



# Scientific Evolution and Thematic Structure of Knowledge Management and Artificial Intelligence Research in Construction Engineering (2016–2025)

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**ABSTRACT.** The integration of knowledge management and artificial intelligence has become a key driver of innovation and digital transformation in construction engineering. This study investigates the development of this research domain through a bibliometric analysis covering the period 2016–2025. Bibliographic records were retrieved from the Scopus and Web of Science databases, resulting in a final corpus of 1,188 journal articles after screening and data-cleaning procedures. VOSviewer was employed to analyze publication trends, international collaboration networks, keyword co-occurrence patterns, and thematic evolution.

The findings indicate a substantial expansion of scientific activity over the last decade, reflecting the increasing relevance of intelligent technologies in construction-related knowledge processes. The international collaboration

network is led by China, the United Kingdom, the United States, and Australia, which act as major knowledge hubs within the field. Four thematic domains were identified: digital transformation and innovation, construction safety and risk management, knowledge representation and BIM-enabled systems, and language-based artificial intelligence. The technological analysis revealed that BIM-integrated AI, machine learning, fuzzy logic, and artificial neural networks constitute the most widely adopted approaches, whereas large language models, natural language processing, blockchain technologies, semantic knowledge systems, and Industry 5.0 represent emerging research directions. The results highlight the transition from traditional knowledge-based practices toward intelligent, interconnected, and data-centric construction ecosystems. This study contributes to the literature by mapping the intellectual structure of the field and identifying future opportunities for research and technological advancement in construction engineering.

## INTRODUCTION

The construction industry is undergoing a profound digital transformation driven by the increasing adoption of advanced information technologies and artificial intelligence (AI). As construction projects become more complex and knowledge-intensive, organizations face growing challenges related to knowledge acquisition, storage, sharing, and application throughout the project lifecycle. In this context, knowledge management has emerged as a strategic capability that enables organizations to improve decision-making, enhance innovation, and preserve valuable expertise across multidisciplinary project environments. The foundational work of Nonaka and Takeuchi (1995) emphasized the importance of knowledge creation and organizational learning, while Davenport and Prusak (1998) highlighted knowledge as a critical source of competitive advantage.

Recent technological developments have significantly expanded the scope of knowledge management in construction engineering. Advanced informatic technologies, digital platforms, and intelligent systems are increasingly being integrated into construction processes to improve information management and operational performance. For example, Zhang et al. (2024) reported that emerging digital technologies are accelerating the transformation of construction toward intelligent and data-driven environments. Similarly, Li et al. (2024) demonstrated that digitalization plays a critical role in enhancing intellectual capital and sustainability performance in construction-related activities. These developments indicate that knowledge management is no longer limited to documentation and information sharing but is becoming closely linked to digital innovation and organizational transformation.

Artificial intelligence has become one of the most influential technologies supporting this transition. Machine learning, deep learning, neural networks, fuzzy logic, and intelligent decision-support systems are increasingly applied to construction planning, risk management, safety monitoring, and resource optimization. Park et al. (2024) illustrated how deep learning techniques can improve predictive capabilities in complex environments, while Aghimien et al. (2024) highlighted the growing role of intelligent technologies in enhancing workforce safety within construction projects. In addition, ontology-based systems and knowledge graphs have been adopted to facilitate knowledge representation and information retrieval. Gao et al. (2024) proposed an ontology-guided approach for construction planning, whereas Xia et al. (2024) developed a knowledge-graph-based case database to improve access to engineering management knowledge.

More recently, the emergence of generative artificial intelligence, large language models (LLMs), and natural language processing technologies has created new opportunities for knowledge-intensive activities. Zeng et al. (2025) demonstrated the application of graph-enhanced prompt tuning for safety-related knowledge classification, while Silalahi (2025) explored the potential of generative AI systems to support intelligent recommendations and decision-making processes. These advances suggest a shift from traditional knowledge-based systems toward semantic and language-driven approaches capable of extracting, organizing, and generating knowledge from large volumes of structured and unstructured information.

Despite the growing volume of research, the scientific landscape at the intersection of knowledge management, artificial intelligence, and construction engineering remains fragmented. Existing studies often focus on specific technologies, applications, or project contexts, making it difficult to obtain a comprehensive understanding of the field's evolution, dominant themes, collaboration patterns, and emerging research directions. Furthermore, the rapid emergence of technologies such as blockchain, Industry 5.0, semantic knowledge systems, and large language models has created new research frontiers that require systematic investigation.

To address this gap, the present study conducts a bibliometric analysis of knowledge management and artificial intelligence research in construction engineering during the period 2016–2025. By examining publication trends, international collaboration networks, thematic structures, technological applications, and emerging research themes, this study provides a comprehensive overview of the field and identifies future directions that may guide both academic research and practical innovation within the construction industry.

## **RESEARCH PROBLEM**

The construction industry generates large volumes of knowledge throughout the planning, design, execution, and operation phases of projects. However, the effective management of this knowledge remains a persistent challenge due to fragmented information flows, multidisciplinary project environments, and the increasing complexity of construction processes. In recent years, artificial intelligence technologies have emerged as promising tools for enhancing knowledge acquisition, analysis, sharing, and decision-making. Despite the growing interest in this intersection, the scientific landscape remains fragmented, with limited understanding of its evolution, dominant research themes, technological applications, and emerging directions. Consequently, a comprehensive bibliometric assessment is needed to systematically examine how knowledge management and artificial intelligence research has developed within construction engineering and to identify the key trends shaping the field.

## **RESEARCH SIGNIFICANCE**

This study contributes to the literature by providing a comprehensive bibliometric overview of knowledge management and artificial intelligence research in construction engineering over the period 2016–2025. By integrating publication trends, collaboration networks, thematic structures, technological applications, and emerging research directions, the study offers a holistic perspective on the development of this rapidly evolving domain. The findings contribute to both academic and practical contexts by identifying influential research areas, highlighting technological advances, and revealing opportunities for future investigation. Furthermore, the results provide valuable insights for researchers, practitioners, and policymakers seeking to promote innovation, digital transformation, and knowledge-driven decision-making within the construction industry.

## **RESEARCH QUESTIONS**

To provide a comprehensive understanding of the development of knowledge management and artificial intelligence research in construction engineering, this study examines five complementary dimensions: scientific growth, international collaboration, thematic structure, technological applications, and emerging research trends. These dimensions are addressed through the following research questions:

RQ1: How has scientific production on knowledge management and artificial intelligence in construction engineering evolved between 2016 and 2025?

RQ2: Which countries have played a leading role in knowledge management and artificial intelligence research in construction engineering, and how are international collaboration networks structured?

RQ3: What are the main thematic clusters that characterize knowledge management and artificial intelligence research in construction engineering?

RQ4: Which artificial intelligence technologies and knowledge-based approaches are most frequently applied in construction engineering research?

RQ5: What emerging themes and future research directions can be identified from the temporal evolution of keywords and international research networks?

## **RESEARCH OBJECTIVES**

The main objective of this study is to analyze the scientific evolution and thematic structure of knowledge management and artificial intelligence research in construction engineering during the period 2016–2025. Specifically, the study aims to identify publication trends, examine international collaboration patterns, map the intellectual and thematic foundations of the field, determine the most frequently applied artificial intelligence technologies, and identify emerging topics that may shape future research and innovation in construction engineering.

## **METHODOLOGY**

This study employed a bibliometric approach to analyze the scientific development of knowledge management and artificial intelligence research in construction engineering between 2016 and 2025. Bibliographic records were retrieved from the Scopus and Web of Science Core Collection databases using the search query (ALL ("Knowledge Management") AND ALL ("Artificial Intelligence") AND ALL ("Construction engineering")). The initial search identified 2,289 records. After applying the publication period filter (2016–2025), the dataset was reduced to 1,787 documents. Subsequently, the search was restricted to journal articles, resulting in 1,188 records for analysis.

The retrieved records were exported and consolidated into a unified database. Duplicate entries were identified through DOI verification and bibliographic screening, ensuring data consistency and eliminating redundant records. The final dataset was then processed using VOSviewer to generate bibliometric maps and network visualizations.

The analysis comprised four complementary procedures. First, publication trends were examined to assess the evolution of scientific output over time. Second, country co-authorship networks were analyzed to identify leading contributors and international collaboration patterns. Third, keyword co-occurrence analysis was conducted to determine the thematic structure of the field. Finally, overlay and density visualizations were used to identify emerging topics and research frontiers. In addition, a content analysis of article abstracts was performed to classify the artificial intelligence technologies applied in construction engineering research and to examine their relative prominence within the literature.

## **DATA COLLECTION INSTRUMENT**

The data collection instrument consisted of a structured bibliographic search strategy applied to the Scopus and Web of Science Core Collection databases. The search query was designed to retrieve scientific publications related to knowledge management, artificial intelligence, and construction engineering published between 2016 and 2025. The bibliographic records obtained through this process were consolidated, screened, and analyzed as the primary dataset of the study. To ensure transparency, reproducibility, and data availability, the processed dataset used in this research has been deposited in Figshare and is publicly accessible through the following DOI: <https://doi.org/10.6084/m9.figshare.32519178>.

## **COMPILATION AND COMMENTARY ON PREVIOUS STUDIES**

Knowledge management has long been recognized as a critical organizational capability for creating, sharing, and applying knowledge to improve performance and innovation. The seminal work of Nonaka and Takeuchi (1995) introduced the SECI model, establishing the theoretical foundation for organizational knowledge creation, while Davenport and Prusak (1998) emphasized the strategic value of knowledge as a source of competitive advantage. In construction engineering, these principles have gained increasing relevance due to the sector's dependence on information-intensive processes, multidisciplinary collaboration, and continuous learning.

Recent studies have demonstrated that artificial intelligence is significantly transforming knowledge management practices within construction environments. Research on Building Information Modeling (BIM) has highlighted its role as a central platform for knowledge integration, information sharing, and collaborative decision-making throughout the project lifecycle (Dobrucali et al., 2024). Similarly, ontology-based systems

and semantic technologies have been increasingly employed to enhance interoperability and knowledge representation in complex construction projects, enabling more efficient information retrieval and organizational learning processes (Liu et al., 2025).

The literature has also documented the growing application of machine learning, neural networks, fuzzy logic, and data-driven decision-support systems to address challenges related to project planning, risk assessment, safety management, and resource optimization (Reklitis et al., 2025; Wang et al., 2024). These technologies have expanded the scope of knowledge management from traditional documentation and knowledge-sharing practices toward predictive and intelligent decision-making systems. Furthermore, recent investigations have reported the emergence of advanced artificial intelligence approaches, including natural language processing, large language models, and generative AI, which facilitate automated knowledge extraction, semantic analysis, and intelligent information retrieval (Mobadersani et al., 2026; Zeng et al., 2025).

Bibliometric studies have similarly reported a rapid expansion of research at the intersection of knowledge management, digital transformation, and artificial intelligence, highlighting the increasing importance of Industry 4.0 technologies, blockchain applications, and intelligent construction ecosystems (Choudhury & Routray, 2024). These developments suggest a progressive transition from conventional knowledge-based systems toward integrated digital environments capable of supporting real-time collaboration, automation, and data-driven innovation.

The findings of the present study extend previous research by providing a comprehensive overview of the scientific evolution, thematic structure, technological landscape, and emerging trends that characterize knowledge management and artificial intelligence research in construction engineering. Unlike earlier studies that focused on specific technologies or applications, the current analysis demonstrates how the field has evolved into a multidisciplinary research domain where BIM, semantic knowledge systems, digital transformation, language-based artificial intelligence, and intelligent analytics increasingly converge to address the complexity of modern construction projects.

## **RESULTS AND DISCUSSION**

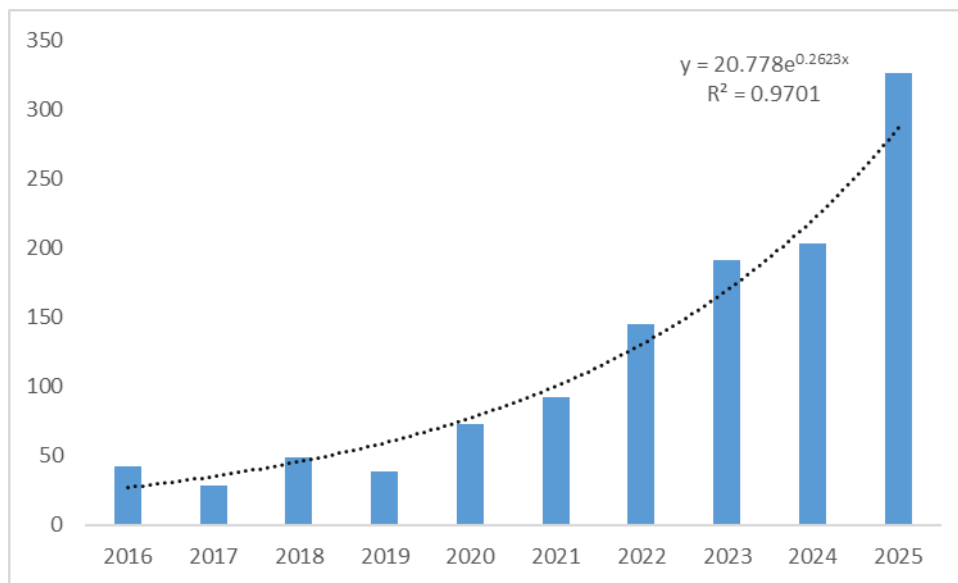
RQ1: How has scientific production on knowledge management and artificial intelligence in construction engineering evolved between 2016 and 2025?

Figure 1 reveals a clear exponential growth pattern in scientific production related to knowledge management and artificial intelligence in construction engineering during the study period. The fitted exponential trendline ( $R^2 = 0.9701$ ) indicates a strong and sustained increase in research activity, suggesting that the field has transitioned from an emerging topic to a consolidated area of investigation. While publication output remained relatively limited between 2016 and 2019, a significant acceleration became evident after 2020, with annual publications increasing continuously and reaching their highest level in 2025.

The thematic evolution of the literature also reflects important shifts in research priorities. Early studies primarily focused on knowledge management practices, decision-support systems, organizational learning, and knowledge-based systems applied to construction projects. As the field matured, research expanded toward Building Information Modeling (BIM), ontology-based knowledge representation, construction management, and risk assessment. More recently, the literature has increasingly incorporated advanced artificial intelligence approaches, including natural language processing, information retrieval, semantic technologies, large language models, digital transformation, blockchain, Industry 4.0/5.0, and intelligent safety management systems. This progression demonstrates a movement from traditional knowledge codification and management frameworks toward data-driven, intelligent, and digitally integrated construction environments.

The results suggest that future research is likely to continue converging around the integration of knowledge management with emerging AI technologies, particularly semantic intelligence, generative AI, digital twins, and automated decision-support systems designed to enhance productivity, safety, and sustainability in construction engineering.

Figure 1. *Evolution of scientific production on knowledge management and artificial intelligence in construction engineering during the period 2016–2025*



Note. The exponential trendline ( $R^2 = 0.9701$ ) indicates a strong and sustained increase in scientific production throughout the study period. Source: Authors' elaboration based on Scopus and Web of Science data.

RQ2: Which countries have played a leading role in knowledge management and artificial intelligence research in construction engineering, and how are international collaboration networks structured?

The country co-authorship analysis reveals a mature and globally connected research landscape characterized by five distinct collaboration clusters. China occupies the most prominent position within the network, supported by strong collaborative relationships with the United Kingdom, Australia, Hong Kong, and several European and Asian countries. The United Kingdom and the United States also serve as strategic intermediaries that facilitate knowledge exchange across regional groups. The density visualization highlights China, the United Kingdom, the United States, Australia, and Malaysia as the principal centers of scientific activity, indicating their substantial influence on the development of research at the intersection of knowledge management, artificial intelligence, and construction engineering. Furthermore, the overlay visualization reveals the increasing participation of countries such as Saudi Arabia, Egypt, Bangladesh, Jordan, Oman, and Pakistan, suggesting a recent expansion of research efforts beyond traditionally dominant regions. These findings demonstrate that scientific advancement in this field is increasingly driven by international collaboration, fostering the diffusion of knowledge, technological innovation, and interdisciplinary research across diverse geographical contexts.

Figure 2. International collaboration network of countries in knowledge management and artificial intelligence research in construction engineering.

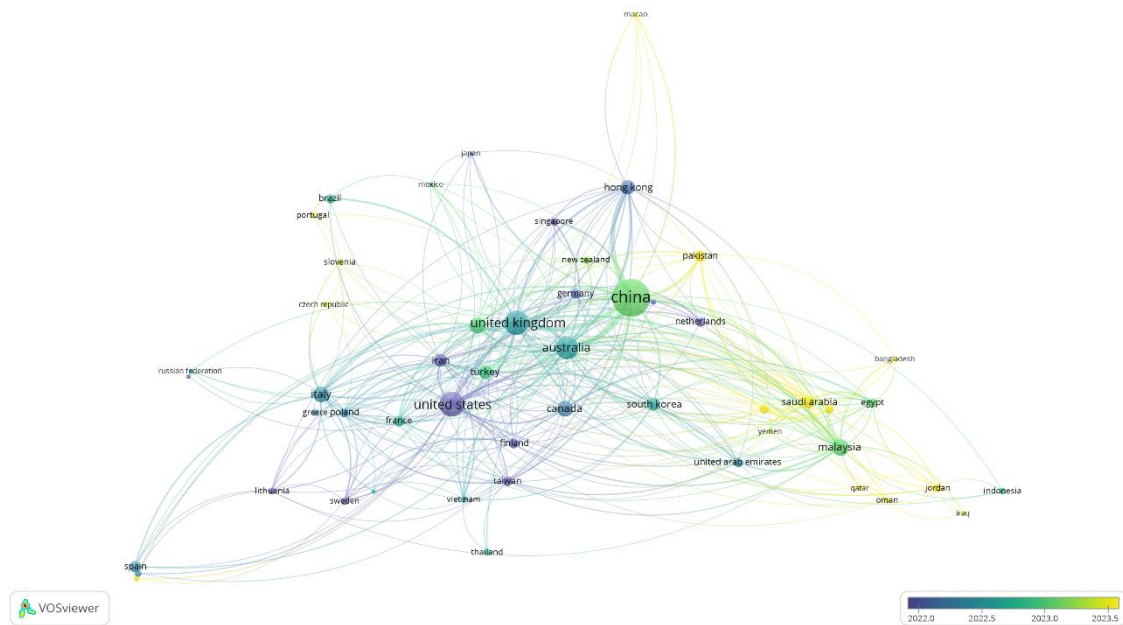
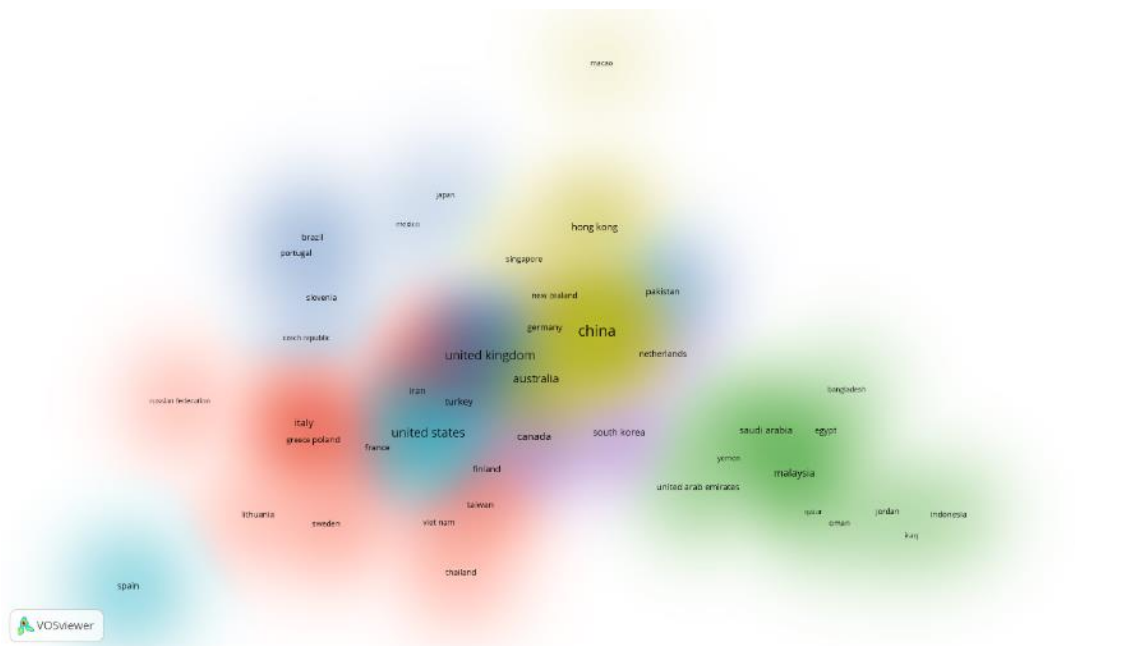


Figure 3. Country density visualization of scientific collaboration in knowledge management and artificial intelligence research in construction engineering



RQ3: What are the main thematic clusters that characterize knowledge management and artificial intelligence research in construction engineering?



Table 1. Main Thematic Clusters Identified in Knowledge Management and Artificial Intelligence Research in Construction Engineering

Cluster	Main Keywords	Research Theme
Red	Construction industry, digital transformation, innovation, blockchain, Internet of Things (IoT), Industry 4.0, supply chain management	Digital Transformation and Innovation in Construction
Green	Risk assessment, construction safety, safety, human, hazards, accidents, neural networks	Construction Safety, Risk Management, and Human Factors
Blue	Ontology, architectural design, building information modeling (BIM), knowledge representation, data integration	Knowledge Representation, BIM, and Intelligent Design Systems
Yellow	Natural language processing, semantics, information retrieval, language processing, large language model, extraction	Language-Based Artificial Intelligence and Semantic Knowledge Management

RQ4: Which artificial intelligence technologies and knowledge-based approaches are most frequently applied in construction engineering research?

As shown in Figure 5 and Table 2, BIM-integrated artificial intelligence emerged as the most frequently applied technological approach in construction engineering research, accounting for 24.8% of all identified AI-related occurrences. This finding highlights the central role of Building Information Modeling as a platform for integrating intelligent systems that support project coordination, design optimization, and information management throughout the construction lifecycle. Machine learning (15.7%) and fuzzy logic (14.6%) also demonstrate a strong presence in the literature, reflecting the widespread use of predictive analytics and decision-support methods for addressing uncertainty and improving operational performance. Furthermore, Table 3 illustrates that these technologies have been applied across diverse domains, including risk prediction, cost estimation, project monitoring, and knowledge management. The distribution of technologies further reveals an ongoing technological evolution within the field. While expert systems, fuzzy logic, and artificial neural networks have traditionally supported knowledge-based decision-making processes, recent studies increasingly incorporate deep learning, digital twins, and large language models (LLMs). The growing presence of LLMs, transformer-based architectures, and generative AI indicates a shift toward semantic knowledge management, automated information retrieval, and intelligent knowledge generation. Collectively, these results suggest that construction engineering research is progressively moving from rule-based and expert-driven approaches toward more adaptive, data-centric, and digitally integrated AI solutions.

Figure 5

Frequency of artificial intelligence technologies identified in the abstracts of construction engineering studies (2016–2025).

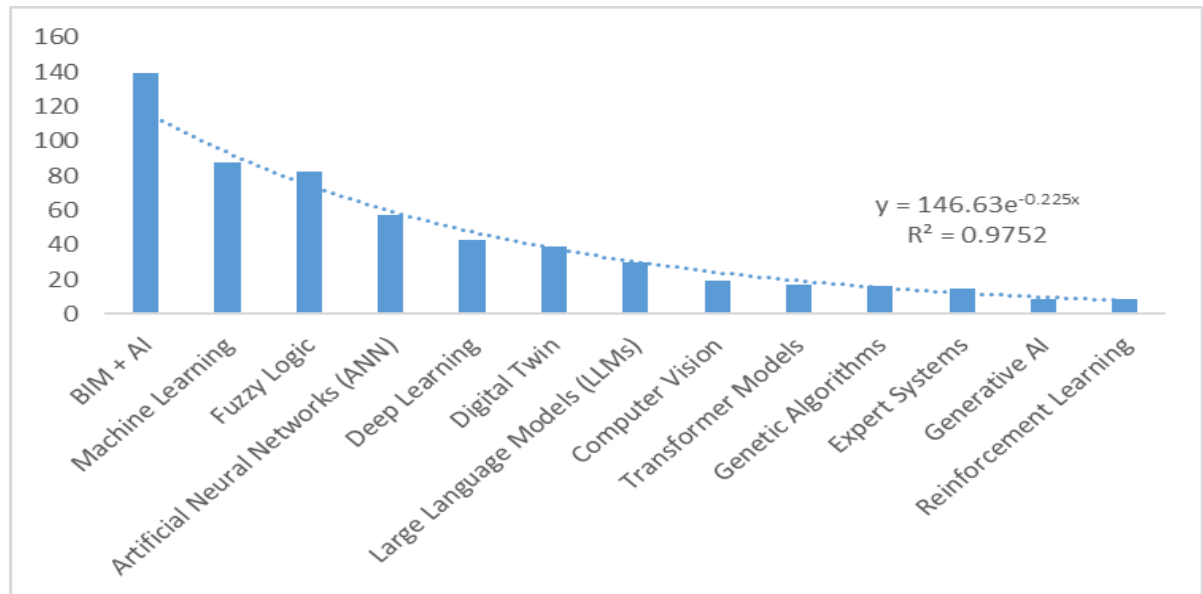


Table 2 Artificial Intelligence Technologies Identified in Construction Engineering Research

Rank	Technology	Frequency	Percentage (%)
1	BIM + AI	139	24.8
2	Machine Learning	88	15.7
3	Fuzzy Logic	82	14.6
4	Artificial Neural Networks	57	10.2
5	Deep Learning	43	7.7
6	Digital Twin	39	7.0
7	Large Language Models (LLMs)	30	5.4
8	Computer Vision	19	3.4
9	Transformer Models	17	3.0
10	Genetic Algorithms	16	2.9
11	Expert Systems	15	2.7
12	Generative AI	9	1.6
13	Reinforcement Learning	9	1.6

Table 3 Representative Applications of Artificial Intelligence Technologies in Construction Engineering

<b>Technology</b>	<b>Representative Application</b>
BIM + AI	Design optimization, project coordination, and information integration
Machine Learning	Risk prediction, productivity analysis, and project performance forecasting
Fuzzy Logic	Multi-criteria decision-making and uncertainty management
Artificial Neural Networks	Cost estimation and safety assessment
Deep Learning	Automated monitoring and intelligent decision support
Digital Twin	Real-time project monitoring and lifecycle management
Large Language Models (LLMs)	Knowledge retrieval, semantic analysis, and information management
Computer Vision	Safety monitoring and defect detection
Transformer Models	Information extraction and predictive analytics
Expert Systems	Knowledge-based decision support
Generative AI	Automated content generation and knowledge assistance

RQ5: What emerging themes and future research directions can be identified from the temporal evolution of keywords and international research networks?

As illustrated in Figure 6 and detailed in Table 4, the temporal evolution of keywords reveals a clear transition toward advanced artificial intelligence and digitally enabled knowledge management systems in construction engineering. The most recent research themes are concentrated around Language-Based Artificial Intelligence, including large language models (LLMs), natural language processing, and question-answering systems, reflecting increasing interest in automated knowledge extraction, semantic reasoning, and intelligent information processing. At the same time, the emergence of Semantic Knowledge Systems highlights the growing importance of ontologies, information retrieval, and knowledge representation for improving interoperability and knowledge integration across construction projects. The overlay visualization also reveals a strong emphasis on Digital Construction Transformation, driven by Industry 4.0, Industry 5.0, and digital transformation initiatives aimed at developing smart and connected construction ecosystems. In parallel, Blockchain-Enabled Construction is gaining attention as a mechanism for secure knowledge sharing, traceability, and decentralized information management. Additional emerging directions include Intelligent Analytics and Data Processing, supported by data mining, text classification, and object detection techniques for predictive decision-making, as well as AI for Construction Safety, which leverages hazard detection, sentiment analysis, and safety analytics to improve workforce protection and risk management. Collectively, these

themes suggest that future research will increasingly focus on the integration of generative AI, semantic technologies, blockchain infrastructures, and intelligent analytics to support more efficient, collaborative, and sustainable construction environments.

Figure 6

Keyword overlay visualization showing emerging research themes in knowledge management and artificial intelligence research in construction engineering.

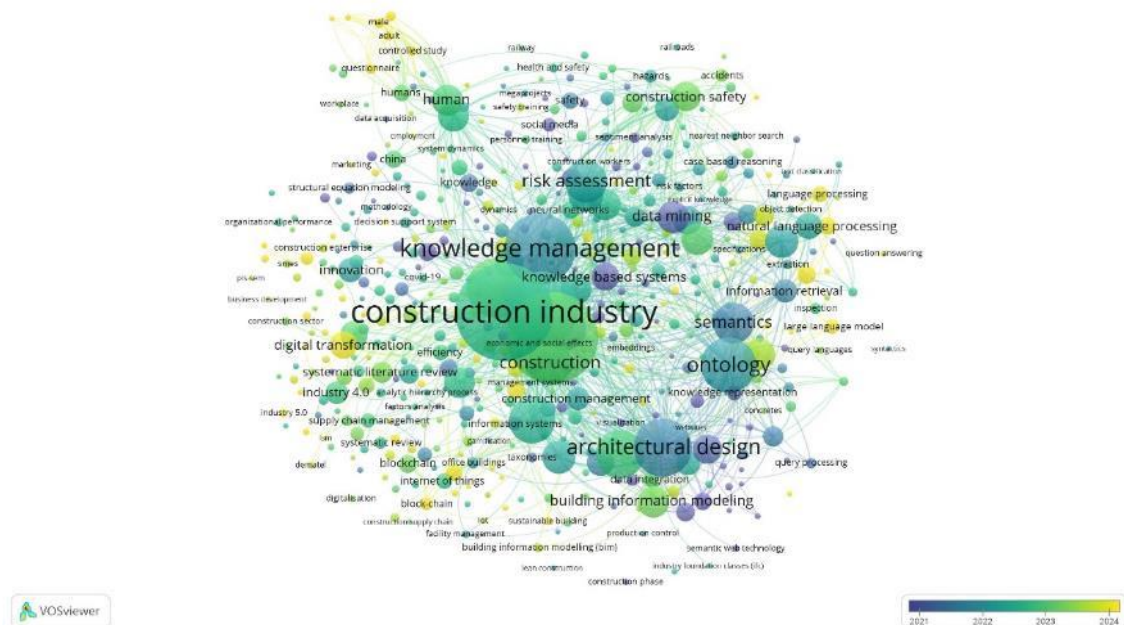


Table 4. Emerging Research Themes and Future Directions in Knowledge Management and Artificial Intelligence Research in Construction Engineering

Rank	Emerging Theme	Key Technologies	Research Direction
1	Language-Based Artificial Intelligence	Large Language Models (LLMs), Natural Language Processing (NLP), Question Answering	Automated knowledge extraction, reasoning, and intelligent information processing
2	Semantic Knowledge Systems	Ontologies, Semantics, Information Retrieval, Knowledge Representation	Intelligent knowledge management and semantic interoperability
3	Digital Construction Transformation	Industry 4.0, Industry 5.0, Digital Transformation	Smart and digitally integrated construction ecosystems
4	Blockchain-Enabled Construction	Blockchain Technologies	Secure knowledge sharing, traceability, and decentralized information management
5	Intelligent Analytics and Data Processing	Data Mining, Text Classification, Object Detection	Predictive analytics and AI-supported decision-making
6	AI for Construction Safety	Hazard Detection, Sentiment Analysis, Construction Safety Analytics	Risk prevention, safety monitoring, and workforce protection

Overall, the results provide a comprehensive view of the evolution and current configuration of knowledge management and artificial intelligence research in construction engineering. The analysis reveals a dynamic and increasingly interconnected field shaped by sustained scientific growth, strong international collaboration, and the progressive integration of advanced digital technologies into construction processes. The thematic structure highlights the coexistence of established research areas, such as safety management and knowledge representation, with emerging domains centered on semantic intelligence, language-based AI, and digital transformation. Furthermore, the identified technological and thematic trends indicate that future developments will be driven by intelligent knowledge systems capable of supporting data-driven decision-making, interoperability, and innovation across the construction lifecycle. Together, these findings demonstrate the growing strategic importance of combining knowledge management and artificial intelligence to address the complexity, efficiency, and sustainability challenges facing the construction industry.

## **CONCLUSION AND RECOMMENDATIONS**

This study provides a comprehensive bibliometric overview of knowledge management and artificial intelligence research in construction engineering during the period 2016–2025. The findings demonstrate the progressive consolidation of the field, characterized by increasing scientific interest, expanding international collaboration, and growing thematic diversification. The intellectual structure of the literature reflects the convergence of knowledge management principles with advanced digital technologies, positioning artificial intelligence as a key enabler of innovation within construction engineering.

The analysis reveals that contemporary research is increasingly oriented toward intelligent knowledge ecosystems capable of supporting information integration, decision-making, and organizational learning throughout the construction lifecycle. In particular, the emergence of semantic technologies, language-based artificial intelligence, and data-driven approaches indicates a shift toward more sophisticated mechanisms for managing and exploiting knowledge in complex construction environments. At the same time, the expansion of international collaboration networks suggests that the development of this research domain is becoming more geographically distributed and interdisciplinary.

From a practical perspective, the results highlight the growing relevance of integrating artificial intelligence capabilities into construction management processes to improve knowledge accessibility, information quality, and

operational effectiveness. The identified research trends also suggest that future construction systems will increasingly rely on intelligent digital infrastructures that combine automation, semantic reasoning, and collaborative knowledge sharing.

Based on these findings, future research should prioritize empirical investigations of generative artificial intelligence, large language models, semantic knowledge systems, and blockchain-enabled knowledge management frameworks in real construction settings. Additionally, greater attention should be given to comparative studies across countries and project contexts to better understand the factors influencing technological adoption and knowledge transfer. Such efforts will contribute to the development of more resilient, intelligent, and sustainable construction ecosystems while advancing the theoretical foundations of knowledge management and artificial intelligence research.

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