IKSAD INSTITUTE
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INTERNATIONAL ISTANBUL MODERN SCIENTIFIC RESEARCH CONGRESS -IV

16-18 DECEMBER 2022

PROCEEDINGS BOOK

EDITED BY
Prof. Dr. Osman ERKMEN

ISBN: 978-625-6404-15-1

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By
IKSAD Institute

www.istanbulkongresi.org
Issued: 30.12.2022
ISBN: 978-625-6404-15-1

CONGRESS ID
ISTANBUL INTERNATIONAL MODERN SCIENTIFIC RESEARCH CONGRESS –IV

DATE and PLACE
16-18 DECEMBER 2022, ISTANBUL
FACE TO FACE AND ONLINE

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EVALUATION PROCESS
All applications have undergone a double-blind peer review process

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INVESTIGATION OF THE USE OF BUILDING INFORMATION MODELING (BIM) IN TRANSPORTATION INFRASTRUCTURE

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ABSTRACT
The share of transport infrastructure in the economy occupies an important place in the financial indicators of many countries. Depending on the population growth, the need for flexible and cost-effective technological tools and methods in sustainability, including maintenance and repair of infrastructure services, is increasing daily. Building Information Modeling (BIM) is a method to prepare 3D models of buildings, including their materials and characteristics while performing advanced energy efficiency analyses that can reduce construction time and material waste. BIM has been widely adopted in vertical architecture for construction, maintenance, and repair works, and there is significant potential for these methods to be useful in the transportation industry. This study aims to examine the intersections of transportation infrastructure in the context of BIM with a current literature review and discuss the results. Based on these discussions, current issues and trends, application and use, emerging technologies, benefits and challenges, limitations, areas where research is needed, and future needs are discussed. Furthermore, the benefits of integrated modeling with geographic information systems (GIS) BIM in construction projects related to transportation infrastructure and the provision of spatial accuracy in this context were highlighted. Although academic studies mainly focus on roads, highways, and bridges, it is evident that the use of BIM in transportation infrastructures is increasing. Transportation infrastructure companies and academia should collaborate to calibrate these results. In addition, the major shortcoming in the literature is that the standards and regulations on this topic are not yet mature.
Keywords: Building Information Modeling (BIM); Geographic Information Systems (GIS); Transportation Infrastructures; Interface Management

1. INTRODUCTION
Transportation infrastructures can be considered the backbone of nation, as the timely, reliable, and efficient transportation of people, information, and products from one point to another contributes significantly to economic and social development. With aging

transportation infrastructures and increasing population growth, more efficient and cost-effective technologies are needed to build, monitor, rehabilitate, and repair structures [**1**]. The transportation industry, which has adopted many proven technologies and methods from the construction industry, has been a major driver in developing and deploying innovative technologies. This method, used primarily in vertical architecture, is known as Building Information Modeling (BIM). The project committee defines the standard: "BIM is a digital representation of a facility's physical and functional characteristics. It is also a source of information through which reliable results are exchanged so that decisions can be made throughout the life cycle, from preliminary design to demolition" [**2**]. Related to this, it is understood that BIM has important uses and contents that can be used in the life cycle management of a facility. Since the purpose of BIM is to capture all information and processes related to the design and construction of a facility, it can also be used for operations and maintenance. BIM is widely used in the construction industry. Although its application in transportation infrastructure has been slow [**3-5**], Industry and academia are making more and more efforts to use BIM in construction infrastructure and produce knowledge-based products. However, no comprehensive review of efforts specific to transportation infrastructure has been conducted yet. The literature studies in the future mainly include BIM applications in administrative processes of buildings, data management applications, and civil infrastructure facilities [**1**]. This paper reviews BIM-related research areas to further facilitate applications in transportation infrastructures.

2. BUILDING INFORMATION MODELING (BIM)

2.1. USING BIM IN VERTICAL ARCHITECTURE

In general, BIM can be used in vertical architecture for the following purposes:

- Visualization,
- Production workspace drawings,
- Automatic production,
- Evaluations related to the regulation,
- Forensic analysis,
- Facilities management
- Cost calculation,
- Structure sequence,
- Disagreement,
- Intervention and conflict research [**6**],

Although it is possible to summarize the benefits of BIM into ten groups, as shown in **Figure 1**, it should be emphasized that the activities that take place from the design process to operation are addressed in different dimensions (**Figure 2-3**).

Figure 1. Advantages of BIM [**7**].

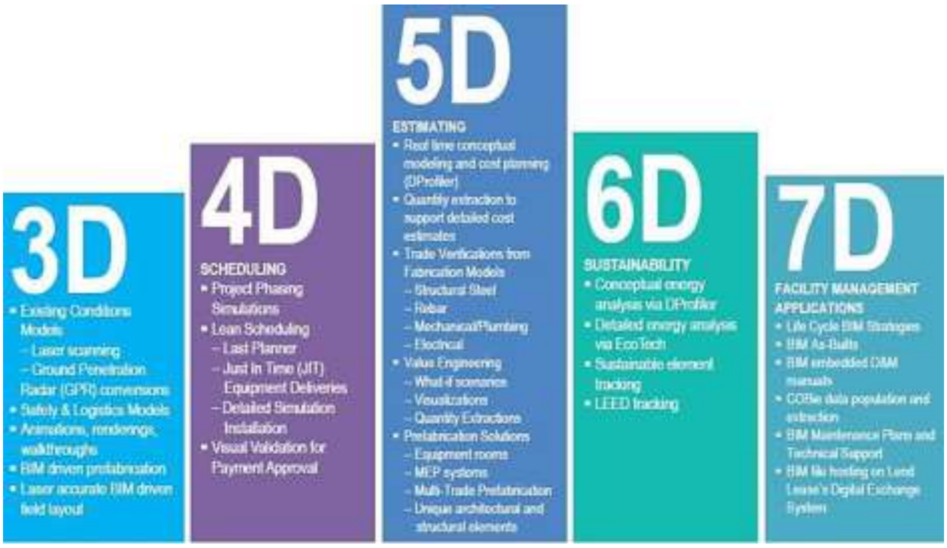

Figure 2. Dimensions of BIM [**8**].

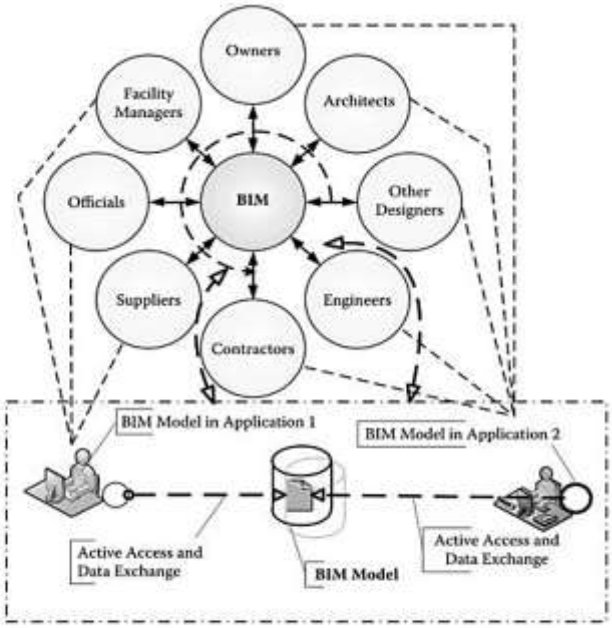

Figure 3. BIM Concept [**9**].

2.2. USE OF BIM IN TRANSPORTATION INFRASTRUCTURES

Worldwide, BIM is mainly used for vertical construction, from design to construction to operation and maintenance [**10**]. Construction projects such as highways, bridges and viaducts, which are among the transportation infrastructure activities, are based on data obtained from the field. At the same time, these projects contain a high percentage of excavation elements. However, the construction activities in vertical architecture are independent of these factors. When the projects in vertical structures are examined, it is seen that they use the Cartesian coordinate system as a single reference. However, when horizontal building projects are examined, they use more than one station and alignment curves. Traditional computer aided design tools primarily use the Cartesian coordinate system. This difference poses a major obstacle to the direct application of traditional BIM for transport infrastructures. **Figure 4** shows the number of articles applying BIM to a transportation infrastructure [**1**]. It can be seen from the research articles that the application of BIM is more common for bridges, highways, and expressways than for other transportation services.

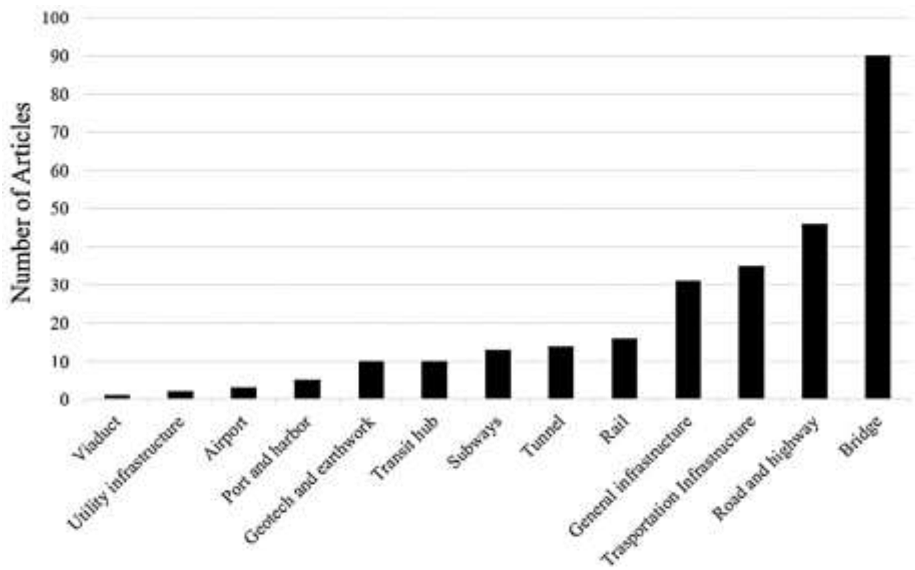

Figure 4. Frequency of Articles by Transportation Infrastructure [**1**].

Since the applications of BIM in transportation are so diverse and the industrial application is relatively new, there are many gaps in the literature in this area. It is significant to note here that a study may focus on more than one transportation infrastructure (e.g., bridges, viaducts, and highways). On the other hand, although the number of BIM applications for transportation infrastructure has increased, the focus has been mainly on highways, expressways, and bridges. It can be seen that the scope for large projects such as tunnels, ports, airports, and viaducts are still limited (**Figure 4**). Developing BIM specifically for these structures can help improve project management, operations, and maintenance while avoiding unnecessary expenditures. However, if we think about smart cities, autonomous vehicles, and intelligent transportation systems, it can be said that there is great potential for the application of BIM technologies. However, the lack of a single standardized format for sharing BIM across different software is a major limitation. Many studies have been carried out to prevent this restriction. However, considering the scope of current standards, it is seen that this situation is limited to large transportation structures (Bridge, highway, railway and tunnel).

2.3. INTERFACE MANAGEMENT IN BIM

Integrating other project management methods for infrastructure construction with BIM can be considered an important literature gap that can produce meaningful results. For example, various project risk management models can be evaluated using developed methods or probabilistic theories (such as Monte Carlo simulation) to gain a deeper perspective. BIM can perform a risk assessment for stakeholders and help visualize the analysis results at this stage, which can increase project success (see **Figure 5**) [**11**].

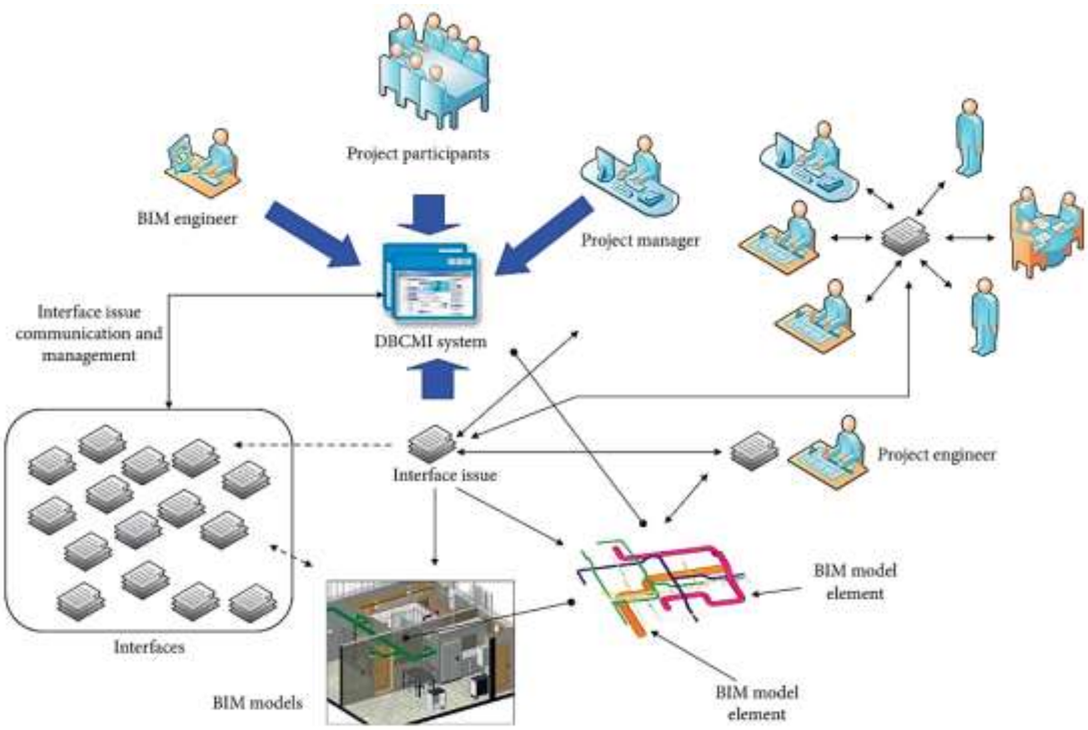

Figure 5. Implementation of the BIM System for Interface Management in Construction [**11**]

Documentation of projects in the as-built phase plays a key role in corporate facility management. Although there are some efforts to use laser scanning technology, the investigation and evaluation of other image capture technologies could be an interesting subject for future research. Accurate reporting of project results is critical to ensure that infrastructure projects are completed on time and within budget. BIM can be evaluated and adapted to this context's alternative and comparable infrastructure project requirements.

Identifying BIM-based reports to address information deficiencies and for more detailed management of infrastructure projects in the future is an important research topic. BIM can be integrated with advanced technologies to focus on finding and resolving legal issues, automatically increasing the efficiency and safety of the construction process for projects requiring work at height. This can help identify hazard indicators early and improve safety during infrastructure construction. Given the risk of collisions and crashes during the construction of high-rise bridges on complex work such as crossing projects, further study into approaches such as occupational health and safety could fill safety gaps in this area. Overcoming the technological shortcomings and challenges of using and combining advanced technologies with BIM can be a common denominator among construction, industry, and surveying researchers. Finally, the use of BIM to assess the environmental effects of infrastructure development is very important area that has received little attention. The benefits of BIM can be enhanced in terms of providing comprehensive information for the sustainability of the project.

3. SPATIAL IMPORTANCE IN BIM AND ITS INTEGRATION INTO GEOGRAPHICAL INFORMATION SYSTEMS

As with any engineering solution, positional accuracy is important in BIM-based projects. For these structures from the land:

- Terrestrial geodetic methods, Laser Scanning Systems, Total Station, Global Navigation Satellite System (GNSS),
- Photogrammetric methods (digital images taken with digital aerial cameras),
- Remote sensing methods (digital satellite images),

the geospatial information obtained by these methods must be accurate, current, and sensitive. Particular attention should be paid to this aspect for BIMs to be created for transportation infrastructure facilities. Here, location accuracy is closely related to the location accuracy of BIM. When collecting information about structures from the land;

- Feasibility studies for obtaining spatial information
- Establishment of a geodetic measurement network in which spatial information is collected,
- Calibration of the measuring instruments used in the measurement network,
- Optimization of the measurement network,
- Coordinate calculations in the measurement network,
- Transfer of spatial data obtained in the field to the computer environment,
- Drawings and models created in the computer environment,

must be considered.

Geographic information systems (GIS) work with graphical information and databases based on this information. As mentioned earlier, positional accuracy is important in implementing projects here. Spatial analysis in 3D-modeled BIMs can be easily performed in the environment of geographic information systems. The integrated operation of urban information systems and BIM projects in urban areas will ensure that information on this subject can be accessed quickly, reliably, accurately, currently, and sensitively. In particular, the implementation of transportation infrastructure along with BIM projects in the GIS environment will provide benefits and advantages in many of the areas as given below:

- Determination and monitoring of deformation and wear of transportation infrastructures over time,
- Cost analysis can be easily performed in all processes and phases from the design of these infrastructures to their project, from construction to operation,
- Facilitation of project management in terms of issues such as time, human resources, materials, and equipment in these infrastructures,

- Optimization of route projects and optimization of route projects such as emergency exits, walkways for the disabled, electricity, internet, water, and sewerage in large terminal structures such as airports, train stations, and bus stations,
- Planning of these buildings that require energy, such as lighting and heating,
- Planning of environmental measures,
- Preventing cost losses in advance through appropriate spatial analysis for the place selection of these buildings,
- Obtaining all kinds of angle, length, area, and position information in the interiors of buildings.
- Working with up-to-date, sensitive and accurate spatial information about buildings

4. CONCLUSION AND RECOMMENDATIONS

Developing a country's transportation infrastructure is critical to its economic development. One of the most crucial problems facing a country's transportation system is aging and deteriorating infrastructures that cannot meet the demands of the times. With the rapid expansion of these networks, conventional management systems are becoming inefficient, making autonomous management systems necessary. By combining BIM with infrastructure management technologies, such as GIS, transportation networks are becoming more reliable, sustainable, and efficient. Moreover, it can reduce maintenance costs and risks associated with operational activities while generating significant revenue for all stakeholders.

In the literature, BIM is primarily used in administrative processes for existing buildings, data management applications, and civil infrastructure facilities. An overview of BIM-related research areas is presented in this study to facilitate the application of BIM in transportation infrastructures.

Although academic works mainly focus on roads, highways, and bridges, it is evident that the use and application of BIM in transportation infrastructures is increasing. The major shortcoming in the literature is that the standards and regulations on this topic are not yet fully developed. Transportation infrastructure companies and academia should collaborate to calibrate these results.

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