A Systematic Review of the Digital Transformation of the Building Construction Industry

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RESEARCH ARTICLE

A Systematic Review of the Digital Transformation of the Building Construction Industry

KHALID K. NAJI[1], MURAT GUNDUZ[1], FAHID HAMAD ALHENZAB[2], HAMED AL-HABABI[2], AND ABDULLA HAMAD AL-QAHTANI[2]

[1]Civil and Environmental Engineering Department, College of Engineering, Qatar University, Doha, Qatar
[2]Engineering Management Department, College of Engineering, Qatar University, Doha, Qatar

Corresponding author: Hamed Al-Hababi (ha099923@student.qu.edu.qa)

ABSTRACT Construction sector spending makes a significant contribution to the global economy, with approximately $10 trillion being spent on building and construction activities annually. However, the construction industry has traditionally been perceived as slow to adapt to new technologies compared to other sectors. Recently, the construction industry has experienced a substantial shift towards Digital Transformation. As new technologies have emerged, the construction industry has begun to realize the importance of Digital Transformation in the pre-construction, construction, and facility management phases. A high degree of Digital Transformation has been seen regarding site monitoring, wearables, sensors, and identifying hazards. This paper intends to sketch a global picture of digital technologies implemented in the construction industry throughout the entire project lifecycle. By fully analyzing more than 200 papers, the paper finds that various aspects of the construction industry, including technologies, policies, regulations, and infrastructures, are still in the early stages of Digital Transformation. The findings from this review will help researchers and practitioners in the construction industry understand the global picture of digital technology implementation and where the construction industry stands in the Digital Transformation process. This paper also serves as a starting point for future work on Digital Transformation in the construction industry. The research paper is limited to vertical aspects in building projects and does not include horizontal integration. Finally, this study will give a guideline with successful examples of which technologies are being used in specific phases, so future researchers can get a holistic view of the use of digital technology in the entire building environment.

INDEX TERMS Digitalized construction industry, digital construction, digitalization, digital transformation, pre-construction, construction, facility management, industry 4.0 technologies, construction 4.0, emerging technologies, critical success factors, smart buildings, infrastructure, policies.

I. INTRODUCTION

The Construction industry has benefited considerably from the shift from traditional to digital transformation requirement worldwide. Numerous technologies have been utilized recently in the building life cycle. Building Information Modeling (BIM), virtual reality, augmented reality, mixed reality, 3D printing, cloud computing, artificial intelligence (AI), big data, and the internet of things (IoT) are all examples of digital technologies, in addition to robotics, drones (unmanned aerial vehicles), mobile and wearable devices, and smart data 3D printing, cloud computing, artificial intelligence (AI), big data, and the internet of things (IoT) are all examples of digital technologies, in addition to robotics, drones (unmanned aerial vehicles), mobile and wearable devices, and smart data [1]. However, it has been determined that the construction industry is a delayed adopter of digital innovations. Due to the fragmented nature of the construction industry, these technologies operate in silos, making integration mandatory. Therefore, the digital transformation roadmap is mandatory to reduce fragmentation and ensure the high performance and productivity of the construction

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industry. The construction industry is experiencing significant benefits from the implementation of emerging technologies, which have improved productivity and effectiveness across various aspects of construction projects. These technologies, such as Digital Transformation, have had impacts across the entire project lifecycle, from pre-construction, construction to the facility management phase. Digital Transformation improves the identification of potential design and construction issues, facilitates collaboration between stakeholders, and enhances the integration of people, processes, and context within a built environment [2], [3], [4]. In addition, [5] explains that the Cyber-Physical System.

(CPS) framework, developed based on five primary development environments, has shown significant positive effects on completion times and quality in construction projects. However, [6] stated that adopting new technologies in the construction industry faces challenges such as the absence of relevant policies and regulations, project complexity, and the industry's fragmented nature. Furthermore, [7] mentioned that upper management in the construction sector must prioritize Digital Transformation initiatives and implement them in the vision and mission statements of public and private sector organizations. The paper places significant emphasis on the vertical dimensions of construction projects while neglecting horizontal integration in order to delve extensively into the three phases of vertical integration. Specifically, it examines pre-construction, construction, and facility management as distinct phases within buildings.

A. RESEARCH GAP

Previous research papers examine the advantages, methodologies, and challenges that hinder implementing digital transformation within the construction domain. Nevertheless, as far as the authors are aware, and as indicated by the summary table of the previous literatures, there has been limited effort to mention a global review of digital technologies' usage, benefits, and challenges in the three core phases of preconstruction, construction, and facility management. Most of the paper delineates distinct technologies or concentrates on specific phases. From this point, the primary objective of this paper is to provide a comprehensive examination of articles that present digital technologies within the construction sector, focusing on their proven effectiveness. By conducting a comprehensive review of the latest literature on the application of digital technologies in the construction industry, as well as the policy and infrastructure drivers that influence the industry's digital transformation, this study contributes to the body of knowledge of the digital transformation aspects in the construction industry. Furthermore, the paper investigates the infrastructure and policies necessary to facilitate digital transformation during these phases. Therefore, it hereby fills the gap concerning the three phases (pre-construction, construction, and facility management) for which articles highlight specific technologies.

B. DIGITAL TRANSFORMATION CONCEPT IN CONSTRUCTION INDUSTRY

To understand the terms of digital transformation, [8] define digital transformation as an endeavor to empower established business models by integrating cutting-edge technologies. According to [9], digital transformation is a process that integrates information, storage, communication, and networking technologies to revolutionize services by substituting manual procedures for digital ones or upgrading obsolete digital technology to more recent iterations. As a result, it has been demonstrated that Digital Transformation can impact any sector or organization [10]. It is a "digital technology-based improvement" to the business process, according to [11]. Digital Transformation is defined by [12] as "an ongoing, complex endeavor that has the potential to influence an organization and its activities significantly." Digital Transformation is defined by [13] as a disruptive change process. It has been acknowledged that construction companies can gain a competitive advantage in the market through the adoption and readiness of digital technologies [14], [15]. To enhance the feasibility and scope of digital technology implementation in the construction sector, numerous scholars have identified the obstacles, difficulties, and approaches associated with the integration of various digital technologies [5], [16], [17]. Although different technologies may have their own set of problems with adoption, common issues include a lack of knowledge and understanding about how to use technologies, large initial investments, problems with the technology itself, and legal and contractual issues when using those technologies [18]. Additionally, [19] explains twenty-one primary obstacles that delay digitalization and innovation after reviewing 72 articles. The obstacles are classified into the technology-organization-external environment (TOE) classifications in the real estate field, with particular emphasis on the construction industry.

C. RESEARCH METHODOLOGY PROCESS

The study employs a three-step methodology to do a comprehensive systematic review and analysis, focusing on the potential of adopting digital transformation and addressing existing difficulties and barriers within the construction industry. The first step involves the identification of digital transformation initiatives implemented within the construction industry, as derived from the literature review conducted on Scopus, Google Scholar, Web of Science. The review included papers from ASCE Library. The studies have enabled the identification and selection of digital transformation in terms of digital technologies, policy, regulation, and infrastructure based on keyword analysis and are represented in Figure (11). The second step involves using digital transformation and related terminology as keywords for a literature search through a publishing database. The third step involves a comprehensive examination and qualitative evaluation of the findings obtained from the database search outcome. The methodology used for the present review. In comparison to

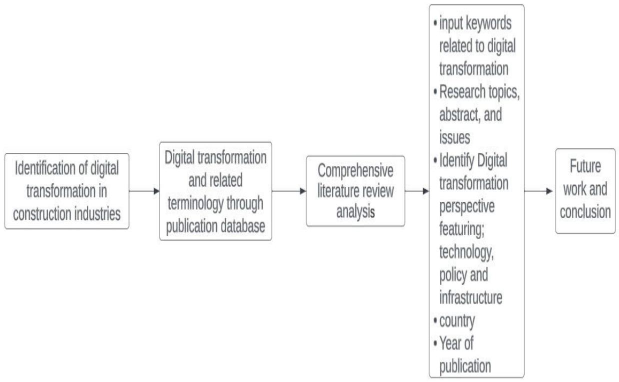

FIGURE 1. Research methodology process.

other databases, this database has a comprehensive scope, including high-quality papers within the field of building, as well as interdisciplinary study subjects [20]

The following are the objectives of this study:

1) Provide a global review of recent papers that describe digital technologies and their application in the construction industry (specifically the pre-construction, construction, and facility management phases) from 2008-2023.
2) Discuss the pervious literature review articles related to Digital Transformation and their limitations in the construction industry along with pre-construction, construction, and facility management.
3) Explain the requirement of policy and infrastructure to implement successful digital transformation in construction industry.
4) Discuss the future of digital transformation applications for the building construction industry.
5) Address future work related to the construction industry's digital transformation in the context of the phases identified in the literature review and limitation of this study.

This paper is organized as follows: Section I introduces critical themes, such as the concept of digital transformation in the construction industry and the importance of digital transformation as a crucial driver of high-performance building construction industry. Section II presents a comprehensive literature review of Digital Transformation aspects in the construction industry. Section III concerns the implication of Digital Transformation application in the construction industry. Section IV discusses the lessons learned and recommendations. Finally, Section V presents the conclusion and directions for future work.

II. LITERATURE REVIEW AND EXPERIMENT

It is important to acknowledge that the current body of research on technology readiness in the construction industry is fragmented, with most studies concentrating on the adoption of particular and specific Digital transformations [21], [22], [23], [24]. Additional research, including that of [17] and [25], was limited to identifying obstacles that hinder individuals' adoption of technology. In recent years, however, the construction industry has been confronted with more complex challenges (particularly those arising from megaprojects), and significant transformations have resulted from implementing numerous technological solutions [26]. AI-BIM [27], AR-BIM–robotic [28], and robotic-laser scanning [29] serve as noteworthy illustrations of the integration of multiple technologies within the realm of construction. Nevertheless, construction companies continue to face a lack of guidance and tools that can effectively assess their technological adoption performance and enable them to attain technological competence or readiness [30]. For example, the study by [31] acknowledges the criticality of digital transformation in the construction industry for substantial productivity increases. Nevertheless, a thorough examination of the Sri Lankan context regarding the development of a tool to evaluate the preparedness of the construction industry for digital transformation has yet to occur. Digital technology can play a crucial role in preventing the misuse of formwork systems like Mivan.

A. SELECTING RELEVANT PAPERS THROUGH DATABASES

The authors identified relevant papers on implementing digital transformation in buildings in Figure (2). First, obtaining articles related to digital transformation in the construction industry based on Scopus, Google Scholar, and Web of Science through "identification". The keyword was used on "Digital transformation", and "Technology transformation" in Scopus, Google Scholar, and Web of Science were (834) articles. The articles were specified in the English language from 2008-2023. After removing duplicates in the remaining articles, (748) were identified as related to digital transformation. After that, (546) were identified through record screening by title and abstract. Also, (202) were excluded due to not being relevant to the construction industry. Next, (403) articles that have full text assessed for eligibility and (143) were not specified in building projects. Then, (15) were excluded that are not available to find as well as not related to Digital Transformation in building construction industry. Finally, (387) studies based on qualitative and quantitative data were included in Figure 2.

This paper employed filtering and specific keywords to identify relevant literature from the Scopus, Google Scholar, Web of Science. The review included pers from ASCE Library databases. Figure 2 shows the systematic literature search process for identifying and selecting publications focused on the construction industry's. Since there were limited resources before 2008, this research focuses on the studies from 2008-2023. In the initial phase, the authors searched for papers published between 2008 and 2023 using the keywords "Digitalized construction," "Digital construction," "Digital transformation," "Pre-construction," "Construction," "Facility management," "Industry 4.0 technologies," "Construction 4.0," "digital technologies," "Smart construction management," and "Smart buildings."

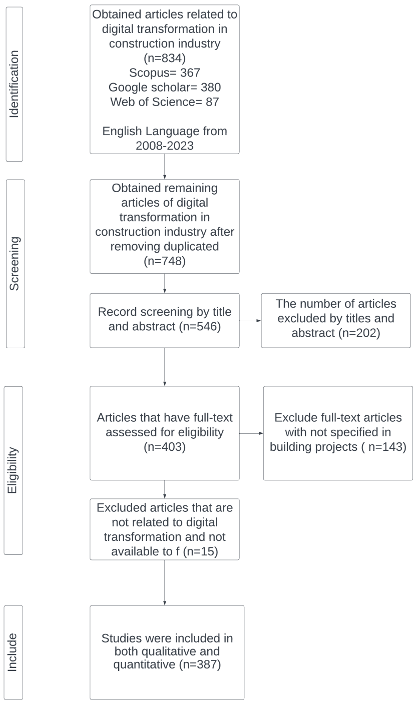

FIGURE 2. **Methodology for selecting and shortlisting articles.**

The following line graph shows in Figure 3 an increase in the number of academic articles analyzing the adoption of digital technologies in the construction industry over the last few years (2008–2023). As a result of this study's emphasis on the digital transformation in the construction industry, the number of articles steadily increases, as other sectors are knowledgeable of the benefits linked to its adoption, such as education, healthcare, and manufacturers. As shown in the last few years, there has been a growing focus among construction companies on digital technologies with the aim of identifying potential benefits such as enhanced productivity, reduced expenses, stakeholder management, a digitalizing process, and improved industry performance.

Subsequently, the digital technologies commonly utilized in the construction industry are classified. This investigation is of the utmost importance in comprehending the diverse applications of digital technology. Figure 4 illustrates the number of articles on each technology over the past few years, from 2008 to 2023.it becomes evident that Building Information Modeling (BIM) has gained the greatest number of articles, equal to 81, throughout the years. As a result, BIM implementation has become a predominant focus in the construction industry throughout all stages of building projects. Furthermore, the number of articles devoted to Internet of Thing, Artificial Intelligence, and Digital Twins (DT) are 38 articles in Internet of Thing, 40 articles in Artificial Intelligence followed by 33 articles on digital twins. This highlights the significance that the construction industry places on data analytics and asset monitoring for the duration of project life cycle. By bringing cutting-edge technology that improve productivity and streamline procedures, construction robotics and automation are transforming the building sector. Construction robotics refers to the use of machines that can carry out repetitive operations like laying bricks, tying rebar, and even erecting entire structures on their own. This decreases labor costs and increases accuracy. The construction sector is experiencing a surge in interest in robotics, with 25 articles highlighting its practicality in buildings. However, challenges such as high implementation costs, specialized training, and ethical considerations like job displacement need to be addressed. The optimism in robotics suggests a need for a balanced examination of its broader implications and practicality in construction processes. Furthermore, Robotics shed the light of a positive trend towards automation and efficiency. Numerous articles have also referred to a variety of other technologies, including drones, 3D printing, virtual reality, augmented reality, GIS, and Cyber-security. In summary, although literature reviews have been conducted on digital technologies within the construction sector, most of them have focused on technologies or phases. The following section will examine the table containing prior literature reviews pertaining to this field of study.

In Figure 5, shows the interdependent ties among all twelve technologies. The numeral within the circular shape represents the overall quantity of research articles that have been published on each respective technology. The numerical value displayed on the widened bar connecting two technologies represents the number of research publications that have used both technologies. Additionally, the width of the bar is directly proportional to the extent of overlap between the two technologies. Specifically, the orange bars demonstrate that all publications pertaining to IoT, GPS, laser scanning, Cybersecurity, and blockchain simultaneously incorporated BIM technology, suggesting a significant reliance on BIM. BIM serves as the primary nexus connecting to other technologies. Furthermore, it should be noted that articles on Internet of Things (IOT) are interconnected with a wide range of technologies, including Building Information Modelling (BIM). There is a lack of research specifically focused on the integration of Building Information Modelling (BIM) with robotics in the construction industry. Moreover, the interconnectedness of robotics and Building Information Modelling (BIM) in the construction industry can be investigated and further analyzed.

According to Figure 6, The number of articles were established in 61 different countries related to digital transformation in construction industry in buildings. In addition, it shows that Asia has 173 articles which China has the largest number of publications papers are 49 articles. Digital transformation has become a trend in Asia, in which nations invest in research and development. In Europe it indicated that Europe are second with 149 articles which Austria has 29 articles. In Africa it shows that 29 articles were identified which South Africa has 12 articles. In North America, it shows that 38 articles which United States of America has 27 articles. Finally, South America were the last which indicated there is only one article which established to Brazil.

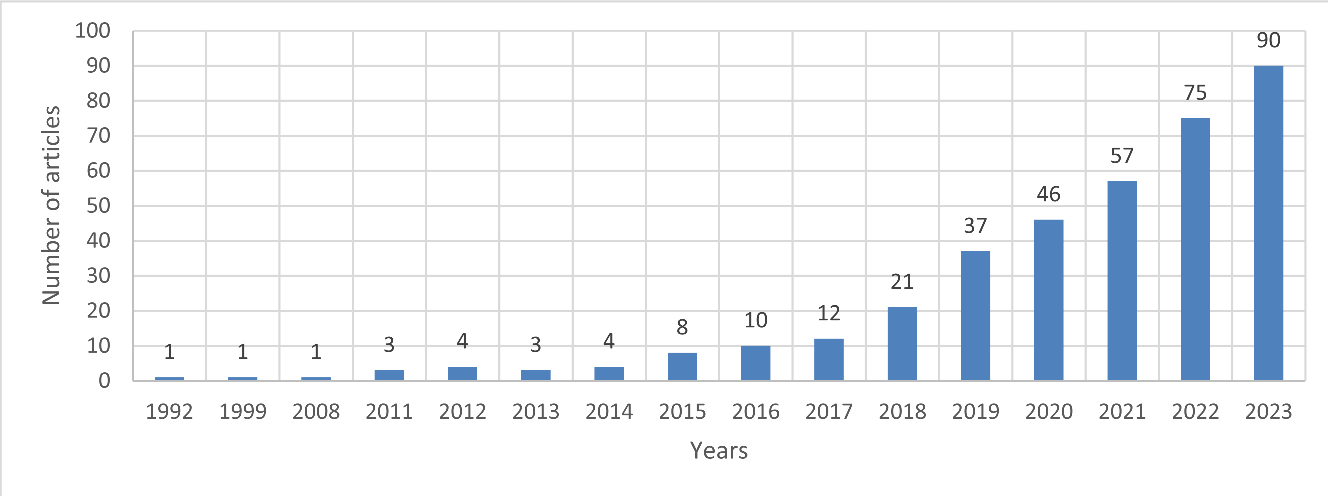

FIGURE 3. Number of articles per years.

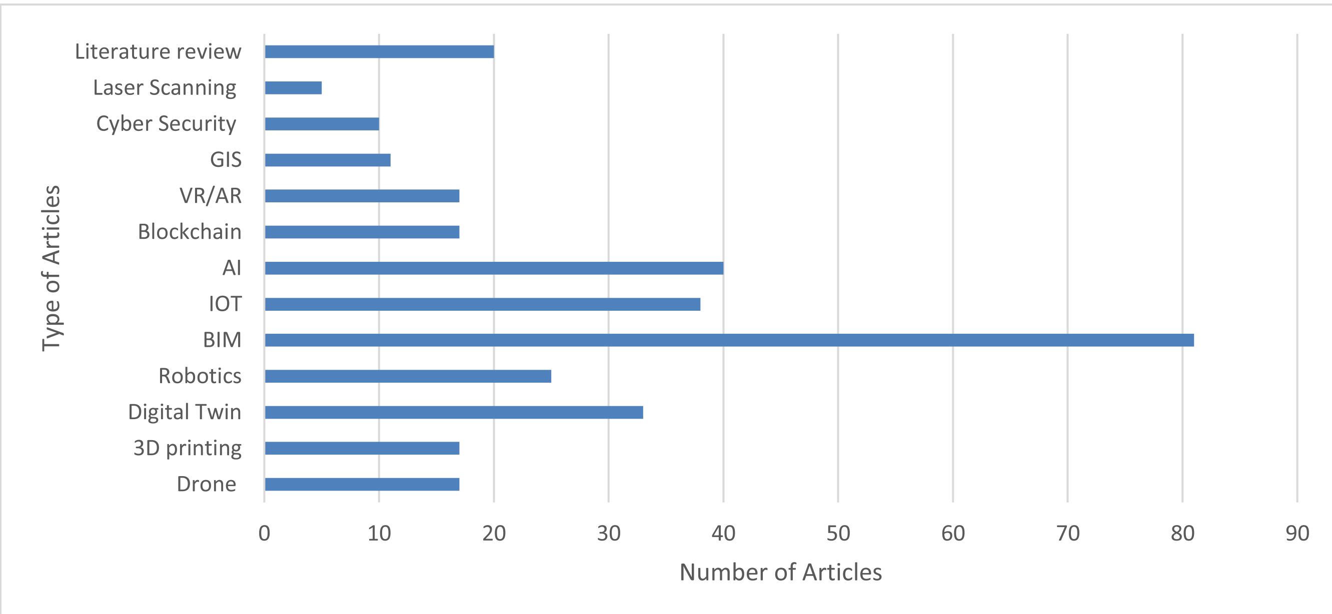

FIGURE 4. Number of published articles related to digital transformation.

Moreover, Digital transformation is an acceleration initiative which indicate that Asia, Europe, and other continents believe that Digital transformation is technologically driven trends that to facilitate communication between stakeholders to allocate resources and improve efficiency and productivity.

Previous research papers examine the variety of advantages, methodologies, and challenges that hinder implementing digital transformation within the domain of construction. Nevertheless, as far as the authors are aware, and as indicated by the summary table of the previous literatures, there has been limited effort to mention a global review of digital technologies' usage, benefits, and challenges in the three core phases of preconstruction, construction, and facility management. Most of the paper delineates distinct technologies or concentrates on specific phases. From this point, the primary objective of this paper is to provide a comprehensive examination of articles that present digital technologies within the construction sector, focusing on their proven effectiveness. By conducting a comprehensive review of the latest literature on the application of digital technologies in the construction industry, as well as the policy and infrastructure drivers that influence the industry's digital transformation, this study contributes to the body of knowledge. Furthermore, the paper investigates the infrastructure and policies necessary to facilitate digital transformation during these phases. Therefore, it hereby fills the gap con-

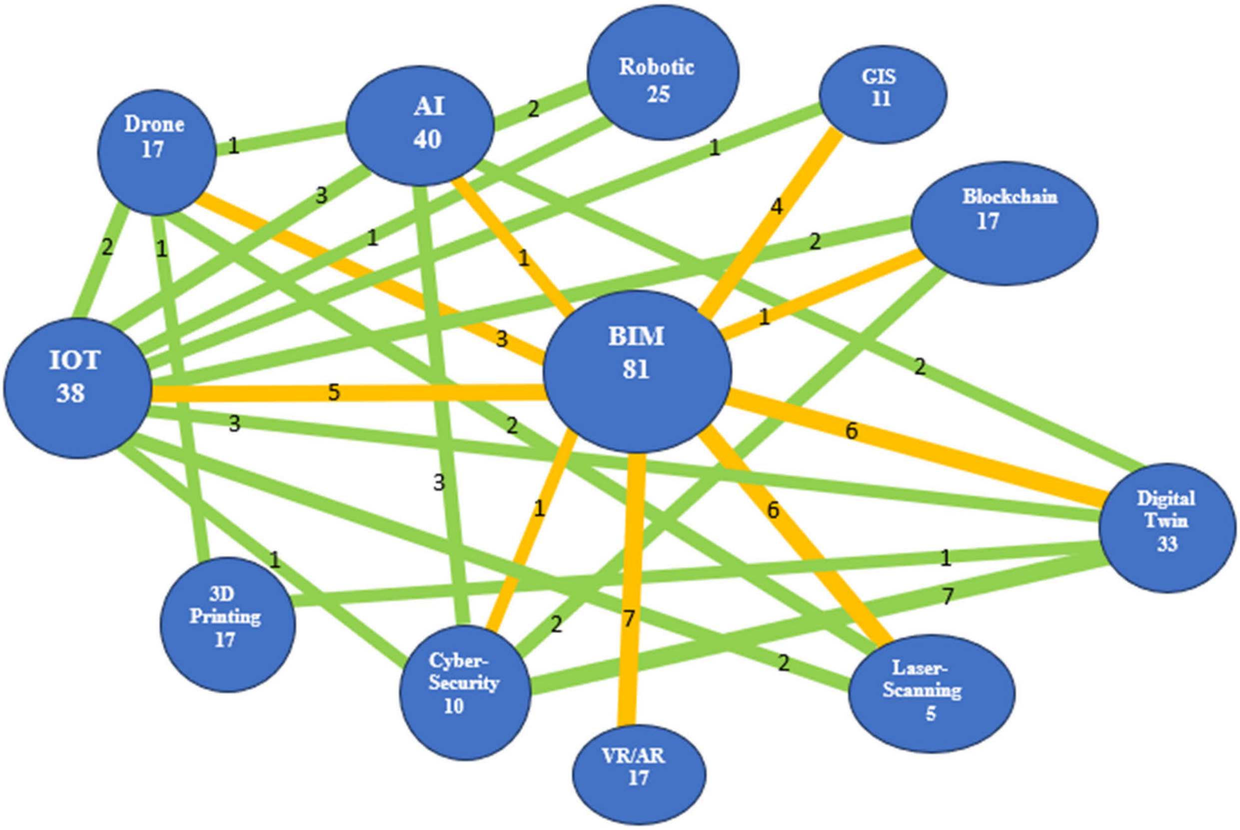

FIGURE 5. Bubble chart for mapping results showing the relationship of digital technology in construction industry for buildings.

cerning the three phases (pre-construction, construction, and facility management) for which articles highlight specific technologies. The research paper is limited to the vertical integration project and does not include horizontal integration. Finally, by conducting this study, it will give a guideline with successful examples of which technologies are being used in specific phases, so future researchers can get a holistic view of the digital technology usage in the entire building environment.

B. TECHNOLOGY AS A FACTOR OF DIGITAL TRANSFORMATION OF BUILDING CONSTRUCTION MANAGEMENT

This section discusses the technologies, policies, and infrastructure factors mentioned in the literature review and presents the importance of these factors in achieving Digital Transformation.

1) DRONES

Drones or unmanned aerial vehicles (UAVs) are increasingly used in the construction industry due to their efficiency and cost-effectiveness in pre-construction site surveying. One advantage of UAVs is their ability to provide a comprehensive view of the construction site, which can help to identify potential challenges and opportunities for the project. Drones can identify potential risks and areas requiring maintenance, remotely tour a property, survey properties, and aid in the creation of as-built property drawings [31]. According to [33] and [34], Capture high-resolution aerial images of construction sites in the construction phase, develop 2D and 3D maps, and help pinpoint potential construction hazards. Drones can also measure the topography of a construction site, develop accurate site models, and monitor construction sites in real-time, providing real-time footage to site managers and workers. They help reduce project costs, minimize the environmental impact, and continuously monitor construction sites to detect potential issues before they become significant problems [34]. Drones have become a valuable tool for construction project management. They provide accurate and up-to-date information on the project's progress, improve safety, reduce the need for in-person communication, and, during public health emergencies such as the Covid-19 pandemic, enable social distancing [35]. When used to aid facility management, UAVs help perform maintenance tasks such as cleaning and roof repair [36] and can be used to inspect building exteriors, including roofs and facades, without needing physical access. Reference [37] mentioned that this technology can help identify maintenance needs and reduce the need for workers to face the hazards of working at heights. Drones can also be used to capture high-resolution images and videos of building components, which can be used to support maintenance activities.

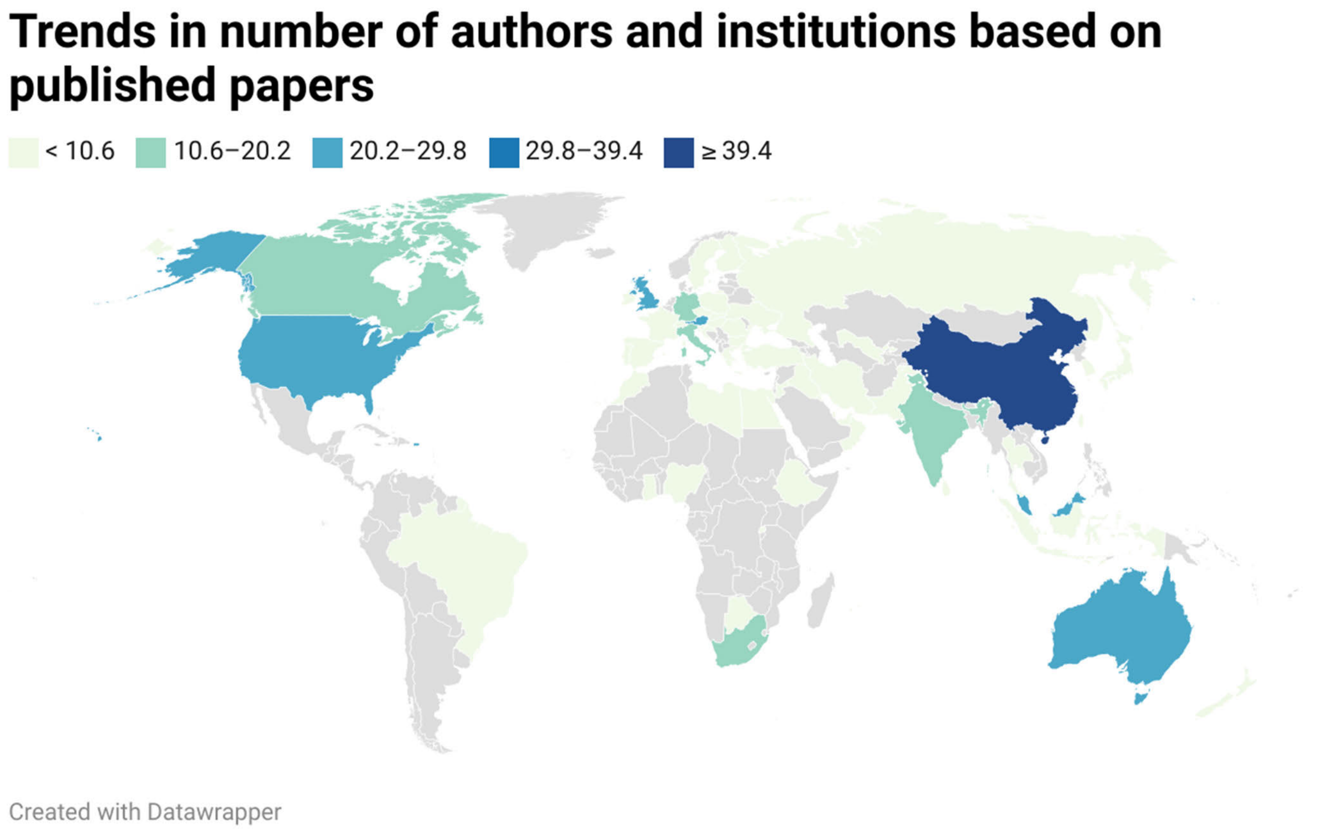

FIGURE 6. Number of authors and institutions based on published papers.

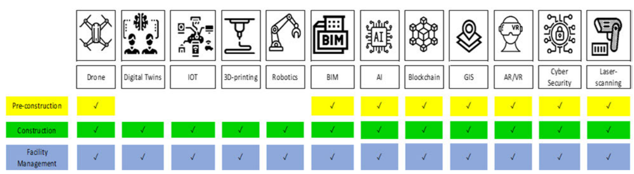

FIGURE 7. Application of digital technologies in various project phases.

2) DIGITAL TWINS

As construction technology advances, Digital Twins (DT) are becoming an increasingly important tool for construction management, providing significant benefits to the industry [38]. DT are virtual replicas of physical assets or systems that simulate, monitor, and optimize performance [39]. There are few literature reviews on the application of digital twins in pre-construction, but the evidence that exists indicates that they can improve safety by simulating hazardous scenarios and assessing project risks by identifying potential bottlenecks or areas of efficiency [40]. They also improve quality control by identifying potential issues before construction begins [41]. In addition, they facilitate collaboration between stakeholders [42]. DT help develop safety protocols and training programs, mitigate potential risks, reduce the likelihood of costly rework or delays, and enable effective communication and real-time collaboration [43]. By providing a virtual replica of a physical asset and enabling real-time monitoring and data analysis, DT are becoming increasingly crucial in facility management. Moreover, DT can be used to model building components and systems, such as HVAC and lighting systems. These digital models can simulate operating scenarios, predict performance, and optimize maintenance activities, for example, during the operation and maintenance [44]. This underlines the necessity of adopting DT applications and comparing the traditional methods of facility management with DT-driven facility management [45]. It has been demonstrated that a cloud based DT may be used to develop accurate information on a physical facility, supporting improved decision-making for facility management practitioners. For instance, [46] discussed the development of DT and the outcomes of a test campaign and sensor evaluation and concluded that digital twins can streamline facility management operations and improve the energy efficiency of buildings.

3) IoT

The Internet of Things (IoT) is the interconnected network of physical objects with sensors, software, and network connectivity [47]. According to [48], during pre-construction, managing resources and equipment requires significant time, reducing productivity. There is a potential solution in that

TABLE 1. Summary of Systematic Review on previous articles.

Title	Research area and limitation	Reference	Year
A Systematic Review of Construction 4.0 in the Context of the BIM 4.0 Premise	The review determines the critical drivers behind Construction 4.0 and evaluates its development during the Fourth Industrial Revolution (4IR), progress, and incorporation with Building Information Modeling (BIM). As predicted by the fourth industrial revolution, the study identifies BIM, the Internet of Things (IoT), and big data (BD) as the principal forces propelling Construction 4.0. Combining BIM with IoT and/or BD yields substantial benefits in real-time monitoring, data exchange and analysis, construction planning, and modeling, according to the analysis. Furthermore, these drivers are utilized primarily during the pre-construction stage of projects, an area that is continually advancing and automating. This article focuses only on BIM, IOT, and big data in the construction phase.	[74]	2021
Machine learning in construction: From shallow to deep learning	This paper conducts a historical examination of the progression of machine learning from shallow to deep learning, with a specific focus on its implementations within the construction industry. This study evaluates its merits and demerits to forecast the future trajectory of machine learning technology in the construction industry. Furthermore, the article suggests future research, proposing that machine learning algorithms be integrated with construction-specific knowledge domains to generate industry-specific deep network models. The paper shows interest in ML in construction practices.	[87]	2021
Deep learning in the construction industry: A review of present status and future innovations	The paper talks about the many hidden benefits of using deep learning to solve common problems in construction, such as predicting energy needs, modeling building occupancy, keeping an eye on structural health, and ensuring everyone stays safe on the job site. Aspects such as construction cost prediction, health and safety, and site planning and management are among the many construction-related applications of deep learning that are examined in the article. The paper is limited to one technology and mainly focuses on the construction phase.	[88]	2020
The Adoption of IOT in the Malaysian Construction Industry: Towards Construction 4.0	This paper is significant for the Malaysian construction industry, specifically for key stakeholders, as it underscores the need to educate the public about the benefits of implementing the Internet of Things (IoT) in forthcoming endeavors. The primary objective is to motivate influential stakeholders in Malaysia's construction industry to acknowledge and contemplate the advantages of integrating the Internet of Things (IoT) into their forthcoming undertakings. The paper is restricted to a specific country, and the field was focused on the construction phase.	[157]	2021
Design and implementation of a smart infrastructure digital twins	The article concentrated on the digital twins technology, which offers a transformative opportunity by facilitating the acquisition and integration of data. This process aims to enhance physical infrastructure assets' design, construction, operation, and maintenance. The ultimate goal of this paper is to contribute to sustainable development and shape a more favorable future. The article is limited to one technology: the digital twins in construction practices.	[145]	2022
Utilizing drone technology in the civil engineering	This paper provides a comprehensive overview of the utilization of unmanned aerial vehicles (UAVs) in civil engineering. The content encompasses the various types of UAVs employed for construction, outlining their advantages and disadvantages. The article is limited to and applicable to one technology: drones in the construction phase.	[161]	2019
Extended Reality for Smart Building Operation and Maintenance: A Review	This article examines virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies as they relate to the operation and maintenance of smart buildings to fill the current gap. An exhaustive analysis, classification, and summary of cutting-edge Extended Reality (XR) technologies are included in the review. The benefits and drawbacks of their potential building operations and maintenance applications are explained. This study is limited to the facility management phase.	[169]	2022
Evaluating the Roadmap of 5G Technology Implementation for Smart	This article examines the present obstacles and benefits of deploying 5G technology across various Smart Facilities Management (SFM) use cases. The paper provides a detailed analysis of the Singapore government's strategy for implementing 5G technology. Additionally, it establishes the 5G Advanced BIM Lab at the National University of Singapore's roadmap for developing SFM use cases. The paper describes how 5G technology facilitates the creation of	[171]	2020

TABLE 1. ***(Continued.)*** **Summary of Systematic Review on previous articles.**

Building and Facilities Management in Singapore	communication channels within the building to maintain and operate the facility while ensuring the longevity of its assets. The article is limited to the asset management of the building phase.		
BIM-enabled facilities management (FM): a scrutiny of risks resulting from cyber attacks	The article highlighted the importance of the BIM-facilities management (FM) cybersecurity-risk matrix to portray what a cybersecurity attack means. The article is limited to the facility management phase.	[179]	2021
Project management processes in the adoption of smart building technologies: a systematic review of constraints	The study identified significant obstacles that hinder the implementation of smart building technologies (SBTs) within project management procedures. The obstacles include a lengthy approval process for new SBTs, structural and organizational complexities within the construction industry, escalated costs linked to smart construction materials and practices, limited awareness of smart building technology, and technical complexities encountered throughout the construction phase. This paper focused only on the obstacles of implementing in the construction phase..	[180]	2020
A Proposed Framework for Construction 4.0 Based on a Review of Literature	This paper does a full literature review and analysis of Construction 4.0's features, benefits, and challenges. It also talks about the technologies that support Industry 4.0, the role of BIM and CDE in the construction industry, and Industry 4.0 in general. It explained the construction 4.0, composed of three parts: the digital and physical layers and digital tools. The study is limited to theoretical aspects, and the paper lacks the required skills and real-life implementation of technologies.	[1]	2020
A Systematic Design Approach in Building Digitalization Services Supporting Infrastructure	This paper argues that establishing a robust digital infrastructure is essential for efficiently operating any carefully planned digital service. Preferably, the configuration of information processes should conform to established guidelines for developing digital infrastructure to ensure the smooth operation and maintenance of buildings. Therefore, this article is limited to the infrastructure and lacks identification of what is required to design the best infrastructure for digital transformation in construction.	[196]	2021
Adoption of smart technologies and circular economy performance of buildings	This study investigates the implementation of intelligent building technologies and assesses the potential impacts of such implementation on the performance of circular economy buildings concerning water and energy consumption. This study is limited to a specific phase in the operation of buildings.	[202]	2020
Integrated implementation of Virtual Design and Construction (VDC) and lean project delivery system (LPDS)	Conducting a systematic literature review (SLR), this study determines the feasibility of integrating LPDS and VDC and establishes implementation procedures to optimize the utilization of VDC features within the Lean environment. In the design and construction phases, the study focuses exclusively on the principles of lean and visual tools.	[221]	2021
Implications of Construction 4.0 to the workforce and organizational structures	This research focuses on the organizational structures and workforce implications of Construction 4.0 during the construction phase. Based on the findings of this study, it is anticipated that conventional construction and robotic technologies will be integrated at some point in the future, resulting in increased job variability and the emergence of new roles in operations and execution. This article did not mention principles on workforce or regulations that support construction 4.0 in pre-construction or facility management phases.	[268]	2019
Literature Review of Digital Twins Applications in Construction Workforce Safety	This article focuses on the use of digital twin applications in construction workforce safety and concludes that DT will greatly impact the safety of the construction workforce. The study is only limited to digital twins in a specific construction phase.	[39]	2020
Methodological-Technological Framework for Construction 4.0	This paper centers on a comprehensive proposal for reference frameworks and associated technologies that may influence the construction industry. It addresses the sector's complexities and particular challenges, including standardizing the unique spaces required for each project, arbitrary cost overruns, and productivity levels significantly lower than the	[5]	2021

TABLE 1. ***(Continued.)*** **Summary of Systematic Review on previous articles.**

	average in other industries. The study does not provide concrete technology implementation scenarios for the various phases supporting the proposed framework.		
A Systematic Review of Digital Technology Adoption in Off-Site Construction: Current Status and Future Direction towards Industry 4.0	This article aims to assess the existing literature concerning OSC off-site construction applications of digital technology. These technologies included the Internet of Things (IoT), radio frequency identification devices (RFID), building information modeling (BIM), sensors, augmented reality (AR), virtual reality (VR), photogrammetry, laser scanning, artificial intelligence (AI), 3D printing, and robotics. This review provides a comprehensive analysis of the present state of digital practices. This study is restricted to off-site construction and does not mention the remaining phases.	[152]	2020
Digital transformation in the construction industry: a bibliometric review	Utilizing bibliometrics, this study investigates and provides a scorecard of the construction industry over the previous decade. The study outlined the diverse features of digital transformation within the construction sector while highlighting possible areas for future research. This research is exclusively concerned with the construction phase of digital technologies and does not concentrate on the pre-construction or facility management phases.	[227]	2021

it is possible to capture and record elevation from one place to another through GPS. In construction, using an IoT approach can improve efficiency, safety, and sustainability. Furthermore, sensors can monitor temperature, humidity, and air quality; wearables can monitor worker safety and productivity; and real-time site maps can be used to identify danger zones and optimize construction processes [49]. IoT devices can also help to reduce waste, prevent accidents and injuries, and improve inventory management [50]. IoT will likely become increasingly important for construction management as construction technology advances. In the facility management phase, the availability of IoT systems is crucial for collecting real-time data, enabling predictive maintenance, optimizing space usage, improving energy management, and enhancing building safety. An IoT network facilitates communication and information sharing between users [51]. IoT systems may facilitate quicker or real-time decision-making when combined with large data sets. Reference [52] demonstrated that IoT technologies can improve the interaction between users and the built environment while facilitating communication via intelligent digital interfaces. Reference [53] noted the use of BIM and IoT for the intelligent scheduling of maintenance work and emphasized the potential for these technologies to improve facility maintenance activities in the context of building maintenance. In addition, [54] emphasized the significance of radiofrequency identification (RFID), which is regarded as a technology enabling IoT.

4) 3D PRINTING

According to [55], 3D printing, also known as additive manufacturing, is a technology used to produce 3D objects by layering materials. It can produce prefabricated structures, building components, and construction materials. It can reduce construction time, costs, and waste and improve quality control [56]. There is, notably, little literature on the applications of 3D printing in pre-construction. 3D printing can produce precast concrete panels, concrete walls, and mortar for walls and facades [57]. 3D printers can be part of Construction 4.0 with a focus on transport constructions [58]. In addition, 3D printing has been used by Chinese companies to produce structural elements and to print concrete houses [59]. Few researchers have explored 3D printing in facility management, although it has been shown to efficiently produce replacement parts and customized components. Reference [60] mentioned the necessity of integrating BIM with 3D printing, but this approach is still not used in the building facility management process. The use of additive manufacturing also mitigates the cost of higher-skill labor, reduces construction time and production costs, and improves safety for workers [61].

5) ROBOTICS

Robotics and automation are becoming increasingly essential in the construction industry as they optimize equipment operations, enhance safety, enhance the understanding of the work environment, and ensure a high-quality environment for building occupants [62]. No literature reviews have examined robotics applications in the pre-construction stage, with most being primarily concerned with the construction phase. Robotics can be utilized for modular construction, wall spraying, producing precast walls and complex structural elements, excavation processes, construction material inspection, material selection, and assisting workers with bricklaying and landscaping, among other manual tasks [9], [63], [64], [65], [66], [67], [68], [69]. Recently, robots have also been integrated into various sectors of the facility management industry [70] proposed using programmable robots to diagnose human vital signs. Furthermore, [71] identified a robotics framework for performing facility tasks such as cleaning, painting, facade removal, fire safety, and building inspection.

6) BIM

BIM is a digital representation of a construction project that employs 3D models, data, and intelligent objects to facilitate the project's planning, design, construction, and operation. In the pre-construction phase, BIM can enhance project team collaboration, decision-making, and communication. BIM is transforming the construction industry and increasing productivity through the use of clash detection to maintain safety and quality standards and to improve project effectiveness, cost management, and quality management [3], [72], [73]. Reference [74] highlighted the importance of BIM usage in the construction industry, while [75] mentioned the use of BIM applications to optimize layout spaces. BIM provides a 3D model of a building that can be used for planning, design, construction, and operations [76]. It is particularly beneficial for the pre-construction design process, including the design of space layouts. BIM helps designers visualize and analyze the structure of the building's spaces, identifying potential issues and optimizing the use of space [77]. During the building phase, projects encounter novel and intricate obstacles, including heightened project intricacy, executing many client adjustments in the execution phase, and functioning in unpredictable circumstances. Project management, performance measurement, design management, client value, culture, human factors, supply chain management, information technology, safety, waste management, and complexity are just a few of the areas where BIM and lean construction are closely related [78]. In the facility management phase, BIM is crucial to integrating data management systems like computer-aided facility management and computerized maintenance management systems, forming a crucial part of the Digital Transformation of facility management [79], [80], [81].

7) AI

Artificial Intelligent (AI) has substantially enhanced business operations, service processes, and construction industry output. Its adoption has resulted in increased automation and competitive advantages over traditional methods. A comprehensive critique, however, would necessitate a more in-depth examination of the potential ethical concerns and biases associated with AI and its impact on the job market and human decision-making [82]. In pre-construction management, AI can enhance the selection of contractors in the tendering stage by analyzing data and criteria to identify the most suitable candidates based on factors such as past performance, experience, expertise, and price. The literature shows that technology usage positively impacts the tendering process, especially when evaluating the submitted tenders of the contractors [83]. AI can reduce bias and subjectivity in the decision-making process by analyzing data objectively, ensuring the selection of the most qualified and capable contractors [84]. AI algorithms can also improve the efficiency of the contractor selection process by quickly analyzing large amounts of data to identify the best candidates, thereby reducing the time and costs associated with the tendering process [85]. Furthermore, by analyzing past performance and relevant data, AI can help ensure the selection of contractors that have a proven track record of delivering high-quality work and meeting project requirements. Despite these benefits, human expertise and judgment are still essential in reviewing and verifying AI analysis results, as AI is not a replacement for human professionals. AI can also be used in the construction phase to improve efficiency, safety, and productivity [86]. It can analyze data on materials and properties to help make informed decisions on material selection, and it can analyze large amounts of data to identify patterns and improve decision-making. AI can also improve worker safety by monitoring vital signs and alerting workers to potential hazards, in addition to enhancing communication and coordination between different teams and equipment on a construction site [87]. Additionally, AI can improve decision-making by analyzing large amounts of data on construction projects to identify trends and patterns [88]. As construction technology advances, AI will likely become an increasingly important tool for construction management [89]. Both AI and machine learning (ML) can be used in facility management to predict maintenance needs before they occur. Such predictive facility management can help reduce downtime and extend the life of building systems. Researchers have explored the use of AI and ML in facility management, revealing that they can effectively predict maintenance needs. The use of AI in the operation of buildings has gained traction among industry professionals. According to [90], many researchers indicate that AI enhances digital twin technology's sensing and actuation capabilities. Reference [91] listed AI as a predictive diagnostic tool in the healthcare industry.

8) BLOCKCHAIN

Pre-construction project tendering procedures currently in use are centralized and depend on the participation of a third party; these procedures raise serious issues with data security, transparency, and traceability because bidders are dependent on the authority and impartiality of the process organizer [92]. One potential use case for blockchain technology is in managing construction contracts. Another is in managing project cost control [93]. Incorporating blockchain technology into an organization's cloud system can improve collaboration and communication among team members. Using a cloud-based blockchain system, all parties involved in a construction project can access the same data in real-time, regardless of location [94], [95]. Blockchain can also enhance transparency and trust in construction projects by facilitating progress payments through time deliverables [96]. Blockchain technology enables automated procurement and supply chain management in the facility management stage through smart contracts. Reference [97] developed a prototype system for implementing blockchain technology into smart buildings for managing repairs and service maintenance. In the proof-of-concept prototype presented by the authors, blockchain technology enabled the formation of smart contracts for facility controls and administration of repairs by timely detecting defects by sensors.

9) GIS

Geographic information systems (GIS) can be used in pre-construction to analyze geographic data to make informed decisions about land development; for example, analysis of changes in soil resources can help to determine the best locations for building projects [98]. This technology has the potential to provide significant benefits in construction, and as construction technology continues to advance, it is likely to become an increasingly essential tool for construction management [99]. GIS is used in facility management by integrating maps with UAVs data for planning, environmental monitoring, and safety surveillance [51]. GIS is also a helpful tool for large-scale space management and optimization. The accumulation and analysis of geospatial data supports various information systems and business procedures for the administration of facilities within buildings. For instance, space availability, utilization, and optimization can be evaluated across complexes to enable large-scale building operations.

10) AR/VR

VR is the development of virtual environments can enhance comprehension among construction project stakeholders and elevate their ability to complete projects successfully. VR technologies can improve efficacy and efficiency in a project's design, planning, and construction [100]. Augmented reality (AR) is an advanced computer technology that provides significant benefits to the construction industry through simulation and visualization, such as allowing the observer to interact with both actual and virtual objects in order to monitor construction progress and compare the as-planned and as-built statuses of the project [101]. During pre-construction, the literature indicates that VR-supported design review enables users to identify marginally more flaws in a 3D model than when using the conventional CAD software method on a PC screen [102]. VR supports clash detection, stakeholder engagement, and communication [103]. Furthermore, VR integration with design in the pre-construction phase can benefit project teams by providing a realistic building design experience and improving design visualization, enabling project teams to make more informed decisions. Contractors can also use VR to review designs with stakeholders and receive real-time feedback, allowing them to adjust [104]. They can perform clash detection in VR to identify and resolve conflicts between design elements before construction starts, reducing the risk of errors and delays. Constructors can also use VR to simulate potential safety hazards and plan emergency procedures. VR can help project teams save time, reduce costs, and improve overall project quality. AR technology can be similarly used in construction to enhance collaboration, safety, and productivity. AR/VR can enable remote collaboration between teams and stakeholders, allowing workers can access information and instructions hands-free through smart devices [105]. It can capture and monitor construction progress and train workers on complex tasks. AR/VR can also provide real-time information on hazards and risks to enhance worker safety [106]. As construction technology advances, AR/VR will likely become an increasingly important tool for construction management [107]. AR and VR also have the potential to significantly transform facility management. These solutions provide facility management personnel with improved capabilities for interacting with the built environment and can facilitate the efficient performance of operational and maintenance tasks within a facility. These technologies allow users to use VR headsets to change BIM models in real-time, and the transfer of BIM data into VR systems can enhance visualization and real-time monitoring compared to the use of BIM technology alone. Additionally, [108] evaluated the utility of AR in facility management through a case study. Their findings showed that AR could facilitate remote collaboration for improved built environment management.

11) CYBERSECURITY

Cybersecurity technology is used to identify risks, threats, and vulnerabilities for project stakeholders (e.g., owner, designers, and contractors), entities (e.g., equipment and assets), and processes (e.g., design-intent discussion and sharing final models) using an agent-based modeling approach [109]. Cybersecurity is crucial in the construction industry due to the involvement of sensitive data and valuable assets. An extensive review of the literature suggests that the applicability of cybersecurity is very minimal in the pre-construction phase due to the nature of this phase. However, construction sites can use cybersecurity to monitor and protect against theft, vandalism, and other security threats while ensuring that sensitive data, such as financial and worker data, is only accessible to authorized parties [110]. Secure messaging platforms and virtual private networks can safeguard communication channels and prevent data leaks [111]. Building designs and specifications are developed digitally and shared with all project participants. During construction, participants are equipped with devices to enhance their daily productivity. On most construction sites, using tablets and mobile devices to collect and share project information is now the norm [112]. Given this trend of increasing digital management of construction processes and data, cybersecurity is expected to become an increasingly important tool for construction management to protect against security threats. In the facility management phase, secure data exchange has the potential to enhance the accuracy and utility of data. However, adopting digital technologies in building and facility management poses significant cybersecurity challenges. As noted by [109], the automation of building management processes increases the risk of cyberattacks. Therefore, robust security measures must be employed to safeguard data and prevent cyber threats in such environments.

12) LASER SCANNING

Laser scanning is utilized in the pre-construction phase of commercial building construction to produce as-built drawings. However, the advantages of this technology are accompanied by certain limitations, with accuracy being a significant concern. With the increasing adoption of laser scanning, its lack of accuracy remains a persistent challenge [113]. However, it has been successfully used to identify clash checks for mechanical, electrical and plumbing (MEP) systems with structural handles [114]. According to [115], integrating BIM with 3D laser scanning will improve construction quality control. During construction, 3D laser scanning can be used to capture current progress in construction sites [116]. [117]stated that 3D laser scanning can capture daily on-site planned activities when combined with site images, site videos, and tracking. In the facility management stage, 3D laser scanning can record highly accurate measurements and extensive information on a building's physical elements, such as walls, floors, ceilings, and MEP systems. This data can then be utilized to generate a virtual 3D model of the structure that can be employed for various purposes. [118] and [119] emphasized the significance of 3D laser scanning and photogrammetry for accurately recording the parameters of items within structures, while according to [120], combining UAV photogrammetry and laser scanning data allows the development of an accurate and complete 3D representation.

C. FACTORS IMPACTING POLICY MAKING AND GOVERNANCE IN BUILDING CONSTRUCTION MANAGEMENT

1) STANDARD PROCEDURES IN CONSTRUCTION MANAGEMENT

Standardizing technology adoption in the construction industry involves defining technology standards, training personnel, developing policies, monitoring performance, and continually improving processes, as mentioned in a case study in Ireland [121]. This standardization process can help to ensure that technology is used effectively and efficiently and that projects are completed on time and within budget. Standard operating procedures should outline how a technology is to be used, who is responsible for using it, and what the expected outcomes are [122]. The study by [123] clearly showed that the absence of policies and standards affects the adoption of Construction 4.0 technologies in South Africa. Digital Transformation highlights the importance of policies and standards in providing a roadmap toward correctly implementing technologies in construction projects.

2) STAKEHOLDER ENGAGEMENT

According to [124], stakeholder engagement brings numerous advantages, such as establishing a collaborative platform for public interest discussions, ensuring inclusivity, and fostering joint action on common concerns. Stakeholders can improve the building process by contributing to change management and technological know-how. Goals and aspirations for Construction 4.0 must be mapped out and should involve the development of a pilot project, definition of capabilities, generation of data, launch of digital enterprise transformation, and plans for an ecosystem-compliant approach [125]. According to [126], BIM facilitated successful stakeholder engagement in Malaysia to achieve Industry 4.0 early in the project lifecycle. In addition, collaborating in real-time will improve decision-making, planning, and management and monitoring of resources.

3) TRAINING SESSIONS

According to [127], there is a skill gap in the industry relating to Construction 4.0 technologies. The study identified nine factors that impact the adoption of these technologies, including a lack of awareness or clarity concerning Industry 4.0, low job security for skilled workers, and dependence on outside talent. The study highly recommended that individuals attend training programs related to technologies to increase their awareness of the Construction 4.0 transformation. Also, associations and organizations should encourage individuals to participate in training programs and aim to attract talented employees to increase productivity and knowledge transfer between generations. Identifying gaps in the current skillset of project workers or new technologies and processes to be implemented is essential [128]. Providing customized training for specific roles or departments and offering ongoing support and resources such as online resources and follow-up training sessions can also be valuable. Training sessions for employers on the benefits of Digital Transformation can improve productivity and efficiency across the construction project lifecycle. According to [129], upskilling and reskilling training sessions improve organizational workforce functioning by providing a future-ready workforce, background information regarding skills involve in Industry 4.0, and a life-long learning framework.

D. FACTORS IMPACTING THE INFRASTRUCTURE OF BUILDING CONSTRUCTION MANAGEMENT

A massive amount of information is transmitted from the pre-construction phase to the construction phase, and from the construction phase to the facility management phase. Ensuring the proper connection, storage, monitoring, and control of this information is essential. IT support for the infrastructure needed to ensure a smooth flow of data is an example of a factor facilitating the development of smart buildings, as indicated by [130]. Digital Transformation can also enhance the experience of project workers and other stakeholders; for example, the student experience of using the systems in smart universities, whereby all data can be managed, secured, and saved [131]. This underlines the importance of a high-quality data connection and IT support for the building. Another important factor is the availability of a well-established storage and data access infrastructure, which supports effective project management, improves collaboration, reduces errors, and ensures access to the latest project data. Generally, regarding the digitalization of buildings, [132]outlines four essential steps: sensing, connecting, storing, and processing data. Sensor devices and cellular networks capable of sending massive volumes of data, such as 5G networks, are necessary to facilitate the sensing and connecting processes. Data storage is vital, since all data must be saved in a safe place, whether on local servers or in the cloud. As defined in [132], cloud computing is the capacity to store organizational data in the cloud. Data centers and server rooms are examples of local hardware storage systems. City representatives must understand the feasibility and outcomes of the infrastructure and contextual factors which enable smart cities, including information technology, proper connection, storage capability, and people's awareness of technology usage [133]. To clarify the need for proper infrastructure, [134] defines the concept of a smart campus and its required infrastructure, noting that communication, storage, and IoT systems are necessary to achieve a smart campus vision and its implementation. Also, the study outlined the three layers of the IoT, namely the application layer, network layer, and awareness layer. Reference [135] acknowledges cloud computing as one of the critical infrastructure components for managing corporate data, mainly when IoT and wireless networks are linked. Establishing a control center for construction work can ensure project success by controlling and monitoring construction and facility management activities. Reference [136] stated that low-latency, high-bandwidth connections, and wireless networks are required to implement digital technologies. Consequently, communication infrastructure is crucial in digitalized smart buildings and the larger Digital Transformation of the construction industry.

III. THE IMPLICATIONS OF DIGITAL TRANSFORMATION FOR CONSTRUCTION MANAGEMENT IN BUILDINGS

According to our investigation of the existing literature, Digital Transformation can revolutionize the construction industry by incorporating tools such as BIM, cloud-based project management, drones, 3D laser scanning, IoT sensors, and AR and VR. For example, BIM software allows stakeholders to collaborate and coordinate while improving the design and cost estimates, reducing errors, streamlining scheduling, and improving asset longevity. Cloud-based project management tools facilitate progress tracking, task management, and information sharing. Drones and 3D laser scanning can provide data for the development of 3D models of buildings for design flaw identification, construction planning, and measuring actual existing buildings. AR and VR can simulate the construction process, enabling stakeholders to understand building designs better and visualize the components of buildings. Robotics and automation are crucial in the construction industry for optimizing equipment operations, improving safety, and ensuring a high-quality work environment. While no existing literature examines potential applications for robotics in the pre-construction stage, during the construction stage, robots can be used in tasks such as modular construction, wall spraying, precast walls, excavation processes, material inspection, and assisting workers with bricklaying and landscape tasks. Robots have also been integrated into various aspects of facility management, such as healthcare, cleaning, painting, facade removal, fire safety, and building inspection.

Digital twins have gained significant attention in construction as they contribute to improving safety, assessing project risks, and facilitating collaboration among stakeholders. They help develop safety protocols and training programs, mitigate risks, reduce rework or delays, and enable effective communication. Digital twins are also crucial in facility management, providing a virtual replica of a physical asset for real-time monitoring and data analysis. They can model building components and systems, such as HVAC and lighting systems, enabling the simulation of operating scenarios, performance prediction, and the optimization of maintenance activities. Cloud-based digital twins can provide accurate information on the physical facility, enabling better decision-making by facility management practitioners. Digital twins can streamline facility management operations and improve building energy efficiency.

IoT can support pre-construction phase productivity and resource management through, for example, the use of GPS devices to capture elevation data. In construction, IoT devices can help optimize construction processes by monitoring temperature, humidity, air quality, worker safety, and productivity. During the facility management phase, the use of IoT can reduce waste, prevent accidents, and improve inventory management. As construction technology advances, IoT will become increasingly important in facility management, collecting real-time data for predictive maintenance, optimizing space usage, improving energy management, and enhancing building safety. IoT networks facilitate information sharing and communication, enabling quicker decision-making when combined with large data sets.

Meanwhile, AI has significantly improved business operations and service processes in the construction industry, offering increased automation and competitive advantages. In the pre-construction phase, AI can enhance contractor selection by analyzing data and criteria, reducing bias and subjectivity in the decision-making process. It can also improve efficiency by quickly analyzing large amounts of data, saving time and costs. In the construction phase, AI can improve worker safety by monitoring vital signs and alerting workers to potential hazards. As construction technology advances, AI will likely become an increasingly important tool for construction management. AI and ML can also be used in predictive maintenance planning as part of facility management to reduce downtime and extend building system life. Blockchain technology offers a decentralized platform that provides security and traceability, creating a potential solution for tendering methods; however, it also raises concerns about data security, transparency, and traceability. Blockchain technology can improve construction contract management and project cost control. It also enhances collaboration, communication, and transparency, allowing real-time data access across all parties. Blockchain further enables automated procurement and supply chain management through smart contracts, enhancing trust and efficiency in construction projects.

GIS is a powerful tool for analyzing geographic data, enabling informed decision-making about land development, construction, facility management, and large-scale space optimization. It integrates maps with data from UAVs for planning, environmental monitoring, and safety surveillance, and supports information systems and business procedures for facility administration. Cybersecurity is crucial in the construction industry, as it helps identify risks, threats, and vulnerabilities in entities, equipment, and processes. It is especially important during the pre-construction phase, where it can monitor and protect against security threats. Secure messaging platforms and virtual private networks can safeguard communication channels and prevent data leaks. As construction technology advances, cybersecurity will become an increasingly important consideration in project management, as digital designs and specifications are shared and devices are increasingly used for daily productivity. Laser scanning is used in pre-construction for commercial building construction, but its accuracy remains a challenge. Integrating BIM with 3D laser scanning can improve construction quality control by capturing daily on-site activities, enabling progress monitoring, and recording physical elements like walls, floors, and ceilings. This data can be used to generate a virtual 3D model for various purposes. Combining UAV photogrammetry and laser scanning data can allow an accurate and complete 3D representation to be developed. Figure 3 summarizes the application of digital technologies in various phases of construction processes. It is obvious that the construction industry is being positively impacted by digital transformation. By enabling collaborative, data-driven project management throughout the entire lifecycle of a building, BIM is transforming the construction industry. Algorithms powered by artificial intelligence analyze vast quantities of data to optimize building processes, forecast project outcomes, and enhance decision-making throughout pre-construction, construction, and facility management. Automation of repetitive tasks, enhancement of productivity, and improvement of safety are all outcomes of robotics implementation in construction activities and building operations. In addition, GIS technology facilitates the visualization, spatial analysis, and management of construction sites, which significantly accelerates the work by aiding in site selection, environmental assessment, and infrastructure planning. Thus, GIS can also be helpful in space management in buildings. Adopting augmented reality (AR) and virtual reality (VR) technologies that improve training, design review, and visualization processes, thereby enhancing project team communication and comprehension. Additionally, additive manufacturing, also known as 3D printing, is transforming the construction industry by facilitating economical production of intricate geometries, customized fabrication, and rapid prototyping. Precise three-dimensional data of construction sites or existing buildings is acquired through laser scanning, which enables precise as-built records, quality assurance, and clash determination. IoT is regarded as the link that enables devices to communicate with one another with minimal human intervention. These technologies have the potential to improve the construction industry, provided that appropriate regulations, policies, and infrastructure are implemented.

IV. LESSONS LEARNED

The literature reviewed in this study leads to the following conclusions:

1) The paper includes a comprehensive global review of digital technologies' usage, benefits, and challenges in the three core phases of pre-construction, construction, and facility management. In addition, it's also important to identify the necessities of these factors that will lead to the successful implementation of digital transformation. (this was added in the research gap)
2) Implementing Digital Transformation in the construction industry requires a clear understanding of the business objectives of a given project or company and the problems that Digital Transformation is intended to solve. This, in turn, involves conducting a thorough analysis of the current state of the business, identifying the areas that require improvement, and defining the desired outcomes for the pre-construction, construction, and facility management phases.
3) The construction industry is complex, involving multiple stakeholders, including clients, architects, engineers, contractors, and subcontractors. To achieve success in Digital Transformation, involving all stakeholders and encouraging open communication and collaboration are crucial.
4) The effective implementation of Digital Transformation in the construction industry requires a focus on data management and analysis. This involves collecting and analyzing data from multiple sources, such as sensors, equipment, and project management software, to gain insights into the performance of the construction process and identify areas for improvement in each of the project phases.
5) Implementing Digital Transformation in the construction industry requires a significant investment in technology, infrastructure, and policy. Well-defined budgets and timelines are essential for successful

implementation, as is a plan for ongoing maintenance and support.

6) It is critical for the construction industry to implement the appropriate digital transformation and advance rapidly toward a proper policy. Guidelines and policies in the construction industry have certain implications, including the following: The implementation of consistent standards and interoperability guidelines can greatly enhance the smooth integration of diverse digital tools and technologies across the construction ecosystem. In addition, governmental bodies have the ability to enact policies that facilitate the enhancement of skills and training initiatives that aim to furnish laborers with the essential technical proficiencies and digital literacy required to utilize emerging technologies in construction endeavors. Moreover, emphasizing the policies and strategies can streamline the process and procedure, which will remove any ambiguity and facilitate digital transformation in the construction industry.

V. CONCLUSION AND FUTURE WORK

The construction industry's Digital Transformation is expected to impact the industry's future significantly. This paper reveals the importance of using new technologies such as BIM, VR/AR, drones, 3D printing, robotics, AI/ML, IoT devices, and digital twins, which are expected to become more prevalent in the pre-construction, construction, and facility management phases. As such, construction professionals must be aware of these trends and adapt their skills and knowledge to stay competitive. Also, this review highlights the fact that policies and infrastructure are critical to improving the construction industry's Digital Transformation. The construction industry is highly regulated, and government policies and regulations significantly impact the industry's adoption of new technologies. This study was conducted to gain a comprehensive understanding of Digital Transformation in the construction industry and to accommodate new digitalization trends towards more significant overall progress. Future work might complement this analysis of overall trends with greater focus on analyzing one phase in more detail. The ongoing Digital Transformation revolution is profoundly reshaping all industries. The construction sector, in comparison to other industries, has historically exhibited a slow pace of technological advancements, which has resulted in its reputation for prolonged transformation. In an effort to comprehend and resolve these obstacles, a multitude of initiatives and studies have been undertaken in recognition of the counterproductive nature of this tradition. The advantages that come with technological advancements are what drive these efforts. This study examines the progression of digital transformation in the domains of pre-construction, construction, and facility management over the period from 2008 to 2023, with the intention of assessing the present condition of construction. The research findings highlight several key points, including the following:

1) This study effectively demonstrates that digital transformation encompasses more than technological progress; rather, it has a profound influence on multiple aspects of the industry. The study examines the progression of Digital Transformation in the domains of pre-construction, construction, and facility management, providing valuable perspectives for future research.
2) The research methodically determines the various factors that impact Digital Transformation implementation in the construction industry. Moreover, it contributes to the ongoing dialogue regarding the application and challenges where policies, integration of technologies, and resistance to change hinder digital transformation initiatives.
3) Even though most of the revised research papers focused on the construction industry's implementation of Building Information Modeling (BIM), there has been a recent shift in emphasis towards the adoption of digital transformation within the sector, and more technologies are being considered in the big picture.

The research article excludes horizontal integration and only discusses vertical aspects of building projects. In order to provide future researchers with a comprehensive understanding of the use of digital technology throughout the building environment, this study will, at the end, provide a guideline with successful examples of which technologies are being employed in specific phases. An essential suggestion is to consider conducting a comparison of particular phases in both vertical and horizontal integration. Additionally, conducting research on the practical implications of the digital transformation on specific building phases, considering its effects on the economy, society, and environment, would be a worthwhile endeavor in the future. Moreover, investigate the interrelationships among the technologies and their effects on the overall performance at various stages.

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KHALID K. NAJI received the M.Sc. degree in structural engineering from The University of Texas at Austin, in 1994, and the Ph.D. degree in construction engineering from the University of Florida, Gainesville, in 1997. He is currently the Dean of the College of Engineering. His research interests include construction engineering and management, with a focus on digital construction systems and solutions.

MURAT GUNDUZ received the master's degree in construction engineering and management from the Georgia Institute of Technology, USA, in 1998, and the Ph.D. degree in construction engineering and management from the University of Wisconsin, Madison, USA, in 2002. He is currently a Professor in civil engineering with Qatar University. His research interests include construction engineering and management, performance measurement, digital construction, and safety and risk management. He is also an Associate Editor of *Journal of Management in Engineering* (ASCE).

FAHID HAMAD ALHENZAB received the master's degree in engineering management from Qatar University, in 2019, where he is currently pursuing the Ph.D. degree in engineering management. He is also the Head of Project with Qatar Petrochemical Company (Q-Chem). His research interest includes digital transformation in pre-construction/design of building projects.

HAMED AL-HABABI received the bachelor's degree in civil engineering from the Florida Institute of Technology, in 2016, and the master's degree in engineering management from Qatar University, in 2019. He is currently a Civil Engineer with Public Works Authority in Building Projects. He is also working on his Ph.D. thesis for digital transformation in building construction.

ABDULLA HAMAD AL-QAHTANI received the master's degree in engineering management from Qatar University, in 2019, where he is currently pursuing the Ph.D. degree in engineering management. He is also the Senior Project Manager of the Qatar Free Zones Authority. His research interest includes digital transformation in facility management of buildings and systems.