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A Bridge Planning Simulation with Building Information Model: Steel Frame Structure

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ABSTRACT: This paper presents a detailed approach to bridge planning and modeling using Building Information Modeling (BIM), focusing on steel frame structures. The implementation of Autodesk Revit Version 2024.1 significantly enhances the precision and efficiency of the planning and modeling process. The methodology involves gathering detailed data references, creating 2D drawings, and developing a comprehensive 3D model for structural analysis and construction design. In the bridge modeling phase, the trusses are constructed using advanced BIM tools, ensuring the structural elements are aligned accurately with the reference framework. This approach facilitates better stakeholder collaboration, improved communication, and more effective resource management. Using BIM technologies and precise data representation in the simulation contributes to better design outcomes, higher accuracy, and improved safety and compliance verification in bridge construction projects. The results demonstrate that integrating BIM in steel frame bridge planning leads to enhanced project efficiency, reduced construction errors, and optimized material use, ultimately supporting long-term sustainability in infrastructure development.

Keywords: bridge planning, steel framed bridge, infrastructure simulation

INTRODUCTION

Bridge planning simulation with BIM and steel frame structures is critical to guaranteeing project security and effectiveness. BIM allows for the creation of detailed digital models that include structural and mechanical components and can be thoroughly studied before construction (Ding, Liu, Liao, & Zhang, 2019). This detailed modelling aids in the early detection of possible difficulties, allowing for more informed decisions that improve bridge performance and safety. Designers can ensure the bridge's robustness and resilience by modelling various scenarios, such as carrying loads and environmental pressures (Hao, Bi, Chen, Pham, & Li, 2023). This proactive strategy reduces the possibility of costly changes or failures throughout the construction process.

One of the primary advantages of adopting BIM in bridge planning is the ability to run thorough simulations and evaluations. Engineers can simulate various loads and stresses the bridge will face, including traffic weight, wind forces, and thermal expansion. This approach aids in understanding how the steel frame structure will perform under different circumstances to guarantee that the design is solid and resilient (Rad, Jalaei, Golpour, Varzande, & Guest, 2021). Identifying possible vulnerabilities or areas of concern during the planning stage lowers the likelihood of structural failure (Vlachakis, Vlachaki, & Lourenço, 2020). This proactive strategy improves the overall longevity and safety of the bridge.

BIM also helps to facilitate collaboration among the numerous stakeholders engaged in the bridge project. Architects, engineers, contractors, and clients may all use and contribute to the BIM model, guaranteeing that everyone involved understands the design and construction process. This collaborative method enhances communication, avoids misconceptions, and ensures all partners agree regarding the project's goals. Additionally, it enables improved resource coordination and scheduling (Abobakirov, 2023). This results in a quicker and simplified construction procedure.

Integrating steel frame structures into the Building Information Model (BIM) has additional advantages, such as exact detailing and material optimization. The digital image of steel components enables accurate manufacture and assembly, reducing waste and errors. BIM's ability to create accurate shop drawings and manufacturing instructions guarantees that steel items are built to precise specifications (An, Martinez, Al-Hussein, & Ahmad, 2020). This results in a more durable build. Steel frame constructions are perfect for bearing the dynamic loads encountered by bridges due to their strength, durability, and flexibility, which improves the construction's overall reliability (Jingquan Wang et al., 2021).

Using BIM in bridge planning for steel frame construction improves project efficiency, safety, and quality. BIM's rich modelling and simulation abilities enable designers to construct more accurate and affordable bridge designs (Yang, Han, Zeng, & Sun, 2021). This strategy lowers the likelihood of structural failures while improving the bridge's overall lifespan performance (Peng, Yang, Bian, Zhang, & Wang, 2022). Innovative technologies such as BIM will be critical as infrastructure requirements rise. Combining BIM with solid materials such as steel will aid in constructing long-lasting bridges.

Literature Review

Bridge Planning

Bridge planning is an essential aspect of civil engineering that guarantees safe and practical construction. Traditional techniques of bridge planning relied mainly on manual computations and 2D drawings, frequently resulting in inefficiencies and inaccuracies (Feng Wang et al., 2022). The emergence of modern technology, such as Building Information Modeling (BIM), has transformed the profession. BIM enables the production of detailed 3D models encompassing all aspects of bridge design, including structural components and mechanical systems. BIM in bridge planning dramatically improves accuracy and minimizes the possibility of design errors, resulting in increased bridge safety and reliability (Wei et al., 2021).

Recent research has also shown great interest in applying steel frame constructions to bridge design. Steel, known for its rigidity, resilience, and adaptability, is an excellent choice for bridge construction, particularly for structures that must handle dynamic loads. Combining steel frame structures with BIM can result in more optimal designs (Basta, Serror, & Marzouk, 2020). The precision provided by BIM enables correct detailing and production of steel components, reducing waste and construction errors. This synergy between BIM and steel frame constructions has been shown to increase the effectiveness and standard of bridge construction projects (Costin, Hu, & Medlock, 2021).

Cooperation among partners is an essential component of bridge planning, which has been improved using BIM. Misunderstandings and a lack of cooperation among architects, engineers, contractors, and clients were common issues in traditional project management.

However, BIM offers a collaborative environment where all stakeholders can access and contribute to the project's unified model (Mohammed, 2020). BIM-enabled collaborative approaches improve communication, align project goals, and provide improved resource and scheduling coordination. The result is more straightforward, more efficient construction management, with fewer complications and price overruns.

Finally, the long-term advantages of incorporating BIM with steel frame constructions into bridge design go beyond the building period. Bridges designed and built using these technologies offer superior long-term performance and durability. BIM allows for ongoing monitoring and maintenance planning by giving precise documentation and a clear picture of the bridge's structural health. This proactive approach to maintenance and the inherent benefits of steel frame structures guarantees that bridges are safe and functioning for their service lives (Simon, 2022). As infrastructure needs rise, these advanced technologies' continued development and deployment will be critical to solving future problems and developing resilient infrastructure.

Steel Framed Bridge

Steel-framed bridges have been a staple of bridge engineering for decades, and they are known for their strength, longevity, and ability to cross large distances. Steel has been used in bridge construction since the nineteenth century, and its use has evolved dramatically as materials science and engineering methods have advanced (Di Lorenzo, Formisano, Terracciano, & Landolfo, 2021). New steel alloys used in bridge building have superior performance qualities, such as high tensile durability and resistance to fatigue and oxidation (Kowal & Szala, 2020). These features make steel an excellent choice for bridges that handle enormous weights and adverse weather conditions.

Modern engineering tools and procedures have improved steel-framed bridge planning and building. Building Information Modeling (BIM) has become a game-changing tool in this area. BIM enables the production of full digital models containing extensive information about the steel parts and how they interact within the bridge structure. BIM in steel bridge design allows for more precise details, increases fabrication accuracy, and decreases the possibility of construction errors (Shim, Dang, & Park, 2018). Integrating BIM with traditional engineering procedures has improved effectiveness and affordability in bridge construction operations.

One of the most significant benefits of steel-framed bridges is their versatility and ease of maintenance. Steel constructions can be built in controlled conditions, which allows for better quality control and speedier on-site assembly (Pasco, Lei, & Aranas Jr, 2022). This prefabrication technology decreases building time and has a lower environmental and community impact. Furthermore, the modular structure of steel components facilitates maintenance and repairs. Steel bridges are easier to maintain over time than other materials because broken sections can be repaired without causing significant disturbance to the whole structure (Khedmatgozar Dolati, Caluk, Mehrabi, & Khedmatgozar Dolati, 2021).

Recent research has additionally concentrated on the sustainability of steel-framed bridges. Steel is highly recyclable, and most modern steel bridges use recycled elements. This helps to reduce the overall environmental impact of the construction procedure. Using robust steels that use fewer resources to attain the same strength improves the long-term reliability of steel bridges (Puklický, 2023). Steel-framed bridges are a sustainable option for future construction projects due to their longevity, recyclability, and low material usage (Seppälä, 2018). As environmental concerns grow, the role of steel in building durable and eco-friendly bridges will remain a primary focus of development and research.

Infrastructure Simulation

Infrastructure simulation is now a critical tool for modern civil engineering, offering a virtual environment to test and improve infrastructure projects before construction. Engineers can use simulation technology to model complicated systems and forecast their behavior under different conditions, allowing them to spot possible problems early in the design process. Infrastructure modelling dramatically improves the results of projects by allowing for a thorough examination of structural performance, distribution of loads, and environmental implications (Costin, Adibfar, Hu, & Chen, 2018). These simulations assist in making educated decisions that improve infrastructure projects' safety, efficiency, and long-term viability.

One of the most significant advances in infrastructure simulation is the incorporation of Building Information Modeling (BIM). BIM provides an extensive framework that integrates 3D modelling with schedule, cost, and efficiency data to generate a multidimensional project perspective. BIM in infrastructure simulation offers a more comprehensive construction planning and management approach. It enables the viewing of building sequences, the detection of potential conflicts, and the optimization of the distribution of resources. This integration simplifies the construction process and eliminates the possibility of costly delays and reworking.

Infrastructure simulation can also be used to maintain and manage existing structures. Simulation technologies can simulate material aging and the impacts of wear and tear over time, allowing engineers to build more effective maintenance procedures. Predictive maintenance models based on simulation data can dramatically increase the lifespan of infrastructure assets by forecasting breakdowns and scheduling timely repairs (Jambol, Sofoluwe, Ukato, & Ochulor, 2024). This proactive maintenance approach protects infrastructure's dependability and safety while lowering maintenance costs.

Sustainability is another crucial area in which infrastructure simulation has a huge impact (Thacker et al., 2019). Simulations can evaluate the environmental performance of construction projects, including energy consumption, carbon dioxide emissions, and resource use. Simulation techniques can create infrastructure that reduces environmental impact while increasing resource efficiency. By including sustainability indicators in the modelling process, engineers may create infrastructure solutions that suit current needs and contribute to long-term environmental objectives (Whyte et al., 2020). As the demand for environmentally friendly buildings develops, the role of simulation in accomplishing these goals will become more essential.

RESEARCH METHODOLOGY

The methodology for this study includes designing a steel-framed bridge using 3D modelling. The obtained data will generate a 3D model of the steel-framed structured bridge using Autodesk Revit programs, including structural details and bridge abutment-specific features. The BIM modelling method will be used on the steel-framed structured bridge project, and its usefulness in improving effectiveness and precision in the design and planning processes will be evaluated.

In addition, this study searches worldwide and national publications for literature references using Google Scholar. Google Scholar provides easy access to high-quality worldwide and national literature sources.

RESULT AND DISCUSSION

Bridge Data Phase

The author thoroughly searches for data references before performing a modeling simulation for bridge planning with BIM. These references are crucial for creating an accurate abutment modelling simulation. The data collected will be simulated using Autodesk Revit software, specifically Version 2024.1, which is well-suited for detailed 3D modelling of structural components. Since the bridge is a Truss Bridge created for small vehicles and pedestrians, the length will be 8 meters long.

One of the buildings that can be modeled and worked on with the Building Information Modeling (BIM) concept is a bridge. A bridge is a structure built to connect two parts of a road that are disconnected due to obstacles. The bridge itself certainly has different shapes, types, and functions, according to the initial plan for building it. One type of bridge commonly built is a steel truss bridge, where the construction is in the form of a series of steel rods that are connected and form a single unit.

Bridge Modelling Phase

To model trusses in Revit, start by opening the architectural template. Please switch to a 3D view to see the existing levels, then create reference planes in Level 1, naming them A and B for clarity. Next, draw model lines to form the framework of the trusses. Use the 'Model Line' tool (shortcut: LI) to draw vertical and diagonal lines and copy them to create a repeating pattern. Switch to the South elevation, set the work plane to reference plane A, and draw additional lines to form the truss structure. Use the 'Copy' command (shortcut: CO) to duplicate and align the trusses across different reference planes. In 3D view, connect these trusses using model lines at various levels, ensuring the structure looks cohesive. Switch to the 'Structural' tab and use the 'Column' and 'Beam' tools to place structural elements. For slanted columns, enable 3D snapping and connect points on the model lines. Alternatively, use the 'Beam' tool (shortcut: BM) and adjust the end level offset to make beams slanted.

Fine-tune the structure by trimming beams and columns using the 'Cope' tool (shortcut: CP), which allows you to make precise cuts and adjustments for a seamless fit. This method ensures that the structural elements align perfectly with the reference framework. Finally, the structure should be reviewed in 3D to ensure accuracy and completeness.

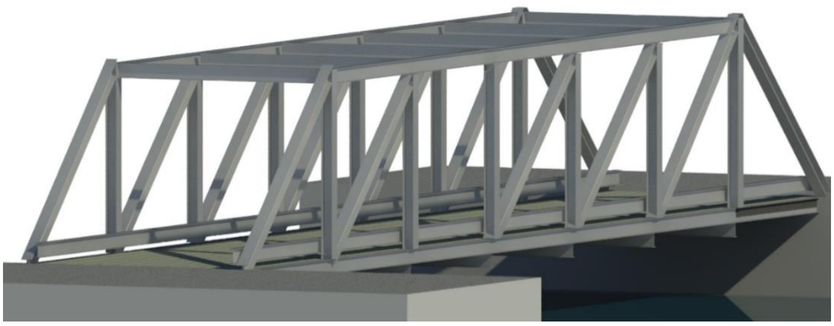

Figure 1. Truss Bridge Model.

Considering the process above, Building Information Modeling (BIM) is a unified technological device. All processes in it work in an integrated manner on a digital model that can be interpreted as a three-dimensional form. The system then manages and produces construction data using 3D, real-time software, and dynamic modeling to increase the productivity of its design and construction.

Before construction, precisely in the planning phase, modeling is needed in the form of Shop Drawings, which will later produce a planning product in the form of DED (Detail Engineering Design) and Built Drawing. At certain stages, this modeling can be done in the post-construction phase to ensure whether the structure of a building is feasible based on the effectiveness and efficiency of work methods, material selection, and function of a building. In addition to modeling, in the planning phase, it is also necessary to first calculate whether the model that has been made can withstand the planned load so that the building does not collapse and experience damage. With BIM, modeling, and calculations can be carried out in line and well-integrated so that the errors caused are fewer than those caused by conventional methods.

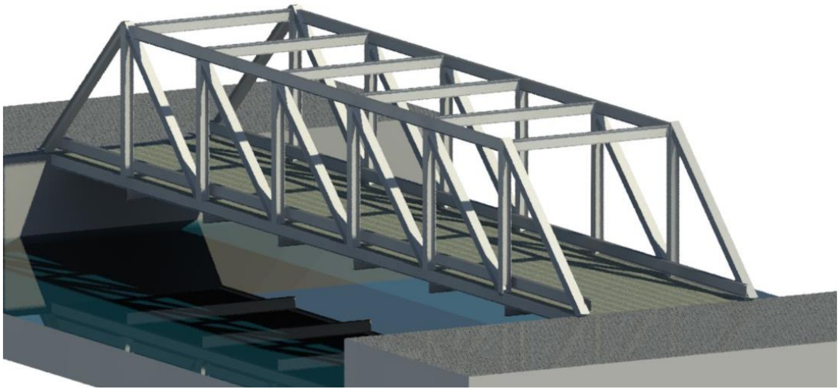

Figure 2. Truss Bridge Model

In a construction project, three essential things must be considered: time, cost, and quality. These three crucial things in their implementation must be controlled as well as possible so that what is arranged in the planning stage can be implemented properly. Things that must be considered in managing the time of a construction project are related to the planning of the Time Schedule and S-curve. Construction costs are associated with the selection of materials, volume of work, and Unit Price of Work from each aspect needed for preparing the Cost Budget Plan. The quality of a construction project must be maintained and guaranteed by the planning and standards made in the technical specifications and ultimately related to the durability of the building when it is completed. With the technology development discussed previously, these aspects can also be controlled with a Building Information Modeling (BIM) system.

One solution in completing bridge planning is to use BIM (Building Information Modeling). The digital model of BIM has a form, geometry, and information that describes the actual building design. This model is a digital object, not just a collection of geometric lines. One model in BIM is a database that can output all the information needed to plan construction, starting from the appearance, floor plan, details, scheduling, and other information. Because the BIM model is a unit, changes to one of the data will be directly applied to the entire model so that if there is a change in the design, the existing reports and data will also change according to the new design. With BIM, reports can be created automatically and integrated, such as making a construction schedule.

In the preparation of the schedule using BIM, it can be seen which objects are being worked on. If there is a design change, such as a change in the number of objects or the object's volume, the schedule will automatically adjust to the new design volume. The results and information obtained from BIM are deterministic, and all variables are inevitable, according to the data entered. In scheduling using BIM, the duration of each object will follow the previously determined data. In fact, in construction practice, some variables are uncertain or probabilistic. Therefore, in designing construction and scheduling methods, data obtained from BIM needs to be integrated with a probabilistic model to describe the actual conditions using probabilistic analysis.

CONCLUSION

The laborious process of gathering complete data references, making detailed 2D drawings, and creating an accurate 3D model with Autodesk Revit Version 2024.1 improves the precision and dependability of bridge planning models in BIM for steel frame constructions. As a result, the simulation establishes a solid platform for structural analysis, construction design, and compliance verification. By utilizing advanced BIM technologies and precise data representation, the bridge planning simulation produces higher accuracy and better design outcomes, ultimately adding to the bridge construction project's success.

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