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Application of BIM technologies in transportation infrastructure: current practices, barriers, and future directions

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Abstract

Transportation infrastructure is a critical backbone of national economic and social development, providing reliable mobility for people and goods. The growing demand for transportation services, combined with the ageing of infrastructure assets, has intensified the need for more efficient, data-driven, and cost-effective technologies for planning, design, construction, operation, and maintenance. Building Information Modeling (BIM), which has been widely adopted in the building sector, is increasingly being explored as a transformative approach for transportation infrastructure; however, its adoption remains uneven and fragmented. This paper presents a comprehensive systematic review of scientific literature and applied reports addressing the application of BIM technologies in transportation infrastructure, including roads, bridges, tunnels, railways, and other linear assets. The reviewed publications are classified according to model types, lifecycle stages, application domains, and supporting digital technologies. The results indicate that BIM is most maturely applied in bridge and highway projects, particularly during design and construction phases, while its potential for operation, maintenance, and asset management is only partially realized. Key barriers to wider adoption include limited interoperability, lack of standardized data models for linear infrastructure, and institutional and organizational constraints. At the same time, strong potential is identified in the integration of BIM with GIS, monitoring systems, and digital twin concepts. The findings provide a structured overview of current practices, highlight research gaps, and outline future directions for advancing BIM-enabled digital transformation in transportation infrastructure.

Keywords: Building Information Modeling; transportation infrastructure; lifecycle management; digital transformation;

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Көлік инфрақұрылымында BIM технологияларын қолдану: қазіргі тәжірибелер, кедергілер және болашақ даму бағыттары

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Түйіндеме

Көлік инфрақұрылымы ұлттық экономикалық және әлеуметтік дамудың маңызды негізі болып табылады, ол адамдар мен жүктердің сенімді қозғалысын қамтамасыз етеді. Көлік қызметтеріне сұраныстың өсуі және инфрақұрылым активтерінің тозуы жоспарлау, жобалау, салу, пайдалану және техникалық қызмет көрсету салаларында неғұрлым тиімді, деректерге негізделген және экономикалық тұрғыдан негізделген технологияларды енгізу қажеттілігін күшейтті. Ғимараттар саласында кеңінен қолданылып келе жатқан Building Information Modeling (BIM) технологиясы көлік инфрақұрылымы үшін де трансформациялық тәсіл ретінде барған сайын қарастырылуда, алайда оның енгізілуі біркелкі емес және фрагменттелген күйде қалып отыр. Бұл мақалада автомобиль жолдары, көпірлер, тоннельдер, теміржолдар және басқа да сызықтық объектілерді қамтитын көлік инфрақұрылымында BIM технологияларын қолдануға арналған ғылыми әдебиеттер мен қолданбалы есептердің кешенді жүйелі шолуы ұсынылған. Қарастырылған жарияланымдар модель түрлері, өмірлік цикл кезеңдері, қолдану салалары және қолдаушы цифрлық технологиялар бойынша жіктелді. Нәтижелер BIM технологияларының ең жоғары жетілу деңгейі көпірлер мен автомобиль жолдары жобаларында, әсіресе жобалау және құрылыс кезеңдерінде байқалатынын көрсетеді, ал пайдалану, техникалық қызмет көрсету және активтерді басқару кезеңдеріндегі әлеуеті толық іске асырылмаған. Кеңінен енгізілуге кедергі келтіретін негізгі факторлар интероперабельділіктің төмен деңгейі, сызықтық инфрақұрылым үшін стандартталған деректер модельдерінің болмауы, сондай-ақ институционалдық және ұйымдастырушылық шектеулер болып табылады. Сонымен қатар BIM-ді геоақпараттық жүйелермен, мониторинг жүйелерімен және цифрлық егіздер тұжырымдамасымен интеграциялау тұрғысынан жоғары әлеует анықталды. Алынған нәтижелер қазіргі тәжірибелерге құрылымдалған шолу жасап, зерттеу олқылықтарын айқындайды және көлік инфрақұрылымын BIM негізінде цифрлық трансформациялаудың болашақ бағыттарын белгілейді.

Түйін сөздер: Building Information Modeling; көлік инфрақұрылымы; өмірлік циклді басқару; цифрлық трансформация;

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Применение BIM-технологий в транспортной инфраструктуре: текущие практики, барьеры и перспективы развития

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Аннотация
Транспортная инфраструктура является ключевой основой социально-экономического развития страны, обеспечивая надёжную мобильность людей и грузов. Рост спроса на транспортные услуги в сочетании со старением инфраструктурных активов усилил потребность в более эффективных, основанных на данных и экономически целесообразных технологиях планирования, проектирования, строительства, эксплуатации и содержания. Технология информационного моделирования зданий (BIM), получившая широкое распространение в строительстве зданий и сооружений, всё активнее рассматривается как трансформационный подход для транспортной инфраструктуры; однако её внедрение остаётся неравномерным и фрагментарным. В данной статье представлен комплексный систематический обзор научных публикаций и прикладных отчётов, посвящённых применению BIM-технологий в транспортной инфраструктуре, включая автомобильные дороги, мосты, тоннели, железные дороги и другие линейные объекты. Проанализированные публикации классифицированы по типам моделей, стадиям жизненного цикла, областям применения и сопутствующим цифровым технологиям. Результаты показывают, что BIM наиболее зрелым образом применяется в мостовых и автомобильных проектах, преимущественно на стадиях проектирования и строительства, тогда как его потенциал в эксплуатации, техническом обслуживании и управлении активами реализован лишь частично. К ключевым барьерам более широкого внедрения относятся ограниченная интероперабельность, отсутствие стандартизированных моделей данных для линейной инфраструктуры, а также институциональные и организационные ограничения. В то же время выявлен высокий потенциал интеграции BIM с ГИС, системами мониторинга и концепциями цифровых двойников. Полученные результаты обеспечивают структурированное представление текущих практик, выявляют исследовательские пробелы и определяют перспективные направления развития BIM-ориентированной цифровой трансформации транспортной инфраструктуры.

Ключевые слова: Building Information Modeling; транспортная инфраструктура; управление жизненным циклом; цифровая трансформация;

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1. Introduction

Transportation infrastructure plays a key role in the functioning of any state, as the reliable, safe, and efficient movement of people and goods directly affects the pace of economic growth and the level of social development. Under conditions of steady population growth, combined with the physical and functional deterioration of a significant share of transportation facilities, there is an increasing need for the adoption of more efficient and economically justified technologies and methods aimed at the construction, operation, monitoring, and rehabilitation of infrastructure assets [1]. In response to these challenges, the transportation sector has experienced intensified efforts toward the development and implementation of innovative solutions, with many technologies and approaches that have previously proven effective in the building industry being adapted for use in infrastructure projects. One of the most effective technologies that has demonstrated substantial benefits in the building sector is Building Information Modeling (BIM) [2].

According to the definition proposed by the U.S. National Building Information Model Standard Project Committee, BIM represents a digital representation of the physical and functional characteristics of a facility and serves as a single, reliable source of information for decision-making throughout all stages of its life cycle, from initial conception to decommissioning [3]. The common misconception of BIM as merely a three-dimensional geometric model leads to a distortion of its fundamental essence, as the core value of BIM lies in the information itself, while the three-dimensional model is only one of the possible means of representing that information. The widespread adoption of centralized approaches to data creation, storage, and sharing has driven a paradigm shift in the Architecture, Engineering, Construction, and Operations (AECO) industry, transforming traditional design practices into information-centric and interdisciplinary collaboration processes. In both academic and professional contexts, BIM is interpreted in multiple ways—as a digital product, a collaborative process, and a lifecycle management tool [4]. The original intent of BIM was to comprehensively capture and structure all information related to the design and construction of a facility in order to support its effective operation and maintenance (O&M) phases.

Although BIM has been actively applied in the design and construction of buildings for several decades, its adoption in transportation infrastructure has been characterized by slower progress and limited practical implementation [5]. In recent years, both the academic community and industry practitioners have increasingly focused on adapting BIM to civil infrastructure assets beyond vertical construction. However, to date, a comprehensive and specialized review dedicated specifically to transportation infrastructure has been lacking. Previous review studies have addressed the application of BIM to existing buildings [6], managerial aspects of BIM implementation [7], the use of BIM as a collaborative platform and data management tool [8], civil infrastructure in a broader sense, infrastructure projects from a contractor's perspective, as well as bibliometric and scientometric analyses of global BIM research [9]. While these studies provide a broad overview of the development of BIM technologies, a systematic analysis of their application to transportation assets—such as bridges, highways, and road networks—remains insufficiently represented in the literature.

In this context, the present paper aims to develop a comprehensive and up-to-date review of studies focused on the application of BIM in transportation infrastructure. The main objective of the study is to provide a critical analysis of existing research directions and practical implementations of BIM in order to identify key trends, challenges, and unresolved issues, as well as to determine перспективes for future research and applied developments. The paper examines current application domains of BIM, the digital technologies employed, their advantages and limitations, and the identified research gaps and emerging needs of the industry. In addition, the study seeks to establish a coherent direction for future research and interdisciplinary collaboration that can enable a more effective exploitation of the potential of digital technologies that have already been successfully implemented in the building sector. A significant outcome of this paper is the synthesis of the current state of research, the identification of critical constraints, and the delineation of promising technological directions required to develop more efficient and economically viable solutions for the modernization, development, and expansion of transportation infrastructure.

2. Materials and Methods

The methodological foundation of this study is a systematic review of scientific publications and applied reports addressing the application of Building Information Modeling (BIM) technologies in transportation infrastructure. The analysis covers studies in which BIM is examined in the context of highways, bridges, tunnels, railway infrastructure, as well as other linear civil infrastructure assets.

The study employed qualitative content analysis and thematic classification methods to examine the selected publications. The reviewed materials were analyzed according to several key criteria, including the stage of the asset life cycle (planning, design, construction, operation, and maintenance), the type of transportation asset, the digital technologies used and their integration methods, as well as the identified benefits and limitations of BIM implementation. Particular attention was given to studies in which BIM was considered not merely as a three-dimensional visualization tool, but primarily as an instrument for information and process management throughout the entire life cycle of transportation infrastructure assets.

The first stage of the study involved identifying scientific journals and information databases that potentially contain publications relevant to the scope of the review. Leading journals in the fields of architecture, construction, civil infrastructure, transportation engineering, information technologies, and related disciplines were examined, along with proceedings of international conferences. Given that a substantial portion of research and pilot projects related to BIM in transportation infrastructure is conducted outside the academic environment, the analysis also included publications from governmental departments, public agencies, professional associations, and industrial organizations.

At the second stage, a comprehensive search for publications addressing BIM in transportation infrastructure was conducted. Due to the diversity of terminology and concepts used in this field, an extended list of keywords and their combinations was developed. The search included not only direct references to BIM, but also related concepts such as Bridge Information Modeling (BrIM), Civil Integrated Modeling (CIM), Civil Information Modeling (CiM), three-dimensional infrastructure modeling, computer-aided design (CAD) for linear assets, and other digital technologies applied in transportation infrastructure. Both academic and applied databases (SCOPUS, EBSCO, Google Scholar) and general-purpose search engines were used. A top-down search strategy was adopted, whereby the process began with broad queries followed by filtering of relevant publications, enabling the identification of studies that may not explicitly use contemporary BIM terminology but are nevertheless pertinent to the subject area.

The third stage involved the collection, filtering, and systematic organization of the selected publications. To minimize the risk of overlooking relevant sources, priority was given to compiling a broad body of literature, followed by the exclusion of non-relevant materials. After the initial screening, the abstracts and keywords of the publications were examined to assess their relevance to the research topic. For publications deemed relevant, an in-depth analysis was conducted, accompanied by the preparation of a concise analytical summary outlining the content, scientific and practical significance, and key findings.

To manage and analyze the large volume of publications, a dedicated application based on Excel VBA (Visual Basic for Applications) was developed to automate the storage, retrieval, and analysis of bibliographic data. The application’s functionality included the input and classification of publications, assignment of thematic categories and keywords, export of references, and execution of analytical procedures. In addition, an import/export function was implemented to enable seamless exchange of bibliographic information with EndNote.

Within the scope of the review, the abstract, keywords, and citation data were recorded for each publication, along with detailed characteristics, including the BIM application domain, life-cycle phase, type of transportation asset, applied technologies and data schemas, as well as the identified benefits and limitations. To analyze the textual data, automated sorting and classification algorithms were developed, along with methods for extracting keywords from abstracts and full-text publications. In total, 478 unique keywords were identified across the analyzed sources and subsequently used for thematic analysis.

It should be noted that, due to the adopted methodology, the review is limited to published and officially accessible materials and does not include ongoing studies whose results have not yet been published. At the same time, given the leading role of industry and governmental bodies in advancing BIM for transportation infrastructure, the review also incorporates reports from projects funded by governmental, professional, and industrial organizations, provided that such reports were officially published.

3. Results

As a result of the conducted systematic review, 189 publications addressing the application of Building Information Modeling technologies in transportation infrastructure were analyzed, including journal articles, conference proceedings, and published reports. The analysis revealed a steady growth of interest in BIM within the transportation sector, particularly after 2012, indicating a gradual transition from experimental and conceptual studies toward practice-oriented applications.

The analysis of publications by information model type revealed a substantial diversity of approaches to data representation and utilization in transportation infrastructure. As shown in Table 1, conventional BIM models and specialized forms such as Bridge Information Modeling (BrIM), which are specifically oriented toward bridge structures, are the most widely adopted. A significant share of the studies focuses on numerical, parametric, and product models, indicating researchers' efforts to adapt BIM to engineering analysis, computational procedures, and the specific characteristics of linear assets. Less prevalent but promising directions include multi-scale models, digital terrain models, and the integration of BIM with Virtual Design and Construction (VDC), reflecting the current stage of BIM maturity in infrastructure projects.

Table 1. Publications regarding BIM for transportation infrastructure based on model type.

Model type	**Publication**
As-built	[5, 10]
Bridge Information Modeling (BrIM)	[11, 12]
Building Environment Information Modelling (BEIM)	[13]
Building Information Modeling (BIM)	[5, 11, 14]
CIM	[15, 16]
Civil Information Modeling (CiM)	[9, 17]
Digital Terrain Model (DTM)	[18, 19]
Finite elements	[20, 21]
Geometric modeling	[22, 23]
Multi-scale model	[24, 25]

Model type	Publication
Numerical modeling	[20, 26]
Parametric models	[22, 23]
Product model	[27, 28]
Tunnel information model	[20, 29]
VDC	[20, 30, 31]

The results of the analysis also showed that a substantial proportion of the publications focus on bridges and highways as the most capital-intensive and critical components of transportation infrastructure. This confirms that these asset types serve as the primary “pilot” domains for BIM implementation, including during the design, construction, and operation phases. In contrast, the application of BIM to railway infrastructure, tunnels, ports, and airports is less extensively represented, indicating the presence of both research and practical gaps in these areas.

The analysis of BIM application areas presented in Table 2 indicates that the primary uses of the technology include planning and schedule simulation (4D), cost estimation (5D), clash detection, data management, visualization, and decision support. A considerable number of publications also address asset management, structural condition monitoring, and inspection processes, highlighting the significant potential of BIM during the operation and maintenance phases of transportation infrastructure.

Table 2. Publication of applications and uses of BIM for transportation infrastructure

Application or use	Publication
Accelerated bridge construction (ABC)	[9, 32]
Adoption	[33, 34]
Advantages and disadvantages	[9, 19]
Analysis	[9, 22]
Appraisal	[33, 35]
Appraisal and assessment	[9, 33]
Asset Management	[9, 33]
Automation	[9, 35]
Best practices	[9, 33]
Bill of Quantities (BOQ)	[9, 36]
Bridge Management System (BMS)	[9, 37]
Cash Flow	[9, 33]
Clash detection	[38, 39]
Collaboration	[40, 41]
Constructibility	[9, 22]
Cost Estimation (5D)	[33, 42]

Application or use	**Publication**
Data management	[18, 33]
Environmental impact	[43, 45]

At the same time, the results indicate that the application of BIM extends beyond traditional design and construction tasks. In several studies, BIM is used as a tool for risk management, safety assurance, resilience analysis, and environmental impact assessment. A distinct group of publications focuses on issues of interoperability, regulatory frameworks, and organizational aspects of BIM implementation, reflecting a transition from isolated technological experiments toward systematic and institutionalized adoption of BIM within the industry.

The aggregated results of the analysis confirm that the current development of BIM in transportation infrastructure is characterized by fragmentation and heterogeneity. On the one hand, there is active advancement of applied solutions and a widening range of tasks addressed through BIM. On the other hand, a continued dependence on specific asset types and software platforms, along with the lack of universal standards and neutral data formats, limits the scalability and interoperability of BIM-based solutions in transportation infrastructure.

4. Discussion

The results of the conducted review confirm that the application of BIM technologies in transportation infrastructure is at an active stage of development and adaptation, which differs significantly from the level of BIM maturity achieved in vertical construction. Despite the steady growth in the number of publications and the expansion of practical applications, BIM adoption in the transportation sector remains fragmented and characterized by heterogeneous implementation approaches.

The dominance of bridge structures and highways within the research landscape, as identified through the analysis of Table 5, reflects both the engineering complexity of these assets and their critical importance in terms of safety, operational costs, and life-cycle performance. The strong focus on Bridge Information Modeling (BrIM) and conventional BIM models indicates that the development of BIM in transportation infrastructure largely relies on the adaptation of existing tools originally designed for buildings. At the same time, the relatively limited number of studies addressing railway infrastructure, tunnels, ports, and airports highlights a substantial potential for expanding the application of BIM within these segments.

The analysis of BIM application areas summarized in Table 6 shows that design activities, schedule planning, cost estimation, and visualization are the most widely addressed tasks. This confirms that BIM in transportation infrastructure is primarily used as a tool to enhance the management and coordination of design and construction processes. At the same time, the significant number of publications focusing on operation, maintenance, condition monitoring, and asset management indicates a gradual shift in the attention of researchers and practitioners toward the full life cycle of infrastructure assets, which is consistent with the original BIM concept as an information foundation for decision-making throughout the entire service life of structures.

One of the key issues identified through the analysis is the problem of interoperability and the lack of neutral data exchange formats tailored to the specific characteristics of linear assets. The diversity of model types, data schemas, and software solutions presented in Table 5, on the one hand, demonstrates an active search for optimal approaches, while on the other hand, it highlights the absence of unified standards capable of ensuring seamless data integration across life-cycle stages and among different project stakeholders. This limitation significantly constrains the scalability of BIM solutions and hinders their widespread adoption at the industry level.

Additional barriers to BIM implementation in transportation infrastructure are institutional and organizational factors. The predominance of public-sector clients, complex contracting procedures, and regulatory constraints often slow down the adoption of innovative digital technologies. At the same time, the results of the review show that the active involvement of governmental authorities and publicly funded pilot projects plays a crucial role in advancing BIM within the infrastructure sector, underscoring the need for strategic governmental support for digitalization initiatives.

An important outcome of the analysis is the identification of a close relationship between BIM and the development of related digital technologies, such as geographic information systems, laser scanning, photogrammetry, sensor-based monitoring systems, and virtual and augmented reality technologies. The integration of these technologies with BIM creates the prerequisites for a transition from static information models to dynamic digital twins of transportation infrastructure. However, the practical implementation of such integrated solutions requires further research, the development of advanced computational platforms, and the improvement of methods for processing large volumes of data.

Overall, the discussion of the results indicates that BIM in transportation infrastructure has significant potential to enhance the efficiency of design, construction, and operation processes; however, its implementation is currently constrained by technological, regulatory, and organizational barriers. Overcoming these limitations is possible through the development of open standards, improvement of interoperability, and strengthened collaboration among the scientific community, industry, and governmental institutions. This provides a foundation for future research aimed at developing sustainable and scalable BIM solutions for transportation infrastructure.

5. Conclusions

This paper presents a systematic review and analytical synthesis of contemporary research and applied developments related to the use of Building Information Modeling technologies in transportation infrastructure. The analysis demonstrates that BIM technologies show a sustained trend toward expanding their application scope and are gradually transforming from auxiliary design tools into a comprehensive information foundation for managing the life cycle of transportation assets.

The results of the study indicate that the highest level of BIM maturity has been achieved in the context of highways and bridge structures, where BIM and Bridge Information Modeling (BrIM) technologies are actively applied during the design and construction stages and are increasingly being introduced into operation, monitoring, and asset management processes. At the same time, the application of BIM to other types of transportation infrastructure, including railways, tunnels, ports, and airports, remains limited, indicating the presence of significant research and practical gaps.

The key factors constraining the wider adoption of BIM in the transportation sector include the lack of unified standards and neutral data exchange formats, insufficient interoperability among software platforms, and institutional and organizational limitations associated with the specific characteristics of infrastructure project delivery. Nevertheless, the results of the review confirm the strong potential of BIM for integration with geographic information systems, remote sensing technologies, laser scanning, and structural health monitoring systems, thereby creating the prerequisites for the development of digital twins of transportation infrastructure.

Overall, it can be concluded that the further development of BIM in transportation infrastructure requires a comprehensive and interdisciplinary approach, including the improvement of regulatory and methodological frameworks, the advancement of open standards, and active collaboration among the scientific community, industry, and governmental authorities. The implementation of these measures will enable the full realization of the potential of BIM technologies and support the transition toward more efficient, sustainable, and economically sound management of transportation infrastructure in the context of the sector's digital transformation.

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References

1. Shi, J., Bai, T., Zhao, Z., & Tan, H. (2024). Driving Economic Growth through Transportation Infrastructure: An In-Depth Spatial Econometric Analysis. *Sustainability*. https://doi.org/10.3390/su16104283.
2. Zhou, D., Pei, B., Li, X., Jiang, D., & Wen, L. (2024). Innovative BIM technology application in the construction management of highway. *Scientific Reports*, 14. https://doi.org/10.1038/s41598-024-66232-5.
3. Abuhussain, M., Waqar, A., Khan, A., Othman, I., Alotaibi, B., Althoey, F., & Abuhussain, M. (2024). Integrating Building Information Modeling (BIM) for optimal lifecycle management of complex structures. *Structures*. https://doi.org/10.1016/j.istruc.2023.105831.
4. National Institute of Building Sciences (NIBS), United States national building information modeling standard version 1—part 1: overview, principles, and methodologies, Final Report, The Northern American Chapter of buildingSMART International (bSI), Washington, DC, 2007 https://buildinginformationmanagement.les.wordpress.com/2011/06/nbimsv1_p1.pdf , Accessed date: 24 October 2025.

A. Bae, D. Lee, B. Park, BIM utilization for optimizing milling quantity and HMA pavement overlay quality, Can. J. Civ. Eng. 43 (10) (2016) 886–896, https://doi.org/10.1139/cjce-2015-0001.

5. Volk, R., Stengel, J., and Schultmann, F. (2014).“Building information modeling (BIM) for existing buildings - literature review and future needs.” Autom. Constr., 38, 109-12, 10.1016/j.autcon.2013.10.023.
6. Q. He, G. Wang, L. Luo, Q. Shi, J. Xie, X. Meng, Mapping the managerial areas of building information modeling (BIM) using scientometric analysis, Int. J. Proj. Manag. 35 (2017) 670–685, https://doi.org/10.1016/j.ijproman.2016.08.001.
7. Z. Aziz, Z. Riaz, M. Arslan, Leveraging BIM and big data to deliver well maintained highways, Facilities 35 (13/14) (2017) 818–832, https://doi.org/10.1108/F-02-2016-0021.
8. Belcher, E., & Abraham, Y. (2023). Lifecycle Applications of Building Information Modeling for Transportation Infrastructure Projects. *Buildings*. https://doi.org/10.3390/buildings13092300.
9. O. Abudayyeh, H.T. Albattaineh, As-built information model for bridge maintenance, J. Comput. Civ. Eng. 17 (2) (2003) 105–112, https://doi.org/10.1061/(ASCE)0887-3801(2003)17:2(105).

A. Bradley, H. Li, R. Lark, S. Dunn, BIM for infrastructure: an overall review and constructor perspective, Autom. Constr. 71 (2016) 139–152, https://doi.org/10.1016/j.autcon.2016.08.019.

10. S.S. Chen, A.M. Shirole, Integration of information and automation technologies in bridge engineering and management: extending state of the art, J. Transp. Res. Board (2006) 1–24, https://doi.org/10.3141/1976-03.
11. S.H. Park, E. Kim, Middleware for translating urban GIS information for building a design society via general BIM tools, J. Asian Architect. Build. Eng. 15 (3) (2016) 447–454, https://doi.org/10.3130/jaabe.15.447.
12. D. Sarkar, Risk based building information modeling (BIM) for urban infrastructure transport project, Adv. Eng. Inform. 10 (8) (2016) 1022–1026, https://doi.org/10.5281/zenodo.1125852.
13. N. Yabuki, Current status of civil construction information modeling (CIM) initiative and projects in Japan, Proc. in Civil Engineering Conference in the Asian Region (CECAR), Aug

31-Sep 2, Waikiki, HI, 2016, pp. 1–6 http://www.eventscribe.com/2016/CECAR7/assets/pdf/267975.pdf.
14. P. Pakkala, J. Myllymaa, J. Sireeni, Bene ts of virtual design and construction in civil engineering in the Nordics, International Road Federation (IRF) Examiner, 12 2017, pp. 27–31 https://www.irf.global/ebooks/IRF-Examiner-17Vol12.pdf.
15. G.D. Reeder, G.A. Nelson, 3D engineered models for highway construction: the Iowa experience, Rep. No. RB33-014, Iowa Department of Transportation, 2015 https://lib.dr.iastate.edu/intrans_reports/130, Accessed date: 23 April 2025.
16. Zhou, Z., Chen, X., Gao, S., Zou, X., & Wu, C. (2023). Overview of Data Management Technology for Transportation Infrastructure based on BIM. *2023 7th International Conference on Transportation Information and Safety (ICTIS)*, 1-9. https://doi.org/10.1109/ictis60134.2023.10243780.
17. Biancardo, S., Viscione, N., Oreto, C., & Russo, F. (2020). BIM Approach for Smart Infrastructure Design and Maintenance Operations. *Transportation Systems for Smart, Sustainable, Inclusive and Secure Cities [Working Title]*. https://doi.org/10.5772/intechopen.94242.
18. Ninić, J., Alsahly, A., Vonthron, A., Bui, H., Koch, C., König, M., & Meschke, G. (2021). From digital models to numerical analysis for mechanised tunnelling: A fully automated design-through-analysis workflow. *Tunnelling and Underground Space Technology*. https://doi.org/10.1016/j.tust.2020.103622.
19. Klinc, R., Gabrščček, D., Česnik, J., Žibert, M., Hostnik, M., & Logar, J. (2021). Development of a Semiautomatic Parametric Method for Creation of an I-BIM Model of a Tunnel for Use in FEM Software. *Journal of Advanced Transportation*, 2021, 1-18. https://doi.org/10.1155/2021/8843277.
20. Vignali, V., Acerra, E., Lantieri, C., Di Vincenzo, F., Piacentini, G., & Pancaldi, S. (2021). Building information Modelling (BIM) application for an existing road infrastructure. *Automation in Construction*. https://doi.org/10.1016/j.autcon.2021.103752.
21. Biancardo, S., Capano, A., De Oliveira, S., & Tibaut, A. (2020). Integration of BIM and Procedural Modeling Tools for Road Design. *Infrastructures*. https://doi.org/10.3390/infrastructures5040037.
22. M. Breunig, A. Borrmann, E. Rank, S. Hinz, T. Kolbe, M. Schilcher, Collaborative multi-scale 3D city and infrastructure modeling and simulation, Proc. in The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-4/W4, Oct. 7-10, Tehran, Iran, 2017, pp. 341–352, https://doi.org/10.5194/isprs-archives-XLII-4-W4-341-2017.
23. M. Breunig, E. Rank, M. Schilcher, A. Borrmann, S. Hinz, R.P. Mundani, Y. Ji, M. Menninghaus, A. Donaubauer, H. Steuer, T. Vögtle, Toward computer-aided collaborative subway track planning in multi-scale 3D city and building models, Proc. in 3D GeoInfo Conference, June 26-28, P.R. China, 2011 http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.468.9191.
24. Shi, C., Jin, Y., Lu, H., & Shi, J. (2023). A BIM-based framework for automatic numerical modelling and geotechnical analysis of a large-scale deep excavation for transportation infrastructures. *Intelligent Transportation Infrastructure*. https://doi.org/10.1093/iti/liad012.
25. Mirboland, M., & Smarsly, K. (2021). BIM-Based Description of Intelligent Transportation Systems for Roads. *Infrastructures*. https://doi.org/10.3390/infrastructures6040051.
26. Antunes, A., Barateiro, J., Marecos, V., Petrović, J., & Cardoso, E. (2024). Ontology-based BIM-AMS integration in European Highways. *Intell. Syst. Appl.*, 22, 200366. https://doi.org/10.1016/j.iswa.2024.200366.
27. Sharafat, A., Khan, M., Latif, K., & Seo, J. (2021). BIM-Based Tunnel Information Modeling Framework for Visualization, Management, and Simulation of Drill-and-Blast Tunneling Projects. *J. Comput. Civ. Eng.*, 35. https://doi.org/10.1061/(asce)cp.1943-5487.0000955.

28. Corrêa, S. (2020). Virtual Design and Construction Application During the Bidding Stage of Infrastructure Projects. *Proc. 28th Annual Conference of the International Group for Lean Construction (IGLC)*. https://doi.org/10.24928/2020/0103.
29. Li, S., Zhang, Z., Mei, G., Lin, D., Yu, J., Qiu, R., Su, X., Lin, X., & Lou, C. (2021). Utilization of bim in the construction of a submarine tunnel: a case study in Xiamen city, China. *Journal of Civil Engineering and Management*, 27, 14-26. https://doi.org/10.3846/jcem.2021.14098.
30. Kenarkoohi, M., & Hassan, M. (2024). Review of accelerated construction of bridge piers - methods and performance. *Advances in Bridge Engineering*, 5. https://doi.org/10.1186/s43251-024-00116-6.
31. Costin, A., Adibfar, A., Hu, H., & Chen, S. (2018). Building Information Modeling (BIM) for transportation infrastructure – Literature review, applications, challenges, and recommendations. *Automation in Construction*. https://doi.org/10.1016/j.autcon.2018.07.001.
32. Liu, Y., Deng, Y., Liu, Z., & Osmani, M. (2024). Integration of Building Information Modeling (BIM) with Transportation and Facilities: Recent Applications and Future Perspectives. *Buildings*. https://doi.org/10.3390/buildings14020541.
33. Shin, M., Jung, J., & Kim, H. (2022). Quantitative and Qualitative Analysis of Applying Building Information Modeling (BIM) for Infrastructure Design Process. *Buildings*. https://doi.org/10.3390/buildings12091476.
34. Valinejadshoubi, M., Moselhi, O., Iordanova, I., Valdivieso, F., & Bagchi, A. (2024). Automated system for high-accuracy quantity takeoff using BIM. *Automation in Construction*. https://doi.org/10.1016/j.autcon.2023.105155.
35. Li, S., Zhang, Z., Lin, D., Zhang, T., & Han, L. (2023). Development of a BIM-based bridge maintenance system (BMS) for managing defect data. *Scientific Reports*, 13. https://doi.org/10.1038/s41598-023-27924-6.
36. Chahrour, R., Hafeez, M., Ahmad, A., Sulieman, H., Dawood, H., Rodriguez, S., Kassem, M., Naji, K., & Dawood, N. (2020). Cost-benefit analysis of BIM-enabled design clash detection and resolution. *Construction Management and Economics*, 39, 55 - 72. https://doi.org/10.1080/01446193.2020.1802768.
37. Hasannejad, A., Sardrud, J., & Javid, A. (2022). BIM-based clash detection improvement automatically. *International Journal of Construction Management*, 23, 2431 - 2437. https://doi.org/10.1080/15623599.2022.2063014.
38. Urlainis, A., & Mitelman, A. (2025). Implementation of a BIM Workflow for Building Permit Coordination in Urban Metro Projects. *J. Inf. Technol. Constr.*, 30, 319-334. https://doi.org/10.36680/j.itcon.2025.013.
39. Kurwi, S., Demian, P., Blay, K., & Hassan, T. (2021). Collaboration through Integrated BIM and GIS for the Design Process in Rail Projects: Formalising the Requirements. *Infrastructures*. https://doi.org/10.3390/infrastructures6040052.
40. Hussain, O., Moehler, R., Walsh, S., & Ahiaga-Dagbui, D. (2023). Minimizing Cost Overrun in Rail Projects through 5D-BIM: A Systematic Literature Review. *Infrastructures*. https://doi.org/10.3390/infrastructures8050093.
41. Oreto, C., Biancardo, S., Abbondati, F., & Veropalumbo, R. (2023). Leveraging Infrastructure BIM for Life-Cycle-Based Sustainable Road Pavement Management. *Materials*, 16. https://doi.org/10.3390/ma16031047.
42. Pibal, S., Bittner, R., & Kovacic, I. (2025). A BIM-Based Framework for Life Cycle, Cost, and Circularity Data Integration in Environmental Impact Assessment. *Sustainability*. https://doi.org/10.3390/su17062656.