



The Importance of Applying Digital Twin Technology and Its Obstacles in Engineering Projects in Syria

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ABSTRACT

This study focuses on defining the industrial revolution and digital transformation, including their associated technologies and how they have impacted the fields of industry and construction. Additionally, it delves into the concept of digital twin technology, exploring its origins, definition, stages, maturity levels, and scale. The study also examines the components of digital twin technology, its ecosystem, characteristics, and key features of its application. Specifically in the field of construction, it discusses the components of digital twin technology and their overlap with building information modeling throughout a building's life cycle. The study emphasizes the importance of data in shaping digital twin models and outlines relevant standards. It also highlights various digital twin platforms used in construction along with machine learning algorithms employed in these systems. Finally, it explores how digital twin technology is used in construction projects and outlines its benefits while also identifying key obstacles to its implementation in engineering projects. The objective of this study is to assess the level of familiarity among workers in the construction industry in Syria with digital twin technology, their understanding of its application, and the primary obstacles to its implementation in engineering projects. A descriptive approach was employed, and a questionnaire was distributed to 36 participants with varying levels of education and engineering experience. The Likert scale was used to evaluate responses, and statistical software SPSS was utilized for quantitative analysis. The findings indicate a low level of awareness and knowledge regarding digital twin technology, resulting in limited comprehension of its significance and relevance in engineering projects. This may be attributed to inadequate exposure to new research and studies as well as the country's crisis. The study concludes with recommendations such as prioritizing training for construction workers, enhancing infrastructure, and conducting additional research on digital twin technology within the construction sector.

Keywords: The fourth industrial revolution ▪ Digital Twins ▪ BIM ▪ Construction industry ▪ Digital transformation

1. INTRODUCTION

The construction and engineering industry is in constant need of development, particularly after the fourth industrial revolution and the technological advancements that came with it. This includes modern technologies like big data, artificial intelligence, 3D printing, the Internet of Things, digital

twin, and others. The integration of these technologies in the field of engineering and construction is a top priority for countries, governments, and companies due to their numerous benefits that can help solve problems and accelerate development. The lifecycle of a building primarily consists of the design, construction, operation, maintenance, and end-of-life stages, where each stage can be divided into superimposed in-

formation layers that require efficient information-exchange strategies for interoperability across all lifecycle stages [1]. Information regarding design details needs to be exchanged between different engineering team members during the design stage, and different stakeholders need to communicate design and construction progress with each other during the construction phase [2]. In addition, the building operation and facility-management teams need to obtain feedback from the building facilities and occupants during operation [3, 4]. A significant effort must therefore be invested to achieve efficient information update and exchange throughout a building's life cycle.

The concept of the Digital Twin originated from the aerospace field [5], and then expanded to industrial manufacturing [6, 7, 8, 9], attracting increasing attention in the built-environment domain in recent years. Existing studies have adopted BIM and IoT technologies for many aspects such as designing a building, monitoring and management of construction processes, building facilities, and indoor environment management [8, 9, 10].

As the world moves towards the creation of a unified digital realm, known as the Metaverse, engineers can now generate 3D models that interact within a digital environment capable of hosting any virtual model. This technology has numerous applications, particularly in the field of Digital Twin technology, which involves creating a digital environment that replicates physical objects and simulates reality to a significant degree. This interactive digital environment is connected to the real world and synchronizes with databases in real time, allowing for graphical analysis and providing an ideal solution for reviewing large projects without incurring construction costs or time delays. The Digital Twin is revolutionizing how buildings are planned, constructed, used, and managed by enabling them to operate at unprecedented levels of efficiency, safety, and comfort. By installing sensors throughout facilities and analysing data collected from them, buildings can respond intelligently to their surroundings and work together with other buildings and infrastructure to achieve long-term benefits. Digital twin technology has many advantages, can be upgraded and developed, is highly efficient in rationalizing energy consumption, and is described as environmentally and human-friendly.

2. RESEARCH METHODOLOGY

To achieve the research objectives, an analytical descriptive approach was employed, utilizing a questionnaire tool to gather data from a diverse sample of parties involved in construction projects in Syria. This sample included engineers, consultants, contractors, and technical training workers. The purpose of the questionnaire was to analyse the relationship between various research hypotheses and determine the level of awareness regarding digital twin technology and the obstacles to its application locally. The questionnaire was designed with multiple-choice questions that encompassed all aspects of the research, including the respondent's job nature, awareness level of digital twin technology, its significance, and obstacles. Previous studies and research hypotheses informed the questionnaire's development.

3. WHAT IS BIM?

BIM (Building Information Modelling) is the process of designing and building collaboratively using one coherent system of computer models. Instead of separate sets of drawings that are used by various design professionals, BIM offers a 3D or 4D interactive model of a building's systems and assemblies.

In the AEC industry, BIM plays a vital role during all phases of a construction project: from planning, designing, construction testing, and commissioning to the final stage of handing over to facility management. It is an important technology that has affected almost all disciplines and can be applied to several topics, making building information models a shared knowledge resource. Developed countries have recognized the benefit of BIM [11]. Although governments and clients play a vital role in mandating BIM, a mixed approach (top-down and bottom-up) is recommended to expedite BIM implementation [12]. Using BIM with partnering agreements improves stakeholder behaviour in construction mega-projects. Enhancing stakeholder relationships reduces disputes, eliminates conflicts of interest, allows knowledge sharing and healthy interaction between project stakeholders, and improves problem-solving techniques [13].

BIM Champions, also known as "change leaders," are responsible for assessing the adoption of BIM and steering its progress in each location. In the UK, their approach involves incorporating it into the Plan of Work. These champions have proven to be a key element in measuring and assessing needs to enable the achievement of technology adoption [14]. A six-step methodology is used to implement BIM: raising awareness; identifying perceived benefits; assessing AEC industry readiness and organizations' capability; identifying barriers; removing barriers; and defining the key factors influencing implementation [11].

Ahmed and Dlask discussed the gradual transition to BIM in Syrian companies and the possibility of applying BIM in Syrian building projects [15]. However, the adoption level of BIM remains much lower than expected [16]. BIM not only helps solve major problems in AEC industry projects and realizes the benefits of implementation, but also improves project performance and efficiency [17]. Currently, the Syrian AEC industry is witnessing the transformation from CAD to BIM, so it must be encouraged by the government and other related firms and individual experts to spread as much as possible in order to keep up with the ever-evolving world of technology [18]. In addition, adoption of Building Information Modelling has increased significantly over the last few years [19].

4. WHAT IS A DIGITAL TWIN?

The Digital Twin concept came into being in relation to Product Lifecycle Management (PLM) in 2002 at the University of Michigan through the work of Michael Grieves [20]. The proposed model has three components: real space, virtual space, and a linking mechanism for the flow of data and information between the two. The model was then referred to as the "Mirrored Spaces Model" [21].

A similar concept in which software models mimic reality from information input from the physical world was imagined by David Gelernter in 1991 and was called "Mirror

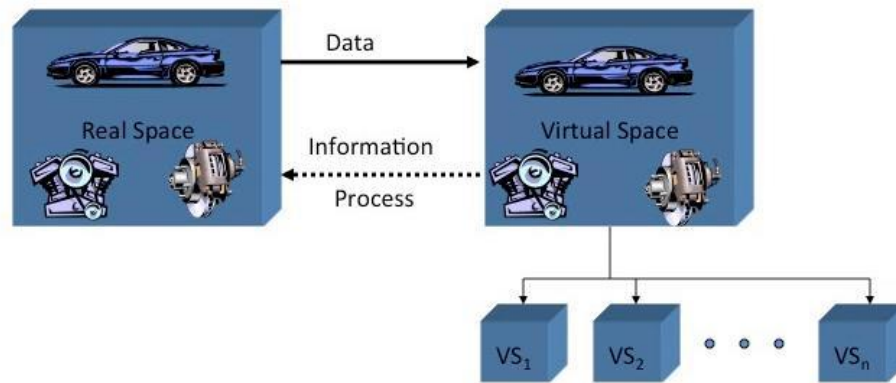


Figure 1. Concept of Product Lifecycle Management (PLM). Resource: Grieves (2016).

Worlds” [22]. The name “Digital Twin” (DT) first appears in NASA’s draft version of the technological roadmap in 2010 [5]. Michael Grieves recently published research about the common misunderstanding that the Digital Twin does not exist unless there is a physical object [23]. According to Grieves, the primary criterion for determining if a digital model is a Digital Twin is whether the model is designed to become a physical product with a physical counterpart.

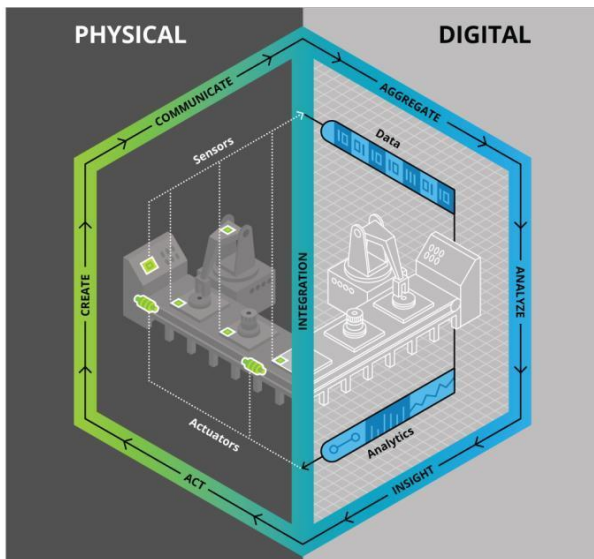


Figure 2. Digital Twin components. Resource: Deloitte University Press (2017).

A Digital Twin binds a virtual representation of a physical object through the bidirectional transfer or sharing of data between the physical counterpart and the digital one, including quantitative and qualitative data related to material, manufacturing, and process, as well as historical data, environmental data, and, most importantly, real-time data. Using these data, DT can perform such tasks as:

- In-depth analysis of the physical twin.
- Design and validation of a new or existing product or process.
- Simulation of the health conditions of the physical twin.
- Increasing the safety and reliability of the physical twin.
- Optimization of a part, product, process, or production line.
- Tracking the status of the physical twin throughout its life-time.
- Predicting the performance of the physical twin.

- Real-time control over the physical twin.

5. DIGITAL TWINS IN AEC

A digital twin in building and architecture is a new, dynamic, updated copy of a physical asset or group of assets—whether a building, city, or infrastructure—that combines design, construction, and operating data in real time. Digital Twins simulate, predict, and inform decisions. They can be thought of as an enhanced version of BIM that uses sensors, drones, and other inputs to gather information about a building. This data is then used to automatically update a digital model [24].

A digital twin can use advanced data analysis and artificial intelligence to continuously learn about a facility. This provides insights into how to best manage the building and its equipment. The concept can be used to analyse how building modifications affect performance, allowing for better investment decisions. From the foregoing, the use of digital twins can be considered an effective tool to help project participants imagine the construction process and detect implementation problems early. It is also a communication tool between parties and can track construction progress through all steps, from design and planning to procurement and construction management [25].

5.1 Investment and Projects Marketing

A building’s digital twin is a powerful marketing tool for real estate developers. Since there is an exact copy of the original building in a virtual environment, potential customers and tenants can “visit” the project even before construction begins. They can walk around the building even if the actual building does not yet exist. Digital twins can be useful as sales tools for real estate companies, especially during health emergencies such as the coronavirus pandemic. Landlords and tenants can walk through the building together via virtual reality technologies, and the project can be presented to financial institutions and potential investors [26].

Therefore, the digital twin can be relied upon as a tool for communication between parties in different disciplines and directions in the project. Building owners have many investment options that they can use the digital twin to test. The results can then be compared and the option with the highest return on investment identified.

5.2 Design Stage

The digital twin plays a major role in the production and creation of digital assets such as graphics, images, and different-dimensional models from BIM, as well as other types of design data and information about how they perform, including user behaviour, usage patterns, and space usage. This requires careful identification of the research object in order to know and record its data to meet the requirements of use. The data must be validated and updated. A digital twin helps manage the comprehensive information of these assets and delivers them as a virtual representation containing graphical and computational data. Sensors, IoT devices, and asset and facility management systems assist in accurately planning the sensor layer and integrating it into the design of the physical asset. The digital twin is updated regularly and can generate alerts when problems are detected. It can also assess the structural integrity of materials over time, prevent conflicts, and increase coordination between components of different systems. Using a digital twin can enhance the process of designing and creating digital assets in two ways:

1. Digital twins help designers and engineers model, simulate, and implement what-if scenarios to improve their design and development in an environment connected to reality. This enables them to adapt the design of their assets to existing assets and the surrounding environment, whether at the level of an individual asset such as a building or engineering unit, or at the neighbourhood or city level.
2. Design can be inspired by data, information, and evidence from various sources in a connected ecosystem that forms a close connection between the design, construction, and operation of built-environment assets. Digital Twin technology helps improve the operational efficiency of the built environment by integrating and automating historical data and information from early stages, such as facility management and maintenance, to improve the performance of the existing design. Incorporating historical data on implementation, asset management, and facilities along with the use of digital twins can enhance the detailed design process. For example, a digital twin can be used at this stage to research environmental, social, and governance standards before making investment decisions. It also allows simulations to be created of how the asset will work and how it will be used by end users, and permits estimation of the cost, specifications, and requirements of equipment for operations and assets.

5.3 Construction Stage

At this stage, the designed and mapped data about the asset is combined, and large amounts of data are generated, updated, used, and stored during the construction process. Any changes captured by sensors, photographs or video, point clouds, drones, and laser scanning can be incorporated into a virtual representation. The sensor layer—including sensors, IoT devices, and asset and facility management systems—is assembled and installed as part of the physical assets and marked on the virtual representation to transmit real operational and asset data from the job site.

BIM technology is integrated into almost every level of the business. Multiple BIM dimensions play an important role

in simplifying and organizing data and information management and estimating time (4D-BIM) and cost (5D-BIM). This increases the possibilities for controlling the supply chain, tracking the necessary flow of materials and ready-made components, and knowing the reserves in warehouses and at suppliers. A building's digital twin can be used to simulate the construction process before any object is placed on site to detect inconsistencies or overlaps between activities scheduled simultaneously, allowing workflow-conflict detection and optimization of the construction schedule. A construction simulation using a digital twin provides a better idea of how a project will use its budget throughout the construction phase [27].

This is useful for planning project procurement and negotiating financing from external institutions, and it helps improve coordination among the parties involved in a project. Construction simulation is useful for managing subcontractors, where lack of coordination between trades is a frequent cause of delays and errors in construction projects [28].

Project managers can analyse several potential cost-performance adjustments and select those that offer the most value to the project. In other words, many projects can be tested in a virtual environment without risk before actual modification. One of the major challenges for construction managers is knowing the current status of a project in real time; the status of the project is constantly changing and progress reports may not reflect the actual status. When a digital twin is used during construction, it can be constantly updated with location information. There is no need for multiple visits by various interested parties, as they can simply check the constantly updated digital form [27].

With mobile devices, drones can facilitate data collection, and with the Internet of Things and laser scanners, engineers no longer need a constant physical presence on a construction site. Reducing site traffic is especially helpful during health emergencies [29].

5.4 Handover

Interoperability integrated with BIM models plays an important role for the facility in transferring and exchanging data in the design and implementation stages, and the importance of this data increases at the facilities-management and operation stage. In the digital twin system, this large volume of data is integrated, processed, and diagnosed to reach optimal solutions, avoid emergency problems, and put the building in a state of readiness. A digital twin aggregates all delivery information into a coherent information form that is easy to access, use, and update during operation, maintenance, overhaul, and end-of-life phases, and promotes information-management best practices while reducing risk.

5.5 Operations and Maintenance

The building uses many complex systems to maintain conditions suitable for use. A proactive maintenance approach is more efficient and less costly than fixing problems after they have occurred, and the digital twin model makes it easier to do this because it contains detailed information on all equipment and components, including their physical characteristics and cost. The model can reflect the exact condition of building elements while showing problems such as me-

chanical wear or poor performance of equipment and devices. Digital twins can be used as simulation tools to analyse how a building will behave under different circumstances, including emergencies [30].

An updated digital twin provides a detailed snapshot of the building, and maintenance staff can schedule repairs off-peak. Artificial intelligence can also be used to analyse construction conditions in real time, predicting non-obvious problems and malfunctions and making planned maintenance more effective [26].

5.6 Stakeholders

The lack of coordination between different stakeholders leads to serious problems during the construction stages. Building information modelling plays a role in developing the entire facility with all specialties through multiple BIM techniques. The digital twin simulates the physical building, which makes it easier to eliminate errors or inconsistencies. It can be used to analyse the building's dynamic response to changes in occupation or energy supply and indicate times for maintenance or modernization. This planning assists in optimal energy efficiency, cost savings, increased sustainability, and meeting the desires of owners and operators. It allows different disciplines to create a coordinated multidisciplinary solution simultaneously, with early validation of detailed design options to improve building performance. The result is a more cost-effective, direct, and sustainable design and construction process that leads to safer and more efficient construction.

5.7 Sustainability

A digital twin is used to perform environmental design testing to improve a building's performance over its entire life cycle while reducing operating and maintenance costs. Building owners seeking Leadership in Energy and Environmental Design (LEED) certification can use digital twins to simulate many designs and options. Comparing different scenarios and maximizing the points earned under the LEED scoring system is time-consuming using traditional methods, but digital twins allow multiple design options to be compared faster and more efficiently. For example, digital twins can simulate several configurations of HVAC systems and building envelopes to determine which configuration offers the highest energy efficiency [31].

5.8 Risk Management

A digital twin enables project personnel to anticipate scenarios by integrating algorithms and data collected from smart IoT sensors to generate predictions and take necessary preventative measures throughout the project life cycle. Safety managers and officers can track the location of hazard areas, workers, and equipment and effectively prevent injuries that may be caused by unsafe location-based behaviours. Hazardous materials can be tracked to ensure they are properly stored and monitored, and early warning signals can be sent to prevent disasters on the job site. Digital Twins can also improve employee training for emergencies by reproducing hazardous situations from real life. Employees can be prepared to handle equipment that is practically impossible to use for training. They can run simulations in the laboratory to understand the risks and benefits of new procedures and

test which modifications deliver the best results.

6. BENEFITS OF DIGITAL TWINS FOR AEC

After presenting the use of digital twins during the different stages of the project, it is clear that a digital twin is more than just a 3D model. Rather, it is a collaborative approach that displays a replica of a building and all kinds of required information in a virtual environment. Its most important benefits for construction projects are outlined below.

6.1 Continuous Monitoring of Construction Progress

- Physical monitoring of the construction site by means of a digital twin verifies that the work performed conforms to plans and specifications.
- Changes in a model generated daily and hourly can be tracked, and if any deviation occurs, immediate action can be taken.
- The condition of concrete, cracks in columns, or any material displacement can be easily checked at the construction site. These discoveries lead to additional inspections, and problems are caught more quickly, leading to more effective solutions.

6.2 Optimal Use of Resources

- Providing data related to equipment, tools, and building materials in a database that can be used in future projects.
- Using supply-chain and procurement management to manage time and resources and prevent workflow conflicts.
- Tracking pre-manufacturing processes to ensure delivery on time and identify ways to increase productivity.
- Better allocation of resources, avoiding wasted production time on unnecessary operations, and dealing with unnecessary materials.
- Avoiding over-allocation of resources and dynamically forecasting resource requirements on site.
- Tracking the use of equipment and machinery and assigning unused items to other jobs, which saves time and money.

6.3 Time and Speed Factor

- Faster completion of project design and approval, where digital data collection with custom entry forms greatly reduces errors compared with paper forms.
- Project managers and their teams can reclaim time spent on routine tasks and focus on valuable activities, significantly reducing paperwork and replacing it with a digital system.

6.4 Reducing Construction and Operating Costs

- Optimizing costs and reducing changes during project implementation, unlike traditional methods in which changes during implementation increase the budget and completion time.
- Enabling owners and operators to reduce costs, avoid future costs, increase occupancy rates, and improve total asset value.
- Running and visualizing virtual scenarios for construction sequencing and logistics, informing workers of required tasks, and reducing costly rework through data-driven decision-making, artificial intelligence, and machine learning.
- Predicting maintenance activities and events to reduce

unforeseen interventions and ultimately streamline costs throughout the operating life of the asset.

6.5 Increasing Productivity and Collaboration

- Vital information about the created asset can be stored, analysed, and constantly updated throughout its life cycle. This information, such as design documents, inventories, material specifications, and schedules, can be easily accessed and used to aid decision-making and defect elimination.
- Coordination and cooperation between remote workers can be enhanced and operations management implemented virtually, enabling the repercussions of crises to be handled more quickly and easily.

6.6 Safety and Security Improvement

- Tracking dangerous personnel and places on a construction site.
- Avoiding unsafe substances and activities in hazardous areas based on real-time information.
- Eliminating human error and reducing time spent resolving issues, troubleshooting, updating changes, and reworking.
- Providing on-site personnel with real-time information and alerts about location, and sending notifications and emergency-response instructions to a worker's mobile device to prevent danger.
- Developing an early-notification system that allows the construction manager to know when a field worker is in an unsafe area.
- Anticipating site congestion through pedestrian-simulation software and introducing the changes necessary for the movement of site activities and individuals to avoid risks.
- Allowing simulations to estimate potential damage caused by natural and man-made disasters.

6.7 Improving Asset Performance and Sustainability

- Improving the performance of renovated buildings by simulating processes and predicting the performance of different materials.
- Enabling building operators to combine previously unconnected systems—from security to HVAC and road-connectivity systems—to gain new insights, improve workflow, and remotely monitor operations.
- Monitoring and controlling water and energy consumption to achieve an environmentally friendly building.
- Contributing to reductions in greenhouse-gas emissions by monitoring and analysing carbon emissions.
- Reducing transportation emissions through visual communication systems for work teams instead of direct meetings.
- Consistently collecting data from electrical and mechanical installations in buildings to be incorporated into the firefighting strategy.

6.8 Education and Training

- A digital twin can create simulation models based on on-site process requirements.
- It assists engineers in clarifying problems related to site operations, embodying those operations with utmost accuracy, and transferring them to other parties.
- Project parties can better explore the processes, systems, and details of the project within the virtual work environment, as well as the exact impact of any element on another.

6.9 Future Applications

- Collecting and analysing data during the life of the facility to develop a database that can be transferred to future projects and provide insights into facility-design criteria.
- Providing rich data to improve the design of future projects, make optimal use of space, and meet residents' requirements.
- Providing the Building Authority with access to updated building information throughout its life cycle, allowing intelligent planning of future projects.
- Using data during the lifetime of the facility to run what-if scenarios, test different strategies for forecasting project progress, and ensure its success.
- Using data collected throughout the project life cycle to develop an effective and safe demolition plan.

7. BARRIERS TO DIGITAL TWINS FOR AEC

The most important challenges facing digital twin technology include the following.

Standards and regulations. Standardizing models, interfaces, protocols, and data is essential for efficient third-party communication, product and human safety, data security, and integrity, especially in industries such as aerospace, automotive, and healthcare [32]. Standards and standards-based interoperability also need to be developed to address the social and organizational challenges introduced by digital transformation within industries [33].

Sensors and data. A lack of device-communication and data-collection standards can compromise the quality of data being processed for DT, which will be reflected in its performance [34]. Loss of data during transfer remains an issue for reasons such as software incompatibilities and data fading due to external environmental interference. In addition, many types of IoT sensors collect either the same environmental data or different data, while their data types may not be homogeneous, which may present difficulties in the data-analysis process.

Design challenges. Challenges arise when building a digital twin model that combines product lifecycle management, a manufacturing execution system, and a process management system. This remains one of the major problems involved in creating a digital twin.

Improving the control strategy. Humans still play an important role in the current application process of the digital twin, and decision-making often depends on them based on the results obtained from researching scenarios. Therefore, the control strategy must be improved through automatic decision-making and feedback loops, enabling real-time automatic control and increasing the number of scenarios analysed to improve the efficiency and reliability of control systems.

Economic challenges. Economic considerations and the volume of investment affect the application of digital twin technology and complementary technologies. One of the biggest challenges DT must overcome to reach its full potential is the high cost associated with implementation. The process of developing ultra-high-fidelity computer models and simulating processes to create a DT is time-consuming and labour-intensive, and requires a large amount of computational power, making DT an expensive investment [35].

Technological challenges. Several technologies come together to make DT a reality, including 3D simulations, IoT/IIoT, AI, big data, machine learning, and cloud computing. Since these technologies are themselves still developing, this impedes the evolution of DT. The infrastructure required to implement DT needs to be improved to enhance the technology's efficacy. Further research is required in high-performance computing, machine learning, real-time virtual-real interaction, intelligent perception, and connection technology, among other areas, to implement DT [36]. Other challenges include implementing real algorithms in simulation software, limited computing power even for relatively simple simulation tasks, incorporating big-data analytics during design into the digital twin model, and collecting real-time data directly from instruments and sensors. One of the most important challenges is preparing the environment, technology, and trainees for a gradual transformation toward using the technology.

8. RESEARCH IMPORTANCE

- The scarcity of studies dealing with the application of digital twin technology in the construction sector in Syria means that this research covers an important research area.
- The research deals with the technological and technical aspects of BIM and digital twin technologies, which will contribute effectively to strengthening their role in Syria.
- The research highlights the importance of digital twins and their benefits during the project stages of design, analysis, construction, operation, management, and sustainability.
- It seeks to confirm the link between the lack of awareness of digital twin technology and its spread in engineering projects in Syria.
- It identifies the obstacles that prevent the application of digital twin technology in engineering projects in Syria.
- It researches ways to generalize the application of digital twin technology in engineering projects in Syria.

9. RESEARCH PROCEDURES

Research approach. The analytical descriptive approach was utilized in the present study. This approach was chosen because it would aid in achieving the desired objectives and generating recommendations and proposals that could potentially help resolve the research problem. The researcher gathered data on the influence of digital twin technology on engineering projects. Specific questions were formulated and presented in a questionnaire distributed to sample members. The collected data was then described and analysed.

Research community. The research community comprises engineering-sector companies, engineering offices, and engineering and technical-education institutions within the construction sector in Syria.

Research sample. The sample comprises units of society selected according to statistical rules. A random sample was chosen from the research population, and 36 responses were obtained.

Research tool. To gather in-depth data, a questionnaire was employed as a research tool due to its objectives, methodology, and community. The questionnaire is widely used in various scientific fields because it saves time and reduces

costs while allowing data collection from a larger number of individuals than other methods. Additionally, it simplifies answering questions that require more time.

9.1 Setup Steps

The researcher began by setting the main objective of the research, which is to investigate the impact of digital twin technology on engineering projects. Next, the measurement fields for the research tool were determined and divided into two sections:

- **Section One:** Personal data, including gender, age, educational level, years of experience, and field of work.
- **Section Two:** Fifteen phrases distributed over three axes: five phrases estimating the level of awareness of digital twin technology in engineering projects; five phrases discovering the importance of using digital twins technology in engineering projects; and five phrases evaluating obstacles to using digital twins technology in engineering projects.

The third step involved formulating research-tool phrases in their initial form according to each domain and the procedural definitions measured in the questionnaire. Some phrases from previous relevant studies were also used. In the fourth step, responses to the phrases were graded using a five-point Likert scale. In the fifth step, the instructions for the research tool were formulated to introduce the purpose of the research to members of the research community. The clarity of statements and their suitability to the respondents' level were taken into account, with an emphasis on recording data for research variables. Finally, the questionnaire was converted into an electronic form using Google and distributed to the target sample through phone applications, email, and social networking sites.

9.2 Questionnaire Themes and Response Levels

9.3 Sample Demographics

9.3.1 Gender

Table 2. Percentage breakdown of the participants' sex. Source: Creations by authors (2022).

What is your gender?	Percentage
Male	40%
Feminine	60%

The sample population was composed of 40% males and 60% females, with the majority of respondents being female.

9.3.2 Age

Table 3. Percentage of the age groups of the research sample. Resource: Creations by authors (2022).

How old are you?	Percentage
Less than 25	29%
From 25 to 35	55%
From 35 to 49	16%

The majority of respondents fall within the 25–35 age bracket, accounting for approximately 55% of the overall sample. Individuals below the age of 25 represent 29% of respondents,

Table 1. Questionnaire themes and levels of response. Resource: Creations by authors (2022).

Theme	Level 1	Level 2	Level 3	Level 4	Level 5
Estimating awareness of applying digital twins technology to engineering projects	Not at all	To a weak degree	Medium degree	To a strong degree	To a very strong degree
Discovering the importance of using digital twins technology	Not important	Of little importance	Of moderate importance	Important	Very important
Evaluating barriers to using digital twins technology	Very weak	Weak	Middle	Strong	Very strong
Scale	1	2	3	4	5

while those aged 35–49 make up 16%, indicating that a significant portion of the participants are categorized as youth.

9.3.3 Educational Level

Table 4. Percentage of the educational levels of the research sample. Resource: Creations by authors (2022).

Educational level	Percentage
Secondary	8%
Average Institute	10%
University	63%
Postgraduate	19%

The majority of respondents held university degrees, making up 63% of the sample. Postgraduate certificates were held by 19%, intermediate institute certificates by 10%, and secondary certificates by 8%. These findings suggest that the majority of participants had an educated background.

9.3.4 Years of Experience

Table 5. Percentage of years of experience for the research sample. Resource: Creations by authors (2022).

Years of experience	Percentage
From 1 to 3 years	55%
From 4 to 6 years	21%
From 7 to 10 years	6%
More than 10 years	18%

The largest group, approximately half the sample, had between one and three years of experience. The next largest group, accounting for 21%, had four to six years of experience, while 18% had more than ten years. The smallest category consisted of those with seven to ten years of experience, making up 6% of the sample.

9.3.5 Employment

Table 6. Percentage of the fields of work of the research sample. Resource: Creations by authors (2022).

Field of employment	Percentage
Construction contracting	39%
Engineering consultancies	44%
Engineering and technical education	17%

The participants were divided into three categories: 44% were from engineering consulting offices, 39% were in the construction-contracting industry, and 17% were in education and technology.

10. ANALYSIS AND RESEARCH

Questionnaires were used in the research area to investigate the significance of implementing digital twin technology and its barriers in engineering projects in Syria.

The first axis: estimating the level of awareness of applying digital twin technology to engineering projects. The first axis included five items to measure the level of awareness of the questionnaire participants. The results show that knowledge of the digital twin concept in general is medium, perhaps because digital twins are relatively new in origin and use across fields of work. The general weighted average of the first axis indicates a weak degree of knowledge and awareness of the digital twin and the way it is used and applied in the engineering field.

The second axis: discovering the importance of using digital twin technology in engineering projects. The second axis of the questionnaire aimed to measure the significance of implementing digital twin technology among the participants. Results revealed that digital twins play a crucial role in the design phase, as they aid in minimizing obstacles and streamlining construction work in subsequent stages. Their importance is also evident in the maintenance and facility-management phase due to their preservation benefits. Similarly, the implementation and handover phases benefit from digital twins' high-quality design phase, leading to fewer obstacles. Although the importance of digital twins in the demolition phase may have decreased due to sufficient information on the building's nature and characteristics, the overall weighted average of the second axis highlights the immense importance of digital twins in all stages of engineering projects' life cycles and their application in the engineering field.

The third axis: assessing the obstacles to using digital twin technology in engineering projects. This axis comprised five items that aimed to gauge the obstacles faced by participants in adopting this technology. The findings revealed that the primary obstacle was the lack of knowledge about digital twin technology, corroborating the first axis of the research. Other barriers include insufficient training, qualifications, and resources. State and university efforts to modernize education and keep up with scientific advancements have begun to address these issues. Plans for training and education in this field are being developed to ensure that the necessary requirements are met.

11. RESULTS AND RECOMMENDATIONS

11.1 Results

1. Digital twin technology has been found to cause a significant transformation in engineering projects across all stages of a facility, from planning and design to analy-

sis, implementation, operation, data management, maintenance, building management, and demolition. It offers advantages such as faster and more efficient project operations, easy information sharing with project parties, improved design efficiency through building-analysis technology, and rapid simulation and performance expectations before and during the operating cycle, which help generate innovative solutions and improvements. Additionally, it reduces costs while increasing project quality and productivity. This results in better customer service by providing a better understanding of the project as well as supporting information throughout the building's life.

2. The research findings indicate a low level of awareness and knowledge regarding digital twin technology in engineering projects. This lack of awareness is due to several reasons, including failure to keep up with new studies and research and a lack of interest in this sector resulting from the crisis that passed through the country and the blockade that followed it.
3. The research highlighted the significance of infrastructure development and staying up to date with technical advancements to overcome challenges hindering the use of modern technologies in the construction industry. This will enhance service quality and improve urban conditions.
4. Real-time visual management through digital twin technology was found to be crucial for project personnel to comprehend the detailed status of the entire facility. High-density data streams are continuously processed and analysed in real time through a centralized control platform, which is more efficient than traditional manual work.
5. Artificial intelligence and data-analysis skills were identified as essential in engineering projects. They play a vital role in diagnosing, evaluating, and treating building conditions in collaboration with virtual-reality techniques and visual management.
6. The research revealed that insufficient expertise and trained personnel are among the primary challenges facing digital twin implementation.

11.2 Recommendations

1. Focus on training and qualifying workers in digital twin technology for buildings. This should be included in training courses at engineering institutes and colleges, with qualified courses and trainers provided. Cooperation with qualified companies to offer necessary support is also essential. Specialized and accredited training courses should be prioritized.
2. Unions should play an active role in raising awareness and promoting digital twin technology within the engineering community. Workshops should be held to increase awareness of its importance and provide training opportunities. Events and seminars involving construction-sector workers, stakeholders, and real-estate agents are also recommended.
3. Companies and institutions in the construction sector should be prepared and encouraged to undergo digital transformation for engineering projects gradually. This includes completing the necessary preparations for implementation, such as training, technical support, programs, and worker qualification to accept the transition to actual application. Initially, the approach should be applied to

a limited number of projects before moving to larger and more complex projects.

4. To support digitization projects, the government should adopt BIM and digital twin technologies, establish binding rules for their use in major special projects, obtain necessary approvals and licenses from relevant agencies, prepare appropriate specifications, codes, and contracts, and gradually generalize their use in other projects.
5. The government should provide the necessary resources and improve infrastructure to keep up with technological advancements required for implementing digital twin technology, such as artificial intelligence, 5G networks, and robotics, thereby creating auxiliary infrastructure for digital twin implementation.
6. The government should support more studies related to digital twin technology across all areas of the construction sector, including design, operation, and maintenance. It is important to emphasize their significance and compare similar studies to raise the level of engineering work.
7. Obstacles and challenges that may arise during the implementation of digital twin technology in engineering projects should be addressed. These include data privacy and security, interoperability between different software systems, and the need for standardized protocols and procedures. A comprehensive risk-management plan should be developed to mitigate these challenges.
8. The benefits of digital twin technology should be communicated effectively to all stakeholders involved in engineering projects. This includes highlighting its potential to improve project efficiency, reduce costs, enhance safety, and enable better decision-making through data analytics.
9. Continuous monitoring and evaluation of digital twin technology implementation should be conducted to ensure its effectiveness in improving engineering-project outcomes. Feedback from workers, clients, and other stakeholders should be solicited regularly to identify areas for improvement and make necessary adjustments.
10. It is important to stay up to date with the latest developments in digital twin technology and its applications in engineering projects. This can be achieved through participation in conferences, workshops, and training programs focused on this topic.

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