Adaptability Analysis of BIM in Railway Four-Electrical Engineering Postprint

Authors: Wang Ying, Bai Xiaoping, Chen Shanshan, Xu Hao

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

Abstract

Current BIM applications, integrated with various emerging information technologies, have been deployed across multiple domains. Railway Four-Electrics engineering, characterized by multi-disciplinary integration, construction complexity, and extensive cross-regional spans, urgently requires BIM to enhance design and construction efficiency. To facilitate better application of BIM in railway Four-Electrics engineering···

Full Text

Preamble

Adaptability Analysis of BIM in Railway Four-Electric Engineering

Chen Shanshan, Xu Hao
(China Railway Electrification (Wuhan) Design & Research Institute Co., Ltd., Wuhan 430074, China)

Abstract: Current BIM applications are increasingly integrated with various emerging information technologies and have found widespread adoption across multiple domains. Railway four-electric engineering, characterized by multi-disciplinary integration, construction complexity, and extensive cross-regional implementation, urgently requires BIM to enhance design and construction efficiency. This paper analyzes the challenges encountered in BIM application within railway four-electric engineering and proposes corresponding solutions, providing valuable references for the practical implementation of BIM in this specialized field.

Keywords: BIM; Railway Four-Electric Engineering; Adaptability

BIM technology in railway four-electric engineering is currently experiencing rapid development and intensive research, with its application value receiving high-level government attention and broad industry recognition. Railway construction will remain in a peak period for the foreseeable future. However, railway projects are complex systems engineering endeavors that require seamless coordination across different phases and collaborative design among various specialties. Mastering BIM technology can improve work efficiency and quality, mitigate systematic construction risks, and enhance overall project benefits. As BIM technology demonstrates tremendous application value in the engineering and construction sector, its research and implementation in railway construction has become an urgent and critical task, prompting railway organizations to intensify R&D efforts and actively promote related initiatives.

2 Development Trends of BIM Technology Application

Currently, various organizations have offered different interpretations of BIM' s definition. As a novel concept and technology, BIM has attracted widespread attention from scholars and industry practitioners. However, a comprehensive analysis reveals that BIM encompasses two core philosophies [1]: First, BIM provides a visualized approach to information representation, incorporating parametric characteristics of models (geometric and functional attributes) along with associated lifecycle information. Second, this visualized information data is dynamic, real-time, and shareable—information associations are established from the moment of model creation, with any modifications instantly reflected across all relevant platforms.

Based on these concepts, contemporary BIM technology is advancing through two primary avenues: integration with emerging technologies and multi-domain practical applications.

(1) **Integration with Emerging Technologies**
To address practical challenges, researchers and practitioners are exploring the integration of various emerging information technologies with BIM to achieve synergistic effects greater than the sum of their parts. GIS technology, characterized by high standardization and digitalization, primarily facilitates geographic positioning and regional spatial analysis of geospatial data [2]. In contrast, BIM excels at presenting detailed information parameters of buildings themselves. The complementary strengths of these two technologies create a powerful combination, as illustrated in Figure 1 [Figure 1: see original paper].

(2) **Multi-Domain Practical Applications**
BIM possesses the inherent attribute of integrating with multiple information technologies, enabling its application across diverse fields through either secondary development or multi-party collaboration. In non-construction domains, the Technical University of Darmstadt in Germany has developed a "Human Rescue Serious Game" that combines BIM functionality with engineering simulation capabilities (fire, smoke) in serious games, leveraging interactive operations from both systems to

compensate for limitations in existing simulation model data collection methods [6]. Additionally, for pedagogical improvement, Stanford University has incorporated BIM into its "Construction and Construction Management" curriculum, utilizing BIM-based visual models to provide more practical teaching cases [7].

3.1 Overview of Railway Four-Electric Engineering

Railway four-electric engineering encompasses railway construction projects primarily comprising four specialized disciplines: "communication, signaling, power, and electrification (traction power supply)," along with associated supporting facilities and temporary works—traditionally referred to as "post-station engineering." Among these, the overhead contact system (OCS) engineering represents the dominant and critical component. The professional composition and interrelationship diagram of railway four-electric engineering is shown in Figure 5 [Figure 5: see original paper].

In railway four-electric engineering, the communication system serves as the "nerve center" of the railway, forming the information infrastructure that ensures safe railway operations. Its primary mission is to provide multimedia communication capabilities—including voice and image transmission—to guarantee accurate and reliable information delivery. The signaling system functions as the "visualization system" for train operations, responsible for transmitting and monitoring information regarding the operational status of line equipment and dispatching control instructions across the railway network. The power system constitutes the "energy foundation" of the railway, providing uninterrupted power supply to ensure reliable operation of all system loads. The electrification system, also known as traction power supply engineering, primarily supplies electric power to locomotives, providing the essential energy guarantee for train operations.

3.2 Characteristics of Railway Four-Electric Engineering

The distinctive characteristics of each four-electric specialty are as follows:

(1) **Communication Engineering**: This field features extensive application of new materials and equipment, with rapid evolution of communication technologies such as 3G and 4G. The backend control systems are highly complex and require exceptional professional expertise.

(2) **Signaling Engineering**: Highly susceptible to influences from civil engineering and other pre-station construction units, signaling engineering possesses strong technical specialization, making safety, quality, and technical management particularly challenging. Signal circuit structures are intricate, demanding high debugging technical standards. The resource consumption for commissioning within tight schedules is substantial, presenting certain construction risks.

(3) **Power Engineering**: Construction spans extensive geographic areas with numerous intersections involving electric power, municipal infrastructure, and pipelines, creating complex interference factors. Project schedules face multiple constraints, with high uncertainty risks in external power introduction, which in turn restricts joint testing of other specialties.

(4) **Electrification Engineering**: Characterized by numerous professional interfaces and rapid 更新换代 of "four new" technologies (new techniques, new materials, new equipment, and new methods), electrification engineering demands high installation craftsmanship standards. The prevalence of high-altitude operations creates significant construction safety risks. Schedule pressure is intense, and joint testing is difficult, making it a critical specialty for project completion.

While railway four-electric engineering and its individual specialties possess unique attributes and characteristics, they all demonstrate features of strong technical specialization, numerous construction interfaces, difficult installation and debugging, and multiple interference factors—though specific technical standards and management requirements vary across different natural construction environments.

4.1 Challenges in BIM Application for Railway Four-Electric Engineering

Currently, BIM application in railway four-electric engineering remains in its infancy compared to building construction, compounded by the inherent complexities of numerous specialties and intricate interface debugging. While BIM promotion is imperative, it faces multifaceted challenges. For instance, most BIM software solutions are foreign-designed products, while domestic options such as Glodon and Lubansoft have underlying model coding and data storage formats developed according to building construction standards, which inadequately align with railway engineering specifications.

Based on existing research on BIM application in railway four-electric engineering, the primary challenges manifest in the following aspects:

(1) **Insufficient BIM Software Development or Secondary Development**
First, there is a lack of unified software application across specialties, with inconsistent internal standards among software products, resulting in difficult data exchange. No fully mature software product exists that caters specifically to the railway engineering industry for lifecycle management spanning design, construction, implementation, management, and operation & maintenance. Even established vendors like Autodesk cannot provide railway-engineering-specific solutions, necessitating optimization and secondary development of existing BIM design software to meet railway engineering component requirements.

Second, compared to mechanical design and building construction, railway engineering features numerous unique components with specialized functions absent in other industries, requiring custom creation. For example, the railway alignment centerline is not merely a three-dimensional spatial curve; it must incorporate substantial additional information required by various specialties, such as mileage, direction, and gap positions for different disciplines. The true modeling challenge lies not in the curve itself but in attaching this information, which remains inadequately resolved. The linear nature of railway engineering, closely integrated with geographic information, demands secondary development combining software with GIS to enable more comprehensive information attachment beyond simple geometric data.

(2) **Lack of Data Storage Standards**
Due to years of BIM implementation experience, mechanical and building engineering sectors have developed relatively mature data storage methodologies. In contrast, railway engineering has yet to establish unified data storage formats, creating significant obstacles to data circulation within models. Furthermore, domestic and international BIM standard research inadequately covers the railway industry. Whether IFC, IFD, or OMIN-class standards, railway-specific aspects—including lines, tracks, subgrades, bridges, tunnels, stations, signaling, locomotive and rolling stock, and electrification—remain relatively weak.

(3) **Inconsistent Practitioner Competencies**
As an emerging technology, BIM inevitably encounters resistance from practitioners accustomed to traditional workflows, representing a major constraint on its promotion in railway engineering. The challenge extends beyond technicians' reluctance to adopt new technologies; BIM also requires extensive systematic training for mastery. Currently, inadequate BIM training programs, incomplete acceptance by construction enterprises, and insufficient promotion by project owners have placed BIM implementation in an awkward position.

4.2 Countermeasures

Despite these considerable obstacles, railway engineering—and particularly four-electric engineering—requires BIM and similar emerging technologies to optimize processes and enhance efficiency. The following practical countermeasures are proposed:

(1) **Continuous Policy Guidance**
The China Railway Corporation and China Railway BIM Alliance have achieved certain progress in organizing and promoting BIM technology application in railway engineering through recent efforts, demonstrating the necessity of national-level policy guidance. It is recommended that superior government authorities (such as railway bureaus) incorporate BIM technology promotion into specialized railway technology develop-

ment plans. Simultaneously, they should collaborate closely with government agencies experienced in BIM promotion (such as the Ministry of Housing and Urban-Rural Development) to improve implementation approaches. Additionally, learning from BIM application experiences in developed countries' railway sectors can inform domestic policy formulation.

(2) **Substantial Economic Support and Sustained Technical R&D**
R&D costs and technological development proceed in parallel, requiring significant national-level financial support to drive secondary development of BIM professional software for enhanced railway engineering applicability. Enterprises should strengthen their in-house BIM secondary development capabilities to create products with complete or partial independent intellectual property rights, thereby improving design and construction efficiency while reducing costs and ultimately mitigating the economic risks associated with BIM application R&D. Enhanced communication and exchange with BIM platform developers should also be pursued to ensure continuity and extensibility of secondary development interfaces.

(3) **Standard System Improvement**
Research and formulation of the China Railway BIM standard framework and related standards should align with international and national standards (guidelines). Based on IFOminiclass specifications and referencing building industry BIM standards, the China Railway BIM Alliance should organize design and construction units to develop railway-specific BIM standard frameworks and related standards that incorporate railway engineering characteristics.

(4) **Management Model Transformation**
China' s railway industry has yet to establish BIM-based workflows, easily causing procedural confusion and rework. While developing BIM standards and guidelines, government and enterprises must also construct a BIM workflow framework to provide project participants with standardized procedures. Furthermore, management must recognize the urgency and necessity of BIM application, strengthening support from technical training for frontline personnel to ideological transformation among leadership—all essential elements for successful implementation.

5 BIM Application in Railway Four-Electric Engineering

As previously discussed, railway four-electric engineering constitutes a massive, complex, and systematically phased project involving multiple stakeholders—including owners, designers, and contractors—and numerous specialties. The traditional design and construction models employed for many years cannot be transformed into BIM-based approaches overnight. Therefore, the author proposes a phased implementation strategy for BIM application in railway four-electric engineering.

5.1 Preliminary Planning Phase

During the initial stages of railway four-electric construction projects, a progressively detailed project justification process is required. In this phase, BIM can be applied to site analysis, architectural planning, and scheme verification. Additionally, BIM integrated with GIS can create three-dimensional visual electronic sand tables containing information on existing railway networks and other transportation systems in the region, major adverse geological conditions, and geographic information on natural features along the route. Since model elements are parametric and computable, analyses and calculations can be performed based on model information, enabling passenger and freight volume forecasting, determining project functional positioning and construction necessity, and establishing corridor bands for alignment plans by synthesizing natural features along the route and key factors affecting line direction.

5.2.1 Field Survey Phase

Railway field surveys are conducted in two stages: preliminary survey and final survey. During this phase, BIM facilitates the digitization of survey results by establishing a central database for storing multi-disciplinary survey data based on the preliminary railway 3D model—effectively integrating complex survey information within the BIM platform. Furthermore, data from various specialties can be entered and edited in real-time, with other relevant disciplines able to monitor these changes continuously. For instance, alignment and station specialists can access geological data entered by geotechnical specialists in the platform to perform scheme adjustments and borrow pit site selection.

5.2.2 Design Phase

The design phase represents a relatively mature stage for BIM application. Railway design involves over 20 specialties requiring massive amounts of design information exchange. As shown in Figure 6 [Figure 6: see original paper], current models can generate walkthrough animations, enabling comprehensive examination of all project components and critical details to reduce professional conflicts.

This phase should focus on secondary development based on the Revit software platform. Taking the overhead contact system in four-electric engineering as an example, the BIM-based construction plugin framework is illustrated in Figure 7 [Figure 7: see original paper]. This plugin employs parametric technology to provide material and quantity statistics, facilitating scheme comparison and optimization. The Revit model parameter workflow is illustrated in Figure 8 [Figure 8: see original paper].

Regarding construction briefing, project families can integrate spatial and temporal information into a visual 4D model using BIM. Simulation videos can be produced for complex processes, with various briefing data uploaded to create a construction briefing information database based on engineering components, as shown in the application flow diagram in Figure 9 [Figure 9: see original paper].

5.3 Construction Implementation Phase

During this phase, BIM can be utilized for construction schedule simulation, construction organization simulation, material tracking, construction coordination, and as-built delivery. The overhead contact system features complex structures with numerous component types. Coding different component categories facilitates material management and tracking. Using Revit' s inherent model parameter addition capabilities, information such as equipment procurement details, structural physical properties, and responsible personnel can be incorporated, with the workflow illustrated in the diagram below.

5.4 Operation and Maintenance Phase

During the operation and maintenance phase, BIM technology is applied to maintenance planning, asset management, space management, disaster prevention and rescue, and model maintenance. In the operational stage, passenger and freight flow data can be input into the BIM model platform in real-time, enabling dynamic adjustment of train operations through comparative analysis. During maintenance, infrastructure condition data obtained through facility monitoring and inspection systems can be integrated with train operation information to formulate maintenance and repair plans.

Drawing from the development trajectory of BIM application in building construction, BIM implementation in railway engineering will likewise be a progressively deepening process requiring overcoming various challenges and obstacles. Through this adaptability analysis of BIM application in railway four-electric engineering, the author has reflected on existing deficiencies and proposed various countermeasures. BIM technology is poised to achieve even broader application scope and prospects in railway four-electric engineering.

References

[1] Azhar S. Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry[J]. Leadership and Management in Engineering, 2011, 11(3): 241-252.

[2] 郑云, 苏振民, 金少军. BIM-GIS 技术在建筑供应链可视化中的应用研究 [J]. 施工技术, 2015, 44(06): 59-63+116.

[3] 孙鸽梅. 基于 BIM、RFID 和云计算技术的智慧建筑研究 [J]. 硅谷, 2014, 7(01): 52-53.

[4] 初毅, 邵兆通, 武涛. 基于 MR+BIM 技术的信息化建筑工程应用探讨 [J]. 土木建筑工程信息技术, 2017, 9(05): 94-97.

[5] 邵兆通, 何兵, 初毅. 混合现实技术在建筑工程中的应用研究 [J]. 土木建筑工程信息技术, 2017, 9(03): 43-46.

[6] Rüppel U, Schatz K. Designing a BIM-based serious simulation for advanced safety evacuation[J]. Engineering Informatics, 2011, 25(4): 600-611.

[7] Peterson F, Hartmann T, Fruchter R, et al. Teaching construction project management with BIM support: Experience and lessons learned[J]. Automation in Construction, 2011, 20(2): 115-125.