , citation analysis is conducted to identify which papers, authors, or publications have been cited most frequently. In this paper, citation analysis was performed on countries to discern which ones have had the most substantial impact on the research area. Figure 7 illustrates these findings. The figure indicates that although India ranks among the countries that have influenced this area of research, namely Industry 5.0, there remains a need for more research in India to significantly impact the field.

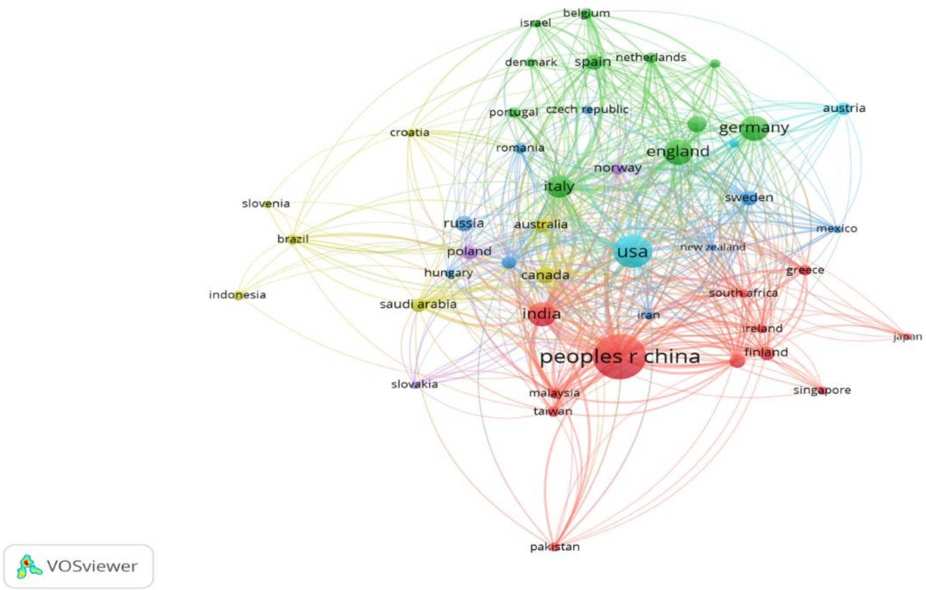

Fig 7 – Citation analysis of Countries

Source – Created using VOSviewer

Co-citation analysis

In co-citation analysis, when two publication titles are cited together within a paper, they are represented as connected in the resulting co-citation analysis map. The term 'co-citation analysis' was first introduced by Henry Small in 1983 (Surwase, et al., 2011). For this study, co-citation analysis was conducted on sources, namely publication titles, with Fig 8 demonstrating the resulting analysis maps. On a co-citation analysis map, clusters can be discerned, each differentiated by a unique colour. These clusters consist of publication titles that are most frequently cited together. These groupings are thematic in nature, suggesting that the included papers follow similar themes (Surwase, et al., 2011). The map is centered around the most frequently cited publication titles from this analysis and excludes newer and less cited publication titles. Such maps equip researchers with a strategic tool for planning the future scope of their studies..

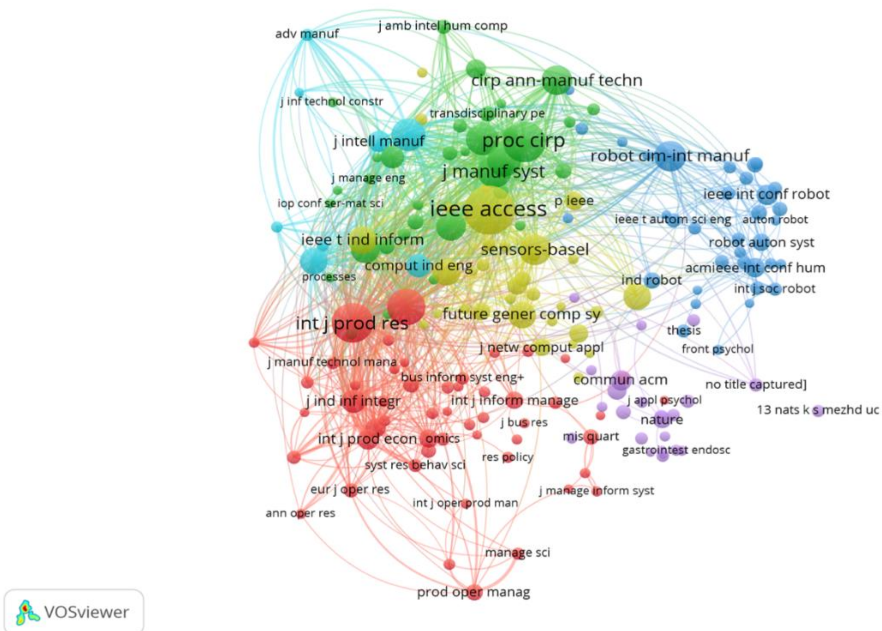

Fig 8 – Co-Citation analysis of publication titles

Source – Created using VOSviewer

Bibliographic coupling

Bibliometric coupling was first introduced by M. M. Kessler in 1963 (Surwase, et al., 2011). It distinguishes itself from co-citation analysis by also incorporating newer publications into the analysis. It achieves this by including publications that are citing other publications, a departure from co-citation, which only incorporates cited publications (Surwase, et al., 2011) (Donthu, et al., 2021). Fig 9 illustrates the bibliographic coupling conducted on publications. The differentiation between the co-citation and bibliographic coupling maps is clearly discernible.

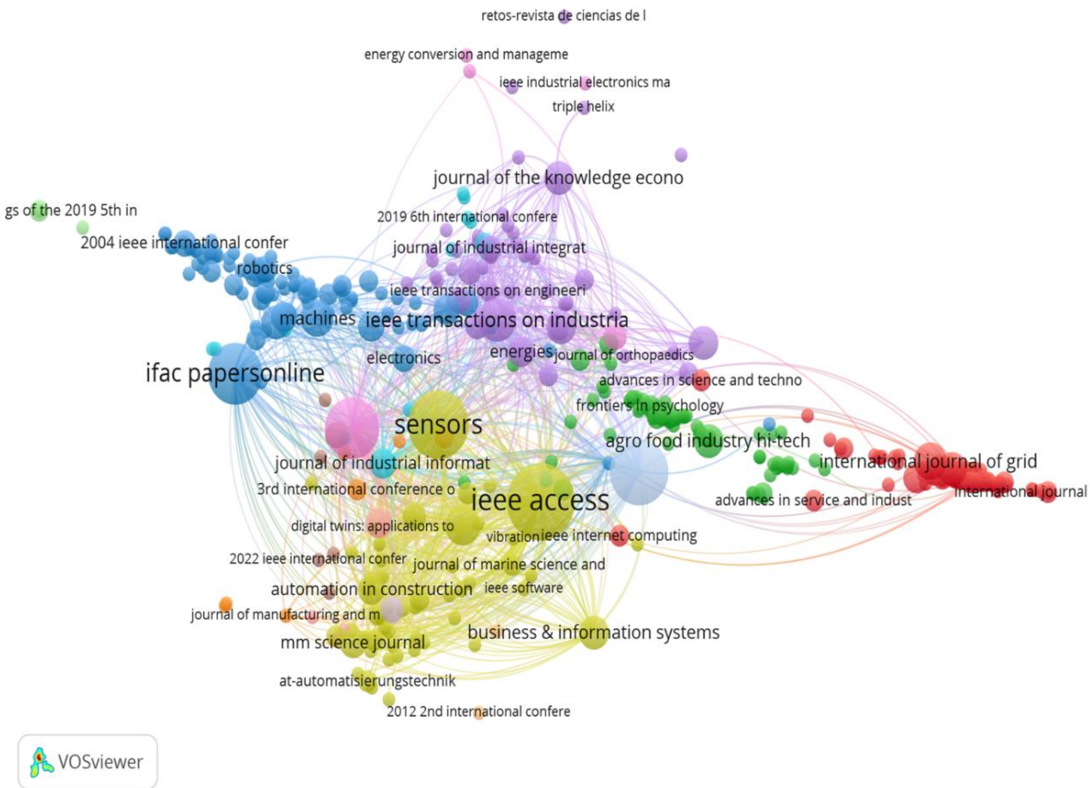

Fig 9 – Bibliographic coupling of publications

Source – Created using VOSviewer

The thematic clusters of publications become significantly clearer in the bibliometric coupling. In total, the co-citation analysis of publications incorporated 186 publications, whereas the bibliographic analysis included 436 publications. This map proves useful in identifying niche publications that may not be detectable through co-citation.

Co-authorship analysis

In their study (Xu & Chang, 2020) suggested that the task of linking and establishing correlations between authors and their work has been greatly facilitated by the advent of new tools and techniques. Co-authorship analysis can highlight which organizations or authors have been involved in recent research in the specified field. This analytical technique can identify areas that might be overlooked in terms of research advancement within a domain. Furthermore, it enables the analysis and understanding of collaborations among authors (Donthu, et al., 2021).

In this study, a co-authorship map of authors and countries was created using VOSviewer. Figure 10 presents an overlay map, utilizing different colours to distinguish which countries have been recently involved in the research and to what extent. Within the domain of Industry 5.0 and associated technologies, the map in Figure 10 delineates which countries have been more active than others in recent research in this area.

Additionally, Figure 11 displays a co-authorship map for authors. Rather than forming a large map, it comprises small, separate clusters that are thematic in nature. The themes derived from these clusters will be discussed in the findings section of the paper.

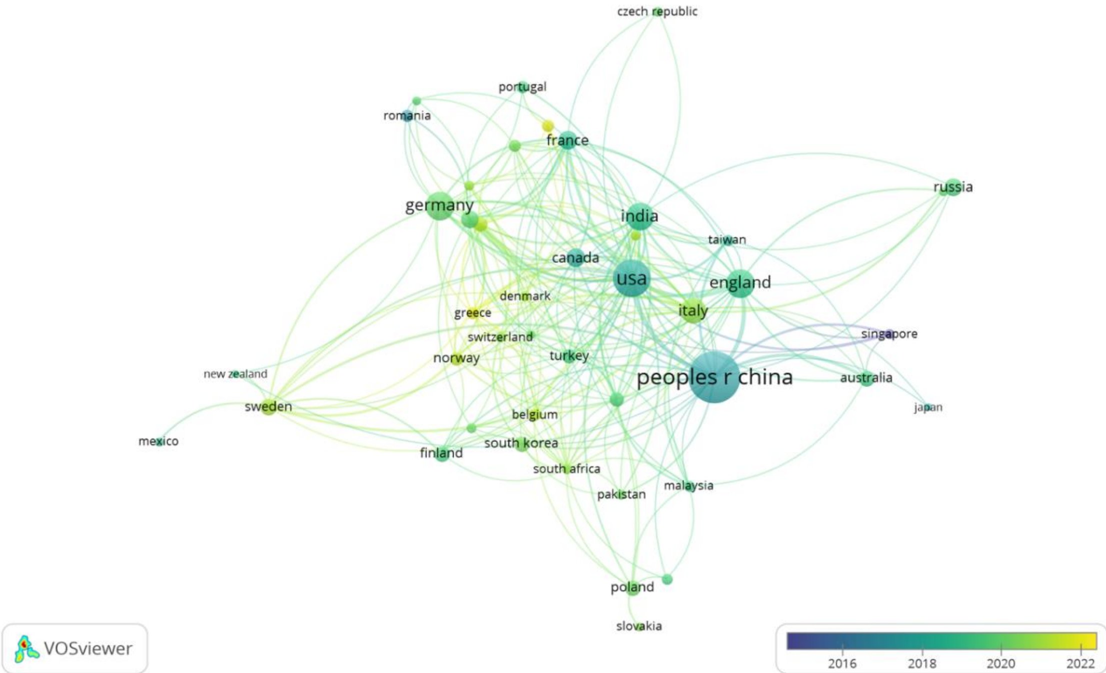

Fig 10 – Co-authorship analysis on countries

Source – Created using VOSviewer

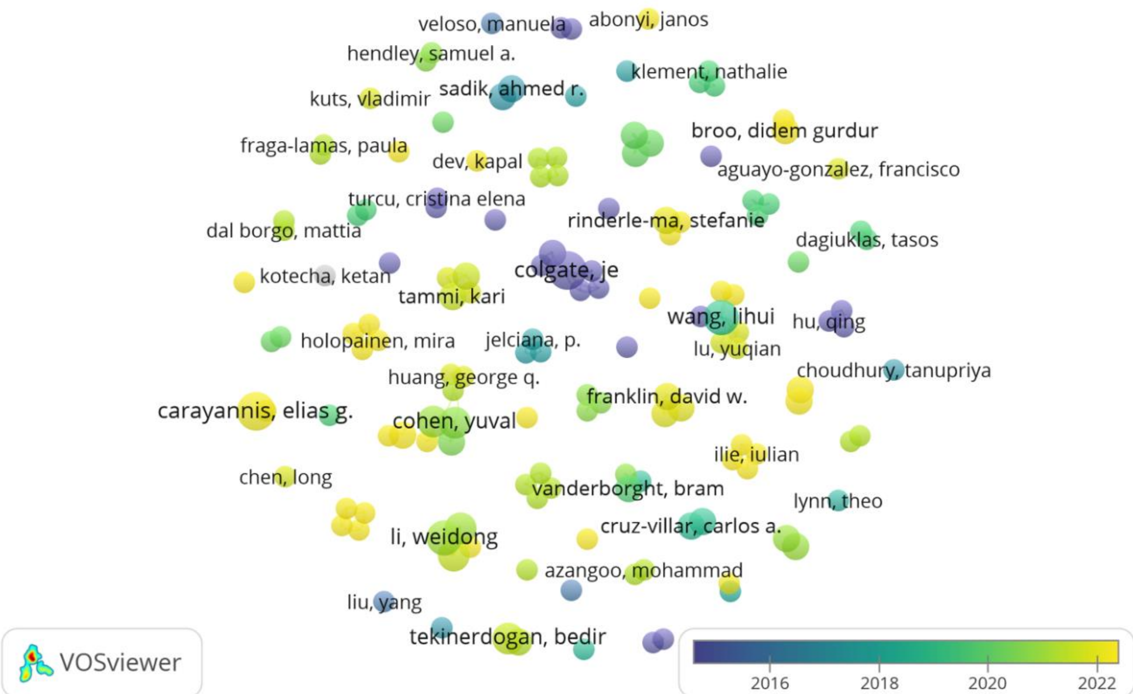

Fig 11 – Co-authorship analysis for Authors

Co-word (co-occurrence) analysis

Co-word analysis, as suggested by its name, is a method designed to discern relationships between words, or more specifically, 'author keywords' (Luc, et al., 2020). In their research, (Donthu, et al., 2021) articulate that co-word analysis fundamentally examines the content of papers, as opposed to merely focusing on the major constituents.

In doing so, it extends its analysis to encompass words that fall within the future research scope and limitations of the articles. This analytical approach opens up the potential to pinpoint themes for future research endeavors. In the context of this study, when co-word analysis was performed on all keywords, the resulting visualization is depicted in Figure 12. This analysis provides a compelling visualization of the connections between the diverse range of keywords used in the collected literature. By revealing these associations, it equips researchers with insights that can be instrumental in identifying and exploring novel research directions. It is through this lens that the role of co-word analysis extends beyond simple analysis, serving as a strategic tool for future research planning.

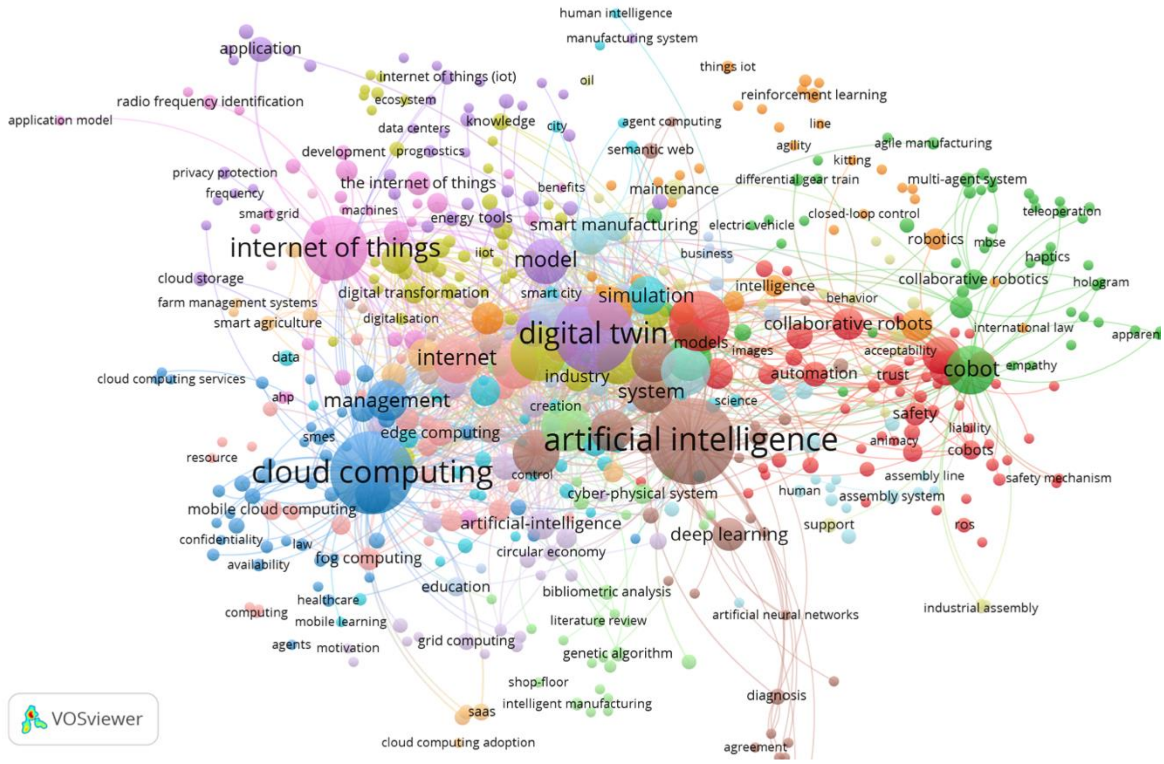

Fig 12 – Co-word analysis of Articles

Source – Created using VOSviewer

This particular analysis has led to the discovery of numerous novel keywords that could serve as focal points for future studies. In essence, citation analysis illuminates past work, bibliographic coupling unveils the present research endeavours of authors, while co-word analysis foreshadows potential future research themes (Donthu, et al., 2021). Indeed, the value of co-word analysis transcends the boundaries of individual studies. It functions as a pivotal instrument that can assist in the identification of relationships and intersections between various domains and Industry 5.0 technologies.

By applying this methodology, a more nuanced understanding of the thematic landscape can be obtained, within which these technologies are embedded. Additionally, this understanding can provide pivotal guidance when outlining the trajectory of future research within this rapidly evolving field.

Findings

Bibliometric analysis is performed in the studies to cater to the specific aims of the said study. In this paper the aims of the study were 1) Execute a bibliometric analysis focusing on the realm of Industry 5.0 and its associated technological advancements. 2) Explore the domains in which these technologies are frequently employed. 3) To discern and delve into both the precedent and emergent research themes that define the evolving sphere of Industry 5.0.

For this purpose the Performance analysis and Science mapping were implemented on the data of 899 scholarly articles gathered from WoS.

The performance analysis was done using Web of Science. Based on the data gathered in Fig 4 the bar chart indicates the number of publications and citations per year. The bar chart reveals the increase in publications and citations over time. In 2002 the citations and publications were as low as 0 & 3 respectively. Both saw a slow rise in numbers over the years.10 years later in 2012 the citations and publications had risen to 160 & 23 respectively. After that a steep increase in the quantity of research can be seen over the years. In 2022 the number of citations and publications are comparatively

higher. According to the data gathered the number of citations and the publications are 3406 & 219 respectively and rising. This shows that has been an increase of research regarding technological innovations and industry 5.0.
Table 2 lists the top 10 authors that were cited the most according to the data gathered for the study. In this list there is no Indian author. This indicates that there needs to be an increase in scholarly research regarding industry 5.0 and new innovations by Indian researchers.
Table 3 lists the top 10 most research upon topics based on the data gathered. Out of these 10 only two technologies i.e. artificial intelligence and robotics are related with industry 5.0. This means although there is an increase in the research there is still a lot of scope for further research on different technologies and industry 5.0. (Kent & Kopacek, 2020) infer in their paper that industrial revolutions have been beneficial in the progress of humanity's well-being, and so will the industry 5.0. People need to concentrate more on the benefits of the revolution and find ways to minimise the negative aspects of it.
Next step in bibliometric analysis is Science mapping. It is analysing and making sense of the data. There are many techniques to perform science mapping. All five of them were performed using VOSviewer in this study. The resulting maps were depicted in the implementation section of the paper.
First citation analysis was performed. The citation analysis of countries shows what countries were cited more and what were cited less. It can be inferred from the map based on the data that countries like U.S.A. and China have more contribution to the research in the area of industry 5.0. In the map it can be clearly seen that there is still a need for more research from India, as India is behind in being cited from many countries like U.S.A. and China. The map shows that many other countries are behind as well. The analysis shows that there needs to more eminent research in this area from around the world if the negative impacts of industry 5.0 are to be diminished.
The second type of analysis that can be done in science mapping is co-citation analysis. A co-citation analysis reviews the references that have been cited together. For this study co-citation analysis was performed on publication titles. This was done to better understand the themes in which the research is being carried out the most. In Fig 8 refers to the map resulting from this analysis. The publications that can be seen clearly on the map are IEEE access, International journal of production research, Sensors, Robotics and computer integrated manufacturing, Sustainability etc….
This information can provide the papers that are affiliated with these publications. According to the data gathered Sensors publication publishes papers related digital twins, cobots and edge computing etc,. Sustainability publishes papers related to cloud computing, cobots, cloud computing etc,. Similarly International journal of production research publishes about industry 5.0, block chain, digital twins etc, and IEEE access about artificial intelligence, industry 5.0, digital twins, cloud computing, machine learning etc.
This shows that the major themes research is mostly clustered around are : industry 5.0, cloud computing, artificial intelligence, digital twins, edge computing, cobots, block chain, machine learning, fog computing.
The bibliographic coupling is used to identify the themes papers are related to by studying the papers that are thematically similar (Li, et al., 2022). Bibliographic coupling uses citing documents rather than cited documents, therefore, researchers could use it to identify publications that are niche and identify the possible upcoming future research themes. For this study bibliographic coupling of publications was done. The analysis is done by analysing when two articles cite same papers. In the resulting map based on the data, clear clusters of publications can be seen. These different clusters are thematic in nature. The smaller clusters are thematic too and can be seen as upcoming coherent research themes.

The following themes were identified:

- Digital twins, machine learning, cobots
- Industry 5.0 and technologies
- Artificial intelligence
- Applications of industry 5.0 and technologies
- Research & understanding of Internet of things
- Application of industry 5.0 to find sustainable, eco-friendly solutions to humanity's problems.
- Transition from industry 4.0 to industry /society 5.0

The above themes could be referred for future research.
Co-authorship analysis is a different type of analysis under bibliometric analysis. It is very different from co-citation and bibliographic coupling. For the purpose of this paper co-authorship analysis was done on countries and what countries have been involved recently or what countries were involved a couple years ago was analysed. According to the map in Fig 9 timeline is explained. The authors from countries Greece, Norway etc have been involved more recently in the research on industry 5.0 and technologies. Authors from USA and China were publishing more papers in the area in 2018 -2020. India was publishing in this area more in 2020.
The co-authorship analysis for authors is a completely different story. Instead of one big map it consists of multiple small thematic clusters. Each cluster consists of a few authors. Largest one consists of 9 authors. Referring to map according to colour grading let's look at the research themes in the area of industry 5.0.

Following are the most recent themes identified:
- Applications of digital twins
- Use of Quintuple Helix Model in industry 5.0 for sustainable economies
- Transition towards industry 5.0 using cobots for better productivity
- Collaborative social robots (Co-s-bots)
- Application of digital twins in architecture
- Industry 5.0 in pharmaceutical sector
- Research on Uncertainty in the application of industry 5.0
- Use of cobots in Job Shop Scheduling/manufacturing
- Transition from industry 4.0 to industry 5.0
- Smart digital solutions using industry 5.0 for Safety and Health 5.0

Some themes from around 2020-2021 :
- Application of digital twins across plethora of industries
- Concept on industry 4.0 and 5.0
- Edge computing & Digital twins for smart manufacturing
- Digital twin web
- Acclimating cobots to same level of skill, experience and using Electroencephalography (EEG) technology for similar emotional state
- Cobots for order batching in assembly line
- Use of Iot and edge computing for enhance networks for reliable communications

Pre-covid era themes(2015-2019):
- Cloud computing
- Passive human-interactive robots
- Social internet of things in healthcare
- Use of industry 5.0 in computer authentication protocols
- Transformable cobots

Co-word analysis was selected for this study to identify the linkages between different industries and industry 5.0 technologies. Fig 12 shows the map created using VOSviewer for co-word analysis.
Artificial intelligence is linked with higher education, augmented reality, diagnosis, digitization, privacy, etc. Cloud computing is found to be linked with education, data mining, resource management, etc. Internet of things is associated with computer architecture, market research, big data, etc. Internet of things, cobots, digital twins, artificial intelligence are all associated with additive manufacturing. Internet of things, digital twins and artificial intelligence are associated with smart manufacturing. Architecture in linked with internet of things, AI, digital twins, quantum computing and cloud computing. Data security is also associated with cloud computing. Health-care industry is also linked with technologies from industry 5.0. Like for precision medicine artificial intelligence, or for teleoperations use of cobots. One of the emerging technologies is 6g which is linked with all digital twins, big data, artificial intelligence, and internet of things.

Discussion

The principal focus of this study was to discern and delve into both the precedent and emergent research themes that define the evolving sphere of Industry 5.0. It was done by using bibliometric analysis as an analysis method. The analysis has revealed several significant themes in both recent and pre-Covid research, painting a comprehensive picture of the evolving research landscape in this field.
The findings show a strong emphasis on the application of advanced technologies such as Digital Twins, cobots, and AI across various industries. These technologies are highlighted in the research themes from all the three eras - pre-Covid (2015-2019), around 2020-2021, and the most recent (2022). This underscores the continuing influence of these technologies in shaping the future of Industry 5.0. Moreover, the emergence of the Quintuple Helix Model, the focus on Industry 5.0's contribution to sustainable development, and the emphasis on human-robot collaboration reflect the broader societal implications of this transition from Industry 4.0 to Industry 5.0. In comparing the findings with those of prior research, it was noted that the emphasis on advanced technologies and human-robot collaboration aligns with the broader narrative in the field of Industry 5.0. However, the analysis also brings forth several novel themes.

An examination of the research landscape from 2015 to 2019 reveals distinct themes that were prevalent during this period:
This study delves deep into the themes that defined the pre-COVID era, from 2015 to 2019. One of the prominent themes during this period was Cloud Computing. The transformative power of cloud computing - with its ability to offer access

to data and software via the internet instead of a local server - has been a significant driver for the development of Industry 4.0, laying the groundwork for the subsequent digital transformations that are witnessed today (Mathur & Nishchal, 2010).

Another prominent theme during this period was Passive Human-Interactive Robots, designed to seamlessly interact with humans in a shared environment without requiring direct input. This theme underscores the initial stages of the collaborative robotic revolution, aligning with the human-centric approach of Industry 5.0 (Worsnopp, et al., 2006). The implications for healthcare, such as streamlined patient monitoring and smarter health management systems, prefigured the significant role IoT plays in today's Industry 5.0 landscape (Miori & Russo, 2017).

Moreover, the potential use of Industry 5.0 in enhancing computer authentication protocols emerged as a theme during this era. The integration of Industry 5.0 technologies, such as AI-driven systems and biometric sensors, in these protocols could offer more secure and personalized methods of user authentication (Mbunge, et al., 2022). Lastly, the concept of 'Transformable Cobots', capable of adapting their physical properties for various tasks and work environments, was a significant theme (Wannasuphoprasit & Chanphat, 2005). This area of study underscored the exploration into advanced robotic technologies that could coexist and synergize with humans in a shared workspace, setting the foundation for the increased integration of cobots in the current state of Industry 5.0.

An exploration of the research themes that were predominant in the period from 2020 to 2021:

One of the significant research focuses of this period was the application of Digital Twins across a vast array of industries (Holmes, et al., 2021). Digital Twins, virtual representations of physical systems, found increased acceptance in diverse fields, ranging from healthcare to city planning. A notable research theme that dominated academic discourse during this period was the concept and implications of transitioning from Industry 4.0 to 5.0. This transition, marked by a shift from automation and data exchange in manufacturing technologies towards a more integrated, human-robot collaboration, was the subject of intense scrutiny and examination (Demir, et al., 2019). Edge Computing, in conjunction with Digital Twins, emerged as a key enabler of smart manufacturing. When integrated with Digital Twins, it enhances monitoring and control of manufacturing processes, paving the way for smart factories, a central tenet of Industry 5.0 (Dong, et al., 2019). Another notable research focus was the interconnection of Digital Twins, or a 'Digital Twin Web'. This network of interactive, virtual models creates an integrated environment where changes to one twin trigger corresponding effects on others, a defining characteristic of Industry 5.0 (Holmes, et al., 2021). During this period, research also focused on developing cobots with similar skills, experience, and emotional states as humans. This theme underscored the evolution of cobot technology towards more sophisticated, human-centric functionality (Nahavandi, 2019). In addition, the practical application of cobots in industrial processes, such as order batching in assembly lines, emerged as a significant research theme. Lastly, the merging of IoT and Edge Computing for enhanced communication networks was a significant theme during this period. This confluence improved real-time data exchange, device connectivity, and overall network reliability—all critical facets of Industry 5.0 (Du, et al., 2022).

Further insights into the evolution of Industry 5.0 can be gained by examining the research themes that have emerged in 2022:

The application of Digital Twins, virtual replicas of physical systems, continued to be a significant theme, albeit with a broader focus. A new theme that has gained traction in 2022 is the application of the Quintuple Helix Model within the context of Industry 5.0. This model represents a five-dimensional approach encompassing knowledge, innovation, and the environment to foster sustainable development (Carayannis & Jancelewicz, 2021). Researchers are now exploring how the co-evolution of these elements could contribute to a more sustainable economy in an era defined by advanced automation and human-machine cooperation. Cobots, or collaborative robots, remain central to the ongoing transition towards Industry 5.0, with research focusing on their potential to enhance productivity in a variety of industrial contexts. The exploration of how cobots can co-exist and co-operate with humans in shared workspaces to optimize operational outcomes has been a major focus (Nahavandi, 2019).

In 2022, interest in Collaborative Social Robots (Co-s-bots) has intensified. These robots are designed to work alongside humans not only in physical tasks but also in social interactions. The use of digital twins in architecture emerged as a significant research theme. Their application in architectural design and building management can yield numerous benefits, such as simulating structural responses, optimizing energy use, and enhancing maintenance and operation processes (Cusano, 2022). Another notable theme is the integration of Industry 5.0 technologies in the pharmaceutical sector. This traditionally protocol- and expertise-driven field has begun to embrace elements like digital twins, AI, and cobots, potentially enhancing drug development, production efficiency, and personalized medicine (Sharma, et al., 2022). Researchers in 2022 have also been addressing the uncertainties and challenges associated with the application of Industry 5.0, indicating a growing awareness of potential risks and the need for effective management strategies (Sharma, et al., 2022).

The use of cobots in complex manufacturing processes, such as Job Shop Scheduling, has also been investigated (Kinast, et al., 2022). By working in tandem with human operators, cobots could potentially increase productivity, improve flexibility, and minimize operational errors. Finally, the pursuit of smart digital solutions using Industry 5.0 for Safety and Health 5.0 has continued into 2022. Research in this area has explored how advanced digital solutions, including IoT, AI, and digital twins, can contribute to safer workplaces and healthier populations in the Industry 5.0 era (Du, et al., 2022).

Bibliometric coupling analysis has yielded several distinct, yet interrelated, thematic clusters, each offering unique insights into the evolving landscape of Industry 5.0:

1. **Digital Twins, Machine Learning, Cobots:** This theme delineates the convergence of digital twins, machine learning, and cobots within an industrial setting, underscoring their increasing prominence in both scholarly research and practical applications (Pizoń, et al., 2022). Each of these technologies brings unique capabilities: digital twins create precise virtual models of physical systems, machine learning provides data-driven predictive capabilities, and cobots offer flexible automation (Karaarslan & Babiker, 2021). Together, they create an integrated system where precise modelling, data-driven predictions, and responsive automation could revolutionize industries, particularly manufacturing (Karaarslan & Babiker, 2021).

Digital twins and machine learning combined can improve prediction accuracy and system efficiency. Digital twins provide a safe environment for testing machine learning algorithms, while machine learning can enhance digital twins with predictive capabilities (AHMED, et al., 2022). This creates a dynamic model that not only replicates the current state of the physical system, but also predicts future states.

Cobots are designed to work collaboratively with humans, offering flexibility that traditional industrial robots lack (Saldaña, et al., 2019). When powered with machine learning, cobots can adapt to varying tasks and environments, learning from human operators and improving over time. Studies on machine learning-powered cobots could be valuable to understand their current capabilities and limitations (Aliev & Antonelli, 2021).

The integration of digital twins and cobots is another promising area. Digital twins can simulate cobots' operations, providing valuable insights into system optimization before physical implementation (Malik & Bilberg, 2018). Research is needed to understand how real-time feedback from cobots can be effectively incorporated into digital twins for ongoing system optimization.

Despite the potential benefits, challenges persist. Machine learning models' explainability and trustworthiness are perennial concerns, particularly in safety-critical applications. Digital twins' accuracy depends on data quality and model assumptions, and cobots' safety and effectiveness in human-robot collaboration need rigorous testing and standardization. Further research can focus on addressing these challenges (Koshiyama , et al., 2022) (Sirigu, et al., 2022) (Saldaña, et al., 2019). Future research might also focus on standardization and interoperability among these technologies, as their benefits are most pronounced when they are integrated. With no one-size-fits-all solution, customization and adaptability to specific industry needs are crucial.

2. **Industry 5.0 and Emerging Technologies:** This theme emphasizes the transformative role of technology in shaping the contours of Industry 5.0, highlighting the influence of advances in automation, data analytics, and human-robot collaboration (Ahmad , et al., 2022) (Hunter , et al., 2022).

By integrating human creativity and decision-making with advanced digital technologies, Industry 5.0 emphasizes the co-existence and collaboration between humans and intelligent systems (Saniuk, et al., 2022).

Emerging technologies, such as Artificial Intelligence (AI), the Internet of Things (IoT), blockchain, quantum computing, and advanced robotics, are fundamentally reshaping the industrial landscape (O¨zdemir & Hekim, 2018). When viewed through the lens of Industry 5.0, these technologies can be harnessed to augment human capabilities, encourage more sustainable practices, and create more personalized products and services (Aslam, et al., 2020). Future research might focus on developing models and frameworks for integrating these technologies within the Industry 5.0 context.

IoT will likely enable more effective collaboration between human workers and smart devices, while blockchain could offer greater transparency and security in the supply chain. Quantum computing promises exponential improvements in data processing and problem-solving capabilities (Pilevari & Yavari, 2020). Studies that examine the role and potential of these technologies in the Industry 5.0 paradigm would be highly valuable (Saldaña, et al., 2019).

Technical issues, such as ensuring reliable and secure data exchange among intelligent systems, need to be addressed. Ethical issues concerning job displacement and privacy are also major concerns. Equally important are regulatory and standardization challenges to ensure safe and equitable technology deployment. Research addressing these challenges will be crucial to pave the way for the successful realization of Industry 5.0 (Günther, et al., 2017) (Alter, 2020).

3. **Role of Artificial Intelligence:** This theme delves into the exploration of AI's function and implications across various sectors, reaffirming its central role in steering the trajectory of the industrial future (Hunter , et al., 2022) (Ahmad , et al., 2022).

The role of AI in today's digital age extends far beyond the realm of technology alone. From healthcare, where AI algorithms can predict disease patterns and aid in diagnostics (Kumar, et al., 2023), to education where personalized learning pathways can be created, the influence of AI is profound (Luckin & Cukurova, 2019). In the business world, AI is driving innovation in sectors such as finance, retail, and logistics, optimizing operations, reducing costs, and improving customer experiences (Makar, 2023).
AI's ability to process vast amounts of data and extract meaningful insights is at the heart of this transition. With advanced techniques such as machine learning and deep learning, AI is being leveraged for predictive analytics, decision-making, and trend forecasting, among other applications (Kuziemski & Misuraca, 2020). However, the deployment of AI also poses significant challenges. Ethical considerations, data privacy concerns, the risk of job displacement, and the need for human oversight and explainability are key issues that need to be addressed (Lee, 2020). Future research should aim to tackle these challenges, focusing on creating ethical AI frameworks, designing privacy-preserving AI models, and exploring the human-AI interaction paradigm.

4. **Application of Industry 5.0 Technologies Across Sectors:** This theme investigates the widespread deployment of Industry 5.0 technologies across diverse sectors, asserting their potential to revolutionize traditional processes and systems (Leng, et al., 2022).

The application of Industry 5.0 technologies extends far beyond the manufacturing sector. Industries such as healthcare, agriculture, logistics, education, and entertainment have all begun leveraging these technologies, melding human creativity and decision-making with machine precision and efficiency (Maddikunta, et al., 2021). For instance, in healthcare, smart devices and AI-powered systems are being used to personalize patient care, while in agriculture, Industry 5.0 technologies enable precision farming and sustainable practices (Rubini & Kavitha, 2021). Similarly, education and entertainment sectors are leveraging these technologies for personalized learning experiences and immersive entertainment (Maddikunta, et al., 2021).
The benefits of applying Industry 5.0 technologies across these sectors are profound. Improved efficiency, enhanced product or service quality, personalized experiences, and greater sustainability are some of the key benefits (Nahavandi, 2019). Future research could delve deeper into quantifying these benefits and developing frameworks to maximize them. However, issues of data privacy and security, the need for significant infrastructure investment, the upskilling of the workforce, and ethical considerations are just a few of the challenges that need to be addressed (Coronado, et al., 2022). Research that focuses on mitigating these challenges will be instrumental in unlocking the full potential of Industry 5.0 technologies.
Adopting these technologies requires businesses to embrace a culture of collaboration, innovation, and continuous learning. Studies focusing on this cultural transformation and strategies to facilitate it will be highly valuable (Haddud & McAllen, 2018).

5. **Exploration and Impact of the Internet of Things (IoT):** This cluster concentrates on the ongoing evolution and consequential impact of IoT, a pivotal technology driving the advent of Industry 5.0 (Kumar , et al., 2022).

The advent of Internet of Things (IoT) has opened avenues for unprecedented connectivity and data-driven decision-making across a multitude of sectors (Kavitha & Chinnasamy, 2021). From Smart Homes that optimize energy use and enhance security, to Industrial IoT that improves operational efficiency and product quality, the applications are vast and continually growing. Healthcare, agriculture, transportation, and even urban planning have started harnessing the power of IoT for improved outcomes and sustainability (Zeadally & Bello, 2021).
Yet, IoT is not without its challenges. Data security and privacy are pressing concerns, given the vast amount of sensitive information IoT devices can collect and transmit (Rustam, et al., 2023). Interoperability and standardization are also significant hurdles, with a diverse range of devices and systems needing to communicate seamlessly (Alcaraz & Lopez, 2022). Furthermore, ethical and societal implications, including job displacement due to automation and digital divides, warrant careful consideration (Mbunge, et al., 2022). In a study (Sundaresan & Durai, 2018) the authors refer to the risks of increasing workloads in multi-core heterogeneous architectures and the complexities faced by users in the context of the Internet of Things, which can lead to challenges in effective implementation, higher energy consumption, and performance issues. Future research also needs to focus on developing robust IoT frameworks that are secure, scalable, and sustainable (Chen & Zhu, 2019). Exploring novel data analytics techniques to handle the massive data generated by IoT devices will be crucial (Alvarez, et al., 2021). Additionally, research focusing on the ethical and societal implications of IoT will help inform guidelines and regulations to ensure equitable benefits (Mbunge, et al., 2022).

6. **Industry 5.0's Contribution to Sustainable and Eco-friendly Solutions**: This theme emphasizes the growing recognition of Industry 5.0 as a potent tool to tackle ecological challenges and foster sustainable development, representing an integration of industrial progress and environmental responsibility (Kasinathan, et al., 2022).

The fifth industrial revolution, Industry 5.0, integrates humans and machines more closely than ever before, emphasizing the value of human creativity, judgment, and craftsmanship alongside automation (ElFar, et al., 2021). By marrying these elements, Industry 5.0 technologies can provide innovative pathways for sustainability, presenting opportunities to minimize waste, maximize efficiency, and create eco-friendly solutions (Leng, et al., 2022).

Specific applications of Industry 5.0, such as advanced robotics, AI, IoT, and digital twins, are being used to drive sustainable solutions. For instance, cobots (collaborative robots) can operate alongside human workers in manufacturing processes, enabling precision and minimizing waste (Aliev & Antonelli, 2021) (Saldaña, et al., 2019). AI and IoT can optimize energy usage and production processes, reduce carbon footprints, and monitor environmental parameters in real-time (Maddikunta, et al., 2021) (Zeadally & Bello, 2021). Digital twins offer virtual environments for testing eco-friendly practices without disrupting actual processes (AHMED, et al., 2022).

Despite its potential, implementing Industry 5.0 for sustainability is not without its challenges (Mbunge, et al., 2022). These include technological hurdles such as interoperability and data security, ethical issues related to job displacement and privacy, and economic concerns over significant investment costs (Alcaraz & Lopez, 2022).

Industry 5.0 also emphasizes the importance of a circular economy, where waste is minimized, and resources are reused and recycled. This marks a promising direction for sustainable and eco-friendly solutions. Future research could focus on exploring ways to leverage Industry 5.0 technologies to facilitate the transition towards a circular economy (Dwivedi, et al., 2023).

7. **Progression from Industry 4.0 to Society/Industry 5.0:** This cluster illuminates the journey from Industry 4.0 to Industry 5.0, shedding light on the multifaceted challenges and opportunities inherent in this transition (Lu, et al., 2022). The technologies associated with Industry 4.0, such as Artificial Intelligence, have raised questions among researchers regarding their impact on the society and planet, particularly in the absence of a human element. These concerns about Industry 4.0 have brought Industry 5.0 into the spotlight. Authors describe Industry 5.0 as a means to continue building technology without compromising sustainable innovation and a human-friendly future (O ̈zdemir & Hekim, 2018).

In the research conducted by (Nahavandi, 2019), the notion of Industry 5.0 is delved into. The researcher projects a future in which Industry 5.0 harmonizes AI with environmental stewardship, leading to practical and effective tech-based solutions. More precisely, the goal of Industry 5.0 is to delegate monotonous tasks in the manufacturing chain to automation, thereby reserving creative functions for humans.

The aforementioned themes illustrate potential avenues for further research exploration. As Industry 5.0 continues to advance, these themes are likely to expand, converge, or diverge in accordance with the dynamic nature of this evolving field. Therefore, it is imperative for both academic researchers and industry practitioners to maintain a close watch on these thematic developments to stay abreast of emerging trends and opportunities within the realm of Industry 5.0.

Limitations

A software other that VOSviewer could be used. More techniques could be used for further analysis. Research was done on industry 5.0 in totality, but it could be done on individual technologies. The study relied on available literature, which may not encompass all possible information on the subject. Although thematic analysis is a robust method for identifying themes, there is an element of subjectivity involved. Different researchers might identify different themes or interpret the same themes differently. Given the rapid pace of advancement in technologies related to Industry 5.0, some findings of this study might become outdated quickly. The themes identified are reflective of the time of the study and may not remain entirely relevant as new technologies and trends emerge.

Scope for future Research

More upcoming themes revealed in the study findings could be researched upon. Bibliometric analysis could be performed on research regarding individual technologies. Given the rapid evolution of Industry 5.0, it would be valuable to conduct similar studies periodically to track the shifting and emerging themes over time. A future research direction could involve assessing the impact of the adoption of Industry 5.0 technologies on various industry metrics, such as productivity, efficiency, sustainability, and worker satisfaction. Future research could explore this further, potentially developing strategies for mitigating these uncertainties and risks. The role of upcoming technologies not yet fully developed or integrated into Industry 5.0 could be another interesting area for future research.

References

1. Aceta, C., Fernández, I. & Soroa, A. (2022), “KIDE4I: A Generic Semantics-Based Task-Oriented Dialogue System for Human-Machine Interaction in Industry 5.0”, Applied Sciences, Vol. 12 No. 3, article no. 1192 [no pagination]
2. Ahmad , S F. et al. (2022), “Academic and Administrative Role of Artificial Intelligence in Education”, Sustainability, Vol. 14 No. 3, article no. 1101 [no pagination]

3. AHMED, I., AHMAD, M., JEON, G. (2022), "Integrating digital twins and deep learning for medical image analysis in the era of COVID-19", Virtual Reality & Intelligent Hardware, Vol. 4 No. 4, pp. 292-305
4. Alcaraz, C., Lopez, J. (2022), "Digital Twin: A Comprehensive Survey of Security Threats", IEEE Communications Surveys & Tutorials, Vol. 24 No. 3, pp. 1475-1503
5. Ali, O., Shrestha, A., Osmanaj, V. & Muhammed, S. (2021), "**Cloud computing technology** adoption: an evaluation of key factors in local governments", Information Technology & People, Vol. 34 No. 2, pp. 666-703
6. Aliev , K., Antonelli, D. (2021), "Proposal of a Monitoring System for Collaborative Robots to Predict Outages and to Assess Reliability Factors Exploiting Machine Learning", Applied Sciences, Vol. 11 No. 4, [no pagination]
7. Alter, S. (2020), "How Facets of Work Illuminate Sociotechnical Challenges of Industry 5.0", Proceedings of ECIS, School of Management at USF, Marrakesh, Morocco
8. Alvarez, Y., Leguizamón, M., Londoño, T. (2021), "Risks and security solutions existing in the Internet of things (IoT) in relation to Big Data", Ingeniería y Competitividad, Vol. 23 No. 1, [no pagination]
9. Aslam, F., Aimin , W., Li , M. & Rehman, K. U. (2020) "Innovation in the Era of IoT and Industry 5.0: Absolute Innovation Management (AIM) Framework", Information, Vol. 11 No. 2, article no. 124 [no pagination]
10. Bhatt, Y., Ghuman, K. & Dhir, A. (2020), "Sustainable manufacturing. Bibliometrics and content analysis", Journal of Cleaner Production, Vol. 260 No. 7, article no. 120988 [no pagination]
11. Broadus, R. N. (1987), "Toward A Definition Of "Bibliometrics"", Scientometrics, Vol. 12, pp. 373-379
12. Broadus, R. N. (1987), "Toward A Definition Of "Bibliometrics"", Scientometrics, [no pagination]
13. Carayannis, E. G. & Jancelewicz, J. M. (2021), "The Futures of Europe: Society 5.0 and Industry 5.0 as Driving Forces of Future Universities", Journal of the Knowledge Economy, Vol. 13 No. 4.
14. Chen, J., Zhu, Q. (2019), "Interdependent Strategic Security Risk Management With Bounded Rationality in the Internet of Things", IEEE Transactions On Information Forensics And Security, Vol. 14 No. 11, pp. 2958-2971
15. Coronado, E. et al. (2022), "Evaluating quality in human-robot interaction: A systematic search and classification of performance and human-centered factors, measures and metrics towards an industry 5.0", Journal of Manufacturing Systems, Vol. 63, pp. 392-410.
16. Cusano, N. (2022), "Cobot and Sobot: For a new Ontology of Collaborative and Social Robots", *Foundations of Science*, pp. 1-13.
17. Demir, K. A., Döven, G. & Sezen, B. (2019), "Industry 5.0 and Human-Robot Co-working" 3rd World Conference on Technology, Innovation and Entrepreneurship (WOCTINE), Vol. 158, pp. 688-695
18. Dong, R. et al. (2019), "Deep Learning for Hybrid 5G Services in Mobile Edge Computing Systems: Learn From a Digital Twin", IEEE Transactions on Wireless Communications, Vol. 18 No. 10, pp. 4692-4707
19. Dong, X., Chang, Y., Wang, Y. & Yan, J. (2017), "Understanding usage of Internet of Things (IoT) systems in China", **Information Technology** & **People**, 2017, Vol. 30 No. 1, pp. 117-138
20. Donthu, N. et al. (2021), "How to conduct a bibliometric analysis: An overview and guidelines", Journal of Business Research, Vol. 133, pp. 285-296
21. Du, A. et al. (2022), "CRACAU: Byzantine Machine Learning Meets Industrial Edge Computing in Industry 5.0", IEEE Transactions On Industrial Informatics, Vol. 18 No. 8, pp. 5435 – 5445
22. Dwivedi, A. et al. (2023), "Studying the interactions among Industry 5.0 and circular supply chain: Towards attaining sustainable development", Computers & Industrial Engineering, Vol. 176, article no. 108927 [no pagination]
23. ElFar, O. A. et al. (2021), "Prospects of Industry 5.0 in algae: Customization of production and new advance technology for clean bioenergy generation", Energy Conversion and Management: X, Vol. 10, article no. 100048 [no pagination]
24. Fairthorne, R. A. (1969), "Empirical Hyperbolic Distributions (Bradford-Zipf-Mandelbrot) for Bibliometric Description and Prediction", Journal of Documentation, Vol. 25 No. 4, pp. 319-343
25. Fatima, Z. et al. (2022) "Production Plant and Warehouse Automation with IoT and Industry 5.0", Applied Sciences, Vol. 12 No. 4, article no. 2053 [no pagination]
26. Fedorov, A. A., Liberman, I. V., Koryagin, S. I. & Klachek , P. M. (2021), "Neuro-Digital Ecosystem Design Technology For The Implementation Of The Industry 5.0 Concept", Научно-технические ведомости СПбГПУ, Vol. 14 No. 3, pp. 19-39
27. Frederico, G. F. (2021), "From Supply Chain 4.0 to Supply Chain 5.0: Findings from a Systematic Literature Review and Research Directions", Logistics, Vol. 5 No. 3, article no. 49 [no pagination]
28. Günther, W. A. et al. (2017), "Debating big data: A literature review on realizing value from big data", Journal of Strategic Information Systems, Vol. 26, pp. 191-209
29. Haddud, A., McAllen, D. (2018), "Digital Workplace Management: Exploring Aspects Related to Culture, Innovation, and Leadership", IEEE, Honolulu, HI, USA
30. Heradio, R. et al. (2016), "A Bibliometric Analysis of 20 Years of Research on Software Product Lines", Information and Software Technology, Vol. 72, pp 1-15
31. Holmes, D. et al. (2021), "Digital Twins and Cyber Security – solution or challenge?" South-East Europe, IEEE, [no pagination]

32. Hunter , B. et al. (2022). "The Role of Artificial Intelligence in Early Cancer Diagnosis", Cancers, Vol. 14 No. 6, pp. 1524.
33. Joseph, P. R. B. & Ezhilmaran, D. (2018), "A secured green computing technique for sustainable information technology using fuzzy classified finger vein biometrics", World Review of Science, Technology and Sust. Development, Vol. 14 No. 4, pp. 359-375
34. Karaarslan, E., Babiker M. (2021), "Digital Twin Security Threats and Countermeasures: An Introduction", IEEE, International Conference on Information Security And Cryptology, Ankara-Turkey, pp. 7-11.
35. Kasinathan, P. et al. (2022), "Realization of Sustainable Development Goals with Disruptive Technologies by Integrating Industry 5.0, Society 5.0, Smart Cities and Villages", Sustainability, Vol. 14 No.22, article no. 15258 [no pagination]
36. Kavitha, D., Chinnasamy, A. (2021), "Ai Integration in Data Driven Decision Making for Resource Management in Internet of Things(Iot): A Survey", IEEE, Jaipur, India
37. Kent, M. D. & Kopacek, P. (2020), "Industry 5.0: Is the Manufacturing Industry on the Cusp of a New Revolution?", Proceedings of the International Symposium for Production Research, Vol. 1, pp. 432 - 441.
38. Kinast, A. et al. (2022), "Combining metaheuristics and process mining: Improving cobot placement in a combined cobot assignment and job shop scheduling problem", Procedia Computer Science, Vol. 200, pp. 1836-1845.
39. Koshiyama , A., Kazim, E. & Treleaven, P. (2022), "Algorithm Auditing: Managing the Legal, Ethical, and Technological Risks of Artificial Intelligence, Machine Learning, and Associated Algorithms", Computer, Vol. 55 No. 4 , pp. 40-50
40. Kumar , R. et al. (2022), "Exploring the Application Sphere of the Internet of Things in Industry 4.0: A Review, Bibliometric and Content Analysis", Sensors, Vol. 22 No.11, article no. 4276 [no pagination]
41. Kumar, P., Chauhan, S., Awasthi, L. K. (2023), "Artificial Intelligence in Healthcare: Review, Ethics, Trust Challenges & Future Research Directions", Engineering Applications of Artificial Intelligence, Vol. 120, article no. 105894, [no pagination]
42. Kuziemski, M., Misuraca, G. (2020), "AI governance in the public sector: Three tales from the frontiers of automated decision-making in democratic settings", Telecommunications Policy, Vol. 44 No. 6, article no. 101976, [no pagination]
43. Lee, J. (2020), "Industrial AI", Springer Singapore, Cincinnati, OH, USA, 1st edition
44. Leng, J. et al. (2022), "Industry 5.0: Prospect and retrospect", Journal of Manufacturing Systems, Vol. 65, pp. 279-295.
45. Li, H., Wu, M., Wang, Y. & Zeng, A. (2022), "Bibliographic coupling networks reveal the advantage of diversification in scientific projects", Journal of Informetrics, Vol. 16 No. 3, article no. 101321 [no pagination]
46. Lu, Y. et al. (2022), "Outlook on human-centric manufacturing towards Industry 5.0", Journal of Manufacturing Systems, Vol. 62, pp. 612-627
47. Luc, P. T., Lan, P. X., Le, A. N. H. & Trang, B. T. (2020), "A Co-Citation and Co-Word Analysis of Social Entrepreneurship Research", Journal of Social Entrepreneurship, Vol. 13 No. 1, pp. 1-16
48. Luckin, R., Cukurova, M. (2019), "Designing educational technologies in the age of AI: A learning sciences-driven approach", British Journal of Educational Technology, Vol. 50 No. 6, pp. 2824-2838
49. Maddikunta, K. et al. (2021), "Industry 5.0: A survey on enabling technologies and potential applications", Journal of Industrial Information Integration
50. Makar, Š. (2023), "Driven by Artificial Intelligence (AI) – Improving Operational Efficiency and Competitiveness in Business", IEEE, Opatija, Croatia
51. Malik, A. & Bilberg, A. (2018), "Digital twins of human robot collaboration in a production setting", Procedia Manufacturing, Vol. 17, pp. 278-285
52. Mathur, P. & Nishchal, N. (2010), "Cloud computing: New challenge to the entire computer industry", Solan, India, IEEE, [no pagination]
53. Mbunge, E. (2022), "Towards emotive sensory Web in virtual health care: Trends, technologies, challenges and ethical issues", *Sensors International,* Vol. 3, [no pagination]
54. Miori, V. & Russo, D. (2017), "Improving life quality for the elderly through the Social Internet of Things (SIoT)", Geneva, Switzerland, IEEE, [no pagination]
55. Nahavandi, S. (2019), "Industry 5.0—A Human-Centric Solution", Sustainability, Vol. 11 No. 16, article no. 4371 [no pagination]
56. Özdemir, V. & Hekim, N. (2018), "Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, ''The Internet of Things'' and Next-Generation Technology Policy", OMICS A Journal of Integrative Biology, Vol. 22 No. 1, pp. 65-76
57. OZKESER, B. (2018), "Lean Innovation Approach in Industry 5.0", ICRES 2018: International Conference on Research in Education and Science, Vol. 2, pp. 422-428
58. Paschek, D., Mocan, A. & Draghici, A. (2019) "Industry 5.0 – The Expected Impact Of Next Industrial Revolution", MakeLearn & Technology Innovation and Industrial Management International Conference 2019, pp. 125-132

59. Pilevari, N. & Yavari, F. (2020), "Industry Revolutions Development from Industry 1.0 to Industry 5.0 in Manufacturing", Journal of Industrial Strategic Management, Vol. 5 No. 2, pp. 44-63
60. Pizoń, J. et al. (2022), "The Role and Meaning of the Digital Twin Technology in the Process of Implementing Intelligent Collaborative Robots", Advances in Manufacturing III, pp. 39-49

61. Romanelli, J. P. et al. (2021), "Four challenges when conducting bibliometric reviews and how to deal with them", Environmental Science and Pollution Research, Vol. 28, pp. 60448-60458
62. Rubini, P.E. & Kavitha, P. (2021), "A comprehensive literature survey for deep learning approaches to agricultural applications", World Review of Science, Technology and Sustainable Development, Vol. 17 No. 2-3, pp. 279-293
63. Ruparelia, N. B. (2016), "Cloud Computing", The MIT Press, Cambridge Massachusetts, p. 280
64. Rustam, R., Bokhadir, A. & Uktam, R. (2023), "An Overcoming the Privacy Paradox: Legal Aspects of Data Protection in the Digital Age", International Journal of Cyber Law, Vol. 1 No. 4
65. Saldaña, M. et al. (2019), "Risks management and cobots. Identifying critical variables", Research Publishing Singapore, Hannover
66. Saniuk, S., Grabowska, S. & Straka, M. (2021), "Identification of Social and Economic Expectations: Contextual Reasons for the Transformation Process of Industry 4.0 into the Industry 5.0 Concept", Sustainability, Vol. 14 No. 3, article no. 1391, [no pagination]
67. Sharma, M. et al. (2022), "Moving Towards Industry 5.0 in the Pharmaceutical Manufacturing Sector: Challenges and Solutions for Germany", IEEE Transactions on Engineering Management, pp. 1-18
68. Sirigu, G., Carminati, B. & Ferrari, E. (2022), "Privacy and Security Issues for Human Digital Twins", IEEE, Atlanta, GA, USA
69. Skobelev, D. P. & Borovik, D. S. (2017), "On The Way From Industry 4.0 To Industry 5.0: From Digital Manufacturing To Digital Society", International Scientific Journal "Industry 4.0", Vol. 2 No. 6, pp. 307-311
70. Smith, L. C. (1981), "Citation Analysis", Summer 1981, http://hdl.handle.net/2142/7190, pp 83-106
71. Sundaresan, Y. B. & Durai, S. (2018), "VEERBENCH – an intelligent computing framework for workload characterisation in multi-core heterogeneous architectures ", World Review of Science, Technology and Sust. Development, Vol. 14 No. 1, pp. 34-51
72. Surwase, G., Sagar, A., Kademani, B. S. & Bhanumurthy, K. (2011), "Co-citation Analysis: An Overview", BOSLA National Conference Proceedings, pp. 178-185.
73. Wang, N. et al. (2019), "The dual Roles of the government in cloud computing assimilation: an empirical study in China", **Information Technology** & **People**, Vol. 32 No. 1, pp. 147-170
74. Wannasuphoprasit, W. & Chanphat, S. (2005), "T-Cobot: Transformable Collaborative Robot" Orlando, Florida, USA, ASME, [no pagination]
75. Worsnopp, T. (2006), "Controlling the Apparent Inertia of Passive Human-Interactive Robots", Journal of Dynamic Systems, Measurement, and Control, Vol. 128 No.1, pp. 44-52.
76. Xu, D. & Xu, Z. (2022), "Bibliometric analysis of decision-making in healthcare management from 1998 to 2021", International Journal Of Healthcare Management, DOI: 10.1080/20479700.2022.2134641
77. Xu, Q. & Chang, V. (2020), "Co-Authorship Network and the Correlation with Academic Performance", Internet of Things, Vol. 12 No. 4, article no. 100307 [no pagination]
78. Xu, X., Lu, Y., Vogel-Heuser, B. & Wang, L. (2021), "Industry 4.0 and Industry 5.0—Inception, conception and perception", Journal of Manufacturing Systems, Vol. 61, pp. 530-535
79. Zafrunnisha, N. (2022), "Library and Information Science Literature: A Citation Analysis", International Journal of Information Dissemination and Technology, Vol. 12 No. 2, pp. 62-66
80. Zeadally, S. & Bello, O. (2021), "Harnessing the power of Internet of Things based connectivity to improve healthcare", Internet