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Systematic Literature Review of Publications on Digital Twin Topics in Certain Research Areas

Rabia ÖZAT [1] **Mualla AKÇADAĞ** [2]

Abstract

One of the key strategies adopted by companies that wish to compete in a sustainable fashion is the idea of the digital twin, which combines the physical product with virtual technology. The development of production models, cost reduction, and keeping up with shifting client wants and needs all depend on the digital twin. In this way, organizations can exhibit a development trend by utilizing the advancements in information and communication technologies, by utilizing techniques like the internet of things, big data, artificial intelligence, and the digital twin, coupled with other technologies. The systematic organization of prior studies on this topic is considered beneficial in terms of both illuminating the present trend and directing future study because the digital twin has grown in importance as a result of the development and dissemination of technology in every field. In this paper, a thorough literature assessment of digital twin research is intended. Vosviwer analysis was used to examine 60 studies from the Web of Science database that were published for this reason. Data on author partnerships, keyword density, support status, institution, country, language, citation, year, publication type, and field of study were investigated using Vosviwer analysis using the Web of Science database. The concept of the digital twin gained popularity as of 2019 when the years in which the studies in the Web of Science database were published were looked at. It was known that the majority of the associated studies were published in the USA, as articles, and in English. The analysis revealed that the most often used keywords in the 60 studies on digital twin were data, digital twin, and industry. According to the survey, research is primarily conducted in fields like smart production, supply chains, and business economy. The systematic literature review has led to an understanding that, in contrast to the domains of smart production, supply chain, and business economics, other topics are less investigated in transportation, public administration, economics, and social sciences. Publishing in less researched regions will close the gap in the literature in this direction.

Keywords: Digitization, Digital Twin, Digital twin Techniques, Cythematics Literature Analysis, Bibliometric Analysis.

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2023, 12 (4), 2388-2410 | Araştırma Makalesi

Belirli Araştırma Alanlarında Dijital İkiz Konulu Yayınların Sistematik Literatür İncelemesi

Rabia ÖZAT [1] **Mualla AKÇADAĞ** [2]

Öz

Fiziki ürün ile sanal teknolojinin birleştirilmesinden oluşan dijital ikiz kavramı, sürdürülebilir rekabet etmek isteyen işletmelerin başvurduğu yeni yöntemlerden biridir. Maliyetlerin azaltılması, üretim modelleri geliştirmesi ve değişen müşteri istek ve ihtiyaçlarını karşılayabilme hızını yakalamada dijital ikiz kritik önem taşımaktadır. İşletmeler bu anlamda bilgi iletişim teknolojilerindeki gelişmelerden faydalanarak nesnelerin interneti, büyük veri, yapay zeka gibi yöntemleri dijital ikiz ile birlikte kullanarak gelişme trendi gösterebilmektedir. Her alanda teknolojinin gelişmesi ve yaygınlaşması sayesinde dijital ikiz önemini artırdığından bu konunun irdelendiği geçmişteki çalışmaların sistematik bir şekilde düzenlenmesinin hem mevcut eğilimin ortaya konulması hem de gelecekteki araştırmalara yön verilebilmesi açısından değerli olduğu düşünülmektedir. Bu kapsamda çalışma ile dijital ikiz konulu araştırmaların sistematik literatür incelemesi yapılması amaçlanmıştır. Bu amaçla yapılan çalışmada Web of Science veri tabanında yayınlanan 60 araştırma Vosviwer analizi ile incelenmiştir. Vosviwer analizi ve Web of Science veri tabanı kullanılarak yazar işbirlikleri, anahtar kelime yoğunluğu, desteklenme durumu, kurum, ülke, dil, atıf, yıl, yayın türü, çalışma alanı ile ilgili veriler incelenmiştir. Web of Science veri tabanındaki çalışmaların yayınlandığı yıllar incelendiğinde dijital ikiz kavramının 2019 yılı itibariyle ivme kazandığı görülmüştür. İlgili çalışmaların en çok İngilizce dilinde, makale olarak ve Amerika'da yayınlandığı anlaşılmıştır. Analiz sonucunda dijital ikiz konulu 60 çalışmada en çok veri, dijital ikiz ve endüstri anahtar kelimelerinin kullanıldığı bulgusuna ulaşılmıştır. Yine çalışma ile araştırmaların ağırlıklı olarak akıllı üretim, tedarik zinciri, iş ekonomisi gibi alanlarda yapıldığı saptanmıştır. Sistematik literatür incelemesi sonucunda akıllı üretim, tedarik zinciri, iş ekonomisi alanlarının aksine taşımacılık, kamu yönetimi, ekonomi, sosyal bilimlerde diğer konuların daha az çalışıldığı anlaşılmaktadır. Bu doğrultuda daha az çalışılan alanlarda yayın yapılması literatürdeki eksikliği giderecektir.

Anahtar Kelimeler: Dijitalleşme, Dijital İkiz, Dijital ikiz Teknikleri, Sistematik Literatür Analizi, Bibliyometrik Analiz.

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Introduction

Utilizing technology, facilitating market entry and sustainability, adapting rapidly to changing conditions, improving operational performance, and offering innovative products and services are just a few of the ways that Industry 4.0 benefits organizations. The digital twin is one of the ideas that emerged with Industry 4.0. Grieves initially suggested the idea of a digital twin in 2003 when he unveiled the "Mirror of Information Model". According to Coralla et. al. (2021, p.24), Grieves defined a digital twin as a sensor-effective digital representation of a physical thing. Also digital twin referred to a life cycle that integrates all data with additional knowledge about physical assets (Hartmann & Auweraer, 2020, p.4).

Businesses can gain from the digital twin by improving the value of their market position, taking advantage of the synergy between production management, acquiring a competitive market, improving the efficiency of logistical operations, and speeding up the process of developing new products. Businesses that want to succeed in all of these industries can use the digital twin to their advantage by utilizing techniques like simulation, the internet of things, business models, know-how, and big data. Despite the fact that it was first utilized in the early 2000s, the number of research determining the effects on results obtained when digital twin technology is supported is limited. As a result, the goal of this study is to identify unused or underutilized areas by conducting a thorough literature evaluation of digital twin studies. In the digital twin investigation, a small number of literature reviews were discovered. It is believed that the digital twin is the focus of a certain area of research. Smart manufacturing (Warke, et. al. 2021; Corallo, et.al. 2021), smart buildings (Ghansah and Lu, 2023; Hou, et. al. 2023), and supply chain and logistics (Abideen, Sundram, Pyeman, Othman, and Sorooshian, 2021) are among these studies. According to the review, a study (Wang and Liu, 2022) is a literature review on the notion of digital twin. In this context, it is hoped that studies in the disciplines of economy, business, management, marketing, transportation, public administration, and other social sciences relevant to the notion of digital twin would be comprehensively examined.

In this part of the study, conceptual definitions are developed in this section of the study to explain the significance of the digital twin in light of the development of technology. The flow chart for the study is provided at the conclusion of the section that conceptualizes the digital twin. Within this framework, studies on digital twins were investigated and data were analyzed using Vosviwer in line with the bibliometric analysis sought after by the research. With the interpretation of the findings from the analysis of the collected data and recommendations for further investigation, the study was concluded.

Digital Twin Conceptual Framework

The digital twin is defined as a system that offers the appropriate degree of data at the appropriate time and establishes modeling by connecting the virtual world and information technologies (Hartman & Aureweraer, 2020). Although there are different definitions of digital twins, they all have one thing in common: there is a link between actual entities and virtual twins. In a nutshell, a digital twin is a digital clone of a living or inanimate entity (Holopainen, Saunila, Rantala, & Ukko, 2022). The digital twin's

relevance grows as a result of its use in all industries and technological advancement. Businesses who engage in digital twin technologies are expected to gain 30% (Pettey, 2017). In this regard, it is critical for firms that wish to compete sustainably to employ digital twins in a variety of operations such as organization, sales, manufacturing, and innovation.

As previously stated, the digital twin is employed using a variety of technologies. 3D printing, big data, artificial intelligence, and the internet of things are the most commonly employed of these technologies. Among these approaches, 3D printing converts computer designs into real objects (Fukawa & Rndfleisch, 2023). One of the most prevalent approaches employed by firms employing digital twins is 3D printing, which brings digital ideas into reality. 3D printing is favoured in many industries, including manufacturing, automotive, aerospace, and new product development. Businesses that use digital twins in conjunction with 3D printing reap several benefits, including cost savings, increased manufacturing efficiency, and improved customer satisfaction.

Big data is another technology connected to the digital twin (Aktan, 2018). Big data is described as huge and heterogeneous data in various quantities that cannot be handled using typical databases. It has become an essential component in delivering a competitive edge for firms as a result of advancements in big data, information, and communication technology. Diversity, speed, volume, realism, and value are all components of big data. The variety of these components is due to the fact that there are several sorts of data (structural, semi-structural, and unstructured). Speed, on the other hand, indicates that the data is always moving and that the pace of production is high. Volume refers to the magnitude of data that cannot be handled using standard means, such as terabytes and petabytes. Another aspect of big data is reality, which refers to how much of the data gathered is correct and dependable. Analyses based on dependable and correct data produce success and efficiency. Finally, the idea of value is tied to the data's meaning and accuracy. Big data is employed in a variety of industries, including banking, communication, insurance, health, education, manufacturing, public, marketing, logistics, and energy.

Another technology employed with the digital twin is artificial intelligence. Shankar (2018) defines artificial intelligence as "a machine ability created by humans to benefit from experience, adapt, and perform." While big data allows for the merging of the real and digital worlds, artificial intelligence focuses on streamlining processes and limiting the usage of human resources. As a result, both strategies are tied to the digital twin. It delivers benefits in fields such as energy, autonomous systems, health, marketing (application of artificial intelligence in promotional brochures), and manufacturing by combining artificial intelligence with digital twin.

One of the most popular approaches for using the digital twin is the internet of things. The digital twin and the internet of things were used to generate the bulk of the models in the research found in the literature review (Chen, L. et. al., 2021; Feng et. al., 2023). The Internet of Things idea is described as the creation, sharing, and exploitation of information using various technological devices (Bahçekapılı, 2018). The Internet of Things is made up of three main components. These components are items, connections, humans, and processes. While objects are made up of multiple sensors, triggers, converters, and hardware, connection refers to the communication mechanisms utilized

in data transfer. People and processes, on the other hand, are service marketing mix elements, and everything generated or sold is realized for the person or process.

The most important advantage of the digital twin, which can be used in almost every sector, is that it enables the copy of complex processes to be checked before they are produced, thanks to its simulation capability. In addition, reducing operating costs and expenses, prolonging the product life, and making analyses are among its other advantages.

Technology is the most prevalent use of digital twins. Companies in the technology sector (Microsoft, IBM, GE, and others) utilise digital twins for their goods and services. Recently, TESLA, which has distinguished itself from its competitors by producing electric vehicles, has begun to employ a particular vehicle digital twin for each chassis number it creates, and the cars may be upgraded in accordance with the demands of the consumers (https://www.hcltech.com/). The digital twin can also be used in the field of medicine. In health care, the digital twin is employed in two ways. The first is hospital layout, and the second is patient care. The digital twin is used in hospital design to develop the hospital building, operating room, patient beds, and service planning. In terms of patient follow-up, digital twins are used to determine patient health information, process control of processes in the patient's body (holter, etc.), and therapy results using sensors. The construction sector, which involves significant investment and labor, has likewise made a swift shift to digitization. The digital twin is crucial in this digitization. The digital twin is employed in the construction sector from the beginning of the design process. All information about the construction is supplied by the digital twin in the interaction between the equipment, the project, and the user (Ceylan, 2019). Aside from these industries, the digital twin is used in agriculture (Raba et. al., 2022; Purcell et al., 2023; Liu et. al., 2023;), renewable energy, energy production, energy infrastructure improvement, metering, and other areas to protect the environment, grow sustainable plants, and produce organic products. It is employed in the field of energy (Meske, Osmundsen & Jubglas, 2021; Teng et. al., 2021; Yu et. al. 2022; Bucullo et. al. 2023; Li et. al., 2023; Korotkova et. al., 2023) in terms of processes such as monitoring. Furthermore, the digital twin is frequently employed in the education, public, manufacturing, and logistics sectors.

The term of digital twin was initially explained in the study, followed by a literature review. In accordance with the systematic literature review, the Web of Science database, which has recognised scientific validity, was searched for related publications in the methodological section of the research. As a consequence of the scanning, the Vosviwer Program examined 60 articles with the terms digital twin in the headline. The findings and discussion section finished the study. Figure 1 depicts the study's flowchart.

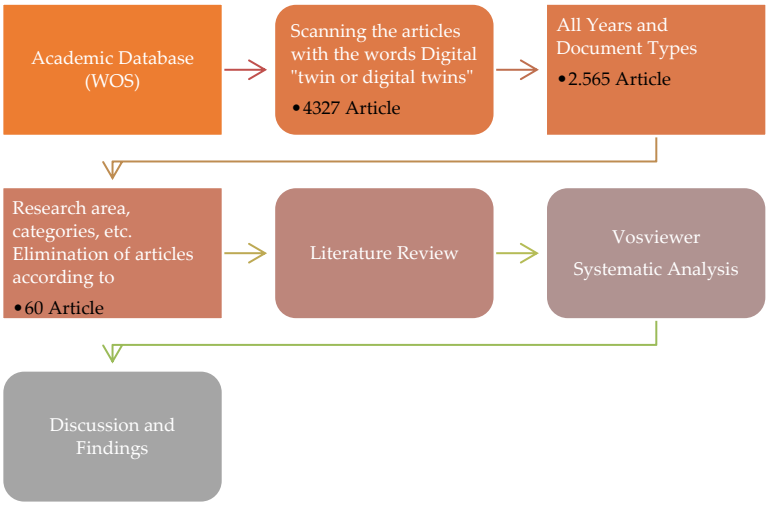

Figure 1: Research Flow Chart

Literature Review

Digital twins are techniques that provide information in real-time by fusing physical and virtual systems with emerging technologies. According to Kamble et. al. (2022) digital twins can improve quality, save time, and aid in the development of sustainable and intelligent manufacturing systems. Digital twins replicate how physical, social, and economic systems operate in real time. More than ever, companies, cities, and communities have been impacted by digital revolutions such as cloud computing, big data, smart cities, machine learning, artificial intelligence, etc. (Batty, 2018, p. 817).

Recent research on digital twins has been done as a result of the digital revolution in many areas, including smart city planning, machine learning systems, logistics and transportation, and smart manufacturing systems. The literature from the WOS database was organized in this fashion for this section of the study, and the papers were reviewed. The words "digital twin" and "digital twins" which are used interchangeably in the literature were added to the WOS database as keywords. Even though the earliest research on the topic date from 1973 and 1993, they were conducted in the engineering discipline. As of 2017, studies on digital twins are widely available. 2022 saw 1615 studies recorded, making it the year with the most research in the WOS database.

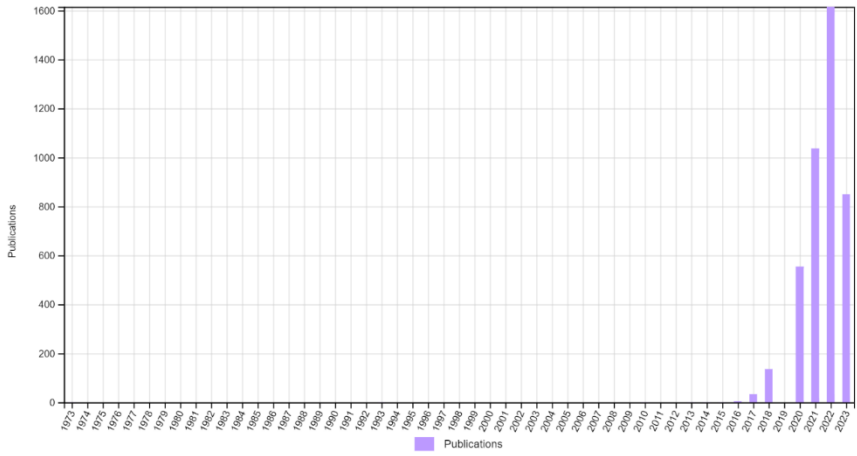

Figure 2: Number of Studies on Digital Twins Published in WOS Database by Years

When 4237 studies were assessed generally, it was discovered that engineering, computer science, automation control systems, and communications systems were the primary study fields. It has been noted that 1449 of the studies are in the field of computer science, 2443 of the studies are in engineering, and the number of research in disciplines like energy, environment, and transportation is constantly rising.

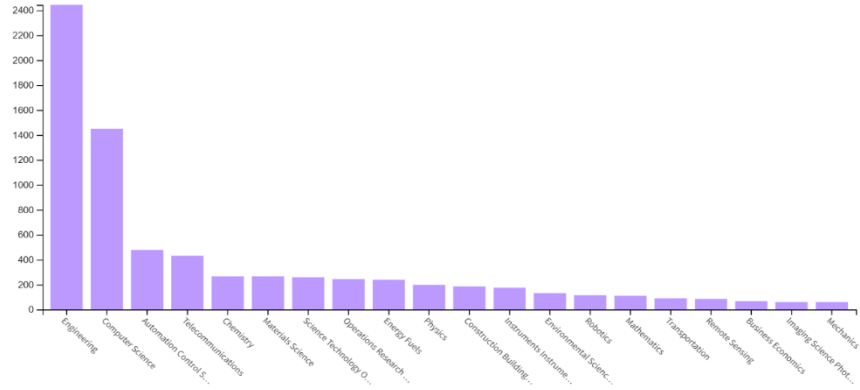

Figure 3: Research Areas of Studies on Digital Twins Published in WOS Database

It can be noted that 98% of the research on the digital twin are written in English when the Table 1 in the WOS database is assessed in terms of the language in which they are published. There is one research written in Turkish, compared to 55 papers written in German.

Table 1: Publication Languages of Studies on Digital Twins Published in WOS Database

Languages	Record Count	% of 4.237
English	4158	98.135
German	55	1.298
Korean	7	0.165
Russian	5	0.118
Italian	4	0.094
Spanish	4	0.094
Chinese	3	0.071
Croatian	1	0.024
French	1	0.024
Portuguese	1	0.024
Turkish	1	0.024

Examining the different study types revealed that 60% of the research were presented as papers, while 30% were published as articles. 25 of the research that were addressed were published as book chapters, and 4 were published as books.

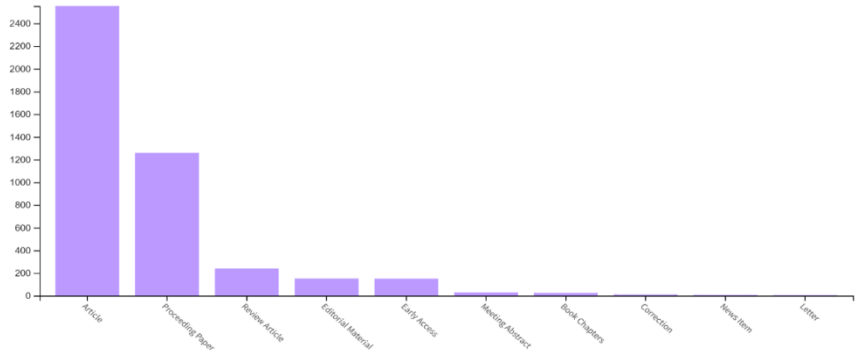

Figure 4: Document Types of Studies on Digital Twins Published in WOS Database

In the WOS database, studies on digital twins are categorized according to study topics, publishing languages, and document types in light of all these broad criteria. This categorization resulted in the retention of 60 studies.

Documents By Publication Citations in Web of Science Database

Table 2 displays the total yearly citations of research-related publications. All years were chosen when looking at the WOS digital twin. Between 2020 and 2023, a publication regarding the digital twin was produced in WOS, and 348 citations were made in this time period. The top 10 most referenced studies as of 2022 are listed in Table 2. The most popular studies are in 2022.

Table 2: Top Ten Publications from WOS Databases with The Most Citations

No	Title	Authors	Journal title	Year (Y)	Total citation (TC)	Citation per Year (TC/Y)
1	Food retail supply chain resilience and the covıd-19 pandemic: a digital twin-based impact analysis and improvement directions	Burgos, D & Ivanov, D	Transportatıon research part e-logıstıcs and transportatıon revıew	2021	118	39,33
2	Digital twin for sustainable manufacturing supply chains: current trends, future perspectives, and an implementation framework	Kamble, SS; Gunasekaran, A. et. al (...); Sharma, R	Technologıcal forecastıng and socıal change	2022	40	20
3	Building an organizational digital twin	Parmar, R; Leiponen, & Thomas, LDW	Busıness horızons	2020	27	6.75
4	Digital twin ıntegrated reinforced learning in supply chain and logistics	Abideen, AZ; Sundram, VPK; (...); Sorooshian, S	Logıstıcs-basel	2021	21	7
5	Metrics development and modelling the mixed reality and digital twin adoption in the context of ındustry 4.0	Sepasgozar, S; Ghobadi, M; (...); Delzendeh, E	Engıneerıng constructıon and archıtectural management	2021	20	6.67
6	Deploying 3d scanning based geometric digital twins during fabrication and assembly in offsite manufacturing	Rausch, C; Lu, Rd; (...); Haas, C	Internatıonal journal of constructıon management	2023	19	6.33
7	Multi-aspect applications and development challenges of digital twin-driven management in global smart ports	Wang, K; HU, QQ; (...); Qian, Xm	Case studıes on transport polıcy	2021	17	5.67
8	Bibliometric analysis of digital twin literature: a review of influencing factors and conceptual structure	Wang, J; Li, XC; (...); Liu, Ql	Technology analysıs & strategıc management	2022	12	6
9	Digital twins in infrastructure: definitions, current practices, challenges and strategies	Broo, DG and Schooling, J	Internatıonal journal of constructıon management	2023	10	3.33
10	Analyzing the ımplementation of a digital twin manufacturing system: using a systems thinking approach	Loaiza, JH and Cloutier, RJ	Systems	2022	7	3.5

The majority of management-related research are found when we examine the assessment of 60 studies in terms of the literature. It is noteworthy that studies are conducted in the management field in the areas of supply chain and logistics, construction, strategic, information, energy, innovation and technology, public management, warehouse, human resources, and production management. Through the use of digital twins in linked disciplines, theoretical and practical explanations were provided.

Numerous case studies are possible because to the ability of the digital twin approach to build a simulation using the real-time data at hand. Akinyemi et. al. (2022) provide a case study for digital twin management that makes use of digital tools including machine learning, artificial intelligence, and data analytics for business operations in the

construction industry. Korotkova et. al.'s (2023) case study, which looked at the use of digital twins for knowledge management from the point of technological adoption via the oil and gas sector, is another example. They suggested a practical strategy for fostering confidence in overstated technologies as a consequence of the study. To use digital twins in an advanced strategic decision-making process in the digital age, another case study has been set up. In the dynamic and ever-changing business environment, Yan et. al.'s (2022) strategic management study aids in making both operational and strategic company choices a more coherent and effective model. In a case study by Pivnicka et. al. (2022), digital twins were used to simulate a human resources management process. A case study has been done on flexible human resource planning in accordance with the best production and logistics plans, and a model for the physical-digital-physical cycle has been proposed. The management of manufacturing and logistics is one area where the digital twin approach is used. Daabrowska et. al. (2022) created a case study on the sugar sector in this area. Digital twin modeling, used for productivity and logistics efficiency in production, has highlighted the impact of internal and external influences on sugar line packaging operations.

The areas where firms may leverage technology and innovation have expanded along with the availability of more digital resources. By demonstrating that digital twins have applications that are both process- and product-oriented, Fukawa and Rindfleisch (2023) stressed that the digital twin is a crucial step of the evolving digital revolution for firms that incorporate Industry 4.0 technology. According to Parmar et. al. (2020), digital twins could have digital representations both in institutions and in physical items. The process of digitalizing corporate operations and merging the data flow made up of institutions, people, and activities is described as being necessary for the creation of corporate digital twins. Timperi et. al. (2023) revealed that digital twins significantly influence the business models of manufacturing companies, producing benefits like cost savings, improved operations, a focus on core competencies, and job growth. This information was revealed in a qualitative study that looked at how the manufacturing sector can benefit from digital twins in a way that adds value to companies. Digital twins will be the main technology of future digital manufacturing systems, a system that maximizes performance and decision-making, according to Van Dyck et. al. (2023), in their work depicting a potential future of digital manufacturing in 2030. It was also stressed that solid governance frameworks, data sharing, balancing the contributions of humans and machines, and balancing value generation are all necessary for the adoption of linked digital twins to be effective.

Feng et. al. (2023) looked at the applicability of digital technology to transportation systems in the realm of transportation, one of the application areas for digital twins. According to their study, the transportation system's capacity to adjust to unpredictable occurrences will improve, communication costs will be reduced by more than 50%, and operational efficiency will rise by around 20%. Yang et. al. (2023), on the other hand, emphasized that digital twins can be effective in real-time monitoring of transactions in automated container terminals, real-time transaction analysis, and real-time loading and unloading in order to benefit from the advantages of digitalization in the transportation system.

The digital twin system is the topic of theoretical and practical investigations in several disciplines, including engineering, energy, management, business, and transportation.

A total of 60 research on digital twins were looked at after the topics of business, economy, transportation, public administration, and other social sciences were ruled out. Out of 60 investigations, 7 studies used bibliometric analysis to perform a literature review on digital twins. The business, economic, scientific, and technological domains include the research topics of bibliometric studies on digital twins. The literature review for the digital twin system for sustainable manufacturing supply chains was created by Kamble et. al. (2022), which among bibliometric research contributed the most to the body of knowledge.

Table 3: Bibliometric studies on digital twins

Authors	Article Title	Times Cited	Publication Year	WoS Categories	Research Areas
Sachin S Kamble, Angappa Gunasekaran, Harsh Parekh, Venkatesh Mani, Amine Belhadi, Rohit Sharma,	Digital twin for sustainable manufacturing supply chains: Current trends, future perspectives, and an implementation framework	40	2022	Business; Regional & Urban Planning	Business & Economics; Public Administration
Abideen, Ahmed Zainul, Veera Pandiyan Kaliani Sundram, Jaafar Pyeman, Abdul Kadir Othman ve Shahryar Sorooshian	Digital Twin Integrated Reinforced Learning in Supply Chain and Logistics	21	2021	Management; Operations Research & Management Science	Business & Economics; Operations Research & Management Science
Wang, J; Li, XC; Wang, P; Liu, QL	Bibliometric analysis of digital twin literature: a review of influencing factors and conceptual structure	12	2022	Management; Multidisciplinary Sciences	Business & Economics; Science & Technology - Other Topics
Dhar, S; Tarafdar, P and Bose, I	Understanding the evolution of an emerging technological paradigm and its impact: The case of Digital Twin	1	2022	BusinessRegional & Urban Planning	Business & EconomicsPublic Administration
Hou, HY; Lai, JHK; Wu, H; Wang, T	Digital twin application in heritage facilities management: systematic literature review and future development directions	0	2023	Engineering, Industrial; Engineering, Civil; Management	Engineering; Business & Economics
Xin, C; Wang, YS	Digital twins and innovation management: a literature review, framework, challenge, and future direction	0	2022	Management; Multidisciplinary Sciences	Business & Economics; Science & Technology - Other Topics
Xin Li; Yuanfei Shen; Haolun Cheng; Fei Yuan; Lucheng Huang	Identifying the Development Trends and Technological Competition Situations for Digital Twin: A Bibliometric Overview and Patent Landscape Analysis	0	2022	BusinessEngineering, IndustrialManagement	Business & EconomicsEngineering

The WOS database contains 56 publications from studies on digital twins in the fields of commerce, economics, transportation, public administration, and other social sciences. Four papers were released as review articles, while 19 studies were released as early

access. Studies on digital twins have shown that there are fewer book chapters than in other genres.

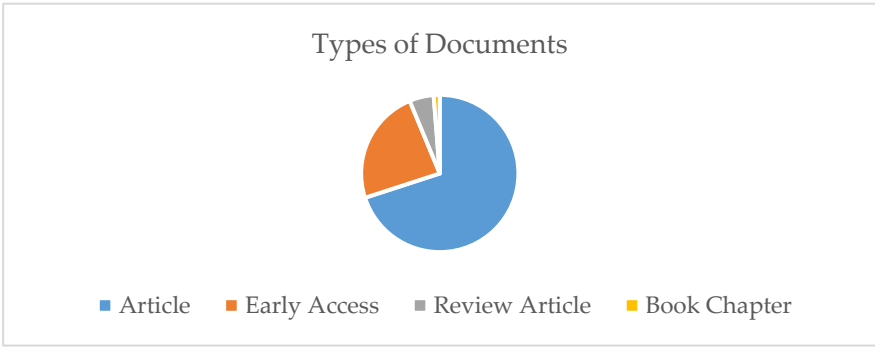

Figure 5: Types of documents in Web of Science

The Table 4 provides an examination of the digital twin studies in the WOS database by year. It can be shown that research on the digital twin have been published in the WOS database as of 2020, and the number of studies has grown significantly in the years that have followed. The most research were conducted between 2020 and 2023 in 2023. It can be seen from the table and the graphic that there were more publications on digital twins published in 2021 than in 2022, but that research done in 2022 earned more citations than those conducted in 2021.

Table 4: Year-Wise Publications in WOS Database

Publication Years	Record Count	% of 60
2023	23	38.333
2021	19	31.667
2022	17	28.333
2020	1	1.667

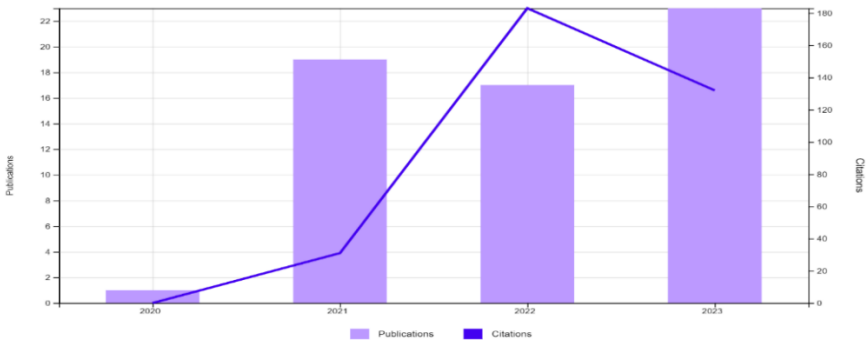

Figure 6: Times Cited and Publications Over Time

The figure lists the fields where references to the research under consideration are most frequently found. The most often mentioned studies are in the area of design and manufacturing, as seen in the table. The studies that have been examined in the research on the disciplines of design and manufacturing have undergone a great deal of evaluation. The demand for topics relating to supply chain and logistics, management, human geography, operations research, and management science is therefore evident.

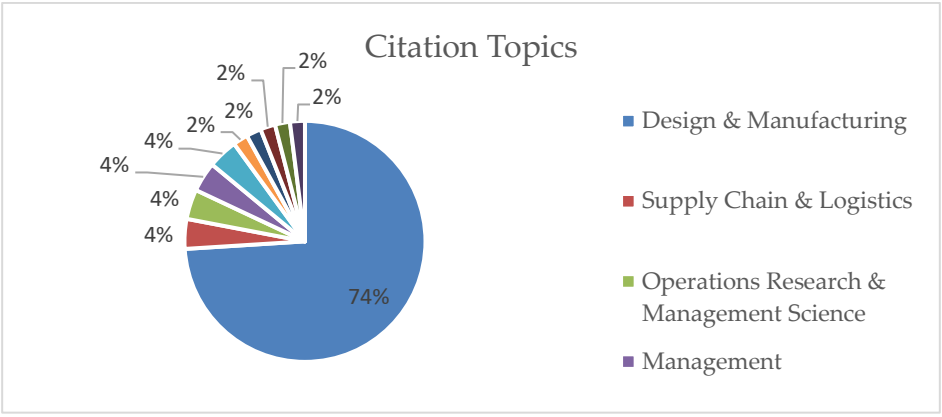

Figure 7: Citation Topics

The table looks at the intensity of 60 digital twin studies in the WOS database. The table indicates that the majority of the studies between 2020 and 2023 is seen in the subjects of engineering, business economics, and other social sciences.

Table 5: Research areas of documents in WOS

Research Areas	**Record Count**	**% of 60**
Business Economics	45	75.000
Engineering	12	20.000
Social Sciences Other Topics	11	18.333
Operations Research Management Science	5	8.333
Science Technology Other Topics	5	8.333
Transportation	5	8.333
Public Administration	4	6.667
Computer Science	2	3.333
Development Studies	2	3.333
Information Science Library Science	2	3.333
Environmental Sciences Ecology	1	1.667
Geography	1	1.667

The universities that made the top 10 out of 115 institutions and the number of associated publications are listed in the table when the 60 research on digital twins analysed in the WOS database are examined in terms of the institutions the authors are affiliated with. The top spot went to Lut University, which had 5 publications.

Table 6: Institutions to which the authors are affiliated (top 10)

Affiliations	**Record Count**	**% of 60**
Lut Univ	5	8.333
Birmingham City University	2	3.333

Edhec Business School	2	3.333
Hong Kong Polytechnic University	2	3.333
Indian Institute of Management Iim System	2	3.333
Minist Nat Resources North Sea Bur	2	3.333
Norwegian University of Science Technology Ntnu	2	3.333
Shanghai Maritime University	2	3.333
State University of Management	2	3.333
State University System of Florida	2	3.333

The table lists the sources of funding for the 60 digital twin studies that were looked at in the WOS database. The organization that has supported digital twin research the most is China's National Natural Science Foundation. Then, it becomes clear which organizations give financing assistance for the research that have been looked at more than time, including Innovation England, UK Research Innovation Ukri, and Fundamental Research Funds for Central Universities. It can be shown that 60 studies received financial backing from 36 distinct entities.

Table 7: Funding Agencies of documents

Funding Agencies	**Record Count**	**% of 60**
National Natural Science Foundation Of China Nsfc	4	6.667
Fundamental Research Funds For The Central Universities	3	5.000
Innovate Uk	2	3.333
Uk Research Innovation Ukri	2	3.333
Bru21 Ntnu Research And Innovation Program On Digital And Automation Solutions For The Oil And Gas Industry	1	1.667
Bundesministerium Fuer Wirtschaft Und Energie Federal Ministry For Economic Affairs And Energy	1	1.667
Business Finland The Finnish Innovation Funding Trade Investment And Travel Promotion Organization	1	1.667
Catalan Agency For Management Of University And Research Grants	1	1.667
Centre For Digital Built Britain Cdbb General Research Project	1	1.667
Centre For Systems Engineering And Innovation Csei Imperial College London	1	1.667
China Postdoctoral Science Foundation	1	1.667
Engineering Physical Sciences Research Council Epsrc	1	1.667
Eu Iof2020 Project	1	1.667
Fundamental Research Funds Of The Educational Department Of Liaoning Province For The Colleges And Universities	1	1.667
German Research Foundation Dfg	1	1.667
Hamburg University Of Technology Tuhh	1	1.667
Hksar	1	1.667
Hong Kong Polytechnic University	1	1.667
Humanities And Social Sciences Youth Foundation Of The Ministry Of Education Of China	1	1.667
Institute Of Business Excellence Ibe Universiti Teknologi Mara	1	1.667
Lloyds Register Foundation Data Centric Engineering Programme The Alan Turing Institute	1	1.667
Mitacs Accelerate And Edge Architects	1	1.667
Nanjing University Of Posts Telecommunications	1	1.667
Natural Science Foundation Of Jiangsu Province	1	1.667
Natural Science Foundation Of Liaoning Province	1	1.667
Natural Sciences And Engineering Research Council Of Canada Nserc	1	1.667
Netherlands Enterprise Agency Rvo	1	1.667
Projekt Deal	1	1.667
Rgc Hk Trs	1	1.667
Russian Science Foundation Rsf	1	1.667
Shanghai Key Projects Of Soft Science	1	1.667
Social Science Program Of Beijing Municipal Education Commission	1	1.667
Spanish Government	1	1.667
State Key Laboratory Of Explosion Science And Technology In Bit China Institute Of Communications Education	1	1.667
Technische Universitat Ilmenau	1	1.667
Tu Berlin	1	1.667

Methodology of the Study

As opposed to other databases, Web of Science has a higher volume of published data, hence that was chosen as the database for the study. The Web of Science database's search function was applied to include articles regarding "digital twins or digital twins" as

keywords or phrases. Added title option to these keywords. 4327 articles were eventually read as a result. 2565 items were found after filtering by Document Types and All Years. Early-looking articles and book chapters have been identified, and the filtering now includes an option for all years. Later, as WOS categories, the filtering was expanded to include business, green sustainable scientific technologies, management, interdisciplinary social science studies, transportation, economics, and development studies. A total of 148 studies were found after the filtering. It was shortened to 60 papers by the writers, who filtered the research to include only studies relevant to their field of expertise in fields including business economics, transportation, public administration, social sciences, and others. The systematic review was selected to use a Vosviwer analysis. The first set of data includes tabular data on the number of studies, research topics, publishing languages, document kinds, bibliometric summary, citation status by years, financing status, data on the ten most cited studies, and affiliation data for the authors' universities. Next, network visualization of the nations, organizations, author partnerships, and common keywords in which the papers were published was carried out using Vosviwer analysis.

Network Analysıs of Author and Co-Author

The Web of Science database is evaluated in Figure 8 in terms of author and co-author collaborative viewpoints. The author collaborations are based on the visual network made using Vosviwer. An author's association with other writers is shown by the total number of co-authoring links. Ten writers were used as thresholds out of a total of 188 authors. There were thus 2 co-authorship clusters discovered. Additionally, this network has created two products. 25 linkages between writers have been made. The clusters that were discovered are as follows, and they demonstrate the authors' active collaboration. It appears that Gunasekarak, A., Kamble, SS., Mani, V., Parekh, H., and Sharma, R. participated on the initial cluster. Belhadi, A., Gupta, S., Kumar, S., Maheshwari, P., and Kamble, SS. seem to be in the second cluster.

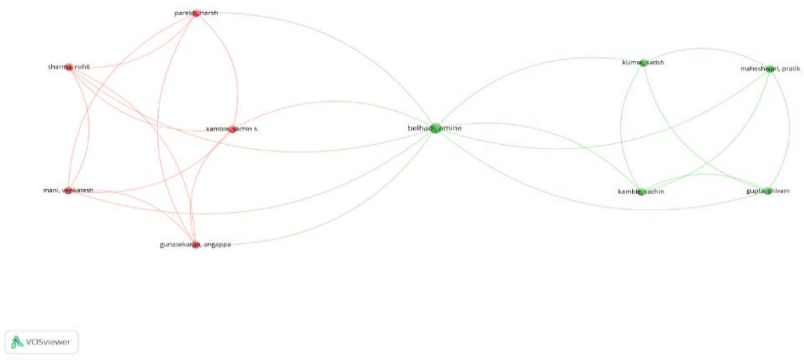

Figure 8: Network visualization of author and co-author for WOS documents

The network visualization of the authors' institutions is shown in figure 9 of research on digital twins. According to the network visualization of the authors' institutions, there are two clusters of institutions. The first cluster includes Edhec Business School, Indian Institute of Management Jammu, and Indian Institute of Management, while the second cluster includes Cadi Ayyad University of Marrakech, Jaipuria Institute of Management, Louisiana State University, Montpellier Business School, Penn State Harrisburg. University Internationale De Rabat, Management Nagpur, and Neoma Business School. Institutions in both clusters are affiliated with Edhec Business School. Studies for the years 2022 and 2023 were conducted in the second cluster.

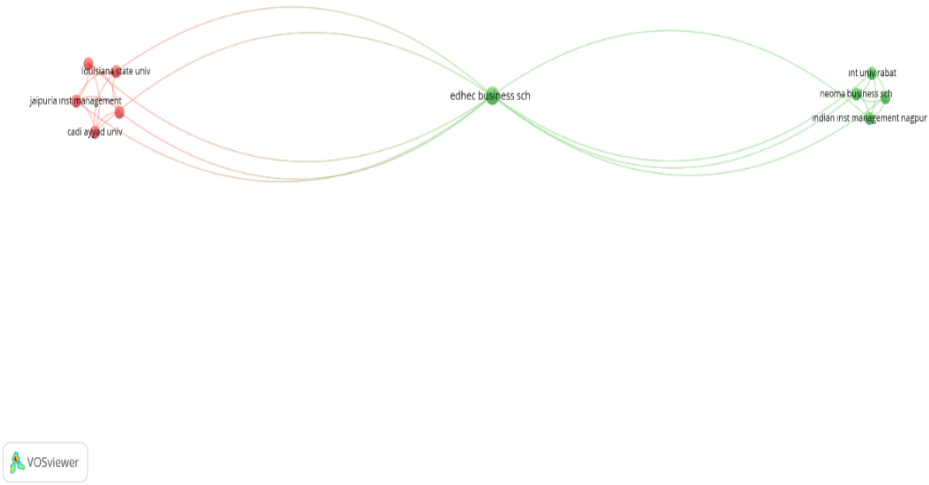

Figure 9: Network visualization of authors' institutions

Network of Co-Occurrence of Author Keywords

Figure 10 and Table 8 show the findings of the study of the existence or proximity of the keywords, which enables the analysis of the keywords in the authors' collaborative works. The keywords used in the source names of the articles are displayed in each circle, per these findings. The circle's size grows in proportion to the writers' increased use of keywords. Associating circles for links display the separation between two keywords. Out of the 274 keywords that were extracted from the chosen articles, 20 keywords with at least two frequent terms were therefore found. Bibliometric analysis, data, digital twins, and industry are highlighted in the first cluster of the network analysis in Figure 1. The second cluster highlights the industries (digital manufacturing, digital transformation, service firms, etc.) where the digital twin is applied. The third cluster highlights the significance of using the digital twin in conjunction with technologies like artificial intelligence and the internet of things. Big data and Industry 4.0 are both featured in the fourth cluster. It concentrated on keywords associated with digital twin application model designs in the last cluster.

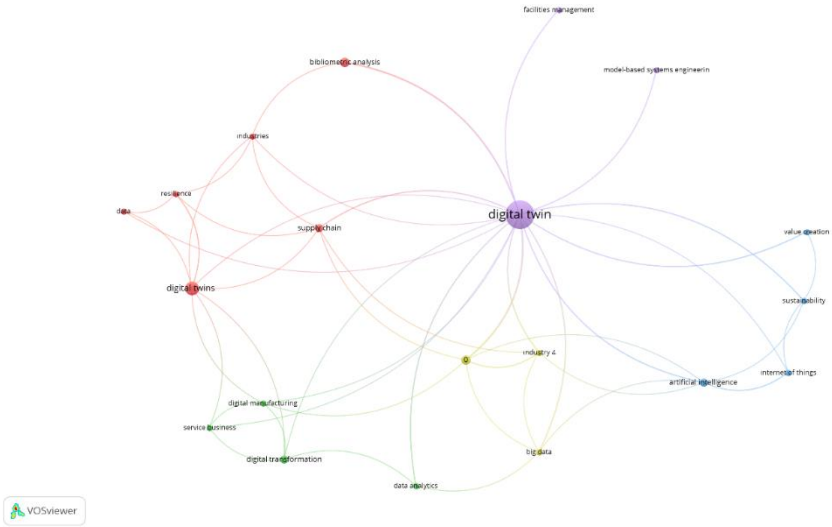

Figure 10: Network analysis of co-occurrence of key words in WOS

The keywords connected to the utilization areas of the digital twin and the methodologies employed in conjunction with them in the research related to the digital twin have been concentrated, as can be seen from the network analysis and clustering table.

Table 8: Results of co-occurrence of author keywords in the Web of Science database

Cluster	Co- Occurrences	Links	Total Link Strength	Author- Keywords
1 Red (6 Items)	9	8	9	Digital Twins
	4	2	5	Bibliometric Analysis
	2	3	3	Data
	2	5	5	Industries
	2	4	5	Resilience
	3	6	7	Supply Chain
2 Green (4 Items)	2	3	4	Data Analytics
	2	5	5	Digital Manufacturing
	3	5	5	Digital Transformation
	2	4	4	Service Business
3 Blue (4 Items)	3	6	8	Artificial Intelligence
	2	3	4	Internet of Things
	2	4	5	Sustainability
	2	2	3	Value Creation
	4	6	10	0 (4.0)

4 Yellow (3 Items)	2	5	6	Big Data
	2	5	7	Industry 4
5 Purple (3 Items)	38	18	33	Digital Twin
	2	1	2	Facilities Management
	2	1	2	Model- Based Systems Engineering

The picture shows a network depiction of the geographic locations of 60 research on digital twins found in the WOS database. The writers' nations' networks were visualized, and it can be seen that there were 27 connections made overall and that 16 countries formed 5 clusters. There have been eleven digital twin studies conducted in the US. The USA ranks top among the studies evaluated with this number, followed by China and Germany with 10 studies each. Studies carried out in the United States have been linked to writers from nine other nations, including China, Germany, Norway, England, Spain, Sweden, India, France, and Morocco. It has been noted that the research carried out in China had authors from five different nations: The United States, Netherlands, Australia, India, and Sweden. It has been observed that the research carried out in Germany had authors from six different nations (United States, Netherlands, England, Taiwan, Poland, and Norway).

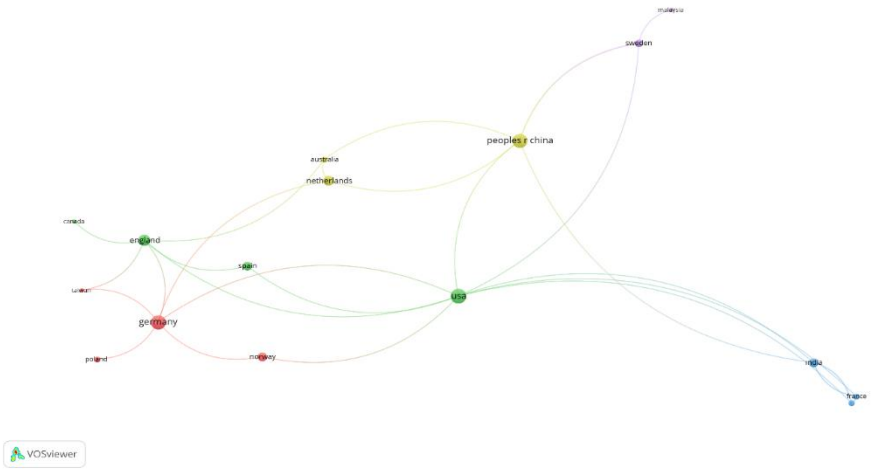

Figure11: Documents by Geographic Locations

Table 9: Clustering network analysis of documents by geographic location

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Germany	Canada	France	Australia	Malaysia
Norway	England	India	Holland	Sweden
Poland	Spain	Morocco	China	
Taiwan	USA			

Conclusion and Discussion

The purpose of this study is to conduct a systematic evaluation of the studies on the notion of the "digital twin," which has been in use since 2003, that have been published in the WOS database. The Vosviwer tool was used in the study to examine the studies in the WOS database. According to research, there are 4327 studies on the idea of a "digital twin" in the WOS database. After filtering all years, research disciplines, and document formats linked to the authors' domains, 60 publications were submitted to a systematic review. The study revealed that 98% of the publications were written in English, 60% were articles, and Burgos & Ivanow (2021) had the most citations (118). Again, as a consequence of the investigation, it was discovered that production-related papers received the most citations, and business economics received the most (75%) in terms of research fields. It was determined that 10 writers out of a total of 188 authors made more joint publications as a result of the study for author and author collaboration in digital twin research in the Vosviwer program, and two clusters were found. There were 25 links found that linked to the writers. There were 274 keywords in all, according to the examination of the keywords the writers had used in their research. It is understood that at least two common keywords are present in 20 of these 274 keywords. The primary focus of the keywords is on data, digital twins, and industry. It is known that the National Natural Science Foundation of China provides the majority of funding for the investigations, which are mostly conducted at Lut University (5). It was also discovered that 60 research, the most of which were published in the USA. Finally, business economics has been investigated the majority of the research fields.

The study's limitations include the preference for using WOS as the database, the collection of data from 20 July 2023 to 5 August 2023, and the filtering of WOS categories (business, green sustainable science technologies, etc.) for business economics, transportation, public administration, social sciences, and other research fields based on document types (book, article, book chapter, etc.). Comparison is challenging due to the lack of a study that is comparable to this study in the literature review. However, it was discovered that a study (Warke et. al. 2021) that was discovered while scanning with the concept of the digital twin in the Wos database and was not subjected to systematic analysis because it was outside the research area was similar in terms of making a bibliometric literature review by using Voswier systematic analysis.

Seven papers that conducted a systematic review of the literature were discovered. It has been acknowledged that these investigations are only in-depth literature surveys. The supply chain and logistics are covered in two of the seven studies that are literature reviews on the digital twin (Abideen et. al., 2021; Sachin et. al., 2022), while field of technology is covered in two more (Xin et. al., 2022; Dhar, Tarafdar & Bose, 2022). The remaining 3 articles (Wang et. al., 2022; Hou et. al., 2023; Xin & Wang, 2022) all take the form of literature reviews and describe the digital twin theoretically. However, this study is a comprehensive evaluation of studies on digital twins from the social sciences, business economics, transportation, and other related domains. Therefore, it is believed that by using these study findings, researchers who intend to publish in the aforementioned disciplines will close the knowledge gap. The literature analysis on the digital twin has revealed that case studies in the form of simulation and model building are common in studies pertaining to businesses, particularly those that focus on production. It is recognized that there have only been a relatively small number of

research on the idea of a digital twin in WOS up until 2019. Furthermore, researches are largely undertaken in the United States, China, and Europe, but although there are studies on digital twins in other countries, they are not published in the WOS indices.

Future research can provide comparisons in terms of efficiency, performance (business performance, export performance, market performance), sustainability, and competition in manufacturing, as well as marketing components (pricing, promotion, product and distribution), logistical operations, and multinational firms that employ or do not use digital twins. In this paper, it is expected to provide benefits in terms of cost reduction, improved production and efficiency, warehousing activities, decision support systems and operational process success, and responding quickly to customer requests and needs in the field of marketing, thanks to the use of digital twins in logistics and supply chain.

Peer-Review	Double anonymized - Two External
Ethical Statement	It is declared that scientific and ethical principles have been followed while carrying out and writing this study and that all the sources used have been properly cited.
Plagiarism Checks	Yes - Ithenticate
Conflicts of Interest	The author(s) has no conflict of interest to declare.
Complaints	itobiad@itobiad.com
Grant Support	The author(s) acknowledge that they received no external funding in support of this research.
Author Contributions	Design of Study: 1. Author (%50), 2. Author (%50) Data Acquisition: 1. Author (%50), 2. Author (%50) Data Analysis: 1. Author (%50), 2. Author (%50) Writing up: 1. Author (%50), 2. Author (%50) Submission and Revision: 1. Author (%50), 2. Author (%50)

Değerlendirme	İki Dış Hakem / Çift Taraflı Körleme
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Etik Bildirim	itobiad@itobiad.com
Çıkar Çatışması	Çıkar çatışması beyan edilmemiştir.
Finansman	Bu araştırmayı desteklemek için dış fon kullanılmamıştır.
Yazar Katkıları	Çalışmanın Tasarlanması: 1. Yazar (%50), 2. Yazar (%50) Veri Toplanması: 1. Yazar (%50), 2. Yazar (%50) Veri Analizi: 1. Yazar (%50), 2. Yazar (%50) Makalenin Yazımı: 1. Yazar (%50), 2. Yazar (%50) Makale Gönderimi ve Revizyonu: 1. Yazar (%50), 2. Yazar (%50)

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