Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 73 (2023) 110–117

Transportation Research Procedia

www.elsevier.com/locate/procedia

International Scientific Conference "The Science and Development of Transport - Znanost i razvitak prometa – ZIRP 2023"

Application of building information modeling (BIM) for transportation infrastructure: a scoping review

Ali Pirdavani[a,b,*], Stephano Muzyka[a], Victor Vandervoort[a], Sander Van Hoye[a]

[a]*UHasselt, Faculty of Engineering Technology, Agoralaan, Diepenbeek 3590, Belgium*
[b]*UHasselt, The Transportation Research Institute, Martelarenlaan 42, Hasselt 3500, Belgium*

Abstract

Abstract—Building Information Modeling (BIM) is an emerging technology frequently and thoroughly implemented in the civil construction sector. Yet a complete BIM implementation developed explicitly for the transportation infrastructure sector remains primarily uncharted. The infrastructure sector plays a crucial role in the economy and society. Because of this substance, it is of belief BIM has great potential to increase the overall efficiency and sustainability in this industry. This scoping review will study the many advantages of BIM, while being conscious of the current research gaps and shortcomings concerning a complete BIM implementation into the transportation infrastructure sector. Additionally, this paper will explore future possibilities and directions for the development of BIM. This scoping research will be conducted using a specific methodology ensuring an accurate representation of the available literature, guaranteeing a comprehensive conclusion regarding the recommendations concerning a full BIM implementation into the transportation infrastructure sector.

Keywords: BIM; Building information model; Transportation infrastructure; Road Infrastructure

1. Introduction

Using BIM (Building Information Model) or other cloud-driven information models is a widely covered topic in the construction sector. The aspects of BIM in implementation in the civil construction sector are extensively featured in papers leaving a clear gap in research focusing on the road infrastructure sector. This scoping review focuses on assessing the current state of research regarding the advantages of using BIM in the infrastructure sector, meanwhile identifying the research gaps in the available literature and arranging a clear view of the benefits and future possibilities while addressing the current drawbacks in implementation and providing recommendations to those challenges.

In comparison to civil construction, the research on BIM implementation in the infrastructure sector is limited yet expanding. Recent studies have shown the various aspects of implementing BIM in the design, execution, and maintenance of infrastructure construction. Infrastructure projects require an effective collaboration between multiple parties, the principal aspect where BIM can show its potential in optimizing efficiency. The studies prove an enhancement in project coordination and communication through BIM. Also, recent studies show the many challenges that come with the practical implementation of BIM into the infrastructure sector due to its infancy. The cost of adopting BIM into mainstream

* Corresponding author. Tel.: +32 11 29 2183
E-mail address: ali.pirdavani@uhasselt.be

10.1016/j.trpro.2023.11.898

infrastructure construction is a clear drawback for most construction companies, as well as the lack of supporting software and logistical challenges such as national guidelines and standardization.

This scoping review paper provides a comprehensive overview of the research into the advantages and possibilities of implementing BIM. Moreover, it contributes to identifying the research gaps and current drawbacks of BIM implementation and provides insight into possible recommendations. The findings will inform future research and contribute to the further development of BIM. This extensive review can conclude with facilitating the implementation of BIM into the infrastructure sector.

2. Research Methodology

A specific research methodology is created to ensure a comprehensive review of the available literature. Based on the research objectives, all-inclusive questions were formulated, which will be answered throughout the paper:

- What advantages does BIM have over the current state of information technology in the infrastructure sector?
- What are the current challenges that limit the development of BIM, and what are the shortcomings in research behind BIM implementation in the infrastructure sector?
- Which emerging technologies can make a difference in the application of BIM in the infrastructure sector?
- What are the first steps and the future directions of the development and application of BIM in the infrastructure sector?

A clear boundary regarding the subject determined by the research questions is set to form a search query resulting in the total findings of papers, later reduced based on specific eligibility criteria (Tafidis et al., 2021). A graphed summary is shown in Fig. 1 regarding the selection process.

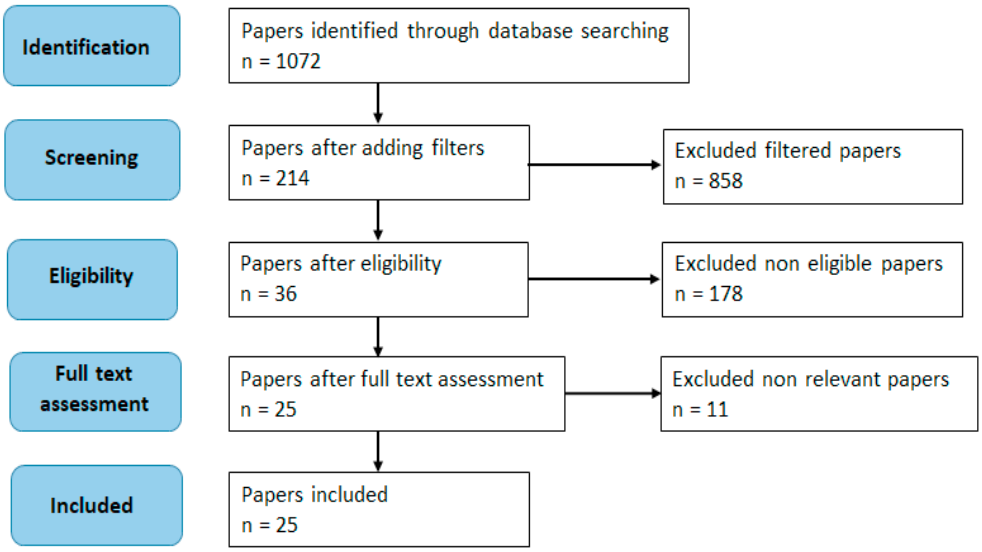

Fig. 1. Literature selection process.

After the literature selection process, all 25 papers will be reviewed, followed by the data charting process. This includes data extraction, where relevant data will be extracted from the selected papers. After the data item charting is done, the extracted data items will be charted for further analysis and efficient utilization of the data items.

3. Synthesis of the results

The research characteristics and charted results specific to every paper will be synthesized in tables to form a

comprehensive summary. This enables a practical discussion based on the research questions and a comprehensive conclusion. Table 1 shows the general information about the used papers.

Table 1 comprises the general characteristics of the specific paper, enabling a clear and comprehensive conclusion in the discussion of results.

Table 1: General study characteristics.

ID	Authors and Publication Year	Reference Country	Methodological approach
1	(Schlosser et al., 2022)	Slovakia	Future possibilities
2	(Juszczyk, 2022)	Poland	Problem-oriented
3	(Vignali et al., 2021)	Italy	Application research
4	(Qu, 2022)	China	Application research
5	(Van Roy & Firdaus, 2020)	Indonesia	Problem-oriented
6	(Bapat, Sarkar, & Gujar, 2022)	India	Literature review
7	(Bapat, Sarkar, & Gujar, 2021)	India	Key Performance Indicators
8	(Chong et al., 2016)	Australia, China	Comparative analysis
9	(Biancardo et al., 2020)	Italy	Application research
10	(D'Amico et al., 2022)	Italy	Future application
11	(Costin et al., 2018)	US	Literature review
12	(Justo et al., 2021)	Spain	IFC Case Study
13	(Moreno Bazán et al., 2020)	Switzerland	Literature review
14	(Čuš-Babič et al., 2022)	Slovenia	Case Study
15	(Rajadurai & Vilventhan, 2022)	India	Case study, literature review
16	(Keskin et al., 2022)	Turkey/US	Specific implementation
17	(Castañeda et al., 2021)	Colombia	Application research
18	(Aziz et al., 2017)	France, UK	Literature review
19	(Patel & Ruparathna, 2021)	Canada	Sustainability assessment
20	(Fanning et al., 2015)	US	Project comparison
21	(Kraatz et al., 2014)	Australia	Case study
22	(Tezel & Aziz, 2017)	UK	Literature review & case study
23	(Zhou, 2022)	China	Systematic model study
24	(Znobishchev & Shamraeva, 2019)	Russia	Specific implementation
25	(Han et al., 2022)	China	Future possibilities

4. Discussion of results

After conducting a comprehensive synthesis of the results, a complete summary will be made to manage the results in an organized manner. This way, the results will be processed and discussed in clear categories. The results are categorized to form a broad conclusion based on the research questions.

4.1 Nuances of BIM

The findings will be discussed to form a clear understanding of all the specific advantages and possibilities BIM enables in the infrastructure sector. While it is clear to see the possibilities, it is crucial to understand the current shortcomings regarding the research behind BIM and the current challenges limiting development and implementation.

4.1.1 Preconstruction

a) Design stage

One advantage of using BIM in the design stage is that different scenarios can be tested using the information available from the traffic engineering analysis. In transportation infrastructure projects, a traffic engineering analysis is already a standard approach but can be extensively utilized with BIM. BIM enables the preparation of a geometrical model, together with the parameterization of objects allowing the model to be treated as a prototype, enabling testing in the preparatory stage. BIM's features significantly reduce the time involved in the design stage by providing real-time control, making a more effective representation of the model. This model's versatility over traditional 3D computer-aided design (CAD) models results in improved efficiency. More specifically, whereas in 3D CAD models, objects are made up of graphical entities only, BIM allows for objects to be defined with specific parameters such as materials, suppliers, etc. (Juszczyk, 2022; Schlosser et al., 2022; Vignali et al., 2021).

Even when BIM shows its advantages, a significant percentage of the construction industry still relies on traditional practices such as CAD software due to, among other things, the resistance to change. A study showed that after surveying multiple staff members, including department leaders, project managers, etc., they continue to use traditional methods(Qu, 2022). Another study showed, after a survey in Indonesia, more than 60% of respondents are still unfamiliar with BIM terminology. The lack of training, experience, and capability with BIM software shows a core problem for BIM implementation(Van Roy & Firdaus, 2020).

b) Modeling

As BIM is such a dynamically evolving technology, it enables the implementation of much more up-to-date modeling than traditional modeling software. Studies show the benefits of High-Definition BIM as being much more detailed modeling, with enhanced quality and, moreover, the detailed availability of information (Bapat et al., 2021, 2022). Also, the principle of parametrization of objects with material cost and suppliers enables a detailed and effective cost and organizational analysis.

As BIM shows its possibilities in modeling, the latest versions of the technology, such as Infrastructure-BIM, allowing all-inclusive models regarding energy infrastructure, are still not yet developed in Europe. Also, coordination obstacles were found when current 2D designs were converted to 3D models to be compatible with BIM software. It was also found that file sizes were often too large to manage with hardware when researching case studies (Biancardo et al., 2020; Chong et al., 2016). Another study showed that BIM had limitations concerning the availability of data regarding the pavement's surface condition and the structure's deeper layer (D'Amico et al., 2022). The sole data pertaining to the pavement's irregularity and obtaining information about the deeper layers are often unreachable. So not much information is available or of accurate origin.

c) Compatibility

Native software is often used for exporting digital data to the open BIM format as (Industry Foundation Classes) IFC files. This open international interchange format allows compatibility between software and BIM platforms. The IFC format is a neutral information model not directly linked to a specific software manufacturer resulting in enhanced interoperability between individual applications (Costin et al., 2018; Justo et al., 2021). Yet BIM software falls short in integrating land use and traffic engineering data because the data extent and type differ from BIM-supported systems used in the design process. A lack of integration with certain specialist software due to the lack of standardization of structural elements in BIM models makes it inevitable to use other software(Moreno Bazán et al., 2020). Also, as the IFC formats allow for effective interoperability, new IFC formats such as IFC4.3 RC1 and IFC5 are under development (Čuš-Babič et al., 2022).

d) Practical aspects

In the preconstruction phase, BIM can also be implemented to improve the efficiency and accuracy of in-field work. BIM models can be used for field reconnaissance as the models are generated based on existing site plans. Also, the layout of a site can be automatically organized and planned in the early stages before the construction starts. Thus, the site layout, logistics planning, and inventory management can be improved due to the simulation in the BIM model. This ensures that no material will run out during construction and reduces unnecessary waste. BIM also allows for a systematic risk management tool to improve safety, made possible through 4D planning. The safety of all parties involved later in the construction phase ensures a safer environment planned(Rajadurai & Vilventhan, 2022).

Moreover, the construction progression can be determined before the construction resulting in the possibility of scheduling in advance. As a study cites, the combination of the model and schedule from BIM into 3D model review software (e.g., Navisworks) enables analyzing the key points of the project resulting in a compiled schedule. In other words, applying BIM in the practical aspects of preconstruction provides a cost estimation to result in a more efficient construction process hereafter(Castañeda et al., 2021; Keskin et al., 2022).

4.1.2 Construction

a) Scheduling and cooperation

The scheduling during the construction phase can also be improved by implementing BIM. The development of the KanBIM Workflow Management System prototype allows for a workflow visualization during construction by integrating the maturity of tasks and enhancing efficient scheduling(Aziz et al., 2017). A study cited that implementing BIM can reduce project durations by 7%, improving project duration and cost(Patel & Ruparathna, 2021).

Infrastructure projects are often complex and involve the cooperation of multiple stakeholders. Another critical aspect is the management of the cooperation between a wide range of involved specialists. Thus far, no all-inclusive supporting BIM software is yet available. Yet BIM allows for efficient cooperation due to the cloud-driven model, collaborative methodologies, and the open communication it enables. The exchange of BIM models is realized via BIM Collaboration Format (BCF) files. Such files make the interchange of exact model objects possible, limiting the size of the transmitted data and resulting in more efficient cooperation. Users can retrieve specific model information accurately based on their inputs. The collaborative workflow, BIM, enables all stakeholders to work together in a common data environment (CDE). And more importantly, the involved stakeholders can provide design alternatives or adjustments to address problems in their areas of expertise efficiently(Fanning et al., 2015). This enhanced management improves the overall efficiency of a project. As one study proved, an overall gain in productivity could be up to 9% after the implementation of BIM(Kraatz et al., 2014).

b) Lean construction

Some studies also prove the extent to which BIM can be implemented to support lean construction. Features such as clash detections enable 4D/5D visual simulations of possible errors in the design phase and, therefore, can be prevented in the construction itself, as well as the factors explained in the practical aspects of the preconstruction phase, such as inventory management resulting in overall lean project management. Also, enabling stakeholders to access and contribute in a cloud-driven virtual environment empowers more efficient and cost-effectively cooperation(Tezel & Aziz, 2017). A lean process is also enhanced by the improvement of onsite logistics, such as space optimization and inventory management, as cited before. As BIM enables effective decision-making, a study still showed the lack of experience slowed down this process.

c) Financial aspect

Certain studies proved an improvement in cost accuracy by 3% and a mitigated cost for unexpected changes by up to 40%. Moreover, the return on investment (ROI) for the implementation of BIM has been reported to be as high as 500%(Kraatz et al., 2014; Patel & Ruparathna, 2021). As BIM shows its potential value as an investment, the high cost of implementation and lack of all-encompassing national standards and skilled personnel still leaves a big bump in the road for companies to invest. Specific studies showed that the implementation of BIM for linear investments is not an easy task. As some pilot projects have been conducted in countries such as Germany, Poland, Australia, and China, it is proven that BIM as a technology is still in its early stages. In most countries, BIM is used at level 1, which involves 2D or 3D models and data exchange. Yet to ensure an effective ROI, BIM must be implemented at level 2, allowing comprehensive analysis from different areas. Another study shows negative cost impacts after the first implementation of BIM, which would be another reason for the holdback on investment(Juszczyk, 2022). A specific case in the United States showed a 70% increase in dollars-per-square-meter when first implementing BIM(Fanning et al., 2015).

4.1.3 Post-construction management

a) Life cycle management

In traditional infrastructure maintenance management, it is often difficult to analyze certain problems, whereas BIM provides a visual analysis monitoring obtained information. This new design approach enables to overview of the entire life cycle of an infrastructure project, including additional information. Thus, BIM is becoming a significant aspect of life cycle management because of the utmost efficient data management(Zhou, 2022). As a result of implementing BIM into the post-construction phase of a project, monitoring, and evaluation are made possible.

Other studies present sustainable road planning- and facility management (FM) tools for the BIM platform. These software integrate the life cycle's social, environmental, and economic dimensions for a full life cycle analysis(Patel & Ruparathna, 2021). BIM and its supporting standards can be used for organizing graphical and sensor-derived information into so-called "meta-data". The data management efficiency is driven by the asset manager establishing a link between the obtained inspection data and the theoretical BIM model stored in a reliable database. Thus, BIM allows for efficient regular maintenance evaluation of the structural safety of infrastructure projects.

Even when BIM has potential in the post-construction phase of an infrastructure project, many shortcomings still need to be considered due to the preliminary approach to implementation. Most infrastructure projects are government contracted, resulting in the government handling maintenance in many cases. This results in the lack of BIM implementation in the post-construction phase. But also, in reality, maintenance applications are not yet fully developed in combination with BIM.

b) Safety management

From a safety management perspective, the advantages of implementing BIM are vital in future infrastructure projects. In more complex civil infrastructure projects such as bridges or tunnels, the workforce is often too theoretical to identify certain problems. Not only this, but also the time-consuming and resource-intensive nature of a safety analysis without the implementation of BIM makes for less profound results and is not worth taking the risk over the investment in BIM. Implementing BIM allows for a systematic risk management tool to improve road users' safety during and after the construction phase. BIM also provides 3D flood simulation and damage assessment taking environmental factors into account to improve the overall safety of an infrastructure project(Rajadurai & Vilventhan, 2022).

4.2 Emerging technologies

After understanding the advantages BIM offers over the current state of construction, it is clear that BIM will have a defined impact on the infrastructure sector. Being such a rapidly evolving technology, BIM will offer increasingly more possibilities as more implementing technologies are transpiring. These emerging technologies will be essential to implementing BIM in the current infrastructure sector. Also, the efficiency of BIM being an actively implemented share in the whole design, construction, and management process will be improved by new emerging technologies.

- *Data capturing and processing*

As a dynamic evolving technology, BIM offers broad compatibility with advanced methods for a more effective and accurate data-capturing process. Many studies show an extensive range of new technologies, such as laser scanning methods, electrical resistivity tomography (ERT) or ground penetrating radar (GPR), and global positioning system (GPS) or geographic information system (GIS) combined with BIM models. Laser scanning and light detection and ranging (LiDAR) techniques enable a very efficient way to measure wide-spread areas accurately. Laser scanning results in a point cloud model of an infrastructure, which has great compatibility with BIM by using intermediate software(Zhou, 2022). As new technologies emerge, laser scanning is being improved in reach, operating speed, and accuracy in combination with unmanned aerial vehicles (UAV) or drones, resulting in mobile laser scanner data (MLD). Other terrain-measuring technologies, such as GPS and radio frequency identification (RFID), are progressively combined with laser scanning technologies. The great accuracy of coordinates and geographical information in combination with GIS showed a progressive improvement in efficiency and compatibility with BIM. Such technologies can be implemented for modeling and deviation detection to analyze infrastructure maintenance projects. Combined with BIM, these technologies enable the as-built documentation to be evaluated with the current situation, enabling a well-maintained pavement due to the graphic representation of the infrastructure(Znobishchev & Shamraeva, 2019).

As laser scanning in combination with GPS/GIS is an effective method for capturing data, it still is limited to surface information. Certain emerging technologies can provide information regarding underground utilities or damages. ERT or GPR and wired or wireless RFID sensors can also be implemented in combination with BIM to provide underground data. A large amount of otherwise unreachable data can be obtained to establish reliable databases that work hand in hand with BIM models, enabling model modifications. Technologies such as ERT can only be carried out on specific points and are limited in the measurement range. Using sensors can extend the range but are financially disadvantageous in comparison to renewable measuring devices. The integration between ground penetrating technologies such as ERT or GPR and surface measuring devices such as MLS has already been successfully carried out in an Italian case study(D'Amico et al., 2022). This resulted in a highly accurate 3D model of the road's pavement with a geometric definition enabled by MLS and underground data obtained with GPR.

- *Virtual reality and augmented reality technologies*

The advantages to infrastructure design and management through a more distinct utilization of the available data by implementing Virtual reality (VR) and augmented reality (AR) result in a more efficient design and construction process by elevating the extent to which data can be used. The ability to compare different scenarios in design and visualize and document the construction process are a few ways to implement and extend the available data through a virtual design. Such possibilities have been explored in a Chinese case study where Navisworks software was integrated, enabling the onsite tracking of the construction progress and enhancing clarity in communication(Chong et al., 2016). Another study presents a new procedural model for the design while implementing visual programming. With software like Rhinoceros and Grasshopper, a complete 3D model including information usable in virtual environments supported by the VisualARQ plug-in was made possible(Biancardo et al., 2020).

The ways through which AR can be implemented in the construction process are with hand-held displays (HHD) or head-mounted displays (HMD). The advantages that come with the implementation of VR or AR are convincing, yet there is a holdback for many construction companies to invest. This is primarily due to the costs that come with implementing such technologies. Not only is adapted software needed, but the cost of obtaining the necessary gear discourages most construction companies from investing.

- *Implementation and management technologies*

BIM-based technologies, such as Integrated-project-delivery (IPD), intelligent management and maintenance models, and visual management practices are being developed to support the management and maintenance. The possibilities, such as touchscreen displays, enable improved model interactivity resulting in enhanced managerial efficiency. Moreover, the combination of BIM with the Internet of Things (IoT) concepts enables an effective implementation of data acquisition exchange and storage, specially developed integrated circuit (IC) prototype systems intended for advanced road construction monitoring and schedule management, enabling efficient data modification and management. In a case study, this principle was applied as an integrated asset management system (IAMS), which replaced 17 separate agency and supplier systems, resulting in a leaner construction process.

In the post-construction phase of transportation infrastructure, it is vital to continue collecting data to maintain the life span intended in the design. Specific technologies such as ERT, GIS, ERP, and RFID can provide such data. The databases of information can be used with BIM to ensure a well-maintained infrastructure due to extensive analyses.

5. Conclusion

Based on the results, the impact BIM can have on the infrastructure sector is revolutionary. As BIM is such a dynamically evolving technology, new possibilities are still being explored. Most of the shortcomings regarding the technical aspect of BIM and its implementation are under development. It can be concluded that the current challenges will be solved shortly as more research is focused on the adoption and integration of these technologies in combination with BIM. However, addressing new issues that will co-occur with new implementation challenges is essential.

The main holdback regarding the full implementation of BIM into the transportation infrastructure is the hesitation of construction companies to invest. This reluctance is due to the cost necessary for a company's efficient implementation of BIM. BIM requires a certain degree of personnel training, but all parties' willingness makes for a very laborious implementation. Also, the probability of a delayed ROI results in hesitancy regarding the investment necessary for fully implementing BIM.

Many studies suggest senior leaders in construction companies must have a comprehensive understanding of BIM and implement it from a strategic point of view. Improving the overall application level requires strengthening the training of personnel and a collaborative effort from all parties involved. This governing commencement should implement comprehensive familiarization schemes covering BIM knowledge and the conviction of the advantages. Furthermore, governments should devise regulations and standards resulting in a nonproprietary, standardized, and neutral exchange format enabling seamless integration of BIM. Another course of action the government should consider is engaging in subsidies, which will result in an accelerated implementation in smaller-scale construction companies. Also, some studies highlight that a stronger collaboration with academia is required for a comprehensive and efficient BIM implementation.

In spite of the fact that BIM is not yet actively implemented in the majority of transportation infrastructure projects, a promising future is to be expected. The advantages achieved by implementing BIM in the design, construction, maintenance, and rehabilitation of infrastructure projects will result in a great motivation to overcome hesitancy and give all the reasons for investing in implementation. Briefly stated, BIM is already a reality in the civil engineering sector and is only a question of time until full integration into the transportation infrastructure sector.

References

Aziz, Z., Riaz, Z. & Arslan, M., 2017. Leveraging BIM and Big Data to deliver well maintained highways. *Facilities,* pp. 818-832.

Bapat, H., Sarkar, D. & Gujar, R., 2021. Evaluation of Key Performance Indicators of Integrated Project Delivery and BIM Model for Infrastructure Transportation Project in Ahmedabad, India through Decision-Making Approach. *Journal of The Institution of Engineers (India): Serie A,* pp. 995-1011.

Bapat, H., Sarkar, D. & Gujar, R., 2022. Application of multi-criteria decision making for evaluation of key performance indicators of integrated project delivery and BIM model for an infrastructure transportation project in

Western India. *International Journal of Construction Management.*
Biancardo, S., Capano, A., de Oliveira, S. & Tibaut, A., 2020. Integration of BIM and Procedural Modeling Tools for Road Design. *Infrastructures ,* pp. 5, 37.
Castañeda, K. et al., 2021. BIM-based traffic analysis and simulation at road intersection design. *Automation in Construction.*
Chong, H. et al., 2016. Comparative Analysis on the Adoption and Use of BIM in Road Infrastructure Projects. *Journal of Management in Engineering - ASCE,* pp. 32, 5016021.
Costin, A., Adibfar, A., Hu, H. & Chen, S. S., 2018. Building Information Modeling (BIM) for transportation infrastructure – Literature review, applications, challenges, and recommendations. *Automation in Construction,* pp. 257-281.
Čuš-Babič, N., Guerra De Oliveira, S. & Tibaut, A., 2022. Interoperability of Infrastructure and Transportation Information Models: A Public Transport Case Study. *Applied Sciences,* p. no. 12: 6234.
D'Amico, F. et al., 2022. Integrating Non-Destructive Surveys into a Preliminary BIM-Oriented Digital Model for Possible Future Application in Road Pavements Management. *Infrastructures,* pp. 7, 10..
Fanning, B., Clevenger, C. M., Ozbek, M. E. & Mahmoud, H., 2015. Implementing BIM on Infrastructure: Comparison of Two Bridge Construction Projects. *Practice Periodical on Structural Design and Construction.*
Han, T. et al., 2022. A BIM-IoT and intelligent compaction integrated framework for advanced road compaction quality monitoring and management. *Computers and Electrical Engineering.*
Justo, A., Soilán, M., Sánchez-Rodríguez, A. & Riveiro, B., 2021. Scan-to-BIM for the infrastructure domain: Generation of IFC-complaint models of road infrastructure assets and semantics using 3D point cloud data. *Automation in Construction.*
Juszczyk, A., 2022. BIM in the construction process – selected problems. *Archives of Civil Engineering,* pp. 623-633.
Keskin, B., Salman, B. & Koseoglu, O., 2022. Architecting a BIM-Based Digital Twin Platform for Airport Asset Management: A Model-Based System Engineering with SysML Approach. *Journal of Construction Engineering and Management.*
Kraatz, J., Sanchez, A. & Hampson, K., 2014. Digital Modeling, Integrated Project Delivery and Industry Transformation: An Australian Case Study. *Buildings ,* pp. 453-466.
Moreno Bazán, Á., Alberti, M., Arcos Álvarez, A. & Trigueros, J., 2020. New Perspectives for BIM Usage in Transportation Infrastructure Projects. *Applied Sciences,* p. no. 20: 7072.
Patel, K. & Ruparathna, R., 2021. Life cycle sustainability assessment of road infrastructure: a building information modeling-(BIM) based approach. *International Journal of Construction Management,* pp. 1837-1846.
Qu, W., 2022. Application of BIM Virtual Technology in Highway Tunnel Construction Management. *Lecture Notes on Data Engineering and Communications Technologies,* pp. 205-212.
Rajadurai, R. & Vilventhan, A., 2022. Integrating road information modeling (RIM) and geographic information system (GIS) for effective utility relocations in infrastructure projects. *Engineering, Construction and Architectural Management,* pp. 3647-3663.
Schlosser, T. et al., 2022. Traffic Planning as a Preliminary Tool in Project Documentation for BIM. *Buildings,* p. no. 3: 381.
Tafidis, P., Farah, H., Brijs, T. & Pirdavani, A., 2021. Safety implications of higher levels of automated vehicles: a scoping review. *Transport Reviews,* pp. 245-267.
Tezel, A. & Aziz, Z., 2017. Visual management in highways construction and maintenance in England. *Engineering, Construction and Architectural Management,* pp. 486-513.
Van Roy, A. F. & Firdaus, A., 2020. Building Information Modelling in Indonesia: Knowledge, Implementation and Barriers. *Journal of Construction in Developing Countries,* pp. 199-217.
Vignali, V. et al., 2021. Building Information Modelling (BIM) application for an existing road infrastructure. *Automation in Construction,* p. Volume 128.
Zhou, Z., 2022. An Intelligent Bridge Management and Maintenance Model Using BIM Technology. *Mobile Information Systems.*
Znobishchev, S. & Shamraeva, V., 2019. Practical use of bim modeling for road infrastructure facilities. *Architecture and Engineering,* pp. 49-54.