AI translation · View original & related papers at
chinarxiv.org/items/chinaxiv-201810.00220

Postprint: All-Element Object BIM Collaborative Design and Construction Management for the Lipu-Yulin Expressway Project

Authors: Long Bo, Peng Xin, Hou Zequn

Date: 2018-10-26T00:00:00+00:00

Abstract

The Guangxi Lipu-Yulin Expressway represents a critical component of the G59 National Expressway Network. Upon completion, this project will augment China' s national expressway network, promote the northward extension of the Beibu Gulf economy, and enhance the capacity of the north-south transportation corridor. The project presents numerous challenges, including substantial scale and spatial distances, complex geological and geographical environments, extensive regional planning coordination requirements, and sophisticated control engineering technologies. During the schematic design phase, Infraworks was adopted as the core platform, while the survey and design phase employed MicroStation as the core platform. Through the utilization of multiple software applications, data pertaining to roads, bridges, structures, and other infrastructure elements were imported into the core platforms to achieve multi-source data fusion. By harnessing the comprehensive advantages of BIM technology to systematically address the project's inherent challenges, integrated BIM application was implemented throughout the entire process, spanning from site surveying to BIM collaborative design and subsequently to construction management. Moreover, during the construction phase, an independently developed construction management system based on the design BIM model was deployed to realize information-based management of the construction process. The BIM technology application in this project encompasses the surveying, design, and construction phases, establishing a comprehensive whole-process application workflow and methodology that integrates preliminary application, collaborative design, and construction management.

ChinaRxiv 中X

Full Text

Preamble

BIM-Based Collaborative Design and Construction Management of All-Element Objects in the Lipu–Yulin Expressway Project

Long Bo, Peng Xin, Hou Zequn
(Guangxi Communications Design Group Co., Ltd., Nanning 530029, China)

Abstract: The Guangxi Lipu–Yulin Expressway represents a critical component of the national expressway network G59 (Hohhot–Beihai). Upon completion, this project will significantly enhance China's national expressway network, extend the economic reach of the Beibu Gulf region northward, and improve north-south corridor capacity. The project faces numerous challenges, including large scale and spatial distances, complex geological and geographical environments, extensive regional planning coordination requirements, and sophisticated control engineering technologies. During the conceptual design phase, Autodesk Infraworks served as the core platform, while MicroStation was adopted as the primary platform for the detailed survey and design phase. Through the integration of multiple software applications, data from roads, bridges, buildings, and other infrastructure were imported into the core platforms to achieve multi-source data fusion. By leveraging the comprehensive advantages of BIM technology, the project systematically addressed each technical difficulty, realizing integrated BIM application across the entire process—from site surveying to collaborative design and through to construction management. During the construction phase, a proprietary construction management system based on the design BIM model was developed to enable information-based construction process management. The BIM implementation in this project spans surveying, design, and construction phases, establishing a comprehensive workflow and methodology for preliminary application, collaborative design, and construction management.

Keywords: BIM; All-element objects; Collaborative design; Construction management

---

1 Project Overview

1.1 Project Profile

The Guangxi Lipu–Yulin Expressway constitutes a vital segment of both the national expressway network G59 (Hohhot–Beihai) and the "6 vertical, 7 horizontal, 8 branch lines" expressway planning framework in Guangxi, specifically designated as "Vertical 2." The route originates at Mengcun, northeast of Lipu County, connecting with the under-construction Shantou-Kunming National Expressway (Yangshuo–Luzhai section), and terminates at Xinqiao Town in Yulin City, linking with the completed Hohhot–Beihai National Expressway

(Yulin–Tieshangang section) [Figure 1: see original paper]. The main line extends 263.1 km, constructed to a four-lane dual carriageway expressway standard. The Lipu–Pingnan section is designed for a speed of 100 km/h, while the Pingnan–Yulin section accommodates 120 km/h. Bridge and culvert design follows the Highway-I vehicle load classification, with other technical specifications conforming to the *Technical Standard of Highway Engineering* (JTGB01-2014). Interchange connection lines are built to secondary highway standards.

1.2 Engineering Challenges

The project presented four primary challenges. First, the large scale and extensive spatial distance—spanning 263.1 km with multiple key nodes and departments—created complex management demands. The conceptual design phase required consideration of numerous natural and human control factors, complicating scheme development and comparison. Second, substantial land acquisition and demolition work, combined with crossings through multiple planning zones and intersections with local roads and railways, posed significant coordination difficulties. Third, control engineering technologies were exceptionally complex, featuring multiple technically sophisticated major bridges and extra-long tunnels. Notable examples include the Wenwu Tunnel (4,705 m), the Xiangsizhou Cable-Stayed Bridge with a 450 m main span (the largest of its kind under construction in Guangxi), and the Pingsan Arch Bridge with a 575 m main span (the world' s largest span arch bridge under construction at the time). Fourth, the geological and geographical environment along the route was highly complex, characterized by interwoven mountains and hills, extensive karst topography, and numerous adverse geological conditions.

---

2 BIM Implementation Strategy

2.1 BIM Application Objectives

Addressing the distinctive characteristics of expressway construction, this project employed oblique photogrammetry, traffic organization simulation, and other advanced technologies alongside BIM modeling. By harnessing BIM' s capabilities for rapid 3D scheme design and adjustment, design optimization, and dynamic clash detection, the project systematically resolved challenges related to large scale, extensive land acquisition, and complex geological conditions. The implementation aimed to establish a seamless workflow from surveying through collaborative design to construction management.

2.3 Software and Hardware Environment

Following comprehensive evaluation of various BIM software platforms' strengths, the project adopted Autodesk and Bentley solutions for different design phases [Figure 2: see original paper]. During conceptual design, road, building, and bridge models from SketchUp, Revit, and Civil3D were imported into Autodesk Infraworks for multi-data fusion. In the detailed design phase, Bentley' s suite of professional software—including MicroStation, PowerCivil, and ProStructures—enabled sophisticated infrastructure design. For construction management, a proprietary system was developed based on the design BIM model. Hardware infrastructure comprised multiple high-memory workstations with high-performance graphics cards, dedicated storage systems, and UAVs for aerial surveying.

---

3 BIM Applications in Design and Construction

3.1 Site Surveying and Mapping

Oblique photogrammetry has gained widespread adoption in engineering applications in recent years. This technology utilizes aerial platforms equipped with multiple sensors to capture ground features from vertical and oblique angles [1]. Specialized software processes these images to reconstruct ground scenes. During the project survey phase, UAVs captured high-resolution orthoimagery along the expressway corridor, generating 3D reality models that served as the foundation for BIM design. This approach simultaneously created accurate 3D terrain surfaces, addressing the limitations of insufficient sampling points in traditional surveying while reducing costs.

Additionally, 3D geological models were established for critical control nodes and complex geological sections. These models facilitated the design of bridge foundations and tunnel structures. For high slopes, 3D mesh models were created and imported into finite element analysis software for structural stress and deformation analysis, providing comprehensive and accurate baseline data for design.

3.2 Conceptual Design Application

Traditional preliminary design phases often suffer from inadequate baseline data and the limitations of 2D drawing expression, frequently resulting in unsatisfactory schemes, untimely adjustments, and poor communication with stakeholders. This project leveraged BIM technology and 3D reality models to construct a comprehensive 3D project environment for rapid conceptual design. The visual models effectively communicated design intent to decision-makers, facilitating intuitive scheme comparison and selection. Furthermore, BIM' s parametric modeling capabilities enabled rapid scheme adjustment and optimization. The integration of BIM models with 3D reality models also provided scientific justification for route selection, alignment optimization, farmland occupation, and building demolition planning.

3.3 Detailed Design Application

During the detailed design phase, BIM technology enabled sophisticated project development. By establishing road cross-section templates, the team rapidly created roadways and high slopes with multi-level benches while automatically classifying and quantifying earthwork volumes. For conventional bridges, parametric component libraries were developed for superstructures and substructures, allowing adaptation to different spans and site conditions through parameter adjustments, thereby significantly improving design efficiency.

For control-structure major bridges, MicroStation and ProStructures were employed to create refined BIM models, resolving the expressive limitations of traditional 2D drawings for complex geometric structures. Three-dimensional parametric cells were used to solidify the steel anchor boxes for cable-stayed bridge pylons, which were previously represented only in parametric tables [Figure 3: see original paper]. BIM' s visualization advantages enabled direct verification of parameter accuracy and identification of dimensional conflicts among components, preventing design changes during construction.

ProSteel, a specialized steel structure software, facilitated detailed design of the steel-concrete composite girders for cable-stayed bridges. The software' s automatic quantity calculation and detailing functions enabled rapid steelwork quantification and 2D drawing generation. Upon completion of the composite girder BIM model, data export enabled 3D numerical simulation for real-time stress analysis, guiding both design and construction [Figure 4: see original paper].

Expressway service areas serve as windows to transportation infrastructure, reflecting regional construction standards and requiring design quality comparable to other expressway components. Service area landscape planning must emphasize harmony with surrounding ecological, natural, cultural, and economic environments [2]. This project employed BIM technology to optimize service area layout and overall scheme design. Cloud-based rendering of the service area BIM model analyzed building illumination intensity at different times, ensuring harmonious integration with the natural environment.

3.4 BIM-Based Whole-Process Construction Management

Leveraging BIM design deliverables, 3D visual technical briefings were implemented for complex structures, enabling construction personnel to better understand design intent, ensuring construction quality, and reducing unnecessary rework. Throughout construction, BIM technology supported refined project management. For technical management, documents and drawings were linked to BIM models, facilitating information retrieval and enabling comprehensive documentation, querying, and traceability. For process control, key process control points were associated with BIM models, creating verifiable records for specific engineering locations and ensuring accountability to control quality from the source. For safety and quality management, site personnel used mobile apps to upload quality and safety issues linked to specific structural elements, enabling immediate problem identification and resolution. For schedule management, linking the project schedule to the BIM model enabled construction sequence simulation, supporting rational schedule development and verification.

---

4 Innovations and Application Outcomes

Through integrated application of BIM technology, 3D reality modeling, and GIS, this project achieved large-scale visualization of the long-distance expressway corridor and rapid presentation and optimization of design schemes, addressing challenges posed by extensive scale and complex geological conditions. BIM' s rapid adjustment capabilities and reality modeling' s accurate environmental reconstruction facilitated optimization of interchange nodes, resolving issues related to large-scale land acquisition and coordination difficulties. The Pingsan West Interchange exemplifies this approach. Two alternatives were developed: a semi-directional modified cloverleaf interchange (Scheme 1) [FIGURE:5(a)] and a full cloverleaf interchange (Scheme 2) [FIGURE:5(b)]. UAV surveying captured authentic site conditions, enabling creation of high-definition orthoimagery and 3D reality models. BIM' s 3D visualization supported multidimensional comparative analysis of the alternatives. Comprehensive evaluation of land acquisition, demolition, and traffic flow analysis ultimately selected Scheme 1, the semi-directional modified cloverleaf, which minimized land use and demolition requirements.

High-definition imagery and 3D reality models also enabled rapid identification of adverse geological conditions in complex sections, addressing design challenges posed by complex geological environments and preventing rework. For the Guantang Viaduct [Figure 6: see original paper], analysis of aerial data indicated potential adverse geological conditions at a bedding slope, rendering the location unsuitable for bridge construction. Field verification confirmed these conditions, leading to adoption of a tunnel solution instead.

Through BIM implementation across surveying, design, and construction phases, this project systematically addressed all technical challenges, achieving integrated BIM application for expressway design and construction while enhancing overall project delivery capabilities. The innovations include:

1. **All-Element Object Information Integration:** The project achieved BIM design for all expressway engineering elements—including roads, bridges, tunnels, and service areas—enabling more intuitive and rational design deliverables while significantly improving work efficiency.

2. **High-Precision 3D Topographic Surveying:** Traditional manual ground surveys often lacked precision, leading to unreasonable designs and frequent construction changes. This project combined aerial photogrammetry with LiDAR, substantially improving measurement accuracy while

saving time and labor costs.

3. **BIM-GIS Integration for Large-Scale Planning:** Through UAV aerial photography and 3D reality modeling [Figure 5: see original paper], realistic models were integrated into the core BIM platform for analysis, providing scientific basis for scheme design and site layout.

4. **Cross-Platform Multi-Source Data Fusion and Sharing:** Based on a unified cloud database and BIM models, lightweight data associations were established among structural data, component attributes, construction schedules, site progress, design documents, construction logs, inspection records, and construction methodology attributes. This architecture enabled management, retrieval, modification, and version control of all BIM model-associated properties through multiple terminal platforms. By aggregating structured and unstructured data under unified management with user-friendly query interfaces, construction management capabilities were enhanced. Hosting BIM models on a unified server enabled simultaneous web, PC, and mobile access, achieving cross-platform and cross-terminal data fusion and sharing.

5. **Design-Construction Integration:** Design-phase BIM deliverables were converted to 2D drawings while also being segmented according to project EBS codes and uploaded to the construction management platform database. This facilitated efficient data transfer from design to construction, achieving seamless BIM integration across phases. By planning BIM implementation from design through construction based on "one data source, one model," the limitations of single-phase or localized BIM applications were overcome.

6. **BIM-Based Construction Information Management:** Leveraging Bentley platform' s openness, a project electronic sandbox system was customized based on MicroStation, with engineering attributes assigned through coding for 3D content management. 3D Tiles reality models generated via ContextCapture were integrated with a custom Web GIS for lightweight web-based reality and model information browsing and sharing, enabling BIM 5D construction management for all project participants.

The successful BIM implementation in this project plays a crucial role in advancing design and construction capabilities for expressway projects in technologically underdeveloped regions, while establishing a foundation for future digital asset management and maintenance decision-making.

References

[1] Xiao Xiongwei. Research and Application of Feature-Invariant Oblique Image Matching Algorithms [D]. Xi'an: Xi'an University of Science and Technology, 2014.

[2] Su Qinghua, Ma Jianrong. Research on Landscape Planning and Renovation

Strategies for Expressway Service Areas [J]. Highway Transportation Science and Technology (Applied Technology Edition), 2016(07): 244-246.

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv —Machine translation. Verify with original.