

## Adaptability Analysis of BIM in Railway Four-Electrical Engineering Postprint

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### Abstract

Current BIM applications, integrated with various emerging information technologies, have been adopted across multiple domains. Railway four-electricity engineering, characterized by multi-disciplinary intersections, construction complexities, and extensive spans across natural regions, urgently necessitates BIM to enhance the efficiency of design and construction. To facilitate better application of BIM in railway four-electricity engineering...

### Full Text

## Adaptability Analysis of BIM in Railway Four-Electric Engineering

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### Abstract

Current BIM applications, integrated with various emerging information technologies, have become prevalent across multiple domains. Railway four-electric engineering—encompassing communication, signal, power, and electrification systems—urgently requires BIM to enhance design and construction efficiency due to its multi-disciplinary complexity, construction challenges, and extensive cross-regional scope. To facilitate better BIM implementation in railway four-electric engineering, this paper analyzes existing application problems and proposes corresponding solutions, providing valuable references for practical BIM deployment in this field.

**Keywords:** BIM; Railway four-electric engineering; Adaptability

BIM technology in railway four-electric engineering is currently experiencing rapid development and in-depth research, having attracted significant government attention and widespread industry recognition. Railway construction will remain at peak levels for the foreseeable future. However, railway projects are complex systems requiring coordinated design across phases and disciplines. Mastering BIM technology can improve work efficiency and quality, mitigate systematic construction risks, and enhance overall project benefits. Given BIM's demonstrated value in engineering construction, its research and application in railway construction has become an urgent priority, with railway organizations intensifying R&D efforts and actively promoting relevant initiatives.

Based on this conceptual foundation, current BIM technology advances along two primary dimensions: integration with emerging technologies and multi-domain practical applications. First, to address practical challenges, researchers and practitioners are integrating 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 handles geographic positioning and spatial analysis of regional data [2], while BIM excels at presenting building information parameters and details. These complementary strengths are illustrated in Figure 1 [Figure 1: see original paper].

## 2 Development Trends in BIM Technology Application

Various organizations have proposed different definitions of BIM. As both a new concept and technology, BIM has attracted widespread attention from scholars and industry practitioners. Comprehensive analysis reveals two core philosophies [1]: First, BIM provides a visual information representation containing parametric characteristics (geometric and functional attributes) and associated lifecycle information. Second, this visual information data is dynamic, real-time, and shared, with associations established from model creation onward, ensuring any modifications are reflected across all relevant platforms.

Building upon these concepts, current BIM technology is being advanced through two main approaches: new technology integration and multi-domain practical application.

First, regarding new technology integration, to solve practical problems, researchers and industry practitioners are attempting to integrate various emerging information technologies with BIM to achieve synergistic effects where the whole exceeds the sum of its parts. Current GIS technology exhibits high standardization and digitalization levels, primarily used for geographic location positioning and regional spatial analysis of spatial geographic information data [2], while BIM is suited for presenting information parameters and details of buildings themselves. The strengths and weaknesses of the two can complement each other, as shown in Figure 1 [Figure 1: see original paper].

BIM models are constrained by the large volume of buildings and local/desktop

application modes, making it difficult to effectively acquire and update information from other sites. The integration of cloud computing [3] with BIM enables cross-regional collaborative work by placing large amounts of information on cloud servers, significantly improving data processing speed and helping project participants coordinate office work and simulate multi-disciplinary cross-construction. This is illustrated in Figure 2 [Figure 2: see original paper].

Beyond information processing technologies, the interaction between humans, computers, and physical environments represents another major application area. Mixed Reality (MR) superimposes required virtual digital information onto real environments through computer processing. Microsoft's MR holographic glasses HoloLens support real-time spatial modeling, real-time spatial tracking, and spatial sound playback, enabling BIM-based three-dimensional model presentation [4] and on-site construction guidance [5], as shown in Figures 3 [Figure 3: see original paper] and 4 [Figure 4: see original paper].

Second, regarding multi-domain practical application, BIM's attribute of integrating with multiple information technologies allows its application in different 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 serious game engineering simulation (fire, smoke) functions, using bilateral operational interactivity to compensate for deficiencies in existing simulation model data collection methods [6]. Additionally, for pedagogical improvement, Stanford University in the United States has applied BIM in its "Construction and Construction Management" curriculum, providing more practical teaching cases based on BIM's visual models [7].

### 3.1 Overview of Railway Four-Electric Engineering

Railway four-electric engineering primarily encompasses four professional disciplines—communication, signal, power, and electrification (traction power supply)—along with related supporting and temporary facilities, traditionally known as "post-station engineering." The overhead contact system 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 railway's "nerve center," providing the information foundation for safe railway operations by offering multimedia communication means for voice, image, and data to ensure accurate and reliable information transmission. The signal system acts as the "visual system" for train operation, responsible for transmitting and monitoring information about equipment status and dispatching commands across the railway network. The power system constitutes the railway's "energy infrastructure," providing uninterrupted power supply for all system loads. The electrification system, also called traction power supply, primarily supplies trac-

tion power for electric locomotives, ensuring train operation.

### 3.2 Characteristics of Railway Four-Electric Engineering

The characteristics of each four-electric discipline are as follows:

First, communication engineering features extensive application of new materials and equipment, rapid technological updates such as 3G and 4G communication technologies, complex backend control system operations, and extremely high specialization. Second, signal engineering is susceptible to influences from civil engineering and other pre-station contractors, while its own strong technical specialization creates significant challenges for safety, quality, and technical management. Signal circuit structures are complex, debugging technical standards are high, resource consumption for commissioning within short timeframes is substantial, and certain construction risks exist. Third, power engineering spans large construction regions with numerous intersections with electric power, municipal, and pipeline systems, resulting in complex construction interference factors. Its schedule is constrained by multiple factors, with high uncertain risks in external power introduction that constrain joint testing of other disciplines. Fourth, electrification engineering is characterized by numerous professional interfaces, rapid updates of “four new” technologies (new techniques, materials, equipment, and methods), high installation process requirements, extensive high-altitude operations with significant construction safety risks, substantial schedule pressure, high difficulty in joint testing, and represents a critical discipline for project completion.

While railway four-electric engineering and its specialties possess individual attributes and characteristics, they all demonstrate strong technical specialization, numerous construction interfaces, difficult installation and debugging, and multiple interference factors when facing different natural construction environments, with varying technical standards and management requirements.

#### 4.1 Problems in BIM Application for Railway Four-Electric Engineering

Currently, BIM application in railway four-electric engineering remains in its initial stages compared to building engineering, as railway four-electric engineering itself features numerous specialties and complex interface debugging. While BIM promotion is imperative, it faces many challenges. For instance, most BIM-related software consists of foreign design tools, while domestic software such as Glodon and Lubansu have model underlying codes and data storage formats written according to building specifications that do not align well with railway engineering requirements.

Based on current research on BIM application in railway four-electric engineering, the main problems manifest in several aspects:

First, insufficient BIM design software development or secondary development.

Professional software applications lack uniformity, and internal standards within software products are inconsistent, making data exchange difficult. No fully suitable software products exist for the railway engineering industry that cover the entire lifecycle from design, construction, and management to operation and maintenance. Even mature vendors like Autodesk cannot provide railway engineering-specific software, forcing optimization and secondary development of existing BIM design software to meet railway engineering component requirements.

Compared with mechanical design and building engineering, the railway engineering industry possesses many unique components with functions unavailable in other industries that require separate creation. For example, the railway alignment centerline is not merely a three-dimensional spatial curve; it requires attaching substantial information needed by other specialties, such as mileage, direction, and gap positions for various disciplines. The attached information, rather than the curve itself, represents the true modeling challenge that remains incompletely resolved. Railway engineering's linear characteristics and close integration with geographic information necessitate secondary development combining software with GIS to enable curves to carry more comprehensive information beyond simple geometric data.

Second, lack of data storage standards. Mechanical and building engineering fields have developed relatively complete data storage methods through years of BIM experience accumulation. For railway engineering, no unified data storage format has been established, creating significant obstacles to data circulation within models. Meanwhile, domestic and international BIM standard research has not covered the railway industry. Whether IFC, IFD, or OmniClass standards, railway-specific aspects such as alignment, track, subgrade, bridges, tunnels, stations, signals, locomotive and rolling stock, and electrification remain relatively weak.

Third, uneven competency among practitioners. As an emerging technology, BIM inevitably creates resistance among current practitioners accustomed to traditional work patterns, representing a major factor constraining BIM promotion in railway engineering. Beyond existing technicians' avoidance of new technology, BIM requires extensive systematic training for mastery. Meanwhile, current BIM training is inadequate, construction enterprises do not fully embrace BIM technology, and owner units do not vigorously promote it, placing BIM implementation in an awkward position.

## 4.2 Countermeasures

Despite numerous obstacles, railway engineering and four-electric engineering require BIM and such new technologies to optimize and enhance efficiency. The following practical countermeasures are proposed:

First, continuous policy guidance. Through recent organizational and promotional efforts, China Railway Corporation and the China Railway BIM Alliance

have achieved certain results in BIM technology application for railway engineering, demonstrating the necessity of national-level policy guidance. It is recommended that higher-level government authorities (such as railway bureaus) incorporate BIM technology promotion into railway technology development special plans, while strongly cooperating with government agencies experienced in BIM promotion (such as the Ministry of Housing and Urban-Rural Development) to improve promotion methods. Learning from developed countries' railway engineering BIM application experiences can inform government policy formulation.

Second, substantial economic support and continuous technical R&D. R&D costs and technology development proceed in parallel. National-level economic support should vigorously promote secondary development of BIM professional software to ensure better suitability for railway engineering. Enterprises should enhance their own BIM secondary development capabilities to form products with complete or partial independent intellectual property rights, improving design and construction efficiency while reducing costs, ultimately mitigating R&D costs and economic risks associated with BIM application. Strengthening communication and exchange with BIM platform developers can ensure continuity and extensibility of secondary development interfaces.

Third, improving system standards. Research and formulation of the China Railway BIM standard framework and related standards should align with international and national standards (guidance). Based on IFC and OmniClass specifications, referencing building industry BIM standards, and combining railway engineering characteristics, the China Railway BIM Alliance should organize design and construction units to conduct research and formulation work.

Fourth, changing management models. China's railway industry has not yet established BIM-based workflows, easily causing confusion in specific work procedures and rework. While governments and enterprises formulate BIM standards and guidelines, they must also establish BIM workflow frameworks to provide workflow templates for project participants. Management must recognize the urgency and necessity of BIM application, strengthening support from technical training for grassroots personnel to ideological transformation of management—both are indispensable.

## 5 BIM Application in Railway Four-Electric Engineering

As previously discussed, railway four-electric engineering is a massive, complex, systematically phased project involving multiple participants including owners, designers, and contractors. The traditional design and construction model used for many years cannot be transformed into BIM mode overnight. Therefore, the author believes BIM should be applied to railway four-electric engineering in phases.

## 5.1 Early Planning Stage

During the initial phase of railway four-electric construction projects, a progressively detailed project justification process is required. In this process, BIM can be applied to site analysis, architectural planning, and scheme demonstration. BIM can also combine with GIS to create three-dimensional visual electronic sandboxes containing existing railway and transportation networks in the region, major adverse geological information, and geographic information along the route. Since model elements are parametric and computable, analysis 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 integrating natural features and important factors affecting route direction.

### 5.2.1 Field Survey Stage

Railway field survey consists of preliminary and detailed survey phases. In this stage, BIM helps digitize survey results by establishing a central database for storing multi-disciplinary survey data based on the preliminary railway 3D model—integrating complex survey data from various specialties within the BIM platform. Additionally, each specialty's data can be entered and edited in real-time, with other relevant specialties able to view data changes at any time. For example, alignment and station specialties can view geological data entered by the geology specialty to perform scheme adjustments and borrow pit site selection.

### 5.2.2 Design Stage

The design stage represents a relatively mature phase for BIM application. Over 20 specialties involved in railway design require massive amounts of design information communication. As shown in Figure 6 [Figure 6: see original paper], current models generate view roaming animations to thoroughly examine models in various project parts and important details, reducing professional conflicts.

This stage should focus on secondary development based on the Revit software platform. Taking the overhead contact system in four-electric engineering as an example, its BIM-based construction plugin framework is shown in Figure 7 [Figure 7: see original paper]. This plugin utilizes parametric technology to provide material and quantity statistics functions, facilitating design scheme comparison and optimization.

For construction briefing, project families can integrate spatial and temporal information into a visual 4D model based on BIM, create simulation videos for complex processes, upload various briefing data, and form a construction briefing information database based on engineering components. The application process is shown in Figure 9 [Figure 9: see original paper].

### 5.3 Construction Implementation Stage

During this stage, BIM can be used for construction schedule simulation, construction organization simulation, material tracking, construction coordination, and project delivery. The overhead contact system has complex structures with numerous component types. Coding different types of components facilitates material management and tracking. Using Revit's model parameter addition function, equipment procurement information, structural physical information, and responsible staff information can be added, with the flowchart shown in Figure 8 [Figure 8: see original paper].

### 5.4 Operation and Maintenance Stage

During operation and maintenance, BIM technology supports maintenance planning, asset management, space management, disaster prevention and rescue, and model maintenance. In the operation phase, BIM model platforms can input passenger and freight flow data in real-time for comparative analysis and train operation adjustment. During maintenance, infrastructure condition data obtained through facility monitoring and inspection systems can be integrated with train operation conditions to develop maintenance plans.

## Conclusion

Judging from BIM application development in building engineering, BIM application in railway engineering will also be a gradual deepening process requiring overcoming numerous difficulties and challenges. Through adaptability analysis of BIM application in railway four-electric engineering, this paper reflects on existing deficiencies and proposes various countermeasures. BIM technology will undoubtedly have broader application scope and prospects in railway four-electric engineering.

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

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