frontiers in Built Environment

TYPE Editorial
PUBLISHED 22 July 2026
DOI 10.3389/fbuil.2026.1905914

Check for updates

OPEN ACCESS

EDITED AND REVIEWED BY
Solomon Tesfamariam,
University of Waterloo, Canada

*CORRESPONDENCE
Salman Azhar,
sza0001@auburn.edu

RECEIVED 10 June 2026
ACCEPTED 11 June 2026
PUBLISHED 22 July 2026

CITATION
Takewaki I, Lu Z, Azhar S, Plevris V, Chen Z, Kaewunruen S and Berardi U (2026) Editorial: Digital transformation in construction: integrating metaverse, digital twin, and BIM.
Front. Built Environ. 12:1905914.
doi: 10.3389/fbuil.2026.1905914

COPYRIGHT
© 2026 Takewaki, Lu, Azhar, Plevris, Chen, Kaewunruen and Berardi. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Editorial: Digital transformation in construction: integrating metaverse, digital twin, and BIM

Izuru Takewaki[1], Zheng Lu[2], Salman Azhar[3]*, Vagelis Plevris[4], Zhen Chen[5], Sakdirat Kaewunruen[6] and Umberto Berardi[7]

[1]Kyoto Arts and Crafts University, Kyoto, Japan, [2]Tongji University, Shanghai, China, [3]Auburn University, Auburn, AL, United States, [4]Qatar University, Doha, Qatar, [5]University of Strathclyde, Glasgow, United Kingdom, [6]University of Birmingham, Birmingham, United Kingdom, [7]Politecnico di Bari, Bari, Italy

KEYWORDS
artificial intelligence, building information modelling, digital twin, immersive technology, metaverse, resilience, sustainability

Editorial on the Research Topic
Digital transformation in construction: integrating metaverse, digital twin, and BIM

Introduction

The Research Topic "*Digital Transformation in Construction: Integrating Metaverse, Digital Twin, and BIM*" brings together scholarship on how data-rich, model-based, and immersive technologies are reshaping the built environment. Its aim is to examine how BIM, digital twins, and metaverse-related technologies can improve sustainability, resilience, safety, productivity, and lifecycle decision-making in construction and infrastructure. This focus is timely because immersive technology for the built world was identified among the World Economic Forum top emerging technologies of 2024 (World Economic Forum, 2024), while buildings and construction account for about 37% of global emissions in recent global reporting (UNEP and GlobalABC, 2025).

This Research Topic was initiated by Professor Izuru Takewaki and developed with the joint support of several specialty sections within *Frontiers in Built Environment*, including Earthquake Engineering, Transportation and Transit Systems, Construction Management, Structural Engineering and Design, Building Information Modelling (BIM), Sustainable Design and Construction, and Structural Sensing, Control and Asset Management. Its interdisciplinary scope was further strengthened through participation from *Frontiers in Environmental Science* and *Frontiers in Virtual Reality*, reflecting the broad relevance of digital transformation, BIM, digital twins, and immersive technologies across the built environment.

The articles in this Research Topic advance the field by moving beyond isolated digital tools toward connected cyber-physical and socio-technical ecosystems. BIM provides structured object, process, and asset information; digital twins extend this information through sensing, feedback, simulation, and lifecycle updating; and metaverse environments offer immersive spaces for visualization, training, coordination, and decision support. This progression is consistent with earlier research that framed the digital twin as a bridge

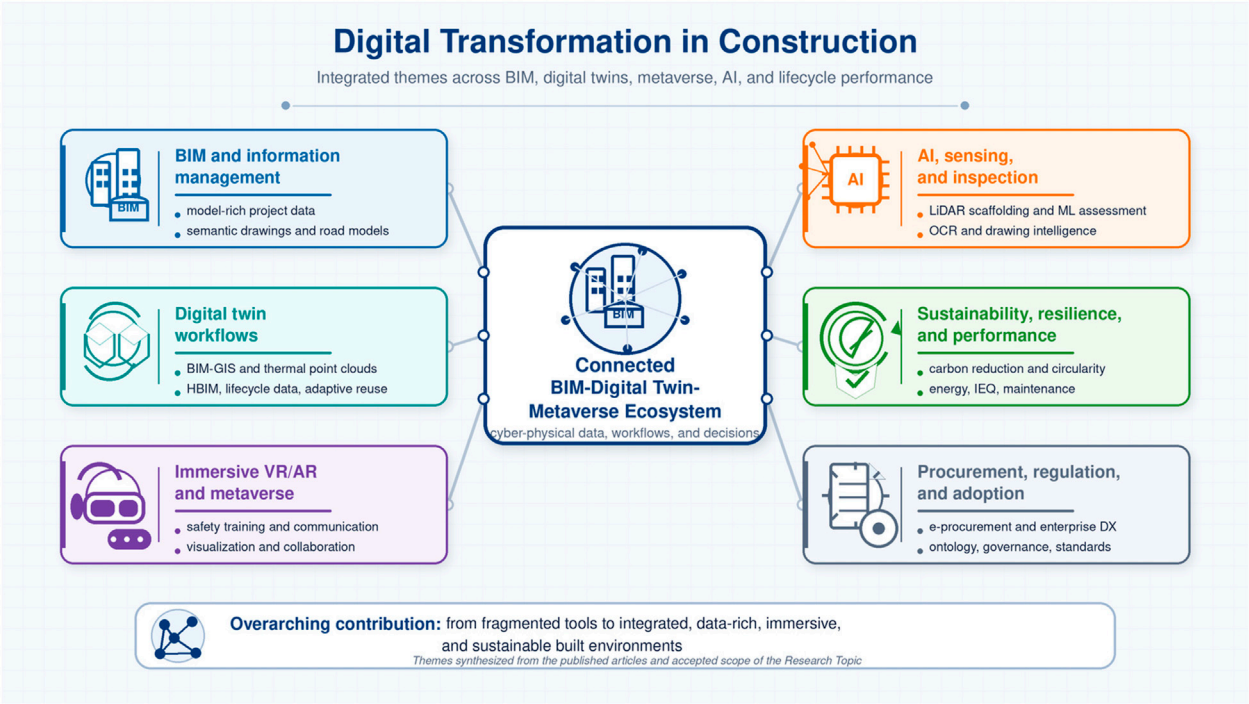


FIGURE 1
Integrated thematic framework of the Research Topic, showing how BIM, digital twins, immersive technologies, AI-enabled sensing, sustainability performance, and governance-oriented adoption collectively support digital transformation in construction and the built environment.

between physical systems and their virtual representations (Kritzinger et al., 2018), emphasized the need for semantic construction digital twins (Boje et al., 2020), and mapped the evolution from BIM to digital twins in the AEC-FM industry (Deng et al., 2021).

This Research Topic contributes to knowledge by connecting research streams that are often examined separately: BIM-based information management, AI-enabled analytics, sensing and reality capture, digital twin workflows, immersive visualization, and digital transformation for sustainability. The papers operate across project, asset, enterprise, and sector scales, addressing safety communication, inspection, drawing digitization, heritage documentation, road models, procurement, carbon reduction, circularity, and regulatory digitalization. Together, they show that digital transformation is not a single technology shift, but a coordinated change in data, workflows, skills, governance, and human interaction.

The broader contribution of the collection is its emphasis on implementation. The papers move beyond conceptual enthusiasm for BIM, digital twins, and metaverse technologies by showing how these tools can be evaluated through pilot studies, computational models, systematic reviews, case studies, and methods papers. They also identify persistent research needs, including interoperability, semantic enrichment, cybersecurity, data governance, ethical use, workforce adoption, and field validation. In doing so, the collection helps define an applied research agenda for a built environment that is more intelligent, resilient, sustainable, and inclusive. Figure 1 summarizes the thematic scope of this Research Topic, showing how BIM-based information management, digital twin workflows, immersive environments, AI-enabled sensing, sustainability performance, and governance-oriented adoption collectively support digital transformation in the built environment.

Organization of the special collection

The published contributions in this Research Topic can be organized around five major sub-themes: digital safety and AI-enabled construction intelligence; digital twins, reality capture, heritage documentation, and circularity; evidence synthesis through systematic and narrative reviews; methods for regulatory digitalization; and opinion-based conceptual framing of the BIM, digital twin, and metaverse transition.

- **Digital safety and AI-enabled construction intelligence:** Baikati et al., in *Integrating BIM and VR for enhanced safety communication and training in construction*, develop BIM-enabled VR safety training for multilingual construction environments. Ying et al., in *An efficient deep learning framework for text detection and recognition in engineering drawings*, propose a deep learning approach for extracting rebar annotations from complex engineering drawings. Kookalani et al., in *Interpretable machine learning for predicting the bearing capacity of double shear-bolted connections: a data-driven evaluation*, combine predictive modeling with interpretability to support data-driven steel design. Prabhu et al., in

Artificial intelligence-driven safety assessment of scaffolding using LiDAR sensing, present a cloud-based workflow for automated scaffolding inspection.

- **Digital twins, reality capture, heritage documentation, enterprise transformation, and circularity:** Ramón-Constantí et al., in *Integrating thermal point clouds into BIM-GIS environments: workflow proposal for multi-layer digital twins*, propose a BIM-GIS workflow for multi-layer thermal digital twins. Li and Willkens, in *Digital transformation through multi-device HBIM workflow: a case study on supporting the adaptive reuse of the Odd Fellows Building in Atlanta, Georgia*, present a scan-to-HBIM workflow for adaptive reuse. Crampen and Blankenbach, in *Data enrichment for semantic segmentation of point clouds for the generation of geometric-semantic road models*, enrich point-cloud segmentation with semantic information for road modeling. Zhao et al., in *Digital transformation of construction enterprises and carbon emission reduction: evidence from listed companies*, provide listed-company evidence on digital transformation and carbon reduction. Shehu et al., in *Opportunities for digital tracking technologies in the precast concrete sector in Sweden*, examine digital tracking technologies for circular economy practices in precast concrete.
- **Systematic and narrative review contributions:** Sornoza-Parrales et al., in *Evolution and research trends in virtual reality and augmented reality technologies for the architecture, engineering, and construction industry: a systematic review and science mapping approach*, use systematic review and science mapping methods to clarify the development of AR and VR research in AEC. Awodele et al. (2026), in *The role of digital technologies in engineering procurement: a systematic literature review*, synthesize literature on AI, blockchain, IoT, BIM, robotic process automation, and e-procurement. Medrano-Sanchez and Martos, in *Strategies for bridge maintenance using BIM: an analysis of methodologies and tools*, review BIM-based bridge maintenance methods and tools. Venkateswarlu and Sathiyamoorthy, in *Sustainable innovations in digital twin technology: a systematic review about energy efficiency and indoor environment quality in built environment*, review how digital twins can support energy efficiency, indoor environmental quality, and sustainable building operation.
- **Methods contribution:** Kabzhan et al., in *Semantic and ontology-based analysis of regulatory documents for construction industry digitalization*, develop an automated approach for analyzing construction regulatory documents using ontology modeling and natural language processing. This contribution addresses a central barrier to digital transformation: converting complex, changing, and text-heavy regulatory requirements into structured knowledge that can support digital workflows
- **Opinion contribution:** Noroozinejad Farsangi et al., in *Transitioning from BIM to Digital Twin to Metaverse*, provide a conceptual framing for the movement from static information models to dynamic digital twins and then to immersive, interconnected metaverse environments. This opinion paper helps anchor the collection by clarifying the conceptual pathway that links many of the empirical, methodological, and review contributions.

Conclusion

Collectively, the papers in this Research Topic show that digital transformation in construction is entering a more integrated and evidence-based phase. The field is moving from stand-alone BIM models and isolated visualization tools toward interoperable digital twins, intelligent sensing, AI-enabled analytics, semantic information structures, immersive interfaces, and digitally supported sustainability strategies. The collection advances knowledge by connecting technical innovation with real problems in safety, infrastructure management, heritage conservation, procurement, carbon reduction, circularity, and regulatory modernization.

Future work may extend this discussion toward generative AI, secure and ethical digital twins, metaverse-enabled collaboration, digital product passports, cyber-physical jobsites, and human-centered adoption.

Author contributions

IT: Supervision, Validation, Writing – review and editing. ZL: Writing – review and editing. SA: Conceptualization, Visualization, Writing – original draft, Writing – review and editing, Formal Analysis. VP: Writing – review and editing. ZC: Writing – review and editing. SK: Writing – review and editing. UB: Writing – review and editing.

Funding

The author(s) declared that financial support was not received for this work and/or its publication.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The authors IT, ZL, SA, VP, ZC, SK, UB declared that they were an editorial board member of Frontiers at the time of submission. This had no impact on the peer review process and the final decision.

Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. Figure 1 is sketched using ChatGPT.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Awodele, I. A., Ramabodu, M. S., Olatunde, N. N., Eze, E. C., Anugwo, I. C., Espinosa, Y. P., et al. (2026). The role of digital technologies in engineering procurement: a systematic literature review. *Front. Built Environ.* doi: 10.3389/fbuil.2026.1870384

Boje, C., Guerriero, A., Kubicki, S., and Rezgui, Y. (2020). Towards a semantic construction digital twin: directions for future research. *Autom. Constr.* 114, 103179. doi: 10.1016/j.autcon.2020.103179

Deng, M., Menassa, C. C., and Kamat, V. R. (2021). From BIM to digital twins: a systematic review of the evolution of intelligent building representations in the AEC-FM industry. *J. Inf. Technol. Constr.* 26, 58–83. doi: 10.36680/j.itcon.2021.005

Kritzinger, W., Karner, M., Traar, G., Henjes, J., and Sihn, W. (2018). Digital twin in manufacturing: a categorical literature review and classification. *IFAC-PapersOnLine* 51 (11), 1016–1022. doi: 10.1016/j.ifacol.2018.08.474

UNEP and GlobalABC (2025). *Global Status Report for Buildings and Construction 2024/25*. United Nations Environment Programme and Global Alliance for Buildings and Construction.

World Economic Forum (2024). *Top 10 Emerging Technologies of 2024*. Geneva: World Economic Forum.