International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 04 | April - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Evaluating the Feasibility of Digital Twin in Architecture Industry

Shivam Thakre[1], Parampreet Kaur[2], Mayuri Rathi[3]

[1]*Student, Amity School of Architecture & Planning, Amity University Chhattisgarh*
[2]*Professor, Amity School of Architecture & Planning, Amity University Chhattisgarh*
[3]*Professor, Amity School of Architecture & Planning, Amity University Chhattisgarh*

---***---

Abstract - This review paper examines the feasibility of adopting digital twin technology in the architecture industry. It examines the current state of digital twin technology, its potential applications, drivers, benefits, and challenges, and compares findings with existing guidelines and standards. The study is based on review literature, including industry reports, surveys, and online articles, due to its rapidly evolving nature. The findings are compared with existing guidelines and standards to identify any alignments, gaps, or contradictions between industry best practices and the literature. The overall assessment indicates that the adoption of digital twin technology in the architecture industry is feasible, but significant challenges and barriers need to be addressed. Key factors supporting the feasibility include growing industry awareness, advancements in enabling technologies, and alignment with existing guidelines and standards. However, challenges include the lack of clear industry-wide standards and protocols, data security and governance concerns, and the need for significant investments in digital infrastructure and organizational change. The study concludes that the feasibility of digital twin adoption in the architecture industry is promising, but successful implementation will require a concerted effort by industry stakeholders to address the identified challenges and align with emerging best practices and standards.

***Key Words*:** Digital twin, Virtual asset, BIM integration, Digital infrastructure, Built Environments.

1.INTRODUCTION

Digital twins are virtual representations of physical assets, processes, or systems that can be used to simulate, analyze, and optimize their real-world counterparts (Grieves & Vickers, 2017). These digital replicas leverage data from various sources, including sensors, to provide real-time insights and enable predictive maintenance, improved decision-making, and enhanced product development (Boschert & Rosen, 2016). Digital twins are becoming increasingly important in industries such as manufacturing, transportation, and healthcare, as they allow for the optimization of complex systems and the prevention of costly failures (Tao, et al., 2018). As technology continues to advance, the capabilities and applications of digital twins are expected to grow, further transforming the way organizations operate and maintain their physical assets.

A positive transformation in the architecture, engineering, and construction industries is provided by the digital twin, a new phase of technology that acts as a real, well-constructed 3D replica that facilitates efficient decision-making and the visualization, stimulation, and analysis of a building's structure and current state in a much more systematic and well-organized manner.

1.1 Historical content

- **Early 2010s:**

Emergence of digital twin concept in manufacturing sector. Early exploration of digital twins in construction for asset modelling and project monitoring

- **Mid 2010s:**

Integration of BIM data into construction digital twin platforms, Improved visualization, data integration, and real-time project monitoring

- **Late 2010s:**

Incorporation of sensors, IoT, and data analytics into digital twins. Expanded capabilities for performance monitoring, predictive maintenance, and asset lifecycle management.

- **Early 2020s:**

Widespread adoption of digital twins across the construction industry, Establishment of dedicated digital twin teams and enterprise-wide strategies, Development of industry standards and guidelines

1.2 Digital Twin in Architecture

The concept of Digital Twin can be traced back to 2002 when Dr. Michael Grieves from the University of Michigan gave a presented on what he called Conceptual Ideal for Product Lifecycle Management (PLM) (Grieves & Vickers, 2017).The PLM concept, which has all the elements of the Digital Twin, considers that each system consists of two systems: the physical system or the real space that has always existed and a virtual system that contains all the information related to the physical system.

The Digital Model (DM) has the least data integration, the data flow between the physical object and the digital is done manually. (Grieves & Vickers, 2017)Changes in the state of the digital or physical object have no direct impact on the state of the counterpart.

When the data transfer between physical and digital objects takes place automatically, one speaks of the Digital Shadow (DS). (Grieves & Vickers, 2017) With full integration of the data flow in both directions between the physical and digital object, it is DT in full expression of the concept.

1.3 Review of literature paper

Analysing the main statements from the research papers, we can provide a short review about the possibility of using digital twins for architecture and construction: A thorough analysis of reviewed literature proves that digital twins technology has great potential and feasibility in architecture and construction projects. The given statement emphasizes the wide range of applications and benefits of digital twins that can be used in building environments.

Firstly, the literature emphasizes the various benefits of adopting digital twins in construction, including improved project monitoring and control, enhanced asset management, optimized construction processes, and better collaboration among stakeholders. These benefits can alleviate some of the main challenges in the construction industry that contribute to project delays, cost overruns and poor communication, making digital twins a realistic solution to improve the overall performance of construction projects.

Furthermore, the research identifies several specific applications of digital twins in construction, such as design optimization, construction planning and scheduling, safety management, and facility management (Daniotti, Pavan, Lupica Spagnolo, Caffi, & Pasini, 2021)These applications highlight the potential of digital twins, which can be used at any stage of the lifecycle of a built asset – from the front-end (FE) or conceptual design phase to the back end (BE) or operational phase. Their potential is further strengthened by the fact that they can be customised to the specific requirements of any construction project and its actors. The literature also highlights the key enabling technologies for digital twins in construction, including the Internet of Things (IoT), Building Information Modelling (BIM), Augmented Reality (AR), and data analytics (Daniotti, Pavan, Lupica Spagnolo, Caffi, & Pasini, 2021)These enabling technologies provide the necessary infrastructure and capabilities to develop and integrate digital twins effectively, further increasing their feasibility in the architecture and construction industry. As these technologies continue to evolve and become more accessible, the integration of digital twins is likely to become more seamless and cost-effective.

Moreover, the reviewed papers discuss the future trends in digital twin technology for the construction industry, emphasizing the integration of advanced technologies like Artificial Intelligence (AI) and Machine Learning (ML) to enhance decision-making and predictive capabilities (Daniotti, Pavan, Lupica Spagnolo, Caffi, & Pasini, 2021)This indicates the ongoing development and refinement of digital twin technology, which can further improve its feasibility and expand its applications in the built environment.

The literature also highlights the potential of digital twins to drive sustainability goals and enable a paradigm shift towards a smart and sustainable built environment (Shahzad, Mbachu, & Separovic, 2021). As sustainability becomes an increasingly important consideration in the architecture and construction industry, the feasibility of digital twins is further enhanced, as they can be leveraged to optimize energy consumption, reduce waste, and improve the overall environmental performance of built assets.

Additionally, the research suggests the feasibility of integrating digital twins with emerging technologies, such as blockchain, to enable secure and accountable information sharing in construction projects (Li, Greenwood, & Kassem, 2021)This integrated approach can address the challenges of data management and transparency, which are critical for the effective implementation of digital twins in the construction industry.

Finally, the literature emphasizes the potential of digital twins to drive the adoption of Industry 4.0 in the construction industry, identifying the key applications and benefits of digital twins in the context of Industry 4.0 (Zaher, Greenwood, & Marzouk, 2022)As the construction industry moves towards increased automation, digitalization, and data-driven decision-making, the feasibility of digital twins is further enhanced, as they can serve as a cornerstone for the industry's transformation.

The review reveals that digital twins in architecture and construction are feasible and offer numerous benefits. These technologies are explored in various applications, providing insights into major enabling technologies and future trends. Research papers show that digital twins can improve the built environment through operations, maintenance, sustainability, design, operation, maintenance, and construction. The integration of digital twins is expected to be more compelling than ever before, making the industry more efficient, sustainable, and innovative. It is expected that digital twins will play a significant role in the evolving architecture and construction industry in the future.

Table 1: analysis and research gap of literature review

Paper Title	Key Topics	Takeaways	Analysis	Research Gaps
Digital twin application in the construction industry: A literature review (10.1016/J.JOBE.2021.102726)	- Definition of digital twins - Benefits of digital twins - Applications of digital twins - Enabling technologies - Challenges and barriers - Future trends	- Comprehensive overview of digital twin adoption in construction - Highlights potential benefits and key enabling technologies - Identifies challenges to wider adoption	- Thorough review of the current state of research - Provides a clear understanding of the digital twin concept and its applications in construction	- Lack of empirical studies demonstrating the impact of digital twins in real-world construction projects - Need for in-depth exploration of the integration of advanced technologies (AI, ML) with digital twins
A review of digital twin applications in construction (10.36680/j.itcon.	- Definition and characteristics of digital twins - Applications of digital twins in construction - Challenges and barriers to adoption	- Detailed overview of various applications of digital twins in construction - Identifies	- Comprehensive review of the existing literature on digital twin applications	- Limited discussions on the integration of digital twins with other emerging technologie

2022.008)	- Future research directions	key challenges, such as data integration and interoperability	in construction - Provides a clear understanding of the current state of research	s (e.g., BIM, IoT, automation) - Need for more case studies and empirical evidence on the benefits of digital twins
Towards a semantic Construction Digital Twin: Directions for future research (10.1016/j.autcon.2020.103179)	- Concept of a semantic construction digital twin - Enabling technologies for semantic digital twins - Research challenges and future directions	- Proposes the concept of a semantic digital twin to enhance data integration and decision-making - Identifies key research areas, such as data modelling, ontology development, and knowledge representation	- Focuses on the specific challenge of data integration and interoperability for digital twins in construction - Provides a roadmap for future research on semantic digital twins	- Limited exploration of the practical implementation and validation of semantic digital twins - Need for more interdisciplinary collaboration (e.g., construction, computer science, knowledge engineering)
Digital Twin: Vision, Benefits, Boundaries, and Creation for Buildings (10.1109/ACCESS.2019.2946515)	- Definition and characteristics of digital twins - Benefits of digital twins in buildings - Boundaries and challenges of digital twin creation - Process for developing digital twins	- Provides a comprehensive understanding of digital twins for buildings - Outlines the key benefits and challenges in creating digital twins	- Offers a clear framework for the development of digital twins in the built environment - Highlights the importance of considering the boundaries and limitations of digital twins	- Lack of focus on the specific applications of digital twins in construction projects - Need for more research on the integration of digital twins with other construction-related technologies
Integrated digital twin and blockchain framework to support accountable information sharing in construction projects (10.1016/J.AUTCON.2021.103688)	- Integration of digital twins and blockchain technology -Accountable information sharing in construction projects -Challenges and benefits of the integrated framework	- Proposes a novel framework that combines digital twins and blockchain to enable secure and accountable information sharing in construction - Highlights the potential benefits of this integrated approach	- Addresses the critical challenge of information sharing and transparency in construction projects - Demonstrates the synergies between digital twins and blockchain technology	- Limited validation of the proposed framework through real-world case studies or pilot implementations - Need for further exploration of the practical implications and scalability of the integrated approach
	-Differentiation	- Clarifies	- Provides a	- Limited

Differentiating Digital Twin from Digital Shadow: Elucidating a Paradigm Shift to Expedite a Smart, Sustainable Built Environment (10.3390/BUILDINGS11040151)	between digital twins and digital shadows - Characteristics and applications of digital twins and digital shadows - Paradigm shift towards a smart and sustainable built environment	the distinction between digital twins and digital shadows - Highlights the potential of digital twins to drive a paradigm shift towards a smart and sustainable built environment	conceptual foundation for understanding the differences between digital twins and digital shadows - Emphasizes the importance of digital twins in achieving sustainability goals in the built environment	empirical evidence on the practical implementation and impact of digital twins in sustainable construction practices - Need for more research on the integration of digital twins with sustainability-related technologies and strategies
Digital Twins in Built Environments: An Investigation of the Characteristics, Applications, and Challenges (10.3390/buildings12020120)	- Characteristics of digital twins in built environments - Applications of digital twins in building and construction - Challenges and barriers to digital twin adoption	- Provides a comprehensive understanding of the characteristics and applications of digital twins in the built environment - Identifies key challenges, such as data integration, interoperability, and user acceptance	- Offers a holistic view of digital twin technology in the context of buildings and construction - Highlights the current state of research and the barriers to wider adoption	- Lack of in-depth exploration of the integration of digital twins with other emerging technologies (e.g., IoT, BIM, AR/VR) - Need for more case studies demonstrating the practical implementation and benefits of digital twins in real-world construction projects
Digital Twin and Industry 4.0 Enablers in Building and Construction: A Survey (10.3390/buildings12112004)	- Concept of Industry 4.0 and its enablers - Role of digital twins in the context of Industry 4.0 - Applications and benefits of digital twins in building and construction	- Provides an overview of Industry 4.0 and its enabling technologies - Explores the synergies between digital twins and Industry 4.0 in the building and construction sector	- Highlights the potential of digital twins to drive Industry 4.0 adoption in the construction industry - Identifies the key applications and benefits of digital twins in the context of Industry 4.0	- Limited discussion on the specific challenges and barriers to the integration of digital twins and Industry 4.0 technologies in construction - Need for more empirical research on the practical implementation and impact of digital twins within the industry 4.0 framework
Digital Twin in	- Concept and characteristics of	- Provides a broad	- Offers a comprehens	- Lack of in-depth

Industry: State-of-the-Art (10.1109/TII.2018.2873186)	digital twins - Applications of digital twins in various industries - Enabling technologies and key challenges	overview of digital twin technology and its applications across different industries - Identifies the key enabling technologies and challenges associated with digital twin implementation	ive understanding of the digital twin concept and its potential applications - Highlights the cross-sectoral relevance of digital twins, including the construction industry	focus on the specific challenges and applications of digital twins in the construction industry - Need for more research on the integration of digital twins with construction-related technologies and processes
Review of Digital Twins for Constructed Facilities (10.3390/buildings12112029)	- Definition and characteristics of digital twins - Applications of digital twins in constructed facilities - Challenges and barriers to digital twin adoption - Future research directions	- Presents a comprehensive review of the application of digital twins in constructed facilities, including buildings and infrastructure - Identifies key challenges, such as data management, interoperability, and workforce skills	- Offers a focused review of digital twin applications in the context of constructed facilities - Provides a clear understanding of the current state of research and future research directions	- Limited discussion on the integration of digital twins with other emerging technologies (e.g., BIM, IoT, AR/VR) - Need for more case studies and empirical evidence on the benefits and challenges of digital twin implementation in real-world construction projects

2 FEASIBILITY ASSESSMENT

Table 2: current and future assessment of digital twin.

S.NO.	AREA	CURRENT STATE	FUTURE OUTLOOK
1.	Adoption	Digital Twins in Construction • Widely adopted tool. • Leading firms have dedicated teams. • Enterprise-wide strategies implemented.	Industry Adoption of Digital Twins • Widespread adoption • Digital twins becoming industry standard
2.	Capabilities	BIM Integration • Enables real-time monitoring. • Facilitates predictive maintenance. • Manages asset lifecycle.	"Mixed Reality, AI, 5G Enhancements" • Expanded sustainability, safety, productivity use cases.
3.	Integration	Digital twins used for individual projects and assets	"Integration of Construction and Citywide Digital Twins" • Enables holistic urban planning and management.
4	Standards	Industry Bodies Develop Interoperability Guidelines • Streamlining data integration.	Establishment of common standards and protocols for construction digital twins
5.	Benefits	"Improved Project Delivery, Operations, Asset Performance" • Increased efficiency, sustainability, innovation.	"Transformative Impact on Construction Industry" • Significant operational, financial, environmental improvements.

*Source: review of literature study

Overall, the table highlights how digital twin technology has become a critical part of the construction industry, with ongoing advancements expected to further enhance its capabilities and impact across the sector.

3 CRITERIA IDENTIFICATION

The successful implementation of digital twins in architectural projects is complex due to internal and external factors. Internal factors include technological readiness, organizational capabilities, and available resources, while external factors include market dynamics, industry standards, and ecosystem collaboration.

Table 3: Internal and External factors

S.NO.	FACTORS	INTERNAL	EXTERNAL
1.	Technological Readiness	Cloud Computing, IoT, BIM Technologies Accessibility • Reliable, compatible technologies. • Proficiency in data management and analytics.	Industry-wide Digital Twins Standards • Creation and integration standards.
2.	Organizational Capabilities	Digital Transformation Plan	Knowledge-Sharing Opportunities

		• Leadership support • Access to expert expertise • Innovative organizational culture • Efficient data governance and management procedures	• Existence of training programs. • Existence of research groups. • Existence of industry associations.
3.	Investment and Resources	Funding for Development, Implementation, and Upkeep • Access to necessary infrastructure, software, hardware. • Allocated funds for organizational change and training.	"Financing, Regulations, Government Initiatives for Digital Twins"
4.	Project-level Factors	Building Project Scale and Complexity • Accessibility of precise data. • Linking decision-making with digital twin data. • Conformity to project objectives.	"Client Demand for Data-Driven, Sustainable Built Environments" • Technological advancements improving digital twins capabilities.
5.	Industry Standards and Regulations	- Conformity to accepted industry norms and procedures	- Frameworks for laws and policies that handle issues with ownership, security, and privacy of data
6.	Market Dynamics and Trends	- Emergence of new business models and revenue streams	- Competitive landscape and the potential for vendor lock-in or market dominance
7.	Social and Cultural Factors	- Acceptance and understanding of digital twin technology among stakeholders -Willingness to adapt to new ways	- Concerns about job displacement and the need for workforce upskilling

*Source: review of literature study

4 FEASIBILITY IN BIM AND RETROFIT.

Digital twin integration in BIM is more feasible due to existing standards and guidelines like ISO 19650 and building SMART International Standards. However, in retrofit and renovation projects, the feasibility is average due to insufficient address of specific demands for digital twins, resulting in adjustments and additional expenses.

Table 4: comparing feasibility in BIM and retrofit

Topic	Standards and Guidelines	Feasibility
BIM Integration	- ISO 19650 - Organization and digitization of information about buildings and civil engineering works, including BIM - This standard provides a framework for effective information management and exchange throughout the building lifecycle, and "the principles and guidelines for BIM implementation in standards like ISO 19650 can be leveraged to support digital twin integration." - building SMART International Standards (IFC, BCF, MVD) - These open standards "provide a foundation for seamless data exchange and integration, which is a critical requirement for the implementation of digital twins."	**High Feasibility** The analysis states that "the integration of digital twins with BIM is highly feasible, as it leverages the existing BIM infrastructure and aligns with industry trends towards data-driven, collaborative, and sustainable practices."
Retrofit and Renovation Projects	Existing standards and guidelines are "focused on new construction and BIM implementation, with limited coverage of digital twin integration for retrofit and renovation projects." - The analysis suggests that "adapting the standards and guidelines to address the specific requirements of digital twins in retrofit/renovation contexts will be necessary.	**Moderate Feasibility** The feasibility of implementing digital twins in retrofit and renovation projects is assessed as "moderate, as it requires significant upfront investments and technical expertise." However, the analysis also states that "the long-term benefits can outweigh the initial challenges, especially for critical or high-value assets."

*Source: existing Standards and Guidelines, review of literature study

Building Information Modelling (BIM) Integration of Digital Twins:
• ISO 19650 and building SMART International Standards facilitate integration.
• BIM framework offers promising integration of digital twins.
• Refit and restoration projects' viability uncertain due to inadequate guidelines.
• Successful implementation often requires adjustments and additional funding.

5 Standard and guidelines

Comparing the outcomes from the grey literature with the present guidelines and standards reveals many overlaps, particularly about the crucial aspects of lifecycle management, integration, and data management. The research also draws attention to the shortcomings of the current standards, which do not specifically address the unique challenges and requirements related to the application of digital twins in the architectural area.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 04 | April - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Table 5: comparing guideline and standards based on different aspects.

Aspect	**ISO 19650-1:2018**	**ISO 16739-1:2018**	**NBIMS-US v3**	**UK BIM Framework**
Scope	Focuses on information management using BIM for buildings and civil engineering works	Provides a data schema for data sharing in construction and facility management	Covers the National BIM Standard for the United States	Provides a framework for the UK's approach to BIM
Data Management	Emphasizes the importance of information management and data exchange throughout the asset lifecycle	Defines the IFC data schema for interoperability in construction and facility management	Includes guidelines for data exchange, modelling, and standards	Emphasizes the importance of data management and collaboration in BIM
Integration	Promotes the integration of BIM with other digital technologies, but does not explicitly mention digital twins	Does not directly address the integration of digital twins	Does not specifically mention digital twins	Does not directly address the integration of digital twins
Lifecycle Management	Addresses the management of information throughout the asset lifecycle	Focuses on data sharing during the construction and facility management phases	Covers the entire asset lifecycle, from planning to operation	Addresses the management of information across the asset lifecycle
Governance	Provides guidance on information management roles and responsibilities	Does not directly address governance aspects	Includes guidelines for BIM implementation and governance	Provides a framework for BIM governance

*Source: existing Standards and Guidelines, review of literature study

The main drawbacks are the absence of industry-wide standards and guidelines that would direct the creation and fusion of digital twins as well as the management and control of data and systems that are integrated with them. The gray literature emphasizes the necessity to close these gaps so that the architecture industry can adopt digital twins more broadly.

The review essentially demonstrates that, although the built environment and construction industries can successfully integrate digital technologies thanks to the policies and practices currently in place, concerted efforts are needed to create best practices and standards that are especially tailored to the efficient application of digital twins in architectural projects.

Take away points:

• Data Management: The BIM standards ISO 16739-1:2018 and NBIMS-US v3 place a strong emphasis on data management and teamwork. Standardized data formats and protocols are necessary for the integration of digital twins.

• Integration: The lack of explicit mention of digital twin integration in ISO 19650-1:2018 points to the necessity of smooth connection with current BIM and Internet of Things technologies.

• Lifecycle Management: Data sharing during the construction and facilities management phases is covered by ISO 19650-1:2018 and ISO 16739-1:2018 standards. Predictive maintenance, decision support, and lifecycle management can all be enhanced by digital twins.

• Governance: NBIMS-US v3 and ISO 19650-1:2018 offer guidelines for information management roles and duties, but strong governance structures are required to handle issues with ownership, data security, and privacy.

• Gaps: There are no clear industry-wide guidelines or standards for the creation and integration of digital twins, and there is a need for governance and management of digital twin-related data and systems.

6 SWOT ANALYSIS

This study aims to analyze the drivers, obstacles, and hazards of digital twin adoption in the architectural sector through a SWOT analysis. The findings will provide strategic advice and a roadmap for addressing risks and leveraging opportunities, ultimately making it easier to integrate digital twins into architectural projects.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 04 | April - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Figure 6.1 SWOT analysis.
*Source: author

7 Digital Twin Implementation Framework for the Architecture Industry

Table 6: evaluation criteria based on review literature.

Aspect	Key Factors	Evaluation
Standards and Guidelines	- Industry Foundation Classes (IFC) for interoperability - ISO 19650 (BIM Standards) - ISO/IEC 27001 (Information Security) - LEED, BREEAM (Sustainability) - ISO 55000 (Asset Management)	High
Digital Twin Capabilities	- Project Monitoring and Control - Asset Management - Construction Process Optimization - Stakeholder Collaboration - Design Optimization - Safety Management - Facility Management	High
Enabling Technologies	- Internet of Things (IoT) - Building Information Modeling (BIM) - Augmented Reality (AR) / Virtual Reality (VR) - Data Analytics - Artificial Intelligence (AI) / Machine Learning (ML)	High (except for AR/VR and AI/ML, which are Moderate)
Integration Capabilities	- BIM Integration - IoT Integration - Blockchain Integration - Industry 4.0 Integration	High (except for Blockchain Integration, which is Moderate)
Challenges and Barriers	- Data Integration and Interoperability - Workforce Skillset - User Acceptance - Scalability and Practical Implementation	High (except for Workforce Skillset and User Acceptance, which are Moderate)
Future Trends	- Advanced Analytics (AI/ML) - Semantic Digital Twins - Sustainability-focused Applications - Integrated Frameworks (e.g., Digital Twin-Blockchain)	High (except for Semantic Digital Twins and Integrated Frameworks, which are Moderate)

*Source: existing Standards and Guidelines, review of literature study

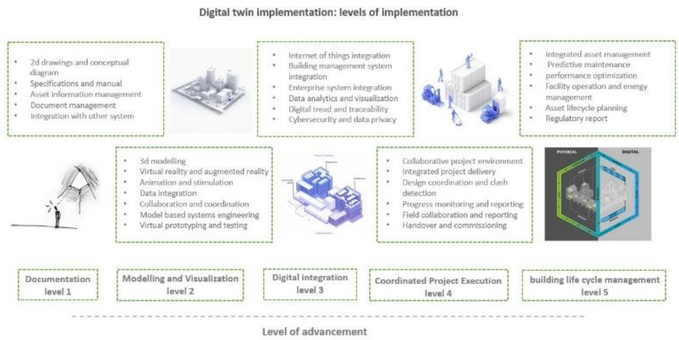

Figure 7.1 Implementation of digital twin in architecture industry.
*Source: author

The architecture industry has high potential for successfully implementing digital twins due to their numerous benefits and the availability of necessary technology. However, challenges such as barriers and potential hurdles need to be addressed to ensure a smooth transition and fully reap the rewards of this new tech. The industry's willingness to embrace new tech gives hope for the future. Addressing these challenges will help ensure the successful implementation of digital twins and ensure the built environment remains adaptable and efficient.

7. CONCLUSIONS

A comprehensive assessment of Digital Twins in Architecture Industry:

• Enhances stakeholder collaboration, asset management, project monitoring, and optimized construction processes.
• Applications include design optimization, construction scheduling, safety management, and facility management.
• Enables technologies like IoT, data analytics, AR, and BIM.
• Future trends include AI and machine learning for improved decision-making and predictive capabilities.
• Aims to achieve sustainability objectives by reducing waste and optimizing energy use.
• Integrates with blockchain for safe and responsible information sharing in construction projects.
• Crucial for Industry 4.0 adoption.
• Literature suggests digital twins can solve built environment issues.

Digital twin technology has shown significant potential in the construction industry by enabling virtual replication and simulation of physical assets, processes, and systems. This technology allows for informed decision-making, resource optimization, and improved project execution through data-driven insights. It has various applications in building design, construction procedures, and facility management. Digital twins can increase productivity and efficiency by modelling and optimizing scenarios before execution. As the construction sector continues to develop, digital twin technology may help integrate new technologies like Building Information Modelling (BIM), the Internet of Things (IoT), and improved materials. Despite challenges such as high implementation costs, a shortage of qualified workers, and resistance to change, the adoption of digital twins is expected to accelerate, enabling construction professionals to deliver projects more efficiently, sustainably, and cost-effectively. Digital twins offer a promising solution to address challenges such as schedule and cost overruns, productivity constraints, and workforce shortages. The continued exploration and implementation of digital twin technology has the potential to revolutionize the construction industry, fostering enhanced collaboration, optimized resources, and unprecedented project management capabilities.

REFERENCES

1. Boschert, S., & Rosen, R. (2016). Digital twin—the simulation aspect. In Mechatronic futures (pp. 59-74). Cham: Springer.

2. Daniotti, B., Pavan, A., Lupica Spagnolo, S., Caffi, V., & Pasini, D. (2021). Digital twin application in the construction industry: A literature review. Journal of Building Engineering, 41,102726.

3. Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems. (2017). In M. &. Grieves, In Transdisciplinary perspectives on complex systems (pp. 85-113). Springer, Cham.

4. Grieves, M., & Vickers, J. (2017). Digital twin: Mitigating unpredictable, undesirable emergent behavior in complex systems. In In Transdisciplinary perspectives on complex systems (pp. 85-113). Cham: Springer, .

5. Li, J., Greenwood, D., & Kassem, M. (2021). Integrated digital twin and blockchain framework to support accountable information sharing in construction projects. Automation in Construction, 126, 103688.

6. Shahzad, A., Mbachu, J., & Separovic, D. (2021). Differentiating Digital Twin from Digital Shadow: Elucidating a Paradigm Shift to Expedite a Smart, Sustainable Built Environment. Buildings, , 11(4), 151.

7. Tao, F., Cheng, J., Qi , Q., Zhang, M., Zhang, H., & Sui, F. (2018). Digital twin-driven product design, manufacturing and service with big data. The International Journal of Advanced Manufacturing Technology, 94(9-12), 3563-3576.

8. Zaher, M., Greenwood, D., & Marzouk, M. (2022). Digital Twin and Industry 4.0 Enablers in Building and Construction: A Survey. Buildings, 12(11).

9. International Organization for Standardization. (2018). ISO 19650-1:2018 -- Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) -- Part 1: Concepts and principles. https://www.iso.org/standard/71691.html

10. International Organization for Standardization. (2018). ISO 16739-1:2018 -- Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries -- Part 1: Data schema. https://www.iso.org/standard/74088.html

11. National Institute of Building Sciences. (2015). National Building Information Modeling Standard -- United States Version 3. https://www.nibs.org/page/standards

12. UK BIM Alliance, Centre for Digital Built Britain, & BSI Group. (2020). UK BIM Framework. https://www.ukbimframework.org/

13. Brilakis, I., Arnaoutoglou, M., Borrmann, A., Cheung, F.F., Dawood, N., Dong, S., Eid, M., El-Omari, S., Ganah, A., Govender, R., Haas, C., Hamela, A., Hosseini, M.R., Ibrahim, Y.M., Itri, M.M., Jayasuriya, S., Jergeas, G., Labi, S., Lee, G., ... Yang, X. (2022). Digital Twins for Constructed Facilities: A Review of Foundations, Challenges and Opportunities. Buildings, 12(11), 2029. https://doi.org/10.3390/buildings12112029

15. Tinsley, A., Kant, P., Freeman, B., Swift, J., Stevens, H., Michael, L., Faux, D., Kent, G., Abraham, P. B., Wang, X., & Beach, T. (2022). Digital Twin and Industry 4.0 Enablers in Building and Construction: A Survey. Buildings, 12(11), 2004. https://doi.org/10.3390/buildings12112004

16. Ghoreishi-Madiseh, S.A., Hassani, F., O'Brien, W.J., & Galiano-Garrigos, A. (2022). Digital Twins in Built Environments: An Investigation of the Characteristics, Applications, and Challenges. Buildings, 12(2), 120. https://doi.org/10.3390/buildings12020120

17. Akanmu, A., & Anumba, C.J. (2021). Differentiating Digital Twin from Digital Shadow: Elucidating a Paradigm Shift to Expedite a Smart, Sustainable Built Environment. Buildings, 11(4), 151. https://doi.org/10.3390/buildings11040151

18. Erkan, I.E., Qureshi, A.J., Jalics, F., & Shovkun, I. (2021). Integrated digital twin and blockchain framework to support accountable information sharing in construction projects. Automation in Construction, 127, 103688. https://doi.org/10.1016/j.autcon.2021.103688

19. Khajavi, S.H., Motlagh, N.H., Jaribion, A., Werner, L.C., & Holmström, J. (2019). Digital Twin: Vision, Benefits, Boundaries, and Creation for Buildings. IEEE Access, 7, 147406-147419. https://doi.org/10.1109/ACCESS.2019.2946515

20.Brilakis, I., Pan, Y., Borrmann, A., Mayer, H.-G., Rhein, F., Neges, M., Dawood, N., Cheung, F., El-Omri, S., &

Moradet, X. (2020). Towards a semantic Construction Digital Twin: Directions for future research. Automation in Construction, 114, 103179. https://doi.org/10.1016/j.autcon.2020.103179

21. Rasheed, A., San, D., Kvamsdal, T., & Vinitsky, A. (2022). A review of digital twin applications in construction. Journal of Information Technology in Construction, 27, 148-176. https://doi.org/10.36680/j.itcon.2022.008