

Application of BIM + VR Technology in Highway Design and Construction

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Abstract: The application of building information modeling (BIM) and virtual reality (VR) has become increasingly popular in highway design and construction, aiming to improve the efficiency and quality of design and construction. BIM and VR technology enable the digital management of expressway design and construction, facilitating a visual, interactive, and immersive operational experience. Using a highway construction project as a case study, this paper illustrates the specific application of BIM + VR technology in highway design and construction. This provides digital, intelligent, and efficient solutions for highway construction, ultimately enhancing the quality and efficiency of the design and construction processes.

Keywords: BIM; VR; Highway design; Construction application

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1. Introduction

China's highway construction industry has been developing rapidly and has become an important part of its economic development. It is necessary to make rational use of various advanced technologies in the design and construction stages. The design and construction scheme can be optimized through the combination of building information modeling (BIM) and virtual reality (VR) [1-4]. At the same time, the information distortion during the transmission process can be reduced, which facilitates the rational utilization of various resources. For example, BIM technology and VR technology can be effectively integrated in the process of expressway construction, in which and the engineering model is built using BIM technology, the model is experienced through VR. In this way, the design plan and construction plan can be better displayed, so as to better meet the needs of road construction.

2. Project overview

The project taken as an example involves a highway route with a total length of about 60 km, which is an important traffic artery in the area. The terrain in this area is dominated by plains and hills, and the climate is semi-humid and semi-arid. Therefore, the highways in this area are highly affected by the mountainous terrain, which makes the construction of highways challenging. Besides, this area also consists of many mountainous and hilly areas.

3. Application of 2BIM + VR technology in expressway design and construction

3.1. The process of BIM + VR technology application

The overall flow of BIM + VR technology application is shown in Figure 1 and Figure 2.

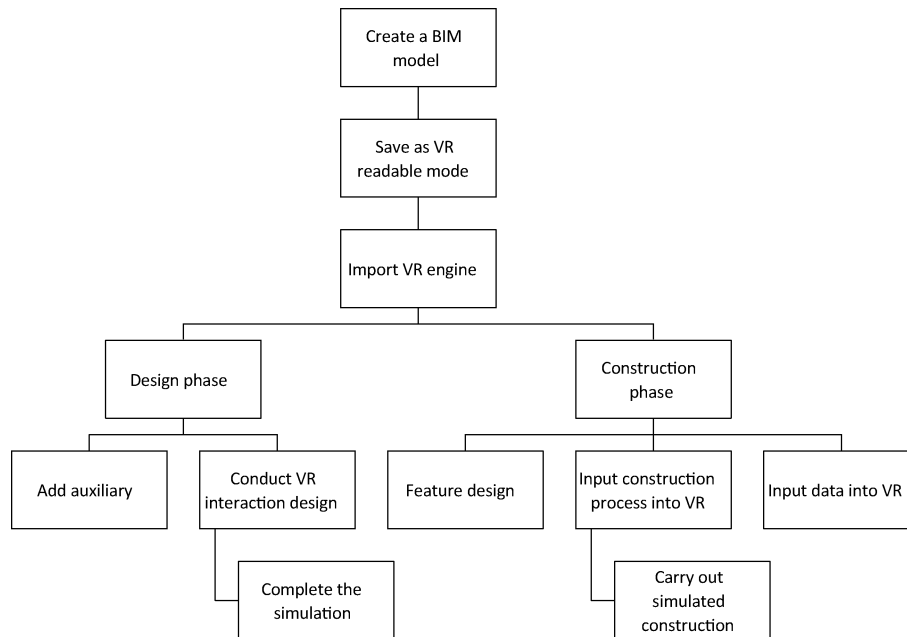


Figure 1 BIM + VR technology application scheme

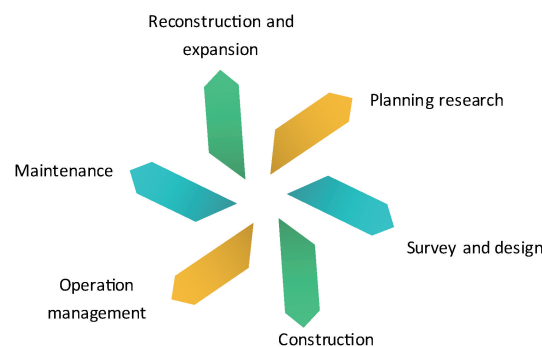


Figure 2 Areas of application

3.2. BIM three-dimensional model

This project used more than ten BIM software from Autodesk, such as Revit and Navisworks, to gather geographical, meteorological, and geological data, including topographic maps, exploration reports, and meteorological data^[5-6]. BIM software was used to establish the geometric model of the highway, including roads, bridges, tunnels, electromechanical equipment, etc. It is necessary to add attribute information while establishing the model, including materials, structures, functions, etc. Incorporating attribute information enhances the model's description and improves efficiency and accuracy. In the process of building a 3D model, it is necessary to establish an associative relationships, including the relationship between structures, the relationship between equipment and pipelines, etc. Establishing associative relationships enhances the model's description and improves the model's reliability and accuracy. Moreover, collision detection should also be carried out during the design stage, including collision

detection between different disciplines, different structures, etc^[7-8]. It is also important to continuously improve the details of the model, which includes tasks such as processing and optimizing details, analyzing and optimizing the structure, and calibration (Figure 3 and Figure 4).

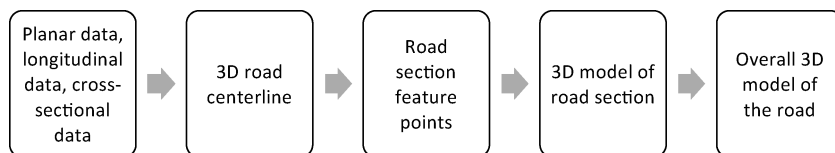


Figure 3 3D model generation process

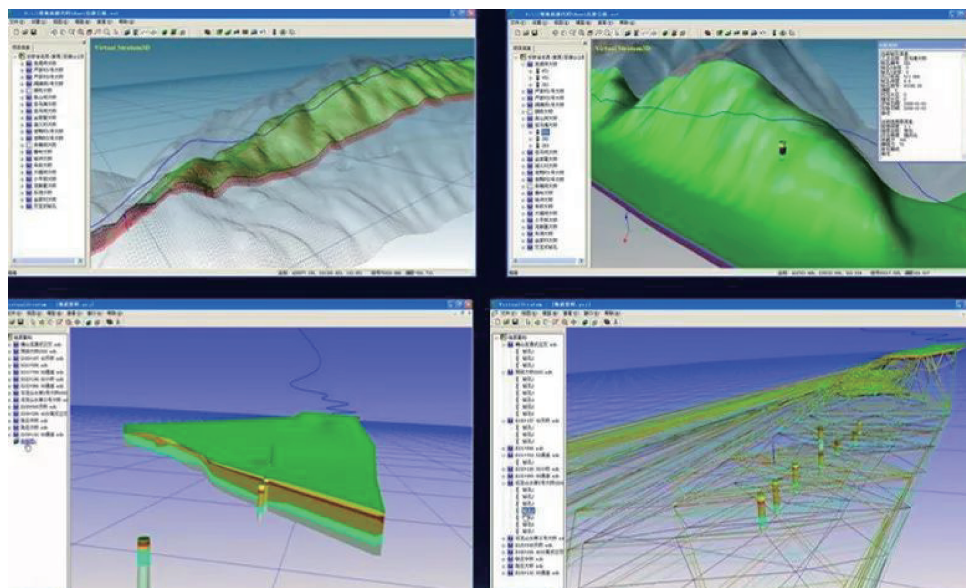


Figure 4 BIM 3D model

3.3. 3D visualization enhanced disclosure

The 3D-visualization-enhanced disclosure simulates and display the design and construction process of the expressway by using BIM technology and 3D visualization technology to improve the accuracy and efficiency of disclosure. The 3D model is visualized in terms of appearance, color, texture, etc. of the model. In the process of 3D visualization, interactive functions can be added, including roaming, zooming, rotation, etc^[9-10]. By adding interactive functions, the disclosure can be made more flexible and convenient. BIM can be used for construction simulation, including the simulation of the construction process and progress. Following the completion of enhanced 3D visualization, disclosure documents can be generated, encompassing design and construction drawings, among others. By outputting disclosure documents, the results of the disclosure process can be recorded and saved to facilitate subsequent construction and management (Figure 5).

3.4. GIS + BIM site layout optimization

Geographic information system (GIS) technology is used to collect geographic information data along the expressway, including terrain, landform, hydrology, meteorology and other data. By processing and managing these data through GIS, we can better understand the geographical environment of the construction site and provide basic data for site layout optimization. In the process of building models, the construction site layout should be considered, including temporary facilities, material storage yards, and

the placement of construction machinery^[11]. The established GIS model is combined with the BIM model to integrate geographic environment information and construction facility information. The GIS+BIM model is utilized for site analysis, encompassing terrain analysis and visual analysis. Upon completion of the site layout optimization design, an optimized facility layout diagram and a road planning diagram is created.

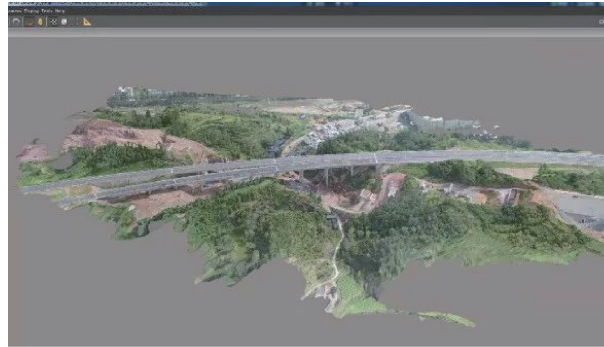


Figure 5 Overall rendering of expressway

3. 5. 3D Collision check optimal design

In this project, Navisworks was employed to detect collisions among prefabricated box girder steel bars and bellows, including 40-meter orthogonal and 30-meter oblique components, and 20 collisions were found. An analysis of the collisions was conducted, and the coordination data was generated, which was submitted to the designer^[12]. The designer optimized the design drawings based on the results of the collision detection, thereby avoiding changes in the design in the later stages and rework.

3. 6. BIM-assisted calculation of engineering quantities

Revit form function was used to obtain the quantities of U-shaped bridges, prefabricated box girders, and cover girders, and a bill of quantities for concrete and steel bars was compiled to provide an accurate basis for project cost and cost control^[13]. For the Ronghe road section, an unmanned aerial vehicle pitch camera was used along with Smart3D to realize the accurate measurement of earthwork excavation, transportation, and other aspects of the road section.

3. 7. Construction simulation based on BIM

In the process of construction simulation, it is necessary to select the appropriate software according to the type of project to ensure that various scenarios can be simulated successfully. The software can be used along with BIM to realize construction simulation, and the data such as the overall progress of the project, resource requirements, and engineering quantities can be managed effectively. Construction simulation refers to simulating various resources involved in the project, and the construction plan can be modified according to the actual situation. In the process of construction simulation, it is necessary to ensure that the project progresses according to schedule, and that different stages of the construction are well-connected^[14-15]. At the same time, it is also necessary to determine the relationship between various resources and predict and evaluate possible problems. Besides, it is necessary to collect, organize, and analyze various information to form a relatively comprehensive plan and perform quantity survey based on the plan to make scientific and reasonable arrangements for the entire project. During the construction simulation process, it's essential to integrate the construction plan with the project's actual situation in order to effectively manage the entire project (Figure 6).



Figure 6 Road rendering

3. 8. Construction simulation using VR

In the process of highway construction, it is necessary to utilize various advanced technologies, and the use of BIM and VR is a great example of that. Specifically, VR technology can be used to simulate various scenes in the highway construction process through models. When using VR for construction simulation, information can be input into the BIM model, and the changes will be simulated accordingly. In this way, various problems in the actual construction process can be effectively solved. For example, in the process of expressway construction, various processes and sites can be virtualized. When problems are found, effective measures can be taken in time to solve them. In addition, it is also possible to simulate and analyze the progress and quality of the entire project, so as to realize the optimization of the entire project (Figure 7).



Figure 7 Signboard rendering

3. 9. BIM collaborative management platform

Many construction companies were involved in the engineering, procurement construction contract, which made communication and coordination between companies relatively difficult. Therefore, the project team proposed a BIM collaborative management platform for roads and bridges, which aimed to achieve resource sharing and efficient collaboration among participating companies such as construction companies, supervision companies, design companies, and consulting companies. This platform effectively connects BIM models from various industries with two-dimensional construction drawings, engineering documents, and materials. This integration was aimed at encompassing project factors such as quality, safety, schedule, cost, and environment. This enabled real-time monitoring of project sites, allowing project managers to swiftly access information from login to query, typically within seconds. Compared to conventional construction, problems were reduced through this platform, and the coordination among

participating enterprises was improved, which in turn increased the efficiency of information exchange between enterprises.

3. 10. BIM intelligent monitoring system

Due to problems such as insufficient control of the construction progress of the expressway project and difficulty in ensuring the quality of the construction link, the project team integrated BIM technology with computer network communication technology to build the Ronghe Expressway Intelligent Monitoring System. The monitoring system showcases on-site construction via video and project completion outcomes. It merges this visual representation with actual project progress within the BIM model and 3D construction simulations based on BIM. This intelligent monitoring system empowers project managers to swiftly understand the project's status. In this way, delays in the construction progress of important sub-projects can be avoided.

4. Conclusion

With the rapid development of our country's economy and society, the demand for transportation is increasing. Concurrently, computer, information, and intelligent technologies are advancing, leading to the widespread adoption of BIM+VR technology in expressway design and construction. This technology can not only improve the level of engineering design significantly, but also increases the efficiency of expressway construction. At present, BIM + VR technology has been effectively integrated with other advanced technologies in many highway projects, and the efficiency of design and construction has been largely improved.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Wang H, 2022, Application Research of BIM Technology in Highway Engineering Design Stage. *Dazhong Science and Technology*, 24(09): 28–30 + 9.
- [2] Gong W, 2020, Comparative Analysis of the Application of LiDAR Technology in Highway Survey and Design with Various Loading Methods. *Highway*, 65(08): 27–31.
- [3] Wei E, 2022, Application of Impact Rolling Technology in the Design of Expressway High-Fill Embankment. *Heilongjiang Communication Science and Technology*, 45(04): 55–57.
- [4] Liu Z, Pei Y, 2022, Application of BIM Technology in the Design and Construction Management of Expressway Interchanges. *North Communications*, 2022(02): 50–53 + 56.
- [5] Chen G, Peng G, 2022, Application of BIM Technology in the Engineering Design of Suxi-Changzhou South Expressway. *Urban Road Bridge and Flood Control*, 2022(01): 221–224 + 244 + 25–26.
- [6] Li X, Deng X, 2021, Application of BIM Technology in Forward Design of Expressway Tunnel. *Western Communications Technology*, 2021(06): 122–125.
- [7] Pan P, Song F, 2020, Exploration and Practice of BIM Technology in the Design of Xi'an Outer Ring Expressway. *Road Construction Machinery and Construction Mechanization*, 37(12): 59–62+ 66.
- [8] Xie Y, 2020, Application of Various Measurement Technologies in the Design and Measurement of Construction Drawings of New Expressways. *China New Technology and New Products*, 2020(14): 80–82.

- [9] Chen W, Zhang F, 2019, Application of BIM Technology in Structural Design of Expressway Service Area. *Building Technology*, 50(07): 812–814.
- [10] Hou Z, Long B, Zhou D, et al. , 2019, Application of BIM Technology in the Survey and Design Stage of Pubei Expressway. *Western Communications Science and Technology*, 2019(04): 160–163.
- [11] Zhang H, Li T, Xiao P, et al. , 2016, Research and Application of Airborne LiDAR Technology in the Survey and Design of Mountain Expressway. *Beijing Surveying and Mapping*, 2016(06): 95–98.
- [12] Han B, 2023, Research on GIS Data Processing Standards Based on a Highway Project. *Intelligent Building and Smart City*, 2023(06): 184–186.
- [13] Lin H, 2023, Blasting Construction Design of Expressway Tunnel in Complex Surrounding Rock Environment: A Case Study of an Expressway Tunnel Project in the “Double Thousand Project” in Henan Province. *World of Transportation Managers*, 2023(02): 79–81.
- [14] Yang L, 2022, Design and Application of Key Technology Design and Application of Digital Intelligence Management and Control System for Expressway Tunnels. *Shanxi Communication Science and Technology*, 2022(06): 103–107.
- [15] Li H, 2022, Research on Design Technology of Expressway Reconstruction and Expansion Project. *Western Communications Science and Technology*, 2022(11): 100–102.

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