Journal of Applied Engineering and Technological Science
Vol 5(2) 2024: 925-940

A BIBLIOMETRIC ARTICLE REGARDING TWIN TECHNOLOGY IN TECHNOLOGY MANAGEMENT FOR THE YEAR 2019-2023: INDUSTRY IN MALAYSIA

Mazzlida Mat Deli[1], Ummu Ajirah Abdul Rauf[2*], Maryam Jamilah Asha'ari[3], 'Ainul Huda Jamil[4], Astri Ayu Purwati[5], Siti Intan Nurdiana Wong Abdullah[6], Fauziah Ismail[7], Siti Norliyana Harun[8]
Graduate School of Business, Universiti Kebangsaan Malaysia, Malaysia[1234]
Faculty of Business, Institut Bisnis dan Teknologi Pelita Indonesia, Indonesia[5]
Nottingham Business School, Nottingham Trent University, United Kingdom[6]
Institut Aminuddin Baki, Malaysia[7]
Institute of Climate Change, Universiti Kebangsaan Malaysia, Malaysia[8]
ummu@ukm.edu.my[2]*

Received : 13 September 2023, Revised: 07 February 2024, Accepted : 16 March 2024
**Corresponding Author*

ABSTRACT
The purpose of this research is to analyze the application of digital twin technology in the efficient management of new innovative technology. The research is directed to perform a bibliometric analysis of the subject topic. The relevancy of the research can be underlined by the fact that digital twin technologies are a popular concept of Industry 4.0. In addition, this research is advantageous to identify the application of digital twin technology in efficient technology management, especially in Malaysia. As a scope, it would highlight possible use cases of digital twin technology. The review of existing literature highlighted that digital twin technology has serious use case potential in supply chain operations. Whereas other scholars argue that digital twin technology can bring out major disruptive innovations to improve the internal competencies of major manufacturing firms. The methodology for the research involves the use of secondary data with bibliometric analysis. It has been identified in the findings that there is a rise in research associated with digital twin technology between the timelines from 2019 to 2022. Furthermore, Chinese Academies are most active in propagating research on variables like digital twins.
Keywords : *Bibliometric, Twin Technology, Technology Management, Malaysia*

1. Introduction

Technology management refers to the management strategy for using technology. It is necessary for every organization to adopt effective plans for the proper utilization of technology for the benefit of human beings and different organizations. The use of digital twins leads to presenting diverse things virtually, which looks like the real one. Thus, it helps the users to predict the impact of the implementation of different tactics and plans they prepare. Implementation of effective methodology and theory supports make the research successful. Hence, it sheds light on the impact of the utilization of digital twins on the different industries of Malaysia. The primary purpose of this research is to identify the role of digital twins in the management of technology in the major manufacturing industry.

The application of digital twin technology helps in adopting the latest tools and technology that help in the rapid manufacturing of various biological products. It faces diverse challenges while utilizing its resources and technology. The spread of the use of technology and technical equipment needs to adopt a significant strategy that can help to manage the use of technology efficiently (Udugama et al., 2021). However, a lack of awareness about the use of technology and proper utilization of technology leads to the generation of issues before the organization. The knowledge about the use of technology supports to detection of growth and other functioning (Gargalo et al., 2022). Nowadays the use of technology helps to improve the quality of services, thus, it leads to bringing a clear image of every functioning of the industry. Thus, the primary reason behind the development of the issue is digitalization, which leads every organization to utilize the technology effectively.

Many of the organisations that are recognised for promoting economic growth and technological innovation have come under criticism for allegedly causing societal issues, especially for manufacturing companies. Long-term development plans place a high priority on sustainable economic development and see green technologies as the driving force of national economic expansion (GreenTech Malaysia, 2016). Malaysia has placed a strong emphasis on sustainable development, which has inspired other organisations to adopt eco-friendly laws and practices (Hanim et al., 2016). The Malaysian government has outlined several SDGs that the manufacturing sector in particular needs to meet by 2030 in order to meet sustainability standards in the areas of economic, environmental, and social aspects of the economy. The goals that were emphasised made clean energy research and technology more accessible. An organisation can project and benefit from a favourable image if it actively incorporates sound green practices into the supply chain and organisational culture (via environmentally friendly products, processes, systems, and technology) (Vanalle et al., 2017). Manufacturing businesses gain from working with upstream suppliers of environmentally friendly production technology, sharing environmental data with these suppliers, and taking green consumers' opinions into account when developing their products, according to Santos et al. (2019).

Sustainability is one of the current manufacturing technology trends. A lot of technological innovations are being used in production, like 3D printing (Jyeniskhan et al., 2023). Although the technique is still in its early phases of development, additive manufacturing could benefit greatly from it (Lu et al., 2020). One significant obstacle, nevertheless, is the absence of a standardised design or structure for producing generic digital twin models for 3D printers (Phanden et al., 2022). Regarding the technology category, inadequate readiness and a lack of digital continuity are technological barriers to technology, according to Mastos et al. (2021). Bag et al. (2022) also emphasised how manufacturers are concerned about using digital solutions since they put them at risk for security breaches. Regarding financial and economic obstacles according to Popescu et al. (2022), certain financial obstacles come with implementing a sustainable transition. These include greater labour expenses as well as unintended costs brought on by poor product quality or more sophisticated products.

Fig. 1. Predicted market of digital Twins from 2019 to 2032
Source: Emergen research (2023)

The market for digital twins is growing day by day and it is predicted to grow further, which is depicted in the above diagram. This reflects the positive use of digital twins, which supports the effective functioning of the manufacturing industry and its effective management of technology, which depends upon diverse factors. The use of digital twins is effective in putting a close eye on the functioning and management of technology for the development of this industry. The digital twins lead to monitoring the process and detecting the issues that may arise in the future (Schmidt et al., 2021). This acts as the predictive model; thus, utilization of this technology efficiently can help to manage the technology efficiently and support managing the processing of the major manufacturing industry. Thus, it is necessary to analyze the role of the utilization of digital twins in the management of the technology of this industry.

2. Literature Review

Theme 1: Role of Digital Twin Technology in Industrial Energy Management

The management of various multinational companies creates a multi-dimensional framework for energy classification as well as other digital twins. Digital twins are applicable

for different phases of the product lifecycle. The innovative technology is applicable in local areas as well as industrial sites. According to Yu et al. (2022), energy industries use digital twin technology for the management of energy as well as the generation of renewable energies. The innovative technologies help to maintain energy-efficient design to achieve the main aim of the organization.

On the other hand, Agostinelli et al. (2021) stated that the innovative technology maintains some particular methods as well as approaches to achieve an automation system that manages energy in the industrial sector. The management of the organization uses integrated dynamic analysis to maintain an efficient level of energy. Digital twin technology reduces the carbon footprint of local as well as industrial cities.

The leaders and management of the technology-based organization used various theories and models to maintain the usage of digital twin technology. Most organizations use scientific management theory to maintain managerial techniques for the organization. According to Bell and Martin (2012), the management of the organization used this theory to make proper communication with employees related to the usage of these technologies. The modern environment of business and the significance of innovative technologies can be properly understood with the help of this theory. The multi-dimensional digital framework helps to create proper proposal related to a project and the theory help to maintain the decision-making process. The energy management of multinational; companies can be possible for proper sustainable planning. The innovation maintains the proper environment for the future generation. Model of digital twins become the assets for an organization. The technology mainly USD detects the changes in the supply chain process. Proper usage of renewable energy becomes the main goal of this innovative technology.

According to Agouzoul et al. (2021), the model of digital twins has become the main reason behind the revolution of industry. On the other hand, Bhatti et al. (2021), stated that smart electric vehicles for future generations become the most important rewards on behalf of digital twin technology. The technology helps to improve the growth of business and it removes the threat of climate change. Energy provides goals for sustainable development. Demographic, globalization, as well as urbanization, can improve with the help of proper usage of innovative technologies. The behavior, as well as characteristics of future generations, are easily detected with the help of this technology. The monitoring process of energy systems like operations and power plant management helped to improve the productivity rate of the organization. According to Yu et al. (2022), digital twins help to improve the system of power grids as well as energy equipment. The technologies improve a deeper understanding of recent issues as well as provide solutions according to the problem. The technology enables strategies of energy management in a smarter way. Digital twins enhance the process of energy management.

Theme 2: Application of Digital Twin for Supply Chain and Operational Purposes

The application of digital twins helps to maintain the function of the supply chain as well as other operations. According to Bhandal et al. (2022), four cluster values as well as their significance in supply chain management become the main role of the digital twin. On the other hand, van der Valk et al. (2022), stated that the variety of optimization potentials become part of supply chain management. Supply chain managers in the digital process help to improve the productivity rate of the organization. Almost every industry is linked between networks and products to maintain the trend of strategic technology. The organization used many resources to maintain the condition of the organization. Digital twins or DT played an important role in improving the future of energy industries. Digital twin technology maintains the process of the supply chain in a systematic process. The tracking devices can manage the systematic process of supply chain management.

According to Kshetri (2021), innovative technology represents an accurate description of products at the macro and micro levels. On the other hand, as stated by Park et al. (2021), the supply chain process personalizes production and improves operational capacity. The innovation technologies help to create proper coordination b between systematic approaches as well as supply chain management processes. Capabilities of the supply chain process and management of value clusters are the important responsibilities of digital twin technology. The

employs of bibliometric, dynamic capability, and as well as network analysis are the main functions of digital twin technology. The prominence of the supply chain becomes the most important party in strategic management (Bhandal et al., 2022). Competition in the market increased day by day and operational management helped to maintain the productivity rate during this time. Market analysis becomes easier work for the usage of innovative technology.

According to Kshetri (2021), digital twin technology helps to maintain company assets and maintain the process of sustainable development. Technical, cost-benefit, and as well as other considerations are the parts of digital twin technology. Various risks related to supply chain management can easily be detected with the help of this innovative technology. On the other hand, Park et al. (2021), stated that the inventory as well as the operational capacity of the organization are properly maintained with the help of various innovative technologies. The management of energy industries follows the resource-based view theory to manage the process of the supply chain. According to Dubey et al. (2019), the resource-based view theory is mainly used to maintain the manufacturing as well as operational process. The performance of the supply chain as well as operational management completely depends on this theory. The culture of the organization and important resources are properly maintained with the help of this theory. The theory helps to under the significance of the analysis of big data. The theory helps to maintain the supply chain process in an eco-friendly process. Sustainable development becomes the main goal of the organization.

In the energy industry, digital twin technology is utilised for energy management and renewable energy generation. It contributes to the preservation of energy-efficient design and the reduction of the carbon footprint of local and industrial towns. Organisations use scientific management theory to communicate effectively with employees about the use of digital twin technologies. This idea aids in decision-making and long-term planning for energy management. The digital twin concept has become the driving force behind the industry's change, and it also plays an important role in the creation of smart electric vehicles for future generations. Digital twins aid in the improvement of power grid and energy equipment systems by offering a deeper awareness of current concerns and enabling wiser energy management techniques. Digital twins provide a multitude of optimisation opportunities in supply chain management, assisting organisations in increasing their productivity rate. The usage of digital twin technology involves the use of dynamic capability and network analysis to improve the capabilities of the supply chain process and value cluster management. The management of energy industries employs the resource-based view theory to manage the supply chain process, which aids in maintaining the supply chain process in an environmentally responsible manner. Digital twins can be used to find more sustainable supply chain activities, such as carbon-optimized routes, more efficient delivery routes, and GHG hotspots along the chain, all of which contribute to long-term development.

These insights and findings highlight the numerous applications and benefits of digital twin technology in industrial energy management as well as supply chain management, emphasising its role in enhancing operational efficiency and sustainability.

3. Research Questions

3.1 What are the trends/what are the research trends in the application of digital twins in technology management studies according to the year of publication?

3.2 Who and how much has been published in the area with regard to the authors, their affiliated organizations, and countries?

3.3 What are the most cited articles?

3.4 What are the most cited publishers?

3.5 What and how much has been published in the area with regard to the subject area?

3.6 What is the influence and research productivity of the topic?

4. Methods

A bibliometric study depicts data on the development of research performance and global trends in the expansion of the scientific literature in a particular field or issue (Vlchez-Roman et al., 2021). According to Verbeek et al. (2002), bibliometrics is the collection, management, and

analysis of bibliographic data gleaned from academic publications. It includes intricate approaches like document co-citation analysis in addition to general descriptive statistics like publishing journals, publication year, and main author classification (Wu and Wu, 2017). For an efficient review of the literature, the creation of a bibliography, and the achievement of relevance and reliable results, respectively, an iterative sequence of appropriate keywords, literature search, and analysis is necessary (Fahimnia et al., 2015). In the current study, the bibliometric analysis combines and measures research growth trends of twin technology in technology management.

The database also provides bibliometric database sources, such as abstracts, references, document types, timelines, citation counts, author, region, and institute listings, and the journal impact factor, for searching the literature in many study fields. As therefore, in the current study, data were exclusively gathered from the Scopus database to prevent concerns with homogenization and overlapping data collection, which are most common when different databases are used. Furthermore, Scopus covers a significant number of articles, according to Aghaei Chadegani et al. (2013). In scientific research, it's crucial to have a broader view of previous research that has been done on a pertinent topic (Bojovi, 2014), as well as a bibliometric analysis profile of the research trajectory and dynamics of the research activities around the world (Liu, 2014). This study conducts a bibliometric analysis of international journal papers that we expect to provide a useful reference for future research. The key research work for this study was determined to be 5 years from 2019 to 2023, which provides a broader view of how research has been evaluated in the last decades. The results were obtained on May 28, 2023.

Only publications written in the English language were shortlisted due to their predominance in academic research. Document type was limited to the research articles that underwent a formal double-blind peer-review process. Other documents such as book chapters, early access, proceedings papers, books, review papers, meeting abstracts, editorial material, data papers, letters, and retracted publications were excluded. Application of the inclusion and exclusion criteria resulted in 8,962 results for 2019-2023, which was considered adequate for analysis. The 8,962 articles including publication year, language, journal, title, author, affiliation, keywords, document type, abstract, and the number of citations were exported to CSV format for all papers that met the criteria (Fernandez-Prados et al., 2021; Eck and Rousseau, 2014). Cooccurrence, Citation, Bibliographic coupling, Co-citation, and themes were examined using VOSviewer (version 1.6.19). The "Links attribute" and the "Total link strength attribute" are two typical weight attributes that were used (Zhang et al., 2016; Ali, Jusoh, and Abbas, 2021). Figure 2 presents the comprehensive gathering procedure for data sources and the search strategy.

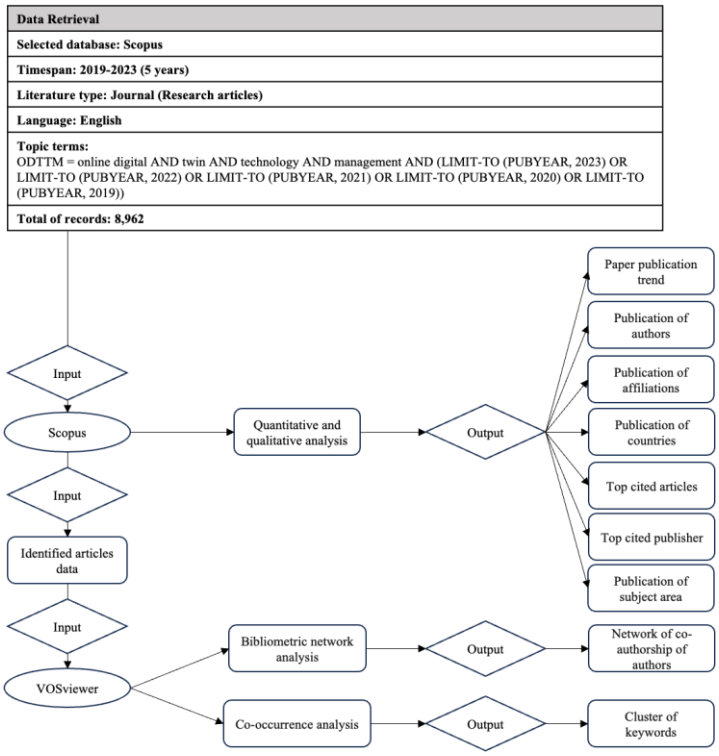

Fig. 2. Research Procedure

4.6 Data Search Strategy (Boolean Table)

This study employed a screening sequence to determine the search terms for article retrieval. It was initiated by querying the Scopus database with online digital AND twin AND technology AND management AND (LIMIT-TO (PUBYEAR, 2023) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019)). The timespan was set from 2019 to 2023. In this period (2019–2023), researchers are starting to focus more on various aspects of research regarding twin technology in technology management.

Table 1 - Boolean table.

And	Or	Nor
Scopus database	Publication year: 2023 or 2022 or 2021 or 2020 or 2019.	Publication year: 2018 or prior.
Keywords: Digital twin, technology management, Industry 4.0, machine learning, and robotics.	Keywords: Energy storage, big data analytics, blockchain, neural networks, emerging technologies, building information modeling, predictive maintenance, deep neural network, supply chain resilience, decision-making, digital economy, construction industry, efficiency, risk management, sustainable and supply chain.	Keywords: Influencer marketing, omnichannel marketing, SaaS, idea, innovator, collaboration, design thinking, domain knowledge, innovation process, teamwork, inventor, entrepreneur, ecosystem, and historical research.

4.7 Data Analysis

The researcher used a secondary data analysis method to maintain the quality of the research. According to Yu et al. (2022), digital twin technology maintains the product lifecycle with the help of a multi-dimensional framework. The energy industry used digital twin technology to provide better services for consumers. The generation of renewable energy become the main responsibility of digital twin technology. The multidimensional framework helps to summarise the whole process of energy management with the help of innovative technologies. Reduction of carbon footprint becomes the main responsibility of digital twin technology. Challenges and solutions of energy management become major responsibilities of innovative technology.

According to Agnusdei et al. (2021), digital tools are applied to manufacturing and production activities in the 4.0 industry era. The researcher collected information about the usage of innovative technologies in modern days. The changing process of industrial production as well as automation is part of technical innovations. Innovative technologies make production affordable cost. The budget as well as the assets of the organization is properly managed with the help of digital twin technologies. The researcher collected information about the negative as well as positive effects of technological innovations.

According to Bhandal et al. (2022), the supply chain, as well as operation management is properly managed by the organization with the help of various innovative technologies. The production of value clusters and the flow of supply chain management are properly maintained with the help of various innovative technologies. According to Zhao et al. (2022), the Internet of Things and building information models are properly managed with the help of innovative technology. The technology controls the method of long-range radio and tastes the effectiveness of the manufacturing process.

According to Khalyasmaa et al. (2023), digital twins have become one of the most emerging technologies that can create a major digital transformation. New development in the industry is only possible with the help of the proper application of digital twin technology. The life cycle of high-voltage power equipment is properly managed for the proper utilization of digital twin technology. According to Kwok et al. (2021), technologies related to virtual reality help to maintain major crises in the organization. The technologies help to provide emergency responses from the staff during times of risk management. The capability of staff of the organization can understand with the help of a proper training process. The management of the organization used various innovative tools to manage the training process.

Polyanin and Tatiana (2021), stated that the innovative management of industrial systems is completely based on digital twin technology. Modern industries use various innovative tools to reduce the cost of production and maintain the position of monopoly. The author used various methods to understand the actual behavior as well as characteristics of innovative management in modern industry. The management used various prototype tools to improve the development process in modern industry. Strategic management can improve with the help of proper usage of digital twin technologies. Digital twin technologies become the most important factor in modern industry. Sustainable and renewable strategies are created with the help of various innovative technologies. The production of value clusters and the flow of supply chain management are properly maintained with the help of various innovative technologies. Every author has focused on beginning forward the digital twins and the technology used for managing them. Along with that, they have focused on the concepts of innovation management, crisis management, quality management, and supply chain management. Digital twins are also effective for the system management of construction projects.

5. Findings

5.1 RQ 1: What are the trends/what are the research trends in the application of digital twins in technology management studies according to the year of publication?

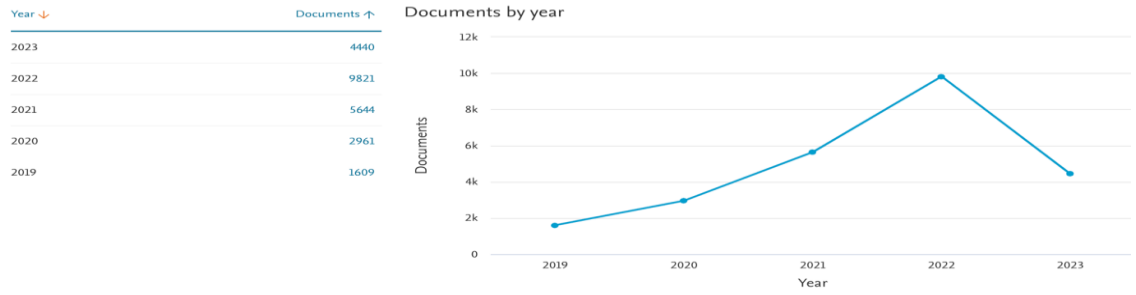

Fig. 6. Research trends in the application of digital twins

From the above graph, a rising trend in research studies associated with digital twin technologies can be identified between the timeline of 2019 to 2022. The trend of online learning studies mostly focuses on the journal of 2022, which is 9821. The journals of 2019 are not in trend as they comprise the journals, which are used in the least numbers. The documents

of 2021 are considered the second highest in trend, which considers 5644 journals. On the other hand, the number of journals used for online learning studies in 2020 and 2023 are 2961 and 4440 respectively. Hence, it depicts the priority gained by different documents from the year 2019 to 2023 and it reflects that the older journals are less reviewed, and they are less in the trend of online studies.

5.2 RQ2: Who and how much has been published in the area with regard to the authors, their affiliated organizations, and countries?

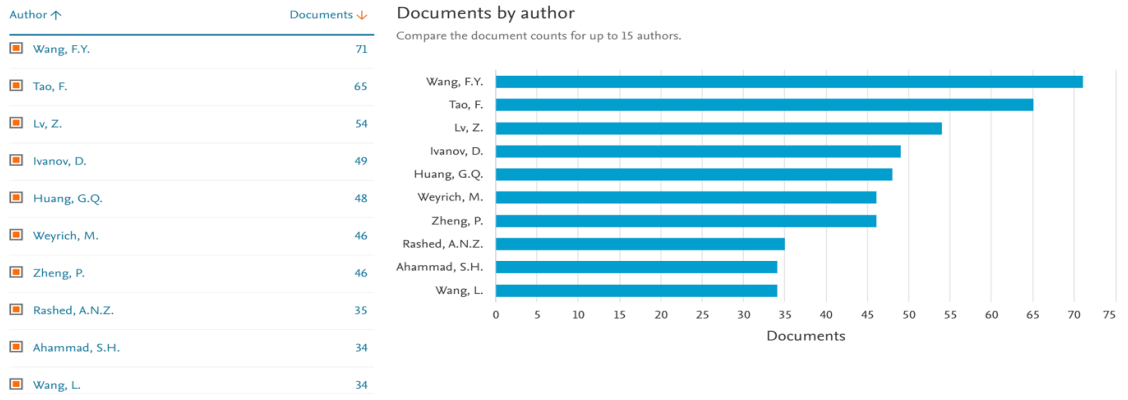

Fig. 7. Number of publications by authors

The above graph clearly represents that Chinese scholars have most actively participated in unfolding applications and use cases of digital twin technologies. Along with that, this section brings forward the name of the author, who is the most famous. It also sheds light on the organization and country that is in trend. Here, in the above diagram, it is found that there are diverse authors whose journals are mostly studied. Among all the authors, Wang F. Y. is known for being in the maximum number of documents. This author is in 71 documents, which reflects that the works of this author are cited in most of the online study resources. Tao, F. is the second most popular one and its work is cited in 65 online study materials. The least number of document counts is found in the work of Wang L., which is 34. There are many other authors whose documents are counted in online studies. These authors include Zheng P., Weyrich, M., Ivanov D., and many others.

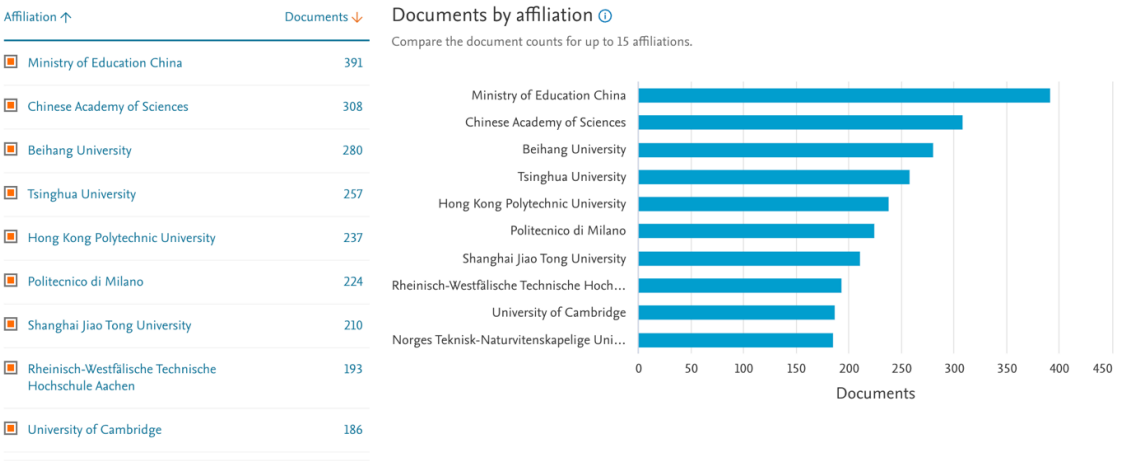

Fig. 8. Number of publications by affiliation

It is depicted in the above diagram; the document counts different affiliations. It is found that there are many affiliations that are used in online study resources. Ministry of Education China brings the maximum number of documents, which is 391. The second highest documents are brought by the Chinese Academy of Sciences, which consists of 308 documents. The least number of documents is found from the University of Cambridge, which is 186. Other than these, Tsinghua University, Hong Kong Polytechnic University, and many others are considered significant affiliations. These affiliations bring different documents for online studies.

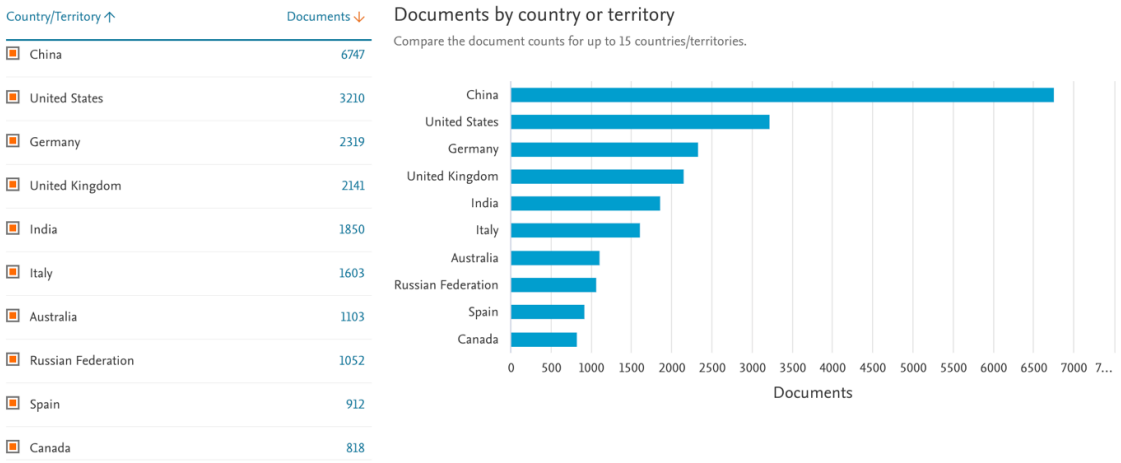

Fig. 9. Number Of Publications By Country

This diagram reflects the number of documents found in the online studies, based on country and territory. It is found that China is the country that brings the maximum number of online resources. China brings 6747 resources and Canada is the only nation that brings the least number of resources for online studies, which is 818. It also states about many other nations and territories like the United Nations, Australia, Spain, the Russian Federation, Italy, India, Germany, and the United Kingdom.

5.3 RQ3: What are the most cited articles?

Table 2 - Top cited articles.

Cites	Authors	Title	Year
52	W Yu, P Patros, B Young, E Klinac…	Energy digital twin technology for industrial energy management: Classification, challenges, and future	2022
41	GP Agnusdei, V Elia, MG Gnoni	Is digital twin technology supporting safety management? A bibliometric and systematic review	2021
35	R Bhandal, R Meriton, RE Kavanagh…	The application of digital twin technology in operations and supply chain management: a bibliometric review	2022
26	Y Zhao, C Cao, Z Liu	A framework for prefabricated component hoisting management systems based on digital twin technology	2022
23	AI Khalyasmaa, AI Stepanova, SA Eroshenko, PV Matrenin	Review of the Digital Twin Technology Applications for Electrical Equipment Lifecycle Management	2023
16	PK Kwok, M Yan, T Qu, HYK Lau	User acceptance of virtual reality technology for practicing digital twin-based crisis management	2021
11	AV Polyanin, AG Tat'iana	The concept of innovation management of industrial systems based on digital twin technology	2021
9	N Rodionov, L Tatarnikova	Digital twin technology as a modern approach to quality management	2021
5	QW Li, P Jiang, H Li	Prognostics and health management of FAST cable-net structure based on digital twin technology	2020
5	H Sun, Z Liu	Research on intelligent dispatching system management platform for construction projects based on digital Twin and BIM technology	2022

A list of the articles is given here, which brings forward the digital twin and effective utilization of this technology. Among all these articles, “Energy digital twin technology for industrial energy management: Classification, challenges and future” is the most cited article, which was written by W Yu, P Patros, B Young, E Klinac, and others. On the other hand, the “Prognostics and health management of FAST cable-net structure based on digital twin technology” is considered the least cited article, which was written by QW Li, P Jiang, and H Li. Along with that, the “Research on intelligent dispatching system management platform for construction projects based on digital Twin and BIM technology” was written by H Sun, and Z Liu, which was also the least cited article.

5.4 RQ4: What are the most cited publishers?

Table 3 - Top cited publisher.

Cites	Authors	Title	Publisher
52	W Yu, P Patros, B Young, E Klinac…	Energy digital twin technology for industrial energy management: Classification, challenges, and future	Elsevier
41	GP Agnusdei, V Elia, MG Gnoni	Is digital twin technology supporting safety management? A bibliometric and systematic review	mdpi.com
35	R Bhandal, R Meriton, RE Kavanagh…	The application of digital twin technology in operations and supply chain management: a bibliometric review	emerald.com
26	Y Zhao, C Cao, Z Liu	A framework for prefabricated component hoisting management systems based on digital twin technology	mdpi.com
23	AI Khalyasmaa, AI Stepanova, SA Eroshenko, PV Matrenin	Review of the Digital Twin Technology Applications for Electrical Equipment Lifecycle Management	mdpi.com
16	PK Kwok, M Yan, T Qu, HYK Lau	User acceptance of virtual reality technology for practicing digital twin-based crisis management	Taylor & Francis
11	AV Polyanin, AG Tat'iana	The concept of innovation management of industrial systems based on digital twin technology	search.proquest.com
9	N Rodionov, L Tatarnikova	Digital twin technology as a modern approach to quality management	e3s-conferences.org
5	QW Li, P Jiang, H Li	Prognostics and health management of FAST cable-net structure based on digital twin technology	iopscience.iop.org
5	H Sun, Z Liu	Research on intelligent dispatching system management platform for construction projects based on digital Twin and BIM technology	hindawi.com

The above table brings forward the list of articles, which brings forward about the digital twin and the effective technology required for this. It also brings the names of the publishers who have published the maximum number of articles. Among all these articles, Elsevier is considered as the publisher with the maximum document count. On the other hand, the "iopscience.iop.org" and "hindawi.com" is considered as the publisher with the least count of documents. They publish five journals each on the other hand Elsevier published 52 documents. Despite that, mdpi.com has published diverse documents on different topics. It has published 41, 26, and 23 documents respectively on the topic "Is digital twin technology supporting safety management? A bibliometric and systematic review", "A framework for prefabricated component hoisting management systems based on digital twin technology" and "Review of the Digital Twin Technology Applications for Electrical Equipment Lifecycle Management". Along with these, it has mentioned many other publishers like e3s-conferences.org, Taylor & Francis, search.proquest.com, and many others. Hence, it can be found that the Energy digital twin technology for industrial energy management: Classification, challenges and future" is the most cited article which was published by Elsevier.

5.5 RQ5: What and how much has been published in the area with regard to the subject area?

Subject area	Documents
Engineering	13469
Computer Science	11646
Mathematics	3273
Energy	3144
Social Sciences	3050
Business, Management and Accounting	2695
Decision Sciences	2615
Environmental Science	2336
Physics and Astronomy	2202
Materials Science	1993

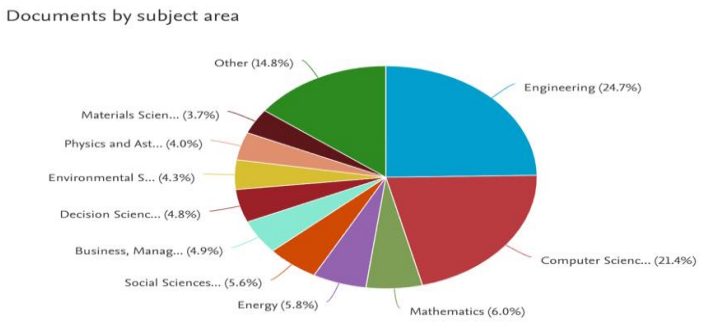

Fig. 10. Number of publications by subject area

The above diagram reflects the subject area based on which most of the documents are written. The subject considers Engineering, computer science, material science, physics and astronomy, environmental science, decision science, business management and accounting, energy, and mathematics. Among all these subjects engineering is the subject area of which the maximum articles are published. There are 13469 articles on engineering and 11646 articles on computer science. On the other hand, material science is considered as the least presented subject as it has the least number of documents, which is 1993. One of the reasons for prominence in engineering and computer science is because in recent decades, there has been a rapid advancement in technology, particularly in the fields of information technology and computer science. This has led to a growing demand for professionals with expertise in these areas to develop and maintain the systems and applications that power our modern world and hence increase in research being conducted. Moreover, engineering and computer science play a significant role in driving economic growth and innovation. They are essential for the development of new products, services, and industries, which in turn create jobs and stimulate economic activity for any country irregardless of developing or developed nations. Besides, these fields can also be applied in an interdisciplinary manner, in which engineering and computer science have applications in a wide range of industries and fields, including healthcare, transportation, energy, finance, and more. As a result, these fields draw interests from researchers, publishers, academicians and practitioners. In hindsight, engineering and computer science are highly relevant to digital twin technology due to their foundational role in developing, implementing, and advancing this innovative approach. Digital twin technology involves creating digital replicas or representations of physical objects, systems, or processes, and it has applications across various domains, including manufacturing, healthcare, urban planning, and more. In terms of engineering, digital twins rely on real-time data from sensors, IoT devices, and other sources to create accurate digital representations. Engineers are involved in designing and implementing these data acquisition systems, ensuring they collect relevant information accurately and reliably. Whereas computer scientists and software engineers develop the software platforms, interfaces, and applications needed to create, manage, and interact with digital twins. As such, with rapidly increasing trends in artificial intelligence, machine learning, blockchain, and quantum computing, all of which drives the growth and innovation in computer science and the subject areas of engineering.

5.6 RQ6: What is the influence and research productivity of the topic?

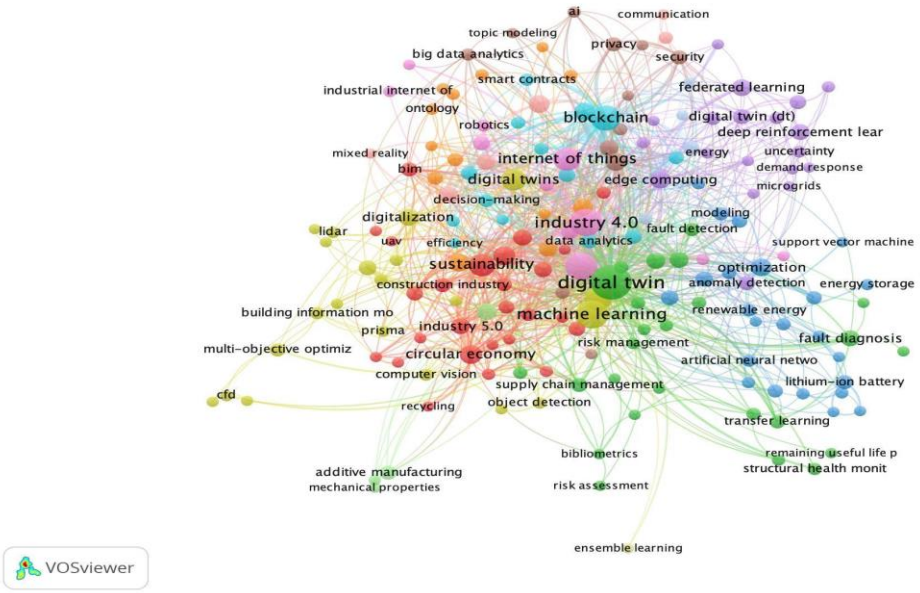

Fig. 11. Network visualization of keywords' co-occurrence

The above diagram visualizes the keywords that are frequently used. the keywords include the digital twin, technology, management, industry 4.0, machine learning, energy storage, big data analytics, blockchain, neural networks, emerging technologies, building information modeling, predictive maintenance, deep neural network, supply chain resilience, robotics, decision-making, digital economy, construction industry, efficiency, risk management, sustainable supply chain, and many others. Among all these keywords are digital twin, machine learning, and industry 4.0.

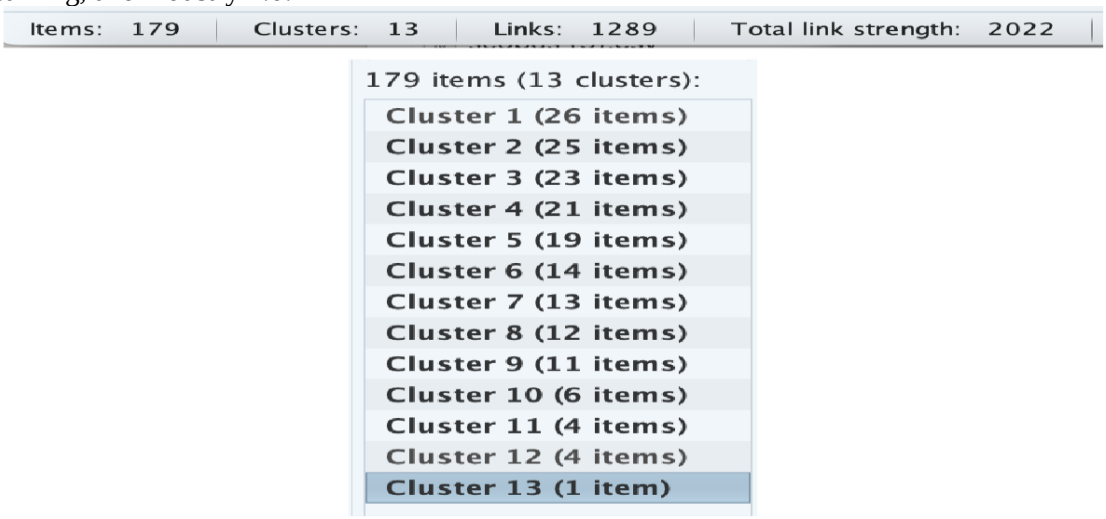

Fig. 12. Keywords cluster generated from VOSviewer

It is depicted in the above diagram about the cluster, which is formed by diverse items. The number of items in one cluster is connected to each other. The first cluster states about 26 items and the second cluster depicts 25 items. Keywords involved in the first cluster include sustainability, industry 5.0, innovation, digitization, and many others. Among those keywords, sustainability is the most used keyword. The second cluster consists of terms like data management, fault detection, digital twin model, network analysis, and many others. The third cluster consists of different key terms among, which optimization is the most used key term, which is used 25 times. Machine learning is considered the most used term of the fourth cluster, and it occurs 110 times. The fifth cluster consists of diverse key terms and edge computing has maximum occurrences. On the other hand, blockchain is the keyword for the sixth cluster, and it occurs 78 times.

Digital transformation is the keyword that is mostly used in the seventh cluster, and it occurs 26 times. The eighth cluster considers big data as the most occurred keyword, which has 26 occurrences. Industry 4.0 has 105 occurrences in the ninth cluster and metaverse has 25 occurrences in the 10th cluster, which has the highest occurrences in those clusters. Simulation occurs 24 times in the 11th cluster and healthcare is the keyword of the 12th cluster. Ensemble learning is the only keyword of the 13th cluster, and it has five occurrences in that cluster.

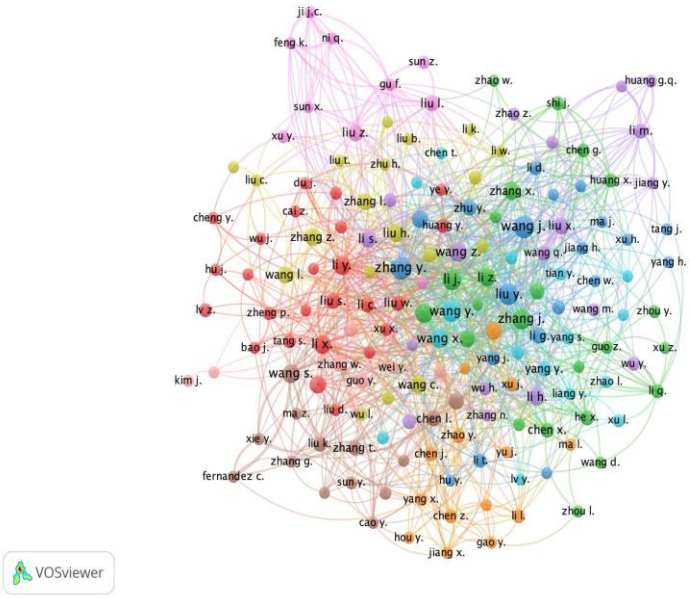

Fig. 13. Network visualization of co-authorship

Table 3 - Authors cluster generated from VOSviewer

Items : 166	Clusters : 10	Links : 1456	Total link strength : 1705

It is reflected here that there are 166 authors who are visualized in the above network diagram. These authors are connected by 1456 links and divided into 10 clusters.

6. Future Research Directions

In the future, it is critical to investigate the synergies between digital twins and other Industry 4.0 technologies such as IoT, AI, and Big Data analytics. Investigating how these technologies interact with digital twins may result in more complex methods to resource management and problem prediction. This channel offers a great chance to improve the effectiveness of digital twin applications in Malaysia's key manufacturing industry.

Furthermore, broadening the scope of research beyond Malaysia's major industry is worthwhile to include other manufacturing sectors will provide a thorough grasp of the versatility and benefits of digital twins. Comparative research across industries can give insight on industry-specific difficulties and possibilities, leading specialised actions for each. This all-inclusive strategy ensures that the advantages of digital twins are fully realised.

Furthermore, quantifying the environmental impact of using digital twins in manufacturing processes is an important subject for investigation. Understanding how digital twins contribute to sustainability goals, resource conservation, and waste reduction is critical for industries seeking to implement environmentally friendly practises. Future study in this area will provide important insights into the environmental implications of using digital twins for technology management in manufacturing.

7. Conclusion

It can be concluded that the study discussed the digital twin's effectiveness for managing the use of technology in the major manufacturing industry in Malaysia. The practical implications of the findings for organizations and practitioners in the fields of energy management and supply chain management can benefit from digital twin technologies to improve operational efficiency and sustainability. Digital twins can be used in energy management to simulate and optimise energy systems, predict energy usage, and find areas for improvement. Digital twins, for example, can be used to simulate and optimise the performance of wind turbines, solar panels, and other renewable energy sources. Digital twins can be used in supply chain management to construct a virtual clone of a physical supply chain system that

uses real-time data from sensors and IoT devices. This can help organisations plan and estimate their future requirements, detect bottlenecks, optimise operations, and improve overall efficiency. Digital twins can also be used to model and identify more sustainable supply chain activities, such as carbon-optimized routes and modes, more efficient delivery routes, and Green greenhouse gas hot spots across the chain.

The use of digital twins helps to make effective utilization of existing resources and raw materials. Along with that, it reflects the use of digital twins for predicting the issues that may occur in the future. It also supports identifying the impact of utilizing technology. Thus, the effective utilization of digital twins is influential in analyzing the positive and negative impacts of using technology. It has also discussed diverse authors, journals, and publishers who have shed light on the use of digital twins. It has also identified the most popular journals that come in the document of online resources. Hence, it can be said that this study is focused on diverse factors concerned with digital twins and technology. Overall, digital twin technology can provide stakeholders with end-to-end insight into real-time performance, enabling more collaboration, accountability, and quicker dispute resolution.

Acknowledgment

The authors would like to thank the Graduate School of Business, Universiti Kebangsaan Malaysia for sponsorship of this research paper under the GSB-2024-017 and GSB-2024-019.

References

Aghaei Chadegani, A., Salehi, H., Yunus, M., Farhadi, H., Fooladi, M., Farhadi, M. and Ale Ebrahim, N. (2013), "A comparison between two main academic literature collections: web of science and Scopus databases", *Asian Social Science*, 9(5), 18-26.

Agnusdei, G. P., Elia, V., & Gnoni, M. G. (2021). Is digital twin technology supporting safety management? A bibliometric and systematic review. *Applied Sciences*, 11(6), 2767. https://doi.org/10.3390/app11062767

Agostinelli, S., Cumo, F., Guidi, G., & Tomazzoli, C. (2021). Cyber-physical systems improving building energy management: Digital twin and artificial intelligence. *Energies*, 14(8), 2338. https://doi.org/10.3390/en14082338

Agouzoul, A., Tabaa, M., Chegari, B., Simeu, E., Dandache, A., & Alami, K. (2021). Towards a digital twin model for building energy management: Case of Morocco. *Procedia Computer Science*, 184, 404-410. https://doi.org/10.1016/j.procs.2021.03.051

Alharahsheh, H. H., & Pius, A. (2020). A review of key paradigms: Positivism VS interpretivism. *Global Academic Journal of Humanities and Social Sciences*, 2(3), 39-43. DOI: 10.36348/gajhss.2020.v02i03.001

Ali, J., Jusoh, A. and Abbas, A. F. (2021). "Thirty- Eight Years of 'Wellbeing' Research: Bibliometric Analysis of Open Access Documents," *Stud. Appl. Econ*., 10, 1–11, doi: 10.25115/eea.v39i10.5412.

Bag, S., Sahu, A. K., Kilbourn, P., Pisa, N., Dhamija, P., & Sahu, A. K. (2022). Modeling barriers of digital manufacturing in a circular economy for enhancing sustainability. *International Journal of Productivity and Performance Management*, *71*(3), 833-869.

Bag, S., Sahu, A.K., Kilbourn, P., Pisa, N., Dhamija, P., Sahu, A.K., 2022. Modeling barriers of digital manufacturing in a circular economy for enhancing sustainability.

Bell, R., & Martin, J. (2012). The relevance of scientific management and equity theory in everyday managerial communication situations. *Journal of Management Policy and Practice*, 13(3). https://doi.org/10.3390/en14082338

Bhandal, R., Meriton, R., Kavanagh, R. E., & Brown, A. (2022). The application of digital twin technology in operations and supply chain management: a bibliometric review. *Supply Chain Management: An International Journal*. https://doi.org/10.1108/SCM-01-2021-0053

Bhatti, G., Mohan, H., & Singh, R. R. (2021). Towards the future of smart electric vehicles: Digital twin technology. *Renewable and Sustainable Energy Reviews*, 141, 110801. https://doi.org/10.1016/j.rser.2021.110801

Bojović, S. M. R. P. Z. E. A. (2014). “An overview of forestry journals in the period 2006–2010 as basis for ascertaining research trends,” *Scientometrics*, 8, 1331–1346.

Dubey, R., Gunasekaran, A., Childe, S. J., Blome, C., & Papadopoulos, T. (2019). Big data and predictive analytics and manufacturing performance: integrating institutional theory, resource-based view and big data culture. *British Journal of Management*, 30(2), 341-361. https://doi.org/10.1111/1467-8551.12355

Eck, V. and Rousseau, R. (2014). *Visualizing bibliometric networks*.

Emergen research. (2023). *Digital Twin Market*, Retrieved from: https://www.emergenresearch.com/industry-report/digital-twin-market [Retrieved on: 8th June 2023]

Fahimnia, B., Sarkis, J. and Davarzani, H. (2015), “Green supply chain management: a review and bibliometric analysis”, *International Journal of Production Economics*, 162, 101-114.

Fernandez-Prados, J. S., Lozano-Diaz, A., Bernal-Bravo, C. and Muyor-Rodriguez, J. (2021). “Influencers and Social Media: State of the Art and Bibliometric Analysis,” 456–460, doi: 10.1109/iciet51873.2021.9419581.

Gargalo, C. L., Udugama, I., Pontius, K., Lopez, P. C., Nielsen, R. F., Hasanzadeh, A., & Gernaey, K. V. (2020). Towards smart biomanufacturing: a perspective on recent developments in industrial measurement and monitoring technologies for bio-based production processes. *Journal of Industrial Microbiology & Biotechnology: Official Journal of the Society for Industrial Microbiology and Biotechnology*, 47(11), 947-964. https://doi.org/10.1007/s10295-020-02308-1

GreenTech Malaysia. (2016). Green Technology Financing Scheme: Empowering Green Businesses. https://www.gtfs.my/

Hanim, K., Rasyikah, M. K., Dina, I. S., Syahirah, A. S., & Normawati, H. (2016). Deforestation and haze in Malaysia: Status of corporate responsibility and law governance. European Proceedings of Social and Behavioural Sciences (EpSBS), 374 383. http://dx.doi.org/10.15405/epsbs.2016.11.02.34

Jyeniskhan, N., Keutayeva, A., Kazbek, G., Ali, M. H., & Shehab, E. (2023). Integrating Machine Learning Model and Digital Twin System for Additive Manufacturing. *IEEE Access*, 11, 71113-71126.

Khalyasmaa, A. I., Stepanova, A. I., Eroshenko, S. A., & Matrenin, P. V. (2023). Review of the Digital Twin Technology Applications for Electrical Equipment Lifecycle Management. *Mathematics*, 11(6), 1315. https://doi.org/10.3390/math11061315

Kshetri, N. (2021). The Economics of Digital Twins. *Computer*, 54(4), 86-90. https://doi.org/10.1108/SCM-01-2021-0053

Kwok, P. K., Yan, M., Qu, T., & Lau, H. Y. (2021). User acceptance of virtual reality technology for practicing digital twin-based crisis management. *International Journal of Computer Integrated Manufacturing*, 34(7-8), 874-887. https://doi.org/10.1080/0951192X.2020.1803502

Liu, W. G. M. H. G. E. A. (2014). “Profile of developments in biomass-based bioenergy research: a 20-year perspective,” *Scientometrics*, 99, 507–521.

Lu, Y., Liu, C., Kevin, I., Wang, K., Huang, H., & Xu, X. (2020). Digital Twin-driven smart manufacturing: Connotation, reference model, applications and research issues. *Robotics and computer-integrated manufacturing*, *61*, 101837.

Mastos, T. D., Nizamis, A., Terzi, S., Gkortzis, D., Papadopoulos, A., Tsagkalidis, N., ... & Tzovaras, D. (2021). Introducing an application of an industry 4.0 solution for circular supply chain management. *Journal of Cleaner Production*, *300*, 126886.

Park, K. T., Son, Y. H., & Noh, S. D. (2021). The architectural framework of a cyber-physical logistics system for digital-twin-based supply chain control. *International Journal of Production Research*, 59(19), 5721-5742. https://doi.org/10.1080/00207543.2020.1788738

Phanden, R. K., Aditya, S. V., Sheokand, A., Goyal, K. K., Gahlot, P., & Jacso, A. (2022). A state-of-the-art review on implementation of digital twin in additive manufacturing to monitor and control parts quality. *Materials Today: Proceedings*, *56*, 88-93.

Polyanin, A. V., & Tat'iana, A. G. (2021). The concept of innovation management of industrial systems based on digital twin technology. St. Petersburg State Polytechnical University Journal. *Economics*, 14(5), 7. DOI:10.18721/JE.14501

Popescu, D., Dragomir, M., Popescu, S., & Dragomir, D. (2022). Building Better Digital Twins for Production Systems by Incorporating Environmental Related Functions—Literature Analysis and Determining Alternatives. *Applied Sciences*, *12*(17), 8657.

Santos, H., Lannelongue, G., & Gonzalez-Benito, J. (2019). Integrating green practices into operational performance: Evidence from Brazilian manufacturers. Sustainability, 11(10), 2956.

Schmidt, A., Helgers, H., Lohmann, L. J., Vetter, F., Juckers, A., Mouellef, M., & Strube, J. (2022). Process analytical technology as a key enabler for digital twins in continuous biomanufacturing. *Journal of Chemical Technology & Biotechnology*, 97(9), 2336-2346. DOI 10.1002/jctb.7008

Taylor, F. W. (2004). *Scientific management*. Routledge.

Udugama, A., Öner, M., Lopez, P. C., Beenfeldt, C., Bayer, C., Huusom, J. K., & Sin, G. (2021). Towards Digitalization in Bio-Manufacturing Operations: A Survey on Application of Big Data and Digital Twin Concepts in Denmark. *Front. Chem. Eng*, 3, 727152. https://doi.org/10.3389/fceng.2021.727152

van der Valk, H., Strobel, G., Winkelmann, S., Hunker, J., & Tomczyk, M. (2022). Supply Chains in the Era of Digital Twins–A Review. *Procedia Computer Science*, 204, 156-163. https://doi.org/10.1016/j.procs.2022.08.019

Vanalle, R. M., Ganga, G. M. D., Filho, M. G., & Lucato, W. C. (2017). Green supply chain management: An investigation of pressures, practices, and performance within the Brazilian automotive supply chain. Journal of Cleaner Production, 151, 250-259. https://doi.org/10.1016/j.jclepro.2017.03.066

Verbeek, A., Debackere, K., Luwel, M. and Zimmermann, E. (2002), "Measuring progress and evolution in science and technology – I: the multiple uses of bibliometric indicators", *International Journal of Management Reviews*, 4(2), 179-211.

Vılchez-Roman, C., Sanguinetti, S. and Mauricio-Salas, M. (2021), "Applied bibliometrics and information visualization for decision-making processes in higher education institutions", *Library Hi Tech*, 39(1), 263-283, doi: 10.1108/LHT-10-2019-0209.

Wu, Y.C.J. and Wu, T. (2017), "A decade of entrepreneurship education in the Asia Pacific for future directions in theory and practice", *Management Decision*, 55(7), 1333-1350.

Yu, W., Patros, P., Young, B., Klinac, E., & Walmsley, T. G. (2022). Energy digital twin technology for industrial energy management: Classification, challenges, and future. *Renewable and Sustainable Energy Reviews*, 161, 112407. https://doi.org/10.1016/j.rser.2022.112407

Zhang, Y., Moe, W. W., Schweidel, D. A., Real, E. C., Clara, S. and Moe, W. W. (2016). "Modeling the Role of Message Content and Influencers in Social Media Rebroadcasting," *Int. J. Res. Mark.*, 1–52, doi: 10.1016/j.ijresmar.2016.07.003.

Zhao, Y., Cao, C., & Liu, Z. (2022). A framework for prefabricated component hoisting management systems based on digital twin technology. *Buildings*, 12(3), 276. https://doi.org/10.3390/buildings12030276