



The Impact of Industry 4.0 and Industry 5.0 Technologies on Project Management in the Construction Sector: A Bibliometric Analysis

Zafer Tarık Taner¹, Prof. Dr. Özlem Parlak Biçer²

¹ Erciyes University, Graduate School of Natural and Applied Sciences, Department of Architecture, Kayseri, zafertariktaner@gmail.com, <https://orcid.org/0000-0001-6898-5019>

² Erciyes University, Faculty of Architecture, Department of Architecture Kayseri, parlako@erciyes.edu.tr, <https://orcid.org/0000-0002-9700-2226>

ABSTRACT

Management has undergone numerous stages before reaching its modern scientific understanding, continuously adapting to changing conditions across different periods while remaining an integral part of practical life. With the growth of the world population and the acceleration of urbanization, the need for industrialization to support environmental, social, and economic activities has increased significantly. Owing to technological advancements, meeting the growing expectations for faster and more flexible production of industrial products through an effective and integrated management approach has become critically important in reducing potential environmental, social, and economic risks. In the construction industry, the unique characteristics of each project further strengthen the strategic role of project management over time. Within this context, the impact of Industry 4.0 and Industry 5.0, shaped by technological innovations, on project management has emerged as an increasingly important field of research. Accordingly, this study primarily evaluates the transformations brought about by Industry 4.0 and Industry 5.0 in the construction sector through a comprehensive literature review incorporating bibliometric analysis. The findings provide concrete contributions to the development of policies and strategies for the adoption of digitalization and emerging technologies in the construction industry, the design of targeted training and awareness programs, and the restructuring of project management processes in a more efficient, flexible, and sustainable manner.

Keywords: Project management, Industry 4.0, Industry 5.0, Construction Management

1. Introduction

In contemporary projects, the involvement of multiple disciplines, the increasing uniqueness of projects, and the growth in project scale have significantly enhanced the importance of project management, making it one of the key determinants of inter-firm competitiveness in the construction sector. Under current technological and economic conditions, the effective evaluation of projects in terms of time and cost has become increasingly critical, with the primary objective being to achieve the highest quality within the optimum time and cost constraints.

To attain this objective, the factors determining optimization in project management must be aligned with the transformations introduced by Industry 4.0 and Industry 5.0 technologies. The negative impacts of factors surrounding the construction production system on project parameters pose significant challenges for both the project management process and project stakeholders. Among these factors, the influence of technological developments has become increasingly evident over time. Today, adaptation to these transformations is inevitable in order to ensure the environmental, social, and economic sustainability of construction production and to enhance project success. In this context, this study examines the transformations brought about by Industry 4.0 and Industry 5.0 in the construction sector through a literature review incorporating bibliometric analysis, with the aim of supporting effective project management practices. The results are expected to contribute to the development of policies and strategies for the adoption of



digitalization and emerging technologies, as well as to guide the improvement of project management processes toward more efficient, flexible, and sustainable practices.

2. LITERATURE REVIEW ON THE IMPACT OF INDUSTRY 4.0 AND 5.0 TECHNOLOGIES ON PROJECT MANAGEMENT

The increase in production volume across sectors and the growing complexity of production processes have led to the emergence of the concepts of Industry 4.0 and Industry 5.0. In the construction sector, the increase in the number of disciplines involved and the need for the effective implementation of project management make it necessary to address the concepts of Industry 4.0 and Industry 5.0 in conjunction with project management. Within this context, the literature review conducted in this study was supported by bibliometric analysis and revealed that the active use of Industry 4.0 and Industry 5.0 applications in the construction sector offers significant potential for solving existing problems and improving processes. However, it was observed that studies on this topic remain limited in the national literature. The data obtained from the review were evaluated and analyzed within the scope of the research.

Oesterreich and Teuteberg (2016) examined the role of digital transformation in the construction industry and analyzed the effects of Industry 4.0 applications on project and construction management processes. The study indicates that the integration of Building Information Modeling (BIM), sensor technologies, and automation systems increases process efficiency, enhances transparency in work processes, and enables more effective management of project risks. Furthermore, it is emphasized that the implementation of these technologies provides advantages in terms of cost savings, quality improvement, and time management; however, shortcomings in technological infrastructure, high implementation costs, and the need for employees to adapt to new systems constitute significant barriers in practice. The study demonstrates that Industry 4.0 technologies play a critical role in transforming project management in the construction industry.

In the study conducted by Ebrahimi (2019), the awareness levels of professionals in the construction industry regarding Industry 4.0 technologies and concepts were measured through a questionnaire survey. The results indicate that the overall average level of Industry 4.0 awareness is relatively low. However, it was found that the majority of participants were more familiar with specific technologies, particularly Building Information Modeling (BIM) and simulation models. In addition, participants were aware of the potential of adopting these technologies to improve decision-making quality and sustainability. These findings suggest that Industry 4.0 has not yet been fully adopted in the construction industry; nevertheless, a certain level of awareness and recognition of specific digital technologies already exists (Ebrahimi, 2019).

Maskuriy et al. (2019) examined the impacts of Industry 4.0 on the construction sector in terms of investment management, project planning, and overall management processes. The study indicates that the integration of Simulation, Building Information Modeling (BIM), and Augmented Reality (AR) technologies into project management reduces organizational complexity and makes processes more transparent and manageable. It is emphasized that these technologies strengthen decision-making mechanisms and contribute to project success. However, low rates of technology adoption, high implementation costs, data security risks, legal and compliance requirements, and the adaptation of personnel to new technologies are identified as the main challenges encountered in practice. Therefore, the study demonstrates that Industry 4.0 technologies offer significant opportunities for project management while also bringing about a multidimensional transformation process. Within this context, the main benefits and challenges identified are summarized in Table 1.



Table 1. Benefits and Challenges of Using Industry 4.0 in Project Management

Benefits	Challenges
Cost and time savings and on-time, within-budget delivery	Low rate of technology adoption
Quality control: improvement of quality	High implementation costs
Effective communication and collaboration	Changes in organizational and coordination processes
Establishing customer relationships	Requirement for advanced skills
Effective safety measures	Exposure to data theft
Branding in the sector and strengthening corporate image	Risk of changes in legal and contractual frameworks
Sustainability assurance: blue/green economy	Personnel adaptation to and effective use of technologies

A study conducted by the Australian Institute of Project Management (AIPM) in 2020 examined the opportunities that could be achieved by integrating the concept of Industry 4.0 into project management practices (AIPM, 2020). The findings of this study can be summarized as follows (AIPM, 2020):

- Through human–robot collaboration, the emergence of an unmanned construction sector will make the industry safer and more attractive for new generations.
- With Big Data and Internet of Things (IoT) technologies, data accumulation in the construction sector will become richer.
- Through system integration technologies, smart processes, products, and machines in production will enable the optimization of construction products.
- Smart contracts will enable transparency, traceability, and secure collaboration (AIPM, 2020).

Within the scope of this research, a survey conducted in Australia revealed that companies were unable to effectively use a comprehensive project management system. Accordingly, it was emphasized that, in order to overcome organizational complexity in the sector, it is necessary to adopt an innovative perspective in project management systems and to integrate the concept of Industry 4.0 into project management processes (AIPM, 2020).

Taner and Parlak Biçer (2021) stated in their study that the impact of technological factors affecting project management on production systems has been increasing day by day, emphasizing the necessity of adapting to these factors. In this context, the interaction between contemporary industrial technologies and the elements that constitute the concept of project management across all phases of building production was revealed. The study determined that the use of these technologies in project management systems would enable successful project management in the national construction industry through the long-term and accurate evaluation of material inputs, as well as the efficient use of labor and machinery.

Maqbool et al. (2022) stated that the construction sector in the United Kingdom is globally recognized for its cyclical fluctuations, inefficiencies, significant environmental impacts, and recurring budget and schedule overruns. In response, the UK Government and construction industry leaders published the Construction 2025 Strategy, aiming to transform the sector by focusing on four key targets: reducing construction time, lowering operational costs, decreasing greenhouse gas emission levels, and improving import/export trade performance. This article investigates whether increased adoption of modern methods of construction can help achieve these objectives. Key data and findings regarding construction cost, duration, greenhouse gas emissions, and trade factors were obtained from the relevant literature. Based on these data, a quantitative survey consisting of 23 questions related to the four main targets was conducted with 134 professionals working in the Architecture, Engineering, and Construction sectors in the United Kingdom.



The results indicate that these targets could contribute to achieving the Construction 2025 objectives. This research has facilitated efforts to achieve input reduction targets within the construction industry (Maqbool et al., 2022).

Zhao and Wang (2023) examined the effects of digitalization in the Chinese construction sector and stated that digital technologies not only increase efficiency in construction projects but also reduce costs. According to their study, the use of Building Information Modeling (BIM) in particular reduced error rates in projects by 25% while simultaneously shortening project duration by 15%. The research also revealed that the main reasons for slow adaptation within the sector are deficiencies in education and inadequacies in digital infrastructure. To accelerate digital transformation, the authors emphasized the need for increased government support, expanded training programs, and greater investment in digital infrastructure within the private sector (Zhao & Wang, 2023).

Musarat et al. (2024) emphasized that stakeholders within the construction sector face challenges in digitalization and evaluated the awareness, challenges, and opportunities related to digitalization in the Malaysian construction industry. From this perspective, a survey-based study was conducted, and responses were collected from field experts who implement digital systems in construction projects. Analysis of the collected data indicated that the Malaysian construction sector is aware of digitalization and considers the Industrial Building System (IBS) as the most important technology. Additionally, while standardized organizational structures applied during the project delivery process were identified as the main driver of digitalization, improved planning and monitoring of procedures emerged as the greatest opportunity. The most challenging aspect of digitalization was found to be the high initial costs associated with the implementation of technologies and standards (Musarat et al., 2024). This study is significant in addressing issues related to the implementation of digitalization in the Malaysian construction sector and in providing a perspective that may accelerate sectoral development.

Ghansah and Edwards (2024) aimed to identify future research directions by synthesizing the existing literature on technological applications used in quality management within the construction sector. The study addressed four main research questions:

- I.** What is the current state of the art in the literature?
- II.** Which digital technologies have been applied for quality assurance in the construction industry?
- III.** In which areas of QA processes have digital technology applications been implemented, and what are these applications?
- IV.** What are the limitations of existing studies and future research directions regarding digital technologies for quality assurance in the construction sector?

The findings of the study indicate an increase in digital technology research related to quality management in the construction industry since 2017. In addition, four types of digitalization were identified: data collection-oriented technologies, decision-oriented technologies, collaboration-based technologies, and technologies related to occupational health and safety. It was stated that these technologies improve quality management in construction and tendering processes and contribute to sustainable quality management through prefabricated-modular construction and supply chain digitalization (Ghansah & Edwards, 2024).

Vararean et al. (2025) analyzed the digital transformation processes of construction firms using the CIMO (Context-Intervention-Mechanism-Outcome) framework and determined that digitalization has a direct impact on cost control, quality improvement, and competitive advantage. The study identified BIM, cloud computing, and IoT-based solutions as the main tools of digital transformation. However, low levels of digital maturity within firms, cultural resistance, technological integration challenges, and high investment costs were identified as the primary factors limiting digital transformation. The study suggests



that, for digital transformation to be successful, managerial leadership should be strengthened, cultural change should be supported, and collaboration between the industry and technology providers should be enhanced (Vararean et al., 2025).

Literature reviews indicate that Industry 4.0 has created comprehensive transformations in manufacturing sectors across economic, environmental, technological, and organizational domains. This transformation encompasses not only the digitalization of production processes but also the restructuring of systems in terms of efficiency, quality, sustainability, and competitiveness. Studies address the impacts of Industry 4.0 technologies within the context of both opportunities and challenges. Among the positive effects, increased efficiency through automation and real-time data management, reduced error rates, improved product quality, and decreased costs are particularly prominent. Artificial intelligence, big data analytics, the Internet of Things (IoT), and autonomous systems make processes more transparent, traceable, and controllable. However, factors such as high investment costs, infrastructure deficiencies, a lack of skilled labor, data security risks, and organizational resistance pose significant barriers to this transformation. Digitalization is not merely a technical change but also necessitates structural and cultural transformation. With the implementation of Industry 4.0 technologies, efficiency, quality, and safety increase, while time and costs decrease; resource utilization is optimized, and processes become more effectively monitorable. Nevertheless, the literature reveals a lack of sector-specific management models based on these technologies and highlights the need for more effective approaches that can balance critical project management elements such as quality, cost, time, and scope.

When studies on the use of Industry 5.0 technologies in project management are examined, Marinelli (2023), in a bibliometric analysis addressing the transition from Industry 4.0 to Industry 5.0 and the role of human–robot collaboration in the construction sector, stated that technological transformation is increasingly evolving toward a human-centered structure. The study indicated that robotics systems, sensors, and data analytics–based applications enhance on-site efficiency; however, they also introduce new challenges related to safety, ethics, costs, and workforce skills. In addition, it was emphasized that in order for human–robot collaboration to become widespread in the construction sector, on-site compatibility, occupational safety standards, and training processes must be further developed. Marinelli suggested that visionary leadership by managers and prioritization of practices that strengthen employee participation are essential for the success of this transformation (Marinelli, 2023).

Kavirathna and Perera (2024) examined the interaction between Industry 5.0 sustainability principles and digital technologies in the construction sector, evaluating nine key technologies such as artificial intelligence, collaborative robots, digital twins, and augmented reality. The findings demonstrate that these technologies make significant contributions to human-centered design, resource efficiency, and environmental sustainability. However, uncertainties regarding human–machine interaction, ethical concerns, investment costs, and inadequacies in on-site implementation were identified as major barriers to transformation. The study emphasized that, for the effective implementation of Industry 5.0 in the construction sector, it is necessary to develop stakeholder-oriented training programs, establish guiding principles, and adapt technologies to field conditions through pilot projects (Kavirathna & Perera, 2024).

In the FARU Journal (2024) study, the focus was placed on the implementation of Industry 5.0 in alignment with sustainability in the construction sector. This research adopted a qualitative approach by collecting semi-structured expert opinions using the Delphi technique to examine the role of human–machine interaction and technology integration during the transition to Industry 5.0. The study identified that core components of Industry 5.0—such as human centricity, sustainability, and resilience—are of critical importance in the adaptation of construction projects. Moreover, it was demonstrated that nine key



technologies, including artificial intelligence, collaborative robots, and digital twins, effectively enhance the efficiency, safety, and sustainability performance of construction processes when applied in accordance with Industry 5.0 principles. The study highlights that the strategic adoption of these advanced technologies provides project stakeholders with opportunities to develop smarter, more resilient, and sustainable practices. Accordingly, the necessity of strategic orientations toward adopting Industry 5.0 principles in the construction sector emerges as one of the key findings of the study.

Akhavan et al. (2025), in their systematic literature review and bibliometric analysis addressing the concept of "Construction 5.0" in the construction sector, revealed that the principles of Industry 5.0 are closely associated with sustainability, human centricity, and resilience objectives in the construction industry. In the study, 78 articles published between 2022 and 2025 were examined, and it was determined that digital twins, artificial intelligence, IoT, robotic systems, and blockchain technologies have high potential in terms of efficiency, safety, and environmental performance within the sector. However, low levels of technological maturity, workforce adaptation challenges, high investment costs, and regulatory deficiencies were identified as the main barriers to digital transformation. The study recommends increasing training programs that support human-robot collaboration, developing standards at the policy level, and disseminating Construction 5.0 applications through pilot projects (Akhavan et al., 2025).

Literature reviews indicate that Industry 5.0 technologies create both opportunities and challenges for project management in the construction sector. Human-centered approaches and technologies such as robotic systems, artificial intelligence, digital twins, and collaborative robots offer significant advantages, including increased efficiency, support for sustainability, and enhanced transparency and traceability of processes. Nevertheless, adaptation to on-site conditions, workforce adaptation, ethical and safety concerns, high investment costs, and regulatory deficiencies are among the main barriers to Industry 5.0 transformation. These findings demonstrate that the effective implementation of Industry 5.0 technologies requires not only technical solutions but also the development of human-centered management approaches, training programs, and policy-level guiding principles. Furthermore, the literature highlights the lack of comprehensive management models based on Industry 5.0 and emphasizes the need for more effective approaches to balance critical project management elements such as quality, cost, time, and sustainability.

As a result of the literature review, it is observed that the impacts of Industry 4.0 and Industry 5.0 technologies on project management processes are addressed within the framework of different management responsibilities. In integration management, Industry 4.0 technologies such as horizontal and vertical integration, cyber-physical systems, and BIM reduce interdisciplinary information complexity and enable real-time information flow, whereas Industry 5.0 emphasizes human-centered technologies such as human-robot collaboration, the Internet of Things, and artificial intelligence. In time and cost management, Industry 4.0 technologies enable real-time task tracking, resource forecasting, and simulation-based planning, while Industry 5.0 allows more visualized, flexible, and human-interactive processes through augmented/virtual reality and digital twin technologies. In quality and scope management, Industry 4.0 enables big data-, BIM-, and simulation-based controls, whereas Industry 5.0 technologies such as blockchain, AR/VR, and digital twins facilitate secure data sharing and real-time on-site verification in production and project processes. In occupational health and safety management, Industry 4.0 enables risk prediction through sensors and cyber-physical systems, while Industry 5.0 offers applications centered on human safety and adaptable to site conditions through artificial intelligence and predictive analytics-supported systems. Literature reviews demonstrate that both paradigms contribute to project management processes in different dimensions and that Industry 5.0, in particular, enhances process efficiency alongside digitalization by emphasizing human-centered and sustainable approaches (Table 2)



(Maskuriy et al., 2019; Oesterreich & Teuteberg, 2016; Akhavan et al., 2025; Rahman et al., 2024).

Table 2. Effects of Industry 4.0 and Industry 5.0 Technologies on Project Management

Knowledge Area	Responsibilities Required Within Management Areas	Industry 4.0 Technology	References (Industry 4.0)	Industry 5.0 Technology	References (Industry 5.0)
Integration Management	Reduction of interdisciplinary information complexity and real-time information flow	Horizontal and Vertical Integration, Cyber-Physical Systems	Maskuriy et al., 2019	Human-Robot Collaboration, Internet of Things, Artificial Intelligence	Akhavan et al., 2025
	Interoperability of system components	Cyber-Physical Systems	Oesterreich & Teuteberg, 2016	Human-Robot Collaboration, Blockchain Technology	Khan et al., 2026
Time Management	Real-time task tracking and scheduling	Cyber-Physical Systems, BIM	Akhavan et al., 2025	Augmented Reality / Virtual Reality	Akhavan et al., 2025
	Reliability of resource and time estimation	Simulation, Internet of Things	Oesterreich & Teuteberg, 2016	AR/VR, Digital Twin	Akhavan et al., 2025
Cost Management	Real-time tracking of design and implementation changes	Simulation, Big Data	Oesterreich & Teuteberg, 2016	IoT and Advanced Data Analytics	FARU Journal, 2024
	Monitoring information sharing and project reports	Internet of Things, Cloud Computing	Akhavan et al., 2025	Blockchain Technology	Nanduri et al., 2025
	Real-time monitoring and forecasting of budget deviations	Big Data, Simulation	Oesterreich & Teuteberg, 2016	IoT and Advanced Data Analytics	FARU Journal, 2024
Quality Management	Process quality measurement and real-time corrections	Big Data	Oesterreich & Teuteberg, 2016	Blockchain Technology, AR/VR	Akhavan et al., 2025
	Material performance analyses	Big Data	Akhavan et al., 2025	AR/VR	Akhavan et al., 2025
Scope Management	Requirements planning and scope validation	Simulation	Oesterreich & Teuteberg, 2016	Blockchain Technology	Nanduri et al., 2025
	Scope control via AR	Augmented Reality	Akhavan et al., 2025	AR/VR	Akhavan et al., 2025
Occupational Health and Safety	Risk analysis and preventive practices	Internet of Things	Maskuriy et al., 2019	Artificial Intelligence	Rahman et al., 2024
	Equipment and workforce integration	Cyber-Physical Systems	Akhavan et al., 2025	IoT and Advanced Data Analytics	Akhavan et al., 2025
	Risk prediction	Simulation	Oesterreich & Teuteberg, 2016	Artificial Intelligence and Machine Learning	Rahman et al., 2024



In this study, the bibliometric mapping method, which enables the quantitative analysis of books, articles, and other academic publications published within a specific field (Aria & Cuccurullo, 2017; van Eck & Waltman, 2010), was employed. This method allows the relationships among scientific disciplines, research fields, areas of expertise, and individual authors or documents to be revealed through visual networks (Chen, 2006). The bibliometric mapping process generally consists of data collection, preprocessing, network construction, normalization, mapping, analysis, and visualization stages. During the data collection phase, databases such as Web of Science (WoS), Scopus, and Google Scholar are commonly used to comprehensively examine academic publications (Börner, 2010). In this study, the Web of Science database was preferred due to its broad coverage and reliable indexing structure. Bibliometric data are visualized through citation, co-citation, bibliographic coupling, keyword relationships, and co-authorship networks. Specialized bibliometric software is used for these analyses (van Eck & Waltman, 2014), and in this study, VOSviewer software—known for its user-friendly interface and strong analytical capabilities—was used to create visualizations and network maps. The study was conducted in three main stages:

- **Stage I:** In the Web of Science database, the terms “Industry 4.0,” “Industry 5.0,” and “project management” were first searched, followed by the concept of “construction management.” The relevant publications were then exported in *plain text file* format for use in VOSviewer.
- **Stage II:** The obtained WoS data were imported into VOSviewer, and distribution and density network maps were created based on keywords, authors, and countries related to project management, construction management, Industry 4.0, and Industry 5.0, according to publication years.
- **Stage III:** The generated bibliometric network maps were analyzed to evaluate the current state, trends, and research intensities in the relevant field.

Through the bibliometric analysis, the current state of academic production in the fields of project and construction management within the scope of Industry 4.0 and Industry 5.0 was assessed. Publications indexed in the Web of Science database were reviewed in order to classify the knowledge base in the research area, identify trends, and define conceptual boundaries. In this way, gaps in the literature were identified, allowing for the development of potential solutions. Additionally, a search was conducted in the Scopus database using the keywords “Industry 4.0, 5.0,” “project management,” and “construction management,” resulting in the identification of a total of 19,057 academic publications. According to the analysis results, the first publication appeared in 2016, followed by a steady increase in subsequent years. The number of publications was recorded as 2,283 in 2021, 2,872 in 2022, 2,966 in 2023, 3,294 in 2024, and 3,178 in 2025 (Figure 1). These data indicate a growing interest in the research area and demonstrate that the concepts of Industry 4.0 and Industry 5.0 have gained a significant place in the project and construction management literature. The increasing number of publications reveals that both theoretical and applied studies have diversified and that the impacts of digital transformation on project management processes are being examined more comprehensively.

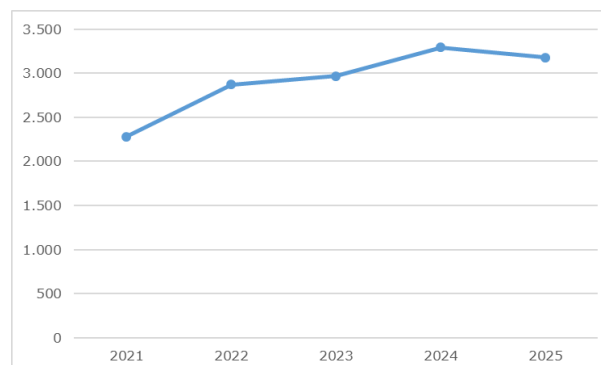


Figure 1. Annual Distribution of the Number of Publications

When examining the interdisciplinary distribution of scientific output in the relevant research area, it is observed that studies are clustered in a multidimensional structure (Figure 2). Among the total publications, the largest share belongs to Engineering with 29.6%, followed by Computer Science with 19.4% and Business, Management, and Accounting with 12.8%. This distribution demonstrates that Industry 4.0/5.0 and construction management processes represent not only a technical transformation but also an integrated evolution with information systems and strategic management disciplines. Additionally, the presence of fields such as Decision Sciences (7.1%), Social Sciences (6.5%), and Energy (4.3%) indicates that the socio-economic and environmental sustainability dimensions of the topic are also at the center of academic interest. In this context, the project management literature benefits from interdisciplinary interactions, enabling the development of more holistic and efficient management models in project planning, monitoring, and execution processes by combining technical, strategic, and sustainability-focused approaches.

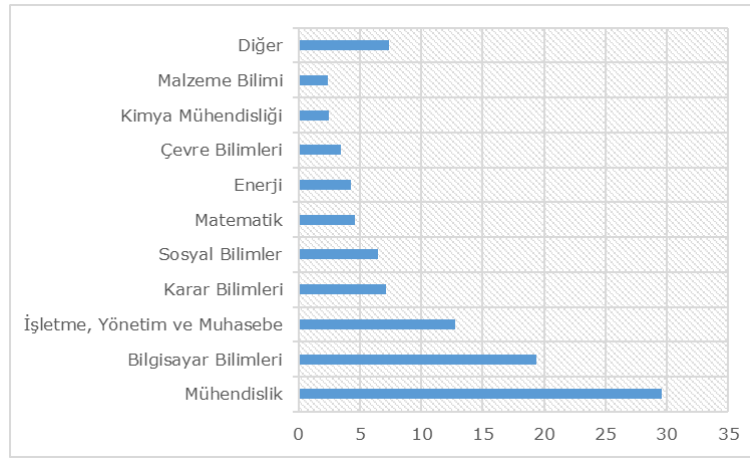


Figure 2. Distribution by Subject Areas

In the analysis conducted by country, the highest scientific production capacities in the relevant disciplines were found in China, Brazil, India, Italy, the USA, the United Kingdom, Germany, Spain, Australia, and Poland, respectively. This ranking indicates that Turkey has not yet achieved the expected level of representation in the global literature within this specific research area (Figure 3). Therefore, increasing Turkey-focused academic studies is of critical importance, both for maximizing local research potential and for enhancing the country's visibility in the international scientific ecosystem. An increase in high-quality publications in this field would also elevate Turkey's position in global competitiveness.

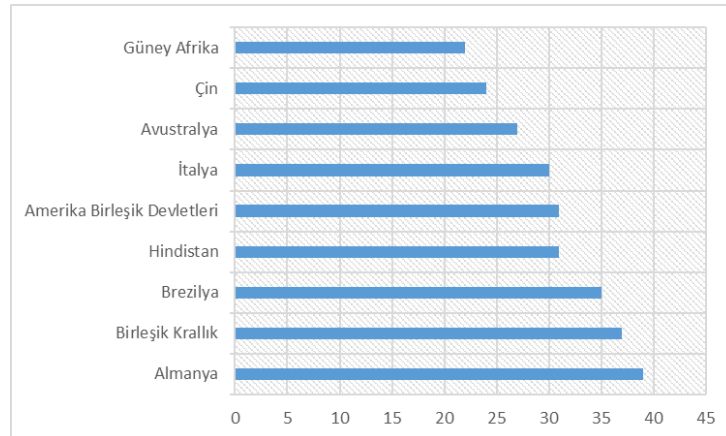


Figure 3. Distribution of Studies by Country

To determine the conceptual framework of the study and the relationships between terms, Scopus data were visualized using VOSviewer software. In the analysis, keywords repeated at least three times were set as the threshold to clarify correlations between concepts. The resulting network map shows that the literature is clustered around three main academic focuses:

- I. Cluster:** Focuses on components that directly form the technical infrastructure of Industry 4.0, such as cyber-physical systems, automation, robotic technologies, and smart manufacturing, symbolizing the evolution of engineering processes through digitalization.
- II. Cluster:** Includes supply chain, quality management, decision support mechanisms, and sustainability, representing the transformative impact of Industry 4.0 and 5.0 paradigms on managerial processes.
- III. Cluster:** Consists of advanced technology concepts such as artificial intelligence, big data analytics, and cloud computing, reflecting the academic counterpart of data-driven decision-making mechanisms at the center of modern research.

The density of connections in the network map demonstrates that the concepts of “Industry 4.0 and 5.0” serve as a bridge across a wide spectrum rather than isolated terms. For instance, the links between “Environmental Management 4.0” and “Sustainability” illustrate the integration of digitalization with ecological goals; “Maturity Models” and “Emerging Economies” depict the adaptation processes of these technologies in different market dynamics. Emphasis on “socio-technical systems theory” and “manufacturing sector” highlights the societal, human, and operational dimensions of technological transformation, while “e-commerce logistics” reflects the direct impact of digitalization on supply networks. Analyses based on concepts such as “semantic ontology” and “knowledge management” further indicate that the subject is not only hardware-related but also has a deep knowledge organization layer. As a result, the network map indicates that the interaction of Industry 4.0 and 5.0 has created revolutionary changes in construction and project management. Approaches that emphasize smart data analytics, digital monitoring tools, and human-machine collaboration have become essential instruments for increasing efficiency, optimizing resources, and proactively managing risks in construction projects. This situation enables the adoption of modern project management approaches that are not only technology-focused but also more integrated, transparent, sustainable, and human-centered.

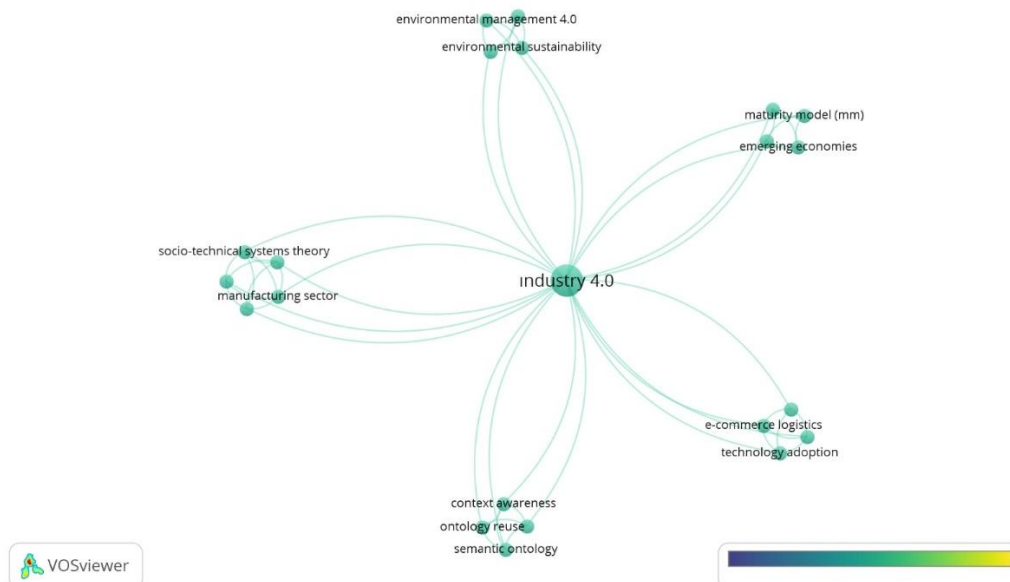


Figure 4. Relationship Diagram of Keywords in the Research Area

The diagram representing the researcher collaboration network concretizes the managerial coordination practices and institutional ties of actors within the ecosystem (Figure 5). The resulting network structure consists of two interconnected main groups, with interactions

between them occurring through the researcher Wang, Lihui. This indicates that the researcher functions as a strategic “bridge” within the network, acting as the primary coordinator overseeing information transfer between different working groups (Burt, 2004). The group located in the lower-left area of the network exhibits frequent and reciprocal ties among its members, forming a hierarchically closed structure. The high-degree connections of the nodes within this cluster suggest that the group is internally focused and adopts an inward-oriented management model that maintains operational cohesion around a specific area of expertise (Wasserman and Faust, 1994).

In contrast, the community positioned on the right side maintains strong internal interactions while exhibiting a more flexible and expandable network structure. This group demonstrates a multidimensional and dynamic form of coordination. The absence of a direct connection between the two sub-communities, aside from Wang, Lihui, highlights the high “betweenness centrality” score of this central figure and underscores the indispensability of this node for the managerial relationships within the network (Freeman, 1977). Therefore, the structural integrity of the network and the continuity of information flow are entirely dependent on the coordination capabilities of this intermediary node. This configuration reflects the “double-core single-bridge” model described in the literature and confirms the critical role of intermediary actors in coordinating distinct expertise pools within networks (Borgatti and Halgin, 2011).

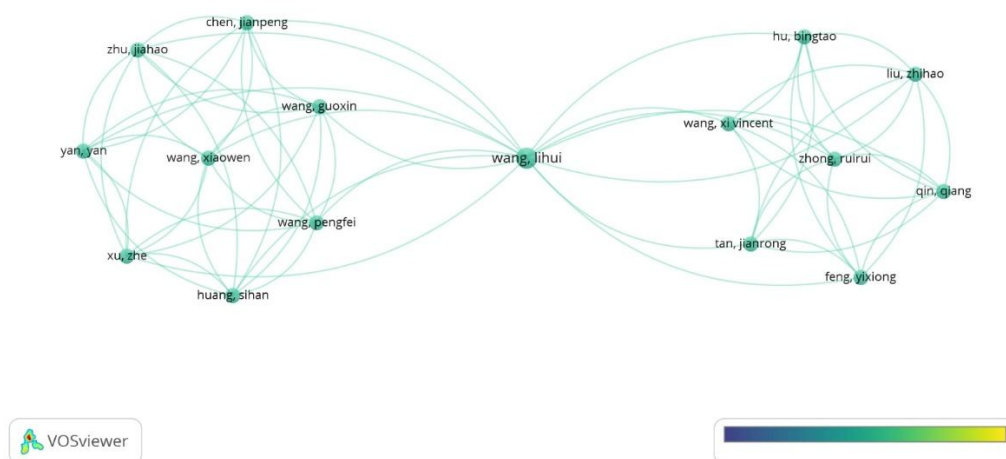


Figure 1. Researcher Network in the Field

The bibliometric study confirmed that the concepts of Industry 4.0 and 5.0 have recently gained momentum in the literature on project and construction management, achieving an interdisciplinary depth. The generated network maps clearly demonstrate the transformative role of digitalization, automation, and advanced technology components across a broad spectrum, from the production phase to strategic management mechanisms.

The theoretical insights obtained from this analysis indicate that, to strengthen Turkey’s position in the global literature, technology adaptation and digital awareness levels need to be examined in depth within the local context. Based on this necessity, a survey targeting construction sector stakeholders was designed to determine the practical implications of academic trends. Measuring stakeholders’ perceptions and knowledge levels through field data will allow for identifying correlations between the conceptual debates in the literature and the realities of industry practice. The field findings will not only provide a snapshot of the current situation but will also serve as a foundation for developing strategic and actionable recommendations aimed at enhancing the technological maturity of the local construction ecosystem.



3. CONCLUSION

This study systematically and comprehensively examined the impacts of the Industry 4.0 and Industry 5.0 paradigms on project management in the construction sector through a bibliometric analysis. The findings reveal that project management in the construction industry has evolved beyond a purely technical application area, transforming into a strategic management practice redefined around digitalization, human-centered approaches, and sustainability.

The analysis indicates that, particularly within the Industry 4.0 context, technologies such as BIM, big data, the Internet of Things, and AI-based applications are extensively addressed in project planning, monitoring, and control processes. These technologies support decision-making in time, cost, and quality management, enhance risk predictability, and strengthen coordination among stakeholders. Although the Industry 5.0 approach is relatively new, the literature increasingly addresses it in terms of human-machine interaction, ethical considerations, and sustainability. This trend highlights that project management in the construction sector is being approached not only from an efficiency perspective but also with human-centered and socially responsible principles. Bibliometric findings show a marked increase in publication numbers in recent years, with research predominantly concentrated in developed countries. This indicates that in developing countries, digital transformation and Industry 5.0-focused applications in the construction sector are still limited, highlighting significant research potential. Moreover, the scarcity of interdisciplinary and practice-oriented studies represents a notable gap in the literature.

In conclusion, Industry 4.0 and 5.0 technologies play a decisive role in enabling project management processes in the construction sector to become more efficient, flexible, integrated, and sustainable. The findings of this study are expected to guide decision-makers, industry professionals, and academics, contributing to the development of digitalization policies, the design of targeted training and competency programs, and the restructuring of project management practices in line with contemporary requirements. Future studies that complement bibliometric analysis with field applications and qualitative research will provide deeper insights into the tangible impacts of the Industry 5.0 approach on the construction sector.

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