Relationship between digital twin and building information modeling : A systematic review and future directions

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ABSTRACT

Purpose: Digital twin (DT) and building information modeling (BIM) are interconnected in some ways. However, there has been some misconception about how DT differs from BIM. As a result, industry professionals reject DT even in BIM-based construction projects due to reluctance to innovate. Furthermore, researchers have repeatedly developed tools and techniques with the same goals using DT and BIM to assist practitioners in construction projects. Therefore, this study aims to assist industry professionals and researchers in understanding the relationship between DT and BIM and synthesize existing works on DT and BIM. Design/methodology/approach: A systematic review was conducted on published articles related to DT and BIM. A total record of 54 journal articles were identified and analyzed. Findings: The analysis of the selected journal articles revealed four types of relationships between DT and BIM: BIM is a subset of DT, DT is a subset of BIM, BIM is DT, and no relationship between BIM and DT. The existing research on DT and BIM in construction projects targets improvements in five areas: planning, design, construction, operations and maintenance, and decommissioning. In addition, several areas have emerged, such as developing geo-referencing approaches for infrastructure projects, applying the proposed methodology to other construction geometries and creating 3D visualization using color schemes. Originality/value: This study contributed to the existing body of knowledge by overviewing existing research related to DT and BIM in construction projects. Also, it reveals research gaps in the body of knowledge to point out directions for future research.

KEYWORDS

BIM; Built environment; Construction innovation; Digital twin; Facilities management; Literature review

REFERENCES

Abanda, F.H., Mzyece, D., Oti, A.H. and Manjia, M.B. (2018), "A study of the potential of cloud/mobile BIMfor the management of construction projects", Applied System Innovation, Vol. 1 No. 2, p. 9.

Abdelrahman, M.M., Chong, A. and Miller, C. (2022), "Personal thermal comfort models using digital twins: preference prediction with BIM-extracted spatial–temporal proximity data from Build2Vec", Building and Environment, Vol. 207, p. 108532.

Abdul Nabi, M. and El-Adaway, I.H. (2020), "Modular construction: determining decision-making factors and future research needs", Journal of Management in Engineering, Vol. 36 No. 6, p. 4020085.

Aish, R. (1986), "Building modelling: the key to integrated construction CAD", CIB 5th International Symposium on the Use of Computers for Environmental Engineering Related to Buildings, Vol. 5, pp. 7-9.

Alizadehsalehi, S. and Yitmen, I. (2021), "Digital twin-based progress monitoring management model through reality capture to extended reality technologies (DRX)", Smart and Sustainable Built Environment, Vol. 12 No. 1, pp. 200-236.

Al-Saeed, Y., Edwards, D.J. and Scaysbrook, S. (2020), "Automating construction manufacturing procedures using BIM digital objects (BDOs): case study of knowledge transfer partnership project in UK", Construction Innovation, Vol. 20 No. 3, pp. 345-377.

Antonino, M., Nicola, M., Claudio, D.M., Luciano, B. and Fulvio, R.C. (2019), "Office building occupancy monitoring through image recognition sensors", International Journal of Safety and Security Engineering, Vol. 9 No. 3, pp. 371-380.

Asadi, I., Mahyuddin, N. and Shafigh, P. (2017), "A review on indoor environmental quality (IEQ) and energy consumption in building based on occupant behavior", Facilities.

Azhar, S., Khalfan, M. and Maqsood, T. (2012), "Building information modeling (BIM): now and beyond", Construction Economics and Building, Vol. 12 No. 4, pp. 15-28.

Badenko, V.L., Bolshakov, N.S., Tishchenko, E.B., Fedotov, A.A., Celani, A.C. and Yadykin, V.K. (2021),"Integration of digital twin and BIM technologies within factories of the future", Magazine of Civil Engineering, Vol. 1 No. 101, p. 10114.

Bastos Porsani, G., Del Valle de Lersundi, K., S_anchez-Ostiz Guti_errez, A. and Fern_andez Bandera, C.(2021), "Interoperability between building information modelling (BIM) and building energy model (BEM)", Applied Sciences, Vol. 11 No. 5, p. 2167.

Bilal, M., Oyedele, L.O., Qadir, J., Munir, K., Ajayi, S.O., Akinade, O.O., Owolabi, H.A., Alaka, H.A. and Pasha, M. (2016), "Big data in the construction industry: a review of present status, opportunities, and future trends", Advanced Engineering Informatics, Vol. 30 No. 3, pp. 500-521.

Bond-Barnard, T.J., Steyn, H. and Fabris-Rotelli, I. (2013), "The impact of a call centre on communication in a programmeanditsprojects", International Journal of Project Management, Vol. 31 No. 7, pp. 1006-1016.

Chen, C., Zhao, Z., Xiao, J. and Tiong, R. (2021), "A conceptual framework for estimating building embodied carbon based on digital twin technology and life cycle assessment", Sustainability, Vol. 13 No. 24, p. 13875.

Christensen, K., Melfi, R., Nordman, B., Rosenblum, B. and Viera, R. (2014), "Using existing network infrastructure to estimate building occupancy and control plugged-in devices in user

workspaces", International Journal of Communication Networks and Distributed Systems, Vol. 12 No. 1, pp. 4-29.
Coraglia, U.M., Simeone, D., Cursi, S., Fioravanti, A., Wurzer, G. and D'Alessandro, D. (2017), "A simulation model for logical and operative clash detection",inProceedings of the 35th International Conference on Education and Research in Computer Aided Architectural Design in Europe, Rome, 20th-22nd September 2017, Vol. 2.
Daily, J. and Peterson, J. (2017), "Predictive maintenance: how big data analysis can improve maintenance",inSupply Chain Integration Challenges in Commercial Aerospace, Springer, Cham, pp. 267-278.
Demianenko, M. and De Gaetani, C.I. (2021), "A procedure for automating energy analyses in the BIM context exploiting artificial neural networks and transfer learning technique", Energies, Vol. 14 No. 10, p. 2956. Deng, Y., Cheng, J.C. and Anumba, C. (2016), "Mapping between BIM and 3D GIS in different levels of detail using schema mediation and instance comparison", Automation in Construction, Vol. 67,pp. 1-21.
Desogus, G., Quaquero, E., Rubiu, G., Gatto, G. and Perra, C. (2021), "BIM and IOT sensors integration: a framework for consumption and indoor conditions data monitoring of existing buildings",Sustainability, Vol. 13 No. 8, p. 4496.
Diakite, A.A. and Zlatanova, S. (2020), "Automatic geo-referencing of BIM in GIS environments using building footprints", Computers, Environment and Urban Systems, Vol. 80, p. 101453.
Eastman, C.M., Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2011), BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors, John Wiley and Sons. Hoboken, New Jersey. Fard, M.M., Terouhid, A.A., Kibert, C.J. and Hakim, H. (2017), "Safety concerns related to modular/ prefabricated building construction", International Journal of Injury Control and Safety Promotion, Vol. 24 No. 1, pp. 10-23.
Glaessgen, E. and Stargel, D. (2012), "The digital twin paradigm for future NASA and US air force vehicles", 53rd AIAA/ASME/ASCE/AHS/ASC structures, structural dynamics and materials conference 20th AIAA/ASME/AHS adaptive structures conference 14th AIAA, p. 1818.
Götz, C.S., Karlsson, P. and Yitmen, I. (2020), "Exploring applicability, interoperability and integrability of blockchain-based digital twins for asset life cycle management", Smart and Sustainable Built Environment, Vol. 11 No. 3, pp. 532-558.
Grieves, M. (2011), Virtually Perfect: Driving Innovative and Lean Products through Product Lifecycle Management, Space Coast Press, Cocoa Beach, FL.
Gunduz, M., Nielsen, Y. and Özdemir, M. (2013), "Quantification of delay factors using the relative importance index method for construction projects in Turkey", Journal of Management in Engineering, Vol. 29 No. 2, pp. 133-139.
Gurevich, U. and Sacks, R. (2020), "Longitudinal study of BIM adoption by public construction clients",Journal of Management in Engineering, Vol. 36 No. 4, p. 5020008. He, R., Li, M., Gan, V.J. and Ma, J. (2021), "BIM-enabledcomputerized design and digital fabrication of industrialized buildings: a case study", Journal of Cleaner Production, Vol. 278, p. 123505.
Helby Petersen, O. (2019), "Evaluating the costs, quality, and value for money of infrastructure public-private partnerships: a systematic literature review", Annals of Public and Cooperative Economics, Vol. 90 No. 2, pp. 227-244.
Hong, Y., and Chan, D.W. (2014), "Research trend of joint ventures in construction: a two-decade taxonomic review", Journal of Facilities Management.

Huynh, D. and Nguyen-Ky, S. (2020), “Engaging building automation data visualisation using building information modelling and progressive web application”, Open Engineering, Vol. 10 No. 1, pp. 434-442.
Jouan, P. and Hallot, P. (2020), “Digital twin: research framework to support preventive conservation policies”, ISPRS International Journal of Geo-Information, Vol. 9 No. 4, p. 228.
Kaewunruen, S. and Lian, Q. (2019), “Digital twin aided sustainability-based lifecycle management for railway turnout systems”, Journal of Cleaner Production, Vol. 228, pp. 1537-1551.
Kaewunruen, S. and Xu, N. (2018), “Digital twin for sustainability evaluation of railway station buildings”, Frontiers in Built Environment, Vol. 4, p. 77.
Kaewunruen, S., Peng, S. and Phil-Ebosie, O. (2020), “Digital twin aided sustainability and vulnerability audit for subway stations”, Sustainability, Vol. 12 No. 19, p. 7873.
Kaewunruen, S., Rungskunroch, P. and Welsh, J. (2018), “A digital-twin evaluation of net zero energy building for existing buildings”, Sustainability, Vol. 11 No. 1, p. 159.
Kaewunruen, S., Sresakoolchai, J., Ma, W. and Phil-Ebosie, O. (2021), “Digital twin aided vulnerability assessment and risk-based maintenance planning of bridge infrastructures exposed to extreme conditions”, Sustainability, Vol. 13 No. 4, p. 2051.
Khajavi, S.H., Motlagh, N.H., Jaribion, A., Werner, L.C. and Holmström, J. (2019), “Digital twin: vision, benefits, boundaries, and creation for buildings”, IEEE Access,Vol.7, pp. 147406-147419.
Khan, M., Khan, N., Skibniewski, M.J. and Park, C. (2021), “Environmental particulate matter (PM) exposure assessment of construction activities using low-cost PM sensor and Latin hypercubic technique”, Sustainability, Vol. 13 No. 14, p. 7797.
Lee, D. and Lee, S. (2021), “Digital twin for supply chain coordination in modular construction”, Applied Sciences, Vol. 11 No. 13, p. 5909.
Lee, D., Lee, S.H., Masoud, N., Krishnan, M.S. and Li, V.C. (2021), “Integrated digital twin and blockchain framework to support accountable information sharing in construction projects”, Automation in Construction, Vol. 127, p. 103688.
Li, J., Li, N., Afsari, K., Peng, J., Wu, Z. and Cui, H. (2019), “Integration of building information modeling and web service application programming interface for assessing building surroundings in early design stages”, Building and Environment, Vol. 153, pp. 91-100
Lin, Y.C. and Cheung, W.F. (2020), “Developing WSN/BIM-based environmental monitoring management system for parking garages in smart cities”, Journal of Management in Engineering,Vol.36No.3,p. 4020012.
Liu, X., Eybpoosh, M. and Akinci, B. (2012), “Developing as-built building information model using construction process history captured by a laser scanner and a camera”,inConstruction Research Congress 2012: Construction Challenges in a Flat World, pp. 1232-1241.
Liu, Z., Zhang, A. and Wang, W. (2020), “A framework for an indoor safety management system based on digital twin”, Sensors, Vol. 20 No. 20, p. 5771.
Liu, Z., Meng, X., Xing, Z. and Jiang, A. (2021), “Digital twin-based safety risk coupling of prefabricated building hoisting”, Sensors, Vol. 21 No. 11, p. 3583.
Lu, Q., Chen, L., Li, S. and Pitt, M. (2020), “Semi-automatic geometric digital twinning for existing buildings based on images and CAD drawings”, Automation in Construction, Vol. 115, p. 103183.

Luka, A. and Guo, Y. (2021), “PlantingSMART: the parametric approach for trees in BIM with full lifecycle application”, Journal of Digital Landscape Architecture, pp. 370-380. Morakinyo, O.M., Adebowale, A.S., Mokgobu, M.I. and Mukhola, M.S. (2017), “Health risk of inhalation exposure to sub-10 mm particulate matter and gaseous pollutants in an urban-industrial area in South Africa: an ecological study”, BMJ Open, Vol. 7 No. 3, p. e013941.
Moretti, N., Ellul, C., Cecconi, F.R., Papapesios, N. and Dejaco, M.C. (2021), “GeoBIM for built environment condition assessment supporting asset management decision making”, Automation in Construction, Vol. 130, p. 103859.
Moretti, N., Xie, X., Merino, J., Brazauskas, J. and Parlikad, A.K. (2020), “An openBIM approach to IoT integration with incomplete as-built data”, Applied Sciences, Vol. 10 No. 22, p. 8287.
Moyano, J., Gil-Ariz_on, I., Nieto-Juli_an, J.E. and Marín-García, D. (2022), “Analysis and management of structural deformations through parametric models and HBIM workflow in architectural heritage”, Journal of Building Engineering, Vol. 45, p. 103274.
Nasaruddin, A.N., Ito, T. and Tuan, T.B. (2018), “Digital twin approach to building information management”, The Proceedings of Manufacturing Systems Division Conference 2018, The Japan Society of Mechanical Engineers, p. 304. National BIM Standard (2022), “Frequently asked questions about the national BIM Standard-United States”, available at: www.nationalbimstandard.org/faqs (accessed 24 January 2022).
Nini_c, J., Koch, C. and Stascheit, J. (2017), “An integrated platform for design and numerical analysis ofshield tunnelling processes on different levels of detail”, Advances in Engineering Software, Vol. 112, pp. 165-179.
O’Grady, T.M., Brajkovich, N., Minunno, R., Chong, H.Y. and Morrison, G.M. (2021), “Circular economy and virtual reality in advanced BIM-based prefabricated construction”, Energies, Vol. 14 No. 13, p. 4065.
Olawumi, T.O. and Chan, D.W. (2018), “A scientometric review of global research on sustainability and sustainable development”, Journal of Cleaner Production, Vol. 183, pp. 231-250, doi: 10.1016/j. jclepro.2018.02.162.
Olawumi, T.O., Chan, D.W., Wong, J.K. and Chan, A.P. (2018), “Barriers to the integration of BIM and sustainability practices in construction projects: a Delphi survey of international experts”, Journal of Building Engineering, Vol. 20, pp. 60-71.
Oliveira, P.P. (2020), “Digital twin development for airport management”, Journal of Airport Management, Vol. 14 No. 3, pp. 246-259.
Oti, A.H., Farrell, P., Abanda, F.H., McMahon, P., Mahamadu, A.M., Mzyece, D., Akintola, A.A. and Prinja, N. (2021), “A BIM-driven framework for integrating rules and regulations in the decommissioning of nuclear power plants”, Construction Innovation, Vol. 22 No. 4, pp. 809-830.
Pan, Y. and Zhang, L. (2021), “A BIM-data mining integrated digital twin framework for advanced project management”, Automation in Construction, Vol. 124, p. 103564.
Pan, Z., Shi, J. and Jiang, L. (2020), “A novel HDF-based data compression and integration approach to support BIM-GIS practical applications”, Advances in Civil Engineering, Vol. 2020, p. 8865107.
Qi, Q. and Tao, F. (2018), “Digital twin and big data towards smart manufacturing and Industry 4.0:360-degree comparison”, IEEE Access, Vol. 6, pp. 3585-3593.
Rausch, C. and Haas, C. (2021), “Automated shape and pose updating of building information model elements from3D point clouds”, Automation in Construction, Vol. 124, p. 103561.

Rausch, C., Lu, R., Talebi, S. and Haas, C. (2021), “Deploying 3D scanning based geometric digital twins during fabrication and assembly in offsite manufacturing”, International Journal of Construction Management, pp. 1-14. doi: 10.1080/15623599.2021.1896942.
Sacks, R., Brilakis, I., Pikas, E., Xie, H.S. and Girolami, M. (2020), “Construction with digital twin information systems”, Data-Centric Engineering, Vol. 1, p. e14.
Sacks, R., Eastman, C., Lee, G. and Teicholz, P. (2018), “BIM handbook: a guide to building information modeling for owners”, Designers, Engineers, Contractors, and Facility Managers, 3rd ed., John Wiley and Sons, New York, NY.
Sacks, R., Koskela, L., Dave, B.A. and Owen, R. (2010), “Interaction of lean and building information modeling in construction”, Journal of Construction Engineering and Management, Vol. 136 No. 9, pp. 968-980.
Schleich, B., Anwer, N., Mathieu, L. and Wartzack, S. (2017), “Shaping the digital twin for design and production engineering”, CIRP Annals, Vol. 66 No. 1, pp. 141-144.
Schimanski, C.P., Pasetti Monizza, G., Marcher, C. and Matt, D.T. (2019), “Pushing digital automation of configure-to-order services in small and medium enterprises of the construction equipment industry: a design science research approach”, Applied Sciences, Vol. 9 No. 18, p. 3780.
Seghezzi, E., Locatelli, M., Pellegrini, L., Pattini, G., Di Giuda, G.M., Tagliabue, L.C. and Boella, G. (2021), “Towards an occupancy-oriented digital twin for facility management: test campaign and sensors assessment”, Applied Sciences, Vol. 11 No. 7, p. 3108.
Shahinmoghadam, M., Natephra, W. and Motamedi, A. (2021), “BIM-and IoT-based virtual reality tool for real-time thermal comfort assessment in building enclosures”, Building and Environment, Vol. 199, p. 107905.
Succar, B. (2009),“Building information modelling framework: a research and delivery foundation for industry stakeholders”, Automation in Construction, Vol. 18 No. 3, pp. 357-375.
Tang, P., Huber, D., Akinci, B., Lipman, R. and Lytle, A. (2010), “Automatic reconstruction of as-built building information models from laser-scanned point clouds: a review of related techniques”, Automation in Construction, Vol. 19 No. 7, pp. 829-843.
Tao, F., Cheng, J., Qi, Q., Zhang, M., Zhang, H. and Sui, F. (2018), “Digital twin-driven product design,manufacturing and service with big data”, The International Journal of Advanced Manufacturing Technology, Vol. 94 Nos 9/12, pp. 3563-3576.
Teisserenc, B. and Sepasgozar, S. (2021), “Adoption of blockchain technology through digital twins in the construction Industry 4.0: a PESTELS approach”, Buildings, Vol. 11 No. 12, p. 670.
Torrecilla-García, J.A., Pardo-Ferreira, M.C. and Rubio-Romero, J.C. (2021), “Overall introduction to the framework of BIM-based digital twinning in decision-making in safety management in building construction industry”, Organ, Vol. 74, pp. 31-38.
Villa, V., Naticchia, B., Bruno, G., Aliev, K., Piantanida, P. and Antonelli, D. (2021), “IoT open-source architecture for the maintenance of building facilities”, Applied Sciences, Vol. 11 No. 12, p. 5374.
Volk, R., Stengel, J. and Schultmann, F. (2014), “Building information modeling (BIM) for existing buildings – literature review and future needs”, Automation in Construction, Vol. 38, pp. 109-127.
Wang, J. and Lu, W. (2021), “A deployment framework for BIMlocalization”, Engineering, Construction and Architectural Management.

White, G., Zink, A., Codec_a, L. and Clarke, S. (2021), “A digital twin smart city for citizen feedback”,Cities, Vol. 110, p. 103064.
Xie, X., Lu, Q., Rodenas-Herraiz, D., Parlikad, A.K. and Schooling, J.M. (2020), “Visualised inspection system for monitoring environmental anomalies during daily operation and maintenance”,Engineering, Construction and Architectural Management, Vol. 27 No. 8, pp. 1835-1852.
Youn, H.C., Yoon, J.S. and Ryoo, S.L. (2021), “HBIM for the characteristics of Korean traditional wooden architecture: bracket set modelling based on 3D scanning”, Buildings, Vol. 11 No. 11, p. 506.
Yu, G., Zhang, S., Hu, M. and Wang, Y.K. (2020), “Prediction of highway tunnel pavement performance based on digital twin and multiple time series stacking”, Advances in Civil Engineering, Vol. 2020, p. 8824135.
Zaballos, A., Briones, A., Massa, A., Centelles, P. and Caballero, V. (2020), “A smart campus’ digital twin for sustainable comfort monitoring”, Sustainability, Vol. 12 No. 21, p. 9196.
Zhang, J., Cheng, J.C., Chen, W. and Chen, K. (2022), “Digital twins for construction sites: concepts, LoD definition, and applications”, Journal of Management in Engineering, Vol. 38 No. 2, p. 4021094.
Zhao, L., Zhang, H., Wang, Q. and Wang, H. (2021), “Digital-twin-based evaluation of nearly zeroenergy building for existing buildings based on scan-to-BIM”, Advances in Civil Engineering, Vol. 2021, p. 6638897.
Zhu, J. and Wu, P. (2021a), “A common approach to geo-referencing building models in industry foundation classes for BIM/GIS integration”, ISPRS International Journal of Geo-Information, Vol. 10 No. 6, p. 362.
Zhu, J. and Wu, P. (2021b), “Towards effective BIM/GIS data integration for smart city by integrating computer graphics technique”, Remote Sensing, Vol. 13 No. 10, p. 1889.
Zomorodian, Z.S., Tahsildoost, M. and Hafezi, M. (2016), “Thermal comfort in educational buildings: a review article”, Renewable and Sustainable Energy Reviews, Vol. 59, pp. 895-906