APPLICATION AND EXPLORATION OF BIM IN CHINA'S HIGHWAY CONSTRUCTION

By
Miss Deshuang ZHU

A Thesis Submitted in Partial Fulfillment of the Requirements
for Master of Engineering ENGINEERING MANAGEMENT
Department of INDUSTRIAL ENGINEERING AND MANAGEMENT
Silpakorn University
Academic Year 2023

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Title	Application and Exploration of BIM in China's Highway Construction
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This article believes that BIM technology can propose good solutions and achieve good results in solving the construction pain points of mountainous highways, and has certain promotion and application value. This article summarizes the common problems that exist in various processes of China's highway projects from project initiation to operation, including highway design, quality control, construction management, and other aspects. Especially when encountering adverse geological factors during highway construction, the application of BIM technology. The application of BIM technology in mountainous highway engineering can greatly optimize site layout, improve project quality, reduce construction costs, improve management efficiency, and enhance the office efficiency of all participating parties. It realizes the uniqueness, timeliness, and sharing of data from all parties, and through the accumulation of digital assets in a project, it can also provide reference for other similar projects, and it provides support for data analysis and data services of mountainous highways.

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CHAPTER 1

INTRODUCTION

1.1 Background

Since the reform and opening up in the last century, China's economy has grown rapidly. The achievements China has made in-road infrastructure construction are widely recognized internationally. Highway is an important part of the modern transportation industry, which can drive the economic development of the areas along the highway and meet the needs of citizens for travel, logistics and transportation. When the People's Republic of China was founded in 1949, the total mileage of roads open to traffic was about 80,000 kilometers, and there was no highway construction. In the late 1980s, the rapid economic transformation led to a sharp increase in the demand for road transportation in China. However, due to the lack of highway mileage and poor quality, economic development has been severely restricted. On June 27, 1984, China began construction of the first highway - the Shenyang-Dalian highway. Since then, important highways such as Fujian highway, Tantalizing highway, Beijing-Shenyang highway and Beijing-Shanghai highway have started construction and opened to traffic one after another. China's highway network is beginning to take shape. By the end of 2020, the total mileage of China's highways has reached 5.1981 million kilometers, and the road density has reached 54.15 kilometers per square kilometer. Figure 1.1 shows the total mileage of national roads and the increase in-road density from 2016 to 2020.

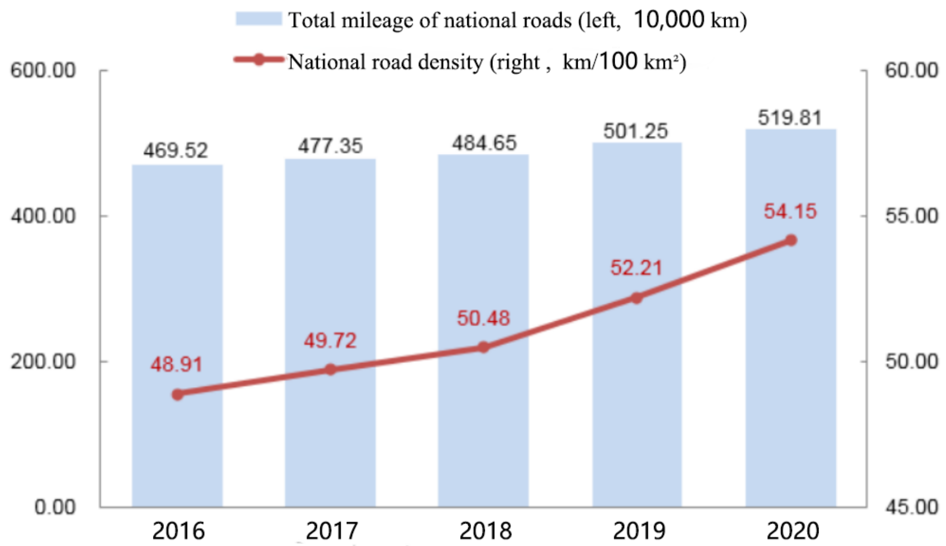


Figure 1.1 Total mileage and density of highways from 2016 to 2020

Highway construction projects are large in size, with many parties participating in the construction, high engineering quality requirements, and complex procedures. However, the applications of digital information in the construction, management, and operation of highways are still mainly based on the initial renderings. Compared with industry, shipbuilding and other industries, highway construction area is relatively backward.

BIM means that after the project engineering information is digitized, the model is constructed through digital information simulation, and the project data of each part of the project is integrated. Through the sharing and communication of model information, project participants can correctly understand and use project information, which helps to improve productivity, reduce costs, and shorten construction periods.

As the pioneer of BIM, the United States can understand the standard definition of BIM as follows:

(1) BIM digitizes the physical and functional characteristics of the project itself, and expresses the project entity digitally so that the project itself can be better edited through the model.

(2) BIM is also a digital technology, which is the management of information data. It can integrate the information of various parts of the building purpose.

(3) The implementation process of the project has various stages such as preparation, planning, construction, completion, and maintenance, and there are many managers between or during each project stage. Using BIM technology, project managers can choose to operate information at each stage of the project in order to better realize the value of the project.

In addition to establishing a specific effect model, BIM technology can integrate information at different stages in the project implementation process. BIM can meet the needs of the highway industry to adapt to the development of the industry.

The application of BIM technology in the implementation of expressway projects can improve the traditional management mode and outdated informatization methods in the past, and then improve the informatization of expressway projects, and finally realize that the project party has an overall understanding of the information at each stage of the expressway, and realizes Improve macro-control and comprehensive capabilities.

Lu et al. (2013) pointed out that the application of CAD is undoubtedly an industrial technology revolution, which has greatly improved production efficiency and effectively promoted the development and progress of construction projects. However, the advantages of CAD are mainly reflected in the design efficiency. Once the drawing design is completed, when a certain part of the drawing needs to be modified later, the overall design must be modified because the data cannot be associated. In addition, CAD cannot be associated with each participating party, resulting in multiple dockings. During this period, there will inevitably be information gaps between the two parties, which will lead to a series of problems during actual construction(Lu, 2013; Yang, 2019; Qing et al, 2014).

Under the above conditions, BIM came into being developed rapidly. It integrates the parties involved in project planning, on-site construction, operation, and maintenance into a comprehensive management platform. Based on BIM technology, the designer constructed a 3D model covering all real information databases of the building. All participating parties can insert, extract, update, modify and share various types of information on the basis of the 3D model, realizing real-time association of all parties.

BIM is an engineering data model that integrates various related information of construction projects based on three-dimensional digital technology. It is also a digital technology applied to design, construction and management. The Facilities Information Council (FIC) gives a more accurate definition: BIM is a computable and operable form of physical and functional characteristics of facilities and related project life cycle information under open industry standards, so as to provide support for decision-making. In order to realize the value of the project better.

BIM technology is another new technology in the construction industry after CAD technology, and its application will surely bring revolutionary changes to the construction industry. Compared with CAD technology, BIM technology has the following characteristics:

(1) BIM is a database formed by a computer three-dimensional model, which stores the whole process information of the building from design, construction to operation after completion.

(2) The information in the whole process of the building is interrelated, and any change to the information in the 3D model database will cause changes to other information associated with the information.

(3) BIM supports collaborative work. BIM technology is based on the open data standard,I.E., FC standard, which effectively supports the data exchange between various application systems in the construction industry and the data management of the whole process of the building.

The information management mode of BIM technology integrates discrete information of different construction parties at different stages, which avoids information ambiguity and inconsistency, reduces the total amount of information, and promotes information sharing and collaborative work, as shown in the figure below.

At present, the users of BIM in China are mainly design units. In terms of the breadth and depth of application, the application of BIM in China is just at the beginning, but it will be gradually promoted and penetrated into various fields of the construction industry.

BIM will become the mainstream technology of the next generation, but the general environment for popularization and application is not yet mature. Compared with foreign countries, my country's existing construction industry system is not unified, lacks relatively complete BIM application standards, and the industry's legal liability for BIM is unclear, resulting in an immature environment for promoting BIM applications in the construction industry.

Zhang pointed out that "the perfection of the platform and market awareness are the main issues facing the development of BIM" .

Many domestic and foreign experts believe that the differences in the existing construction industry system, domestic standards, and norms are obstacles that need to be overcome to promote BIM applications (Zhang, 2010; Wilson et al. 2011).

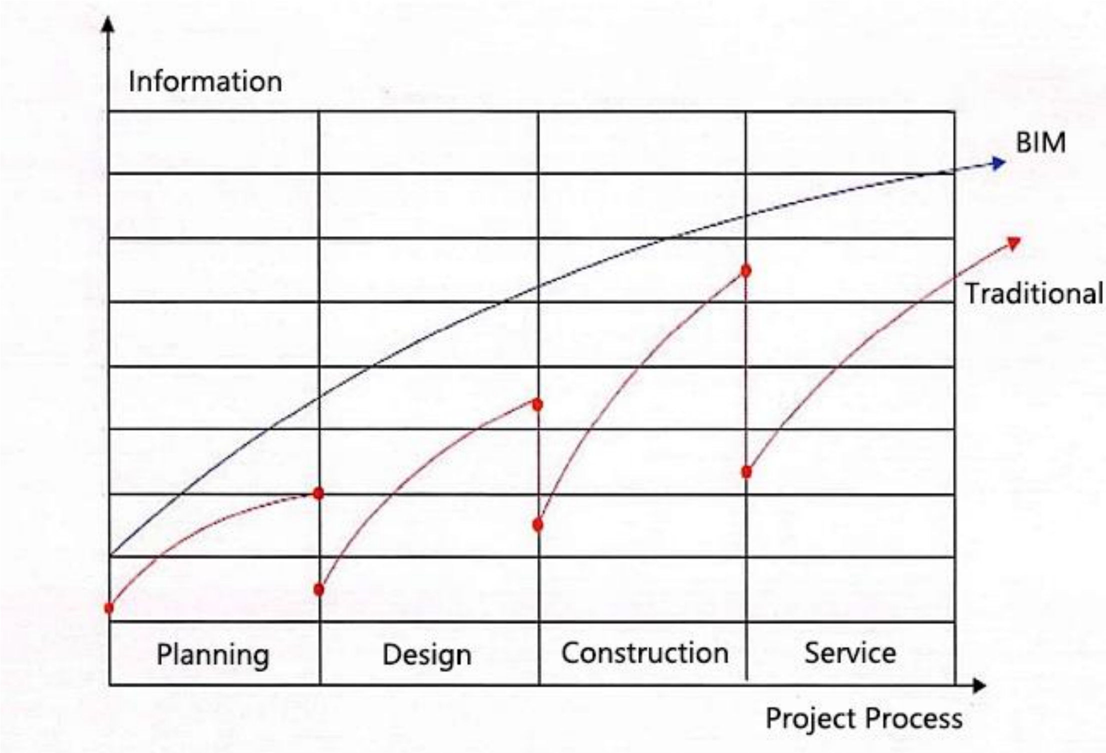


Figure 1.2 Comparison between BIM and traditional models

The application of BIM encounters a "synergy" dilemma. There is a lack of collaborative design in the BIM application process, especially in domestic project operations, where there is a lack of overall management of project information at different stages, different disciplines and participants (Zhang, 2010). BIM-related software involves different disciplines. The concept and technology of BIM provide a new platform for collaborative design, and whether the project is collaboratively designed or not is crucial to the full realization of the value of BIM.

The BIM concept runs through the entire life cycle of the project, but there is a lack of effective management integration at each stage. BIM brings visualization to designers, but that's only one aspect of BIM. The essence of BIM is that information runs through the entire life cycle of the project, which is of great significance to the comprehensive integration of project construction and post-operation management (Zhang, 2009). Relevant scholars have shown that in the construction project information system, BIM has the advantages of integrated management and full life cycle management(Feng et al. 2009). At present, the application of BIM in China basically depends on individual complex projects or the special needs of certain owners (McGraw-Hill Building Information Company, 2009). To fully utilize the advantages of BIM information life cycle integration and realize the deep application of BIM, a lot of work still needs to be done.

The current BIM application is concentrated as a designer-driven model, especially in China. Li Heng, Guo Hongling, etc.(Li et al. 2010) showed from the perspective of utility that the driving mode of the construction unit is more conducive to the main functions of BIM. Xu Junqing, Lu Huimin et al. studied the BIM-based construction supply chain information flow model, and pointed out that the participants in the construction supply chain lack the active application of BIM concepts, which hinders the large-scale application of BIM to the construction industry (Xu et al. 2011). Combined with the current application status, the functions of BIM in the construction phase and operation management phase have not been fully utilized. In order to realize the large-scale application of BIM in the construction industry chain, it is urgent to implement the comprehensive application mode of BIM project life cycle.

In summary, since China introduced BIM technology in 2003, there are still many problems waiting to be solved. The vast construction market hides huge commercial value, and the development prospect of BIM is still very impressive.

This paper research the common problems existing in each process from project approval to operation of China's highway projects, including highway design, quality control, construction management and other main aspects, tries to use BIM technology to solve the above problems, and analyzes BIM in each link effect. At the same time, implement the whole process cost control of the project on this basis, try to compare the cost of the highway project under the traditional method and BIM technology, focus on the cost comparison of each link in the construction process, and then estimate the total cost of the project, Analyze the importance and influence of BIM in the application of cost management.

1.2 Research Objectives

1. To summarize and analyze the common problems in China's highway projects, as well as the application status and existing problems of BIM in them.

2. To analyze in the case of a highway project in China: whether the cost can be reduced by adopting BIM technology.

1.3 Research Significance

At present, CAD technology is still the mainstream in China's construction industry, and the promotion of BIM technology is still limited. At the same time, talents who can skillfully use BIM technology are very scarce. It is hoped that this article can support the promotion of BIM technology in China's construction industry, and at the same time promote the training and introduction of BIM technology talents.

CHAPTER 2

LITERATURE REVIEW

2.1 BIM Development in China

2.1.1 Policies of BIM in China

The Ministry of Housing and Urban-Rural Development issued the "2011-2015 Construction Industry Informatization Development Outline" in 2011, which specifically proposed to popularize and improve the application of the construction industry information management system during the 12th Five-Year Development Plan. , by accelerating the promotion and application of new generation technologies such as BIM, the development of information management technology in the construction engineering industry, and improving the management level. (Jiang, 2012)

The Ministry of Housing and Urban-Rural Development issued "Several Opinions on Promoting the Development and Reform of the Construction Industry" issued by the Ministry of Housing and Urban-Rural Development in 2014. The research and application of BIM in the whole process of project management such as engineering design, construction, operation and maintenance will expand the comprehensive competitiveness and profit of my country's construction projects. (Qiao, 2007)

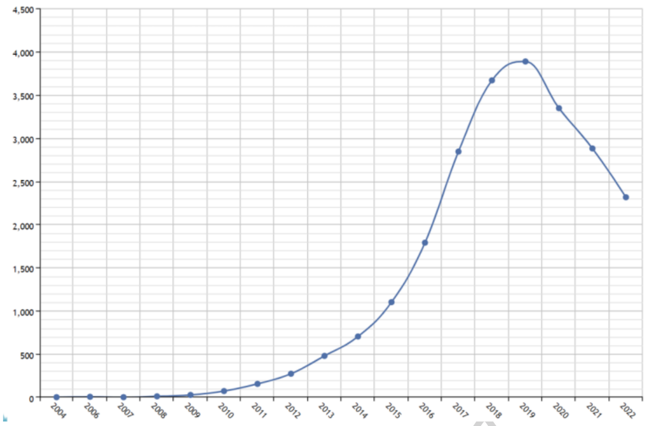
In 2015, the Ministry of Housing and Urban-Rural Development issued the "Knowledge Opinions on Promoting the Application of Building Information Modeling", which requires the legal documents, technical standards and specifications of engineering construction as the basic basis, with engineering construction enterprises as the leading, industry services, policy support and Guide as the basic principle, deepen, popularize and develop the application of BIM in the field of construction engineering, and improve the production efficiency and quality of all participants in the entire life cycle of engineering construction projects. (Zhang, 2017; Li, 2018)

The "Notice on the Construction of Highway BIM Technology Application Demonstration Projects" promulgated by the Department of Transportation in 2017 proposes to accelerate the construction of demonstration projects using BIM technology in my country's highway industry and improve the management level of my country's highway engineering design and construction. Accelerate and vigorously promote the information construction of national highway engineering maintenance management. (Pei, 2017; Rong, et al. 2018)

Under the perfection, guidance and promotion of various policies in China, in order to comprehensively improve the practicality of BIM technology, a large number of research scholars are committed to the research of BIM technology.

2.1.2 BIM Research

After China introduced BIM technology and promoted the application of BIM technology in 2003, the attention of BIM technology in the construction field has always been high. It reached its peak in 2019, and due to the impact of the new crown epidemic, the number of papers began to decrease from 2020, but the overall number can be more than that in 2016



years	Document quantity	years	Document quantity
2004	1	2014	703
2005	0	2015	1100
2006	5	2016	1788
2007	1	2017	2843
2008	11	2018	3667
2009	27	2019	3885
2010	72	2020	3345
2011	155	2021	2879
2012	272	2022	2314
2013	479		

Figure 2.1 The number of published academic papers after 2003

However, based on the statistics of paper data from CNKI(China National Knowledge Infrastructure). The research on BIM technology in China still focuses on the development of BIM technology. As shown in Figure 2.2 and Figure 2.1, the number of research on engineering project management is about half of the technology development direction. This shows that the application of BIM technology in China is still in the stage of mostly theoretical research and less practical application, and the development of China's BIM technology has a long way to go.

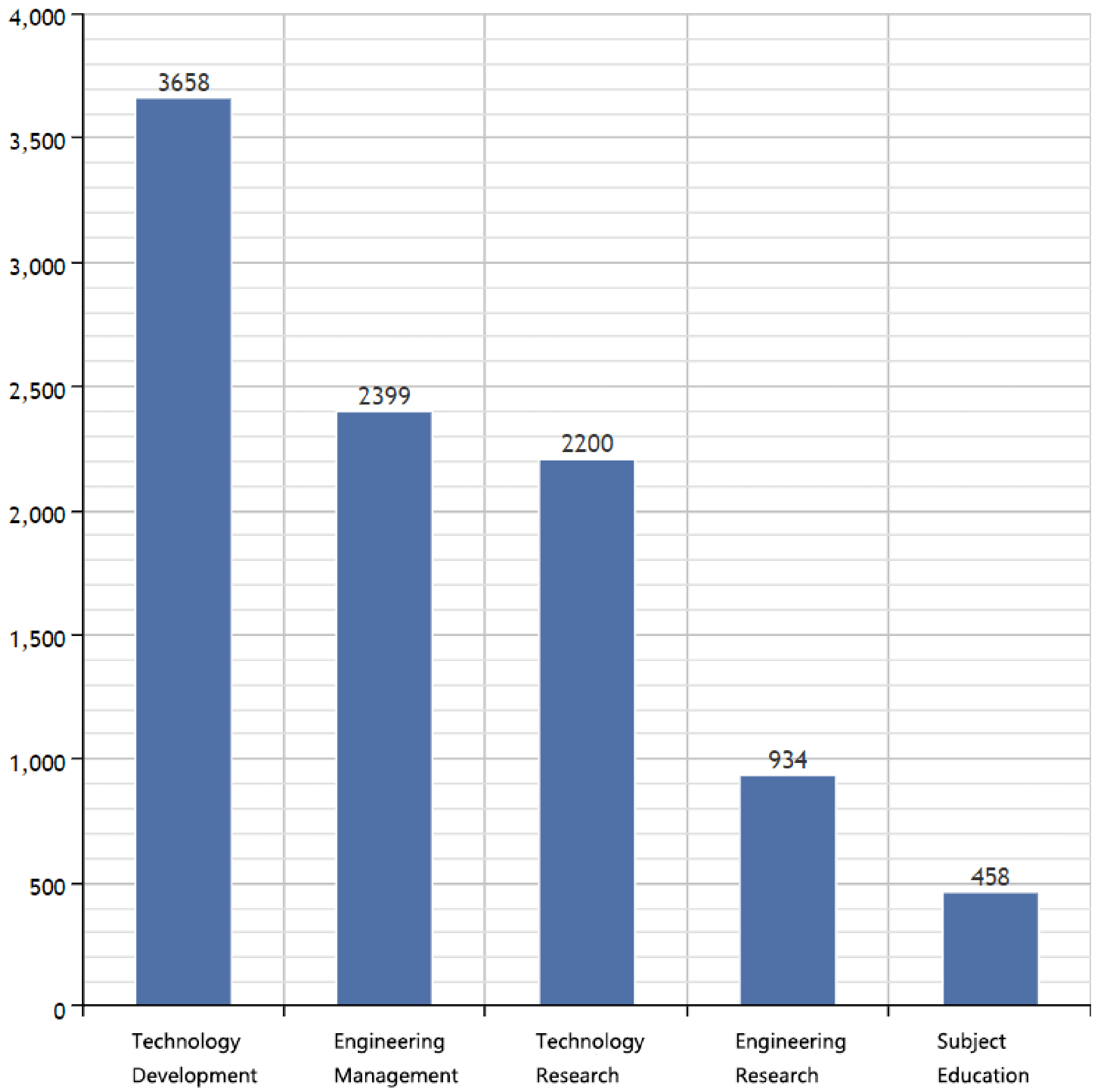


Figure 2.2 BIM literature topic statistics

Wang et al. (2009) think that the digital information model established based on the entity information of the engineering project can realize automatic engineering quantity calculation and cost review, and effectively improve the reliability of cost accounting.

Li et al. (2010) proposed that the use of BIM technology in the early stage of large or complex projects can effectively optimize project design, strengthen the whole process management of construction, and reduce construction costs and construction periods.

Zhang et al. (2011) developed an on-site construction management information platform 4D-CSMS based on 4D model computer-aided design technology. Realized 3D site layout, 4D simulated construction, construction dynamic management and other functions, improved the comprehensive management ability of the construction site, and developed a BIM integration platform based on the whole life of the project to build management. (Hu et al. 2008; Zhang et al. 2011; Zhang et al. 2012a; Zhang et al. 2012b)

He et al. (2012) summarized the typical BIM application cases in China (table) , their application effects existing problems. He thinks that BIM is an emerging technology in the construction industry, and more exploration and practice are needed to perfect its practical application.

He et al.(2016) thinks that using the information model designed by BIM can effectively assist the construction party to optimize the construction plan, simulate the construction, monitor the progress and quality of the construction, improve the efficiency and accuracy of the construction, and then increase the income of the whole life cycle of the project.

Wang et al. (2018) conducted a systematic analysis of BIM, expounded the impact and obstacles of BIM from the aspects of application environment, technical level and actual use, and laid a foundation for the further development of BIM in China. Ma et al. (2018) and others pointed out that BIM still lacks a more complete industry standard, and needs to constantly explore new technology application models.

Shi et al. (2020) summarized and analyzed the practical application of BIM technology in China, and tried to design and build a visual management platform using BIM technology to achieve multi-objective optimization and collaboration of the project.

2.2 Application of BIM in different projects

Usually, engineering projects based on BIM technology are comprehensive projects involving multiple disciplines and links, involving multiple participants such as owners, construction personnel, designers, etc. Some of the participants directly participate in the project construction process, while others may have an indirect impact（Hong et al.）.

Table 2.1 Application of BIM in different projects

Project participants	Application of BIM
Government agency	Promulgate policies, formulate technical standards, and build legal systems
Owner	Demonstrate your architectural intentions and ideas clearly and directly, and accurately convey them to other participants
Designer	It is conducive to cooperation between designers and construction parties, eliminating communication barriers and avoiding misunderstandings.
Contractor	3D collision detection, virtual construction and 3D model verification
Precast processor	Standardize components and improve construction efficiency
Material equipment supplier	Quickly and accurately understand the usage and demand of materials. Develop and adjust material supply plans in a timely and scientific manner

2.2.1 Government agency

Government agencies mainly affect the application process of BIM in project management through the promulgation of policies, the formulation of technical standards, and the construction of legal systems, and provide support for the promotion and promotion of the application of BIM technology.

2.2.2 Owner

The application of BIM is conducive to the owner to clearly and directly express his architectural intentions and ideas, and to convey his inner thoughts to other participants more accurately. In the early stage of the project, the owner can participate in the construction of the BIM project, discuss and discuss with other participants, and complete the project planning. Subsequently, a complete project planning process can be designed according to the architectural intention of the owner and combined with the opinions of different parties to ensure that the project is carried out in an orderly, efficient and smooth manner.

2.2.3 Designer

Designers are the primary users of BIM technology. In order to meet the requirements of high efficiency and energy saving, more and more attention has been paid to the whole project from the design to the later implementation process. In the traditional design field, the design work is faulted and isolated, which brings certain difficulties to the follow-up construction. With the introduction of BIM technology, the entire working mode becomes parallel, interactive and integrated. The application of BIM is beneficial to the cooperation between designers and construction parties. BIM technology can allow the constructor to better understand the designer's intention through the three-dimensional model, and the constructor can also use this form to tell the designer which parts may encounter obstacles or are not feasible during construction. In other words, BIM technology is conducive to closer communication between constructors and designers, eliminating communication barriers, and avoiding understanding deviations.

2.2.4 Contractor

The biggest advantages of BIM application for contractors are:

First, 3D collision detection. During the construction process, due to improper grasp at the initial stage, it is likely to cause collisions of equipment and pipelines in the later stage during the construction process, so that the construction personnel have to dismantle them again, which often requires a lot of energy and effort. cost. The application of BIM technology can simulate the collision process of equipment and pipelines in the form of a three-dimensional model, helping construction personnel to effectively avoid risks in the construction process, reasonably prevent collisions between pipelines and equipment, and reduce misoperations or invalid operations in the project , while also facilitating the optimization of clearance and piping arrangements.

Second, the value of virtual buildings to builders lies in the ability to quickly and intuitively know what the road plan is and what the actual progress is at any time and anywhere. All parties involved can have a good grasp of the progress of the project. BIM technology can truly and scientifically present the construction site through building model simulation, thereby helping construction personnel to discover problems and risks in a timely manner, reduce rework, and improve the correct rate of operation.

Third, 3D model verification. BIM technology can simulate the entire construction process in a three-dimensional view, thereby helping construction personnel to compare and analyze the differences between engineering simulation and actual engineering, so as to adjust the construction plan in a timely manner. At the same time, BIM technology can also help construction personnel to transmit construction progress information to owners through three-dimensional views, so that they can respond as soon as possible and adjust the plan in time (Jiang, 2014).

2.2.5 Precast processor

The BIM model of standardized components contains a large amount of information and standards, which is conducive to the production and design of prefabricated standard components by the prefabrication factory, and then transports the components to the construction site for assembly, which improves the construction efficiency.

2.2.6 Material equipment supplier

Material suppliers are a vital part of engineering project construction. Whether materials are supplied in a timely and scientific manner is the prerequisite for efficient and orderly development of engineering projects. BIM technology can quickly and accurately understand the use and demand of materials through simulation, thereby helping material suppliers to formulate and adjust material supply plans in a timely and scientific manner. Not only that, in the construction of engineering projects based on BIM technology, suppliers can also participate in the early planning of the project, so as to cooperate with the construction team to provide raw materials scientifically and continuously, and can also formulate specific material or equipment production plans to Meet on-site needs.

2.3 Application of BIM in all phases of engineering

The application of BIM technology runs through the entire construction project life cycle (Sun, 2011)。

Table 2.2 Application of BIM in all phases of engineering

Engineering stage	Application of BIM
Decision stage	Help designers make complete, reasonable and scientific project planning
Tender stage	Key engineering projects will be clearly stipulated in the bidding announcement, requiring bidders to use BIM technology for engineering construction.
Design stage	Model building, pipeline layout, three-dimensional coordination, etc. through BIM
Construction stage	Use BIM technology to simulate the construction site, test the effectiveness of the construction plan at the same time, and discover risks in a timely manner to achieve cost control and management
Operation stage	Integrate and analyze equipment maintenance data to help maintenance personnel determine regular maintenance time and carry out targeted maintenance.

2.3.1 Decision stage

In this stage, BIM technology can simulate and evaluate various environments around the construction project in a visual way, so as to help designers make complete, reasonable and scientific project planning, including three-dimensional landscape analysis, environmental analysis, environmental temperature analysis, etc.

2.3.2 Tender stage

Nowadays, many key engineering projects will clearly stipulate in the bidding announcement that bidders are required to use BIM technology for engineering construction, and BIM technology must be used to present design ideas and cost budgets, as well as construction simulations showing construction content.

2.3.3 Design stage

In this stage, model building, pipeline layout, three-dimensional coordination, etc. can be carried out, which is beneficial to help designers to grasp the engineering design process and direction as a whole.

2.3.4 Construction stage

In the preparation stage, construction personnel can use BIM technology to simulate the construction site and test the effectiveness of the construction plan. At the same time, it is also beneficial for construction personnel to review and check the drawings to determine whether the drawings are correct and fit the reality. In the formal construction stage, if the project changes, the BIM model can be used to update the statistical data of the volume along with the design change; in terms of safety, the model can be used for simulations such as deep foundation pit treatment to ensure the safety and security of the construction. Building stability; in terms of construction process, construction personnel can use BIM model to construct 3D or 4D visualization view, decompose WBS engineering structure, and form a relatively complete and reasonable construction schedule to ensure the orderly progress of subsequent construction. At the same time, in terms of construction costs, the 5D construction cost simulation of BIM technology can be used to understand the status of fund usage and risks in a timely manner, so as to efficiently control and manage costs.

2.3.5 Operation stage

At this stage, BIM technology can realize the maintenance and management of equipment in a visualized form. For example, when equipment fails or requires regular maintenance, BIM technology can help maintenance personnel quickly find risk points and failure points, so as to carry out targeted maintenance. At the same time, it can also integrate and analyze equipment maintenance data to help maintenance personnel determine regular maintenance time, thus ensuring the service life of equipment on the one hand, and improving maintenance efficiency on the other hand (Sun et al. 2014).

2.4 Different levels of BIM application

Technology requires gradual development and breakthroughs, and there is an evolution process from primary to advanced, and it can only be maximized through continuous practice and models. The hierarchy of a BIM application is typically divided into seven parts, from lowest to highest.

2.4.1 Regression 3D Model

From the beginning of the design, the application can present the design appearance and concept of the building in the form of a three-dimensional view, realize the paperless operation of the design, improve the design efficiency, and avoid the problems caused by the subjective understanding of the two-dimensional drawings.

2.4.2 Overall plan

As a comprehensive project, the engineering project involves a wide range of areas, is difficult to construct, and has a complicated process. Once an error occurs in any link, it will inevitably trigger a series of reactions, either leading to the suspension of subsequent construction, or prolonging the construction period or increasing costs. . On the other hand, BIM technology can start from the whole engineering project cycle, base on the whole process and the overall situation, control all links as a whole, and ensure the cohesion and coordination between various disciplines.

2.4.3 4D，5D

Everything that exists in the time dimension is 4D, but the current project management technology is difficult to achieve 4D control of the project, the timetable is difficult to understand, and often cannot be implemented in the project, thus hindering the progress of subsequent engineering links. However, everything in the economic environment is 5D, requiring efficient use of various resources. As a part of economic activities, the cost control of engineering projects has always been a difficult problem for engineers. Since the BIM model stores all the information of the construction project, it is actually a copy of the actual project, and this advantage prompts it to break through the limitations of traditional CAD and other technologies and maximize the utilization efficiency of resources.

2.4.4 Team transformation

The engineering project involves a wide range of interests, including multiple stakeholders, and the operation is difficult, requiring coordination and cooperation of all participants and overall consideration. In other words, the construction of engineering projects has extremely high requirements for the cooperation of personnel, the connection of various professional links, and the use of funds. In particular, the cooperation between the teams directly determines the progress and construction efficiency of the project. In the traditional engineering construction mode, unity and cooperation has always been a major difficulty in engineering management, and conflicts among professionals are often seen during the construction process. However, BIM technology effectively solves this problem. Through the efficient integration and sharing of data, communication barriers between professionals and teams are eliminated, and additional costs caused by information blockage or poor communication are reasonably avoided.

2.4.5 Reduce uncertainty

The integration site of the BIM application is to simulate the real construction site into a 3D model, through pre-simulation, discover possible problems and risks in the actual construction process, so as to take effective and active measures to prevent and solve them. Compared with two-dimensional construction drawings, 3D models contain more information, and can allow staff to better see the risks in construction through simulation exercises, so as to better support on-site construction activities.

2.4.6 Industrialization, Automation

BIM technology has the function of data integration and sharing, which can realize the efficient management of data. In addition, models such as the whole process tracking of BIM technology can also effectively promote the industrialization and automation of engineering projects. For example, for the design of complex links, BIM technology can cooperate with industrial production technology to complete difficult tasks through 3D simulation, thereby improving the efficiency and accuracy of engineering construction.

2.4.7 Improve the industrial chain

Project construction involves multiple participants such as government agencies, construction parties, designers, owners, supervisory agencies, material suppliers, etc. It requires the coordination and active communication of all participants to ensure the smooth implementation of the project. However, BIM technology can accurately and intuitively present the key information in the project construction based on the 3D platform in the form of 3D view, so as to facilitate the communication and coordination of all participants.

2.5 Application of BIM on highway

When the People's Republic of China was founded in 1949, the total mileage of highways open to traffic was about 80,000 kilometers, and there was no highway construction. At the end of the 1980s, the rapid transformation of the economy led to a sharp increase in the national road transport demand, but due to the lack of road mileage and poor quality, economic development was severely restricted. On June 27, 1984, China began construction of the first expressway - the Shenyang-Dalian Expressway. Since then, important expressways such as Hujia Expressway, Jingjintang Expressway, Beijing-Shenyang Expressway and Beijing-Shanghai Expressway have started construction and opened to traffic one after another, and my country's expressway network has begun to take shape. By the end of 2020, the total mileage of national roads will reach 5.1981 million kilometers, and the road density will rise to 54.15 kilometers per square kilometer. During this period, the rapid progress of China's construction engineering technology is inseparable from the research and application exploration of road engineering and BIM technology.

Zhang et al.(2014) first applied BIM technology to the construction management process of expressway projects in 2014. According to the zonal distribution characteristics of expressway projects, he developed the "4D construction management system of Xingfen Expressway based on BIM". Aiming at the characteristics of large-scale engineering projects and multiple points and long lines, a plan to establish a multi-fineness BIM model is proposed, which realizes the hierarchical visual construction simulation of the BIM model.

Liu et al. (2016) derived data coding rules through highway characteristics, and created a highway BIM multi-information database, namely the BIM platform. Through BIM platform data fusion mining, simulation and other technologies, develop highway project design scheme optimization, engineering quantity statistics, construction progress deduction, geometric size quality check and other functions, realize the management and application of the whole life cycle of highways, through its It can be seen from the research that BIM technology is the preferred way to realize the life cycle management of highway projects; Liu et al. (2018) studied the decomposition and coding of BIM models in the management process of transportation construction projects. BIM model decomposition and coding mechanism of transportation construction projects. On the basis of unified BIM codes for traffic construction project management, the object system of traffic construction projects is decomposed into BIM entity units that are independent and interrelated according to the professional system. Using BIM coding as a link, realize the interconnection of various business data, meet the needs of multi-business management, realize the coordination and unification of cost, progress, and quality, and the research has strongly improved the level of project management informatization; Cheng Fang et al. (2019) To solve the problem that a large amount of engineering data generated in the process of highway tunnel construction cannot be preserved regularly and the management method is inefficient, the GIS/BIM data integration method is used to conduct management research on it; Jing et al. (2020) A three-level bill of quantities EBS\WBS for high-speed railways that conforms to the characteristics of BIM modeling and meets the general contracting model and the entire cost management process is proposed, and the structural characteristics of each level are described. According to Jing Jing's research, there are differences between the railway bill of quantities and railway BIM standards in terms of engineering decomposition principles, objects, and information expression methods. However, the BIM-based three-level high-speed railway bill of quantities and railway BIM standards can reach a synergy on EBSIWBS. The realization of BIM-based high-speed railway bill of quantities pricing model has laid the foundation.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Research Methods

3.1.1 Descriptive Research

Descriptive research methods play a fundamental role when conducting highway construction research. Through in-depth interviews, this study obtained the most authentic information about highway construction from front-line construction workers. This information includes design concepts, construction technology, operation and maintenance strategies, etc., and also provides background knowledge and research direction for subsequent quantitative research.

3.1.2 Case Study

Highway construction is a complex process involving many factors. Therefore, a single research method may not fully reveal its inherent complexity. The case study method, especially real case studies based on on-site inspections, can provide a deeper understanding of the pain points at each stage of the highway construction process, thereby giving practical significance to the application of BIM technology in highway construction. This study takes two highway construction cases in China as the research object and collects literature, relevant information and data to sort out and analyze the practical problems encountered when using BIM technology during the inspection, design and construction of highway projects, To discuss the practical significance of BIM technology(Cui et al. 2019, Xiang et al. 2021).

3.1.3 Literature Research

This article summarizes and summarizes the research of past researchers by reviewing the literature and provides a basic framework for the research of this article. The literature review provides a solid foundation for this study, revealing the history and current status of BIM technology and highway construction. This research explores libraries, academic journals, and online scholarly resources in depth to ensure that the resulting information is both broad and relevant. Each source is also critically screened and evaluated to ensure its quality and relevance.

3.2 Research Plan

3.2.1 Preliminary Literature Review

In order to ensure that this study builds on and contributes to previous research findings, a literature review is therefore crucial. This step can set a clear context and framework for subsequent research.

Purposive literature collection: clarify the goals of literature collection. Regarding the theme of this study, we will focus on the history, current situation, and challenges of highway construction as well as the application experience and effects of BIM technology in other fields.

Multi-channel literature search: Literature search through academic databases such as CNKI, Web of Science, Google Scholar, etc. to ensure the breadth and authoritativeness of the literature.

Classification and organization of literature: Classify the literature according to its content and source, such as theoretical literature, empirical research, case analysis, etc., to facilitate subsequent in-depth reading and analysis.

Key findings and summary: During the literature review process, key findings and opinions will be recorded to provide direction and reference for subsequent research.

3.2.2 Data Collection and Processing

On the one hand, the literature review provides a solid foundation for this study and reveals the history and current situation of BIM technology and highway construction. Researchers thoroughly explored libraries, academic journals, and online scholarly resources to ensure that the information obtained was both broad and relevant. Every source is critically screened and evaluated to ensure its quality and relevance. On the other hand, this study gained valuable field experience and perspectives through discussions with those involved in highway construction projects.

Data collection and processing are critical steps in research. By collecting and processing data systematically and scientifically, researchers can ensure that the conclusions drawn are both meaningful and reliable. During this process, researchers need to constantly reflect and adjust methods to ensure the quality and integrity of data.

3.3 Validity and reliability

3.3.1 Research Limitations

Sample size: Because highway projects vary greatly in size, location, and complexity, the sample of projects selected in this study may not fully represent all highway projects in China. In addition, since there are also differences in the application of BIM technology, the sample size of the selected projects may also affect the research results.

Data Sources: Although multiple data collection methods were used, each method may be subject to its own inherent biases. For example, interviews with highway construction companies may tend to emphasize the advantages of BIM technology while ignoring its limitations.

Methodological selection: This study mainly relies on literature review and interview survey to explore the application of BIM in highway construction. These approaches may ignore other important factors related to BIM application, such as specific technical difficulties or project management strategies.

Time and resource limitations: Due to time and resource limitations, it may not be possible to cover all aspects related to the application of BIM technology in highway construction.

3.3.2 Ensuring Reliability

To ensure the reliability of the study, the following measures were taken:

Multiple methods were used to collect data: triangulation was used to collect data, combined with literature review and interviews, to explore the application of BIM technology in highway construction from different angles.

Regular discussions: Regular discussions with experts and research teams to ensure the accuracy and completeness of the research methods and their fit with the actual application of BIM technology in highway construction.

Data transparency: To ensure that other researchers can replicate and verify the results of this study, the complete data collection and analysis process is provided.

Consideration of external validity: Although this study mainly focuses on the application of BIM in highway construction in China, it also refers to relevant research in other countries to ensure the comprehensiveness and breadth of the research.

In order to ensure the validity and reliability of the research, this study not only carefully selected appropriate research methods, but also continuously reflected on and verified the research process. It is expected that this study can provide valuable insights and suggestions for the application of BIM technology in highway construction.

CHAPTER 4

Result and Analysis

This article discusses the significance of BIM technology in practical applications from two aspects: the design and construction management of highways in mountainous areas in China. In terms of design, in addition to conventional design, the treatment design of adverse geological factors within the scope of highway construction is also an important evaluation criterion; in the construction management part, it can be discussed one by one from aspects such as quality, cost, schedule and data management. At the same time, we use two mountainous highways in China as construction cases to discuss the practical significance of BIM technology in practical applications.

4.1 Research results

4.1.1 Zhengzhou to Xixia Expressway

The project area of the Yaoshan to Luanchuan section of the Zhengzhou-Xixia Expressway is located in a hilly area with crisscrossing mountains and a surface elevation difference of nearly 700m; the project roadbed width is 26m, using the four-lane highway standard, and the design driving speed is 100km/h , with a total length of 78. 9km. This project has 6 interchanges, two extra-long tunnels of more than 6km, 88 main line bridges, and a bridge-to-tunnel ratio of 58. 9%.

The application exploration of BIM technology in this project is mainly reflected in the two-dimensional design drawings provided by the design department, and then the three-dimensional BIM model is established based on the two-dimensional drawings, and is used in routes, interchanges, roadbeds, bridges, tunnels, and signs and markings. Establish BIM models from different aspects, and use the BIM model to re-check the design.

4.1.2 Chengdu to Yibin Expressway

The Chengdu-Yibin Expressway is located in the central and southern part of Sichuan Province. It is one of the 16 Chengdu radial expressways in the Sichuan Provincial Expressway Planning Network. It is the fastest route from Chengdu to Yibin and an important channel for Chengdu to integrate into the national Yangtze River Economic Belt. The total length of the project is 155km. The entire line is constructed according to the two-way six-lane highway standard. The design speed is 120km/h. It has 4 tunnels, 17 interchanges and 5 service areas (Xiang et al. 2021).
In view of the pain points of the expressway project, such as many construction points and long lines, and based on the actual needs of the project, BIM models of different precision were established through oblique photography, GIS, information technology and other technologies, and a construction management cloud platform was developed to achieve high-speed management in mountainous areas. Digital management of quality management, cost control, construction progress management, material procurement, data management and other aspects during the highway construction process promotes the digital development of highway project construction in mountainous areas.

4.2 Key Points in Mountainous Highway Design

China's geological conditions are complex and there are a large number of mountainous areas. Mountains account for more than 33% of my country's total land area, and hills and rugged plateaus also account for 10%. The total area of various mountainous landforms has exceeded my country's total area. 50% of the area.

Affected by the complex topography of mountainous areas, mountainous highway construction often needs to face diverse geological conditions. Problems such as karst and goaf will not only adversely affect the safety of the project, but also shorten the service life of the project. Therefore, the design of mountainous highways needs to focus on these geological factors and explore corresponding solutions based on practice, so as to achieve the goal of coexisting quality and efficiency in mountainous infrastructure construction.

At present, based on China's existing design experience and taking into account the actual needs of mountainous highway construction, the design focus of mountainous highways can be summarized into the following points:

Comparison and optimization of route horizontal and vertical plans;

Anti-slip design of long longitudinal slope pavements;

Bridge design in karst areas and goaf areas;

Tunnel design in karst and other adverse geological conditions. In the highway design and construction process, these problems need to be solved one by one.

4.2.1 Selection and Optimization of Route Plan

The geological conditions along the mountainous highway project are diverse and complex, which leads to the need to consider more factors during the design process. The first step in the design process is the selection of the route. The rationality, economy, and scientific nature of the route selection are all of great significance. , also plays an important role in subsequent design and construction work. Therefore, formulating a suitable and scientific route plan is the first threshold that needs to be overcome in the construction of mountain highway projects (Cui et al. 2019).

Generally speaking, the following factors need to be considered in the line selection process:

The horizontal and vertical linear design of the selected route must be able to comply with the topography and terrain distribution along the project. Do not blindly pursue high indicators. Usually, the minimum standards required by current regulations are the principle. The route plan chosen should be comprehensive and reasonable, and avoid missing valuable plans as much as possible.

For road sections where adverse geological conditions are widely distributed, remote sensing technology, CAD technology or BIM technology can be used to assist in completing the route selection work. At the same time, the route should avoid crossing areas with complex geological conditions as much as possible to improve the overall construction efficiency.

Route selection should balance the relationship between horizontal, vertical and horizontal aspects. You can try to coordinate the combination of important structures such as tunnels and bridges through digital means such as BIM technology, and repeatedly demonstrate the layout of tunnel dividing and joining lines. In terms of rationality and Find the optimal solution between safety and economy. If necessary, the operating speed theory can be used to evaluate the bridge design plan.

4.2.2 Anti-sliding Problem on Long Longitudinal Slope Sections

Mountainous terrain often has a certain height difference, which generally requires continuous uphill and downhill slopes during design. However, in weather with poor visibility, long longitudinal slopes can easily lead to traffic accidents. In order to improve its safety, in addition to improving the pavement structure and materials, terrain changes must also be considered during the design process to formulate countermeasures.

4.2.3 Treatment of Karst and Goaf Areas

Karst and goaf areas are two types of unfavorable geological conditions that require special attention on mountainous highways. They are difficult to accurately locate during the survey stage, especially in areas where small-scale mining areas are distributed. They often have irregularities, which in turn leads to the formation of highway structures. Stability is potentially threatened. The key to solving such problems is to determine their location and scale and formulate corresponding measures.

4.2.4 Treatment of Deep Cutting Slopes

In the construction of mountainous highways, there are generally many deep cutting points. In order to ensure stability during use, reinforcement and protection should be combined, and the existing conditions of the construction environment should be used to reduce possible damage to the natural environment. Green protection measures are preferred for slope excavation.

4.2.5 Design of Bridges on Special Sections

Karst landforms are generally concealed and difficult to monitor. They may even lead to uneven subsidence of the substrate, adversely affecting infrastructure construction.

For road sections with relatively rich karst geological conditions, the basic method of geological drilling should be adopted: first, it should be completed one by one according to the principle of comprehensive drilling; at the same time, appropriate physical detection measures should be used to assist, so as to comprehensively investigate the underground karst conditions.

For road sections in karst areas with shallow burial depth or scattered distribution, the foundation should be enlarged, and the karst ditch under the foundation should be filled in so that it can meet the basic requirements of engineering construction; there are no large karst caves along the road. And when the overburden is good, and the overburden is stable and there is no long-term erosion by water flow, consider using the enlarged foundation design as a pier; for the section with a large degree of karst development or distribution of multi-layered caves, priority is given to drilling. Construction of hole pile foundation is carried out.

4.2.6 Bridge Pier Top Design

When designing highways in mountainous areas, attention must be paid to the design of pier tops in sections with large longitudinal slopes, which is mainly reflected in the displacement of pier tops, which is also a common problem in actual projects. For example, when a vehicle is driving on a long longitudinal slope, the bridge beams will continue to move forward due to the continuous braking force. This phenomenon is more prominent in one-way sections.

In addition, for road sections with curves, large longitudinal slopes, and high piers, the displacement of the pier top not only includes displacement in the same direction as the bridge, but may also cause torsional displacement and construction displacement. These displacement phenomena often have a serious impact on the stability of the bridge, leaving it in an unsafe state.

4.2.7 Tunnel Design

The treatment of karst geology is an issue that requires attention in the design of mountainous highways. The design of tunnels in karst areas is also an effective measure to ensure the overall quality of the project. The design is mainly carried out from the following aspects.

(1) In addition to adapting to the overall design standards of the project, tunnels in karst areas also need to clarify the geological structural characteristics and geological environment of the project location, and take measures

to deal with it. In this process, the support of BIM technology can be used to design in advance to improve overall efficiency.

(2) Karst geology has a certain degree of concealment, so it is often difficult to detect it in time in the early stages of its development. The large amount of pressurized water that collects and remains near the tunnel will make it difficult to carry out normal construction. Therefore, before construction, advance survey of the construction site should be carried out to ascertain the distribution of nearby groundwater, and the advance survey report should be incorporated into the construction process for unified management.

(3) Tunnel engineering construction needs to pass through karst sections rich in groundwater such as fault fracture zones, and should be reinforced by grouting to strengthen the stability of the tunnel rock mass structure and reduce water permeability. After the grouting operation is completed, it should be tested in time to evaluate whether the effect meets the expected requirements. Only after the test is qualified can subsequent excavation work be started.

(4) When a tunnel needs to cross a water-rich fault, the lining structure often needs to face a higher level of water pressure. In this case, the inner contour and support parameters need to be determined according to the tunnel route, and a circular inner contour needs to be adopted. It should be noted that the temporary support in the early stage of tunnel construction should meet the basic stiffness requirements and be closed in time after meeting the requirements.

4.2.8 Tunnel Design for Other Sections with Poor Geology

The geological conditions in mountainous areas are complex, often accompanied by a large number of goaf. Unfavorable terrain such as bias pressure and steep cliffs may also occur at the entrance of the tunnel. Corresponding treatment needs to be made based on actual engineering conditions.

(1) When a tunnel passes through a goaf, it should be avoided as much as possible. First, the hydrogeological conditions of the area should be clarified, and the corresponding prevention and control plan should be selected based on the distribution and size of the goaf.

(2) When a tunnel needs to pass through weak strata such as faults, its distribution, size and basic properties should first be clarified. At the same time, the development of groundwater should be understood, and targeted measures should be proposed for infrastructure construction. For rock formations with weak properties, advance support can generally be used to improve their stability; the mechanical properties of rock mass are significantly affected by groundwater, which can be treated by grouting; for rock masses with prominent expansion properties, in addition to strengthening the lining, In addition to resisting the penetration of groundwater, the structure should also reserve sufficient space and set up steel supports; for tunnels with harmful gases, the lining should be closed and have good air tightness.

(3) For geological phenomena such as bias pressure and steep cliffs at the tunnel entrance, different measures can be taken according to the actual situation: for bias terrain, the occurrence of upper and lower separation tunnels and multi-arch tunnels should be avoided as much as possible; for steep cliff terrain, in order to Reduce the risk of structural collapse and create a safe and stable environment for the construction process.

CHAPTER 5
CONCLUSION

5.1 Design Stage of Mountainous Highway

The research and application of BIM technology in China's highway survey and design industry is still in the development stage. The prerequisite for applying BIM technology is data interoperability, which is the core of BIM technology. The means, methods or processes of actual application of BIM technology are reflected in the application of BIM models in various stages of the project life cycle. Therefore, how to first solve the standardized establishment and information sharing of three-dimensional highway models in highway survey and design, and finally realize the collaborative work of BIM technology and highway survey and design, is an important issue that BIM technology needs to face in the design stage of mountainous highway projects.

Take the Yaoshan-Luanchuan section of the Zhengzhou-Xixia Expressway as an example. The area where the project is located is a mountainous and hilly area with crisscrossing mountains and a surface elevation difference of nearly 700m. The roadbed width of the project is 26m, and the design adopts the four-lane highway standard. The driving speed is 100km/h and the total length is 78. 9km. In the design stage of this project, the design department first provided two-dimensional design drawings, and then established a three-dimensional BIM model based on the two-dimensional drawings; a BIM model was established for the entire project. While conducting BIM modeling, explore the process of BIM technology in the design stage. Each major uses different methods and software for design modeling according to their professional characteristics, which can be divided into the following major aspects:

Route major: First, build a three-dimensional geographic information model. Based on the intuitive three-dimensional terrain data model, use Autodesk Infraworks 360 software to select corridors and edit route information. Then import the plane and longitudinal section data from Infraworks into Autodesk Civil 3D. The route optimization design is carried out in the software, and finally construction drawings such as overall drawings, horizontal and vertical sections, straight and curved tables can be generated, and the route horizontal and vertical data can be exported for other professional use.

Subgrade pavement: Edit the cross-section template according to the project's subgrade width, subgrade pavement layer thickness, slope settings, etc., define the cross-section template library for different road sections, and use the software corridor function to perform three-dimensional design of the subgrade, pavement, and side slopes.

Bridge: Establish a parametric family library of bridge superstructure and substructure, and determine the center pile number and layout span of the bridge based on the three-dimensional geographic information model and route direction. Generate a 3D bridge model with one click by reading the 3D route data and calling the component models of the superstructure and substructure.

Tunnel: Establish cross-section templates for the main line of the tunnel, pedestrian passages, and vehicle passages, and create a three-dimensional tunnel model based on the three-dimensional route data with horizontal and vertical directions and the grade of the surrounding rock of the tunnel.

5.1.1 Highway Design Modeling Process and Analysis

(1) Road model

The establishment of three-dimensional terrain is based on the plane contour terrain data provided by the surveying and mapping profession. Therefore, the basic surveying and mapping data directly determines the quality of the later design, and the accuracy and scope of the early surveying and mapping data must be guaranteed; take the Zhengzhou to Xixia project as an example , it uses lidar, the most accurate topographic surveying and mapping method in the highway industry, to collect terrain data. The accuracy is controlled within 15cm, which fully guarantees the accuracy and design quality of the project.

When building a road model, you need to create a road cross-section template. Since the width of the roadbed between the main line and the hub is inconsistent, and the thickness of the road structure is different, the roadbed filling and excavation parts need to be set with different slope rates based on geological data. The project needs to create a variety of road cross-section templates that meet various conditions, and in the template Set up corresponding retaining walls, guardrails, etc.

Finally, in order to transfer the model to the construction management and operation and maintenance stages and facilitate the connection of BIM model data with other software, each component of the road template is set with corresponding materials and codes. During cross-section design, the road is divided into corridor sections corresponding to its conditions according to the geological conditions and terrain conditions of the road, and the model is constructed by calling the corresponding created road cross-section template.

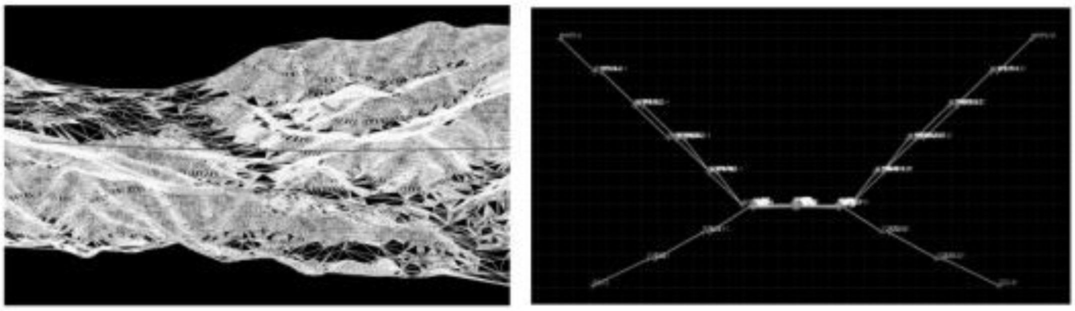


Figure 5.1 Road cross section template (Cui et al. 2019)

Compared with the traditional two-dimensional design, the three-dimensional design constructed by BIM technology can intuitively judge the precise section of the protection form and the required protection form in the three-dimensional road model, while the two-dimensional design needs to judge by viewing each cross section, which is extremely It greatly improves the efficiency and quality of the design; on the other hand, through the 3D road model, we can intuitively find the road sections that require high filling and deep excavation, and adjust the route or adopt corresponding engineering measures according to the geological terrain and other conditions; 3D road model It can be combined with the three-dimensional bridge model to check whether the abutment height and abutment form settings are reasonable.

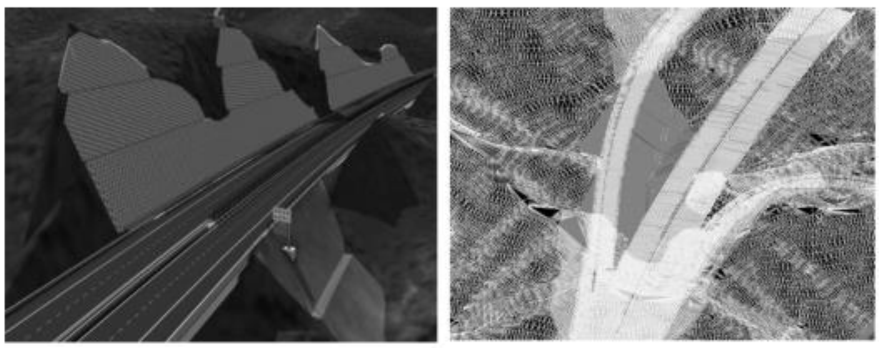


Figure 5.2 Road model (Cui et al. 2019)

(2) Bridge model

Before establishing a bridge road model, designers need to sort out the types of bridge structures and piers, and parameterize the sizes of each component; Set corresponding materials and codes with the lower component library (including ribbed platform, U-shaped platform, column platform, pile-type bridge pier, hollow pier, solid pier, etc.) to meet the data mutual conduction of different software and the lossless BIM data model transferred to the construction stage and operation and maintenance stage;

After completing the arrangement of components, designers can easily and intuitively determine the center pile number, span, number of holes, and upper and lower structural forms of the bridge based on the provided horizontal and vertical data, three-dimensional data, geological data, etc. By directly calling the 3D models of the upper and lower components, the 3D model of the bridge is quickly created, which improves the efficiency of complex bridge design, reduces the chance of human errors in traditional design, and reduces later construction changes.

After the bridge BIM model is established, it can be verified with the two-dimensional design engineering quantities and detailed design issues to ensure the correctness of the design drawings; the complexity of traditional two-dimensional bridge design has led to the investment of more personnel and the coordination of the design of various parts of the bridge. Do errors, omissions, and defects often occur in drawings? The model established through BIM technology can visually display the design of each part of the bridge, making it easier to check problems and correct them in time.

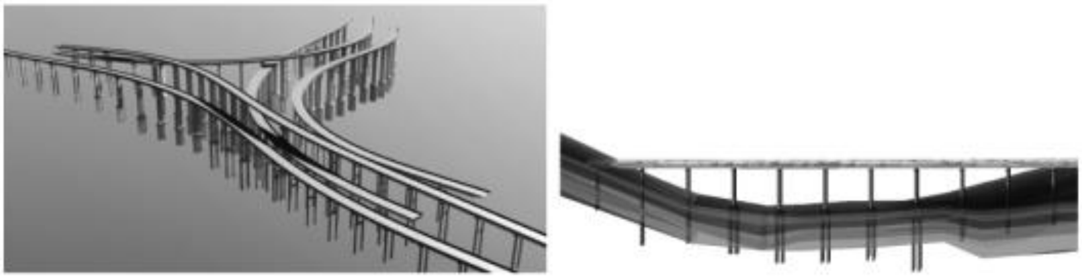


Figure 5.3 Bridge model (Cui et al. 2019)

(3) Tunnel model

The total length of the tunnel in the Zhengzhou-Xixia Expressway project is 18.2km. The tunnel model is mainly divided into two main parts: tunnel body modeling and tunnel door modeling. The tunnel body modeling mainly sets different cross-section templates according to the emergency parking zone, cross tunnels, surrounding rocks, etc. inside the tunnel; the tunnel door modeling is related to the terrain. In the tunnel model, drainage, inverts, linings, pavement structures, etc. can all be included in the template. Set in advance; each structure and material can be counted by setting the corresponding properties and codes.

The tunnel BIM model can also be combined with structural analysis software, ventilation and lighting and other performance analysis software to perform tunnel structure stress calculation and safety evaluation analysis, which greatly improves the overall design efficiency.

(4) Logo signage model

This project mainly uses Autodesk Revit to create the signage model, and forms a corresponding family library to facilitate direct call and modification in other projects. By placing the three-dimensional model of the signs in the three-dimensional road model, through virtual driving simulation, you can visually check whether the placement of the signs is reasonable and whether the content of the signs is standardized, making it easier for designers to modify and count the corresponding engineering quantities.

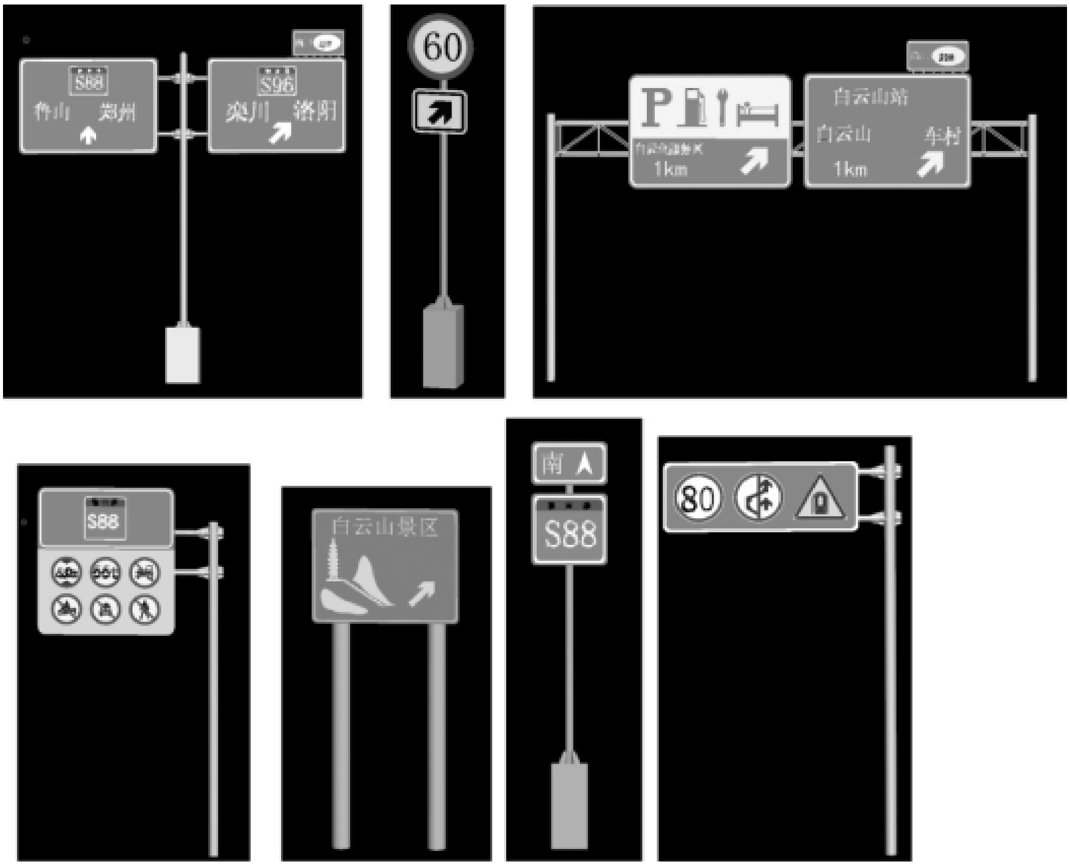


Figure 5.4 Signage model (Cui et al. 2019)

(5) Model summary

On the basis of high-precision three-dimensional terrain, the professional models are summarized. The summarized model contains the structural information, route information, coding, etc. of each profession; after the model is summarized, the collision problems of each profession can be clearly seen intuitively and 360 degrees. Look at every detail of each project and analyze the rationality and existing problems of each major; based on the complexity of the mountainous area where the Zhengzhou-Xixia Expressway project is located, the application value of the BIM model in the design phase has been greatly reflected.

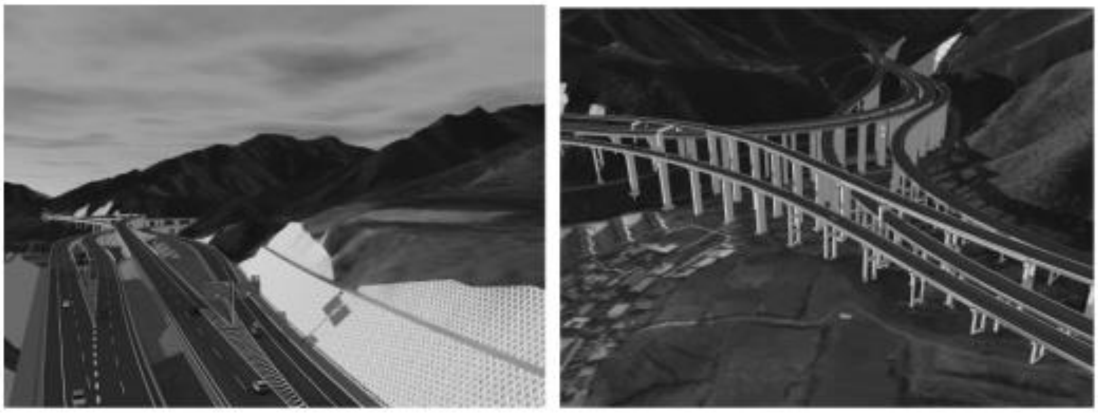


Figure 5.5 Total model (Cui et al. 2019)

5.1.2 Summary

(1) Model establishment

BIM model establishment relies on road data information and three-dimensional terrain. The three-dimensional model constructed in this way has high accuracy and is less error-prone. The road model generates road surfaces and slopes based on the compiled template, which can visually and clearly check whether the overall design of the highway is reasonable. For bridges, it can use the information in the parametric construction library to generate corresponding models, and accurately reflect the surrounding conditions of the entire bridge based on the three-dimensional terrain, so that the bridge head position can be accurately optimized. Once the entire model is established, the number of related projects can be counted conveniently and efficiently, and the overall road concept can be grasped macroscopically.

(2) Three-dimensional visualization design

BIM road design can truly realize horizontal, vertical and horizontal linkage design. When one piece of data is modified, it can be updated in real time and other related data can be quickly corrected, greatly reducing risks caused by poor information communication. When viewing the design plan, three-dimensional visualization is used to promote multi-disciplinary collaborative design and provide a good visual experience to facilitate reporting and communication.

(3) Design quality and accuracy

Traditional 2D design is limited by problems such as inter-professional communication and data disconnection. The design results often have errors, omissions, collisions, and missing problems (errors and omissions generally refer to errors in the equipment list and material list listed during the design). and missing equipment or materials. Collisions and missing materials generally refer to improper layout of equipment in engineering design drawings, causing equipment, pipelines, and cables to be too close to each other during actual installation, resulting in collisions) BIM technology can improve existing problems in two-dimensional design, Accurate statistics can be used to calculate engineering quantities, improving design quality and accuracy. The final drawings generated have strong guiding significance for construction.

(4) Digitization of design results

After the BIM model is established and summarized, later digital management can be realized. The BIM model replaces traditional paper documents, making handover and storage more convenient, and can be reviewed in a timely manner, providing favorable conditions for the later planning, design and use of the entire road network.

5.2 Construction Stage of Mountain Highway

The Chengdu-Yibin Expressway is located in the central and southern part of Sichuan Province. It is one of the 16 Chengdu radial expressways in the Sichuan Provincial Expressway Planning Network. It is the fastest route from Chengdu to Yibin and an important channel for Chengdu to integrate into the national Yangtze River Economic Belt. The total length of the project is 155km. The entire line is constructed according to the two-way six-lane highway standard. The design speed is 120 km/h. It has 4 tunnels, 17 interchanges and 5 service areas.

This project is based on BIM technology. In view of the multiple line lengths of highway engineering points and the actual needs of the project, BIM models of different precisions are established through oblique photography, GIS, informatization and other technologies, and a construction management cloud platform is developed to realize the management of highways in mountainous areas. Digital management such as mid-construction quality management, cost control, construction progress management, material procurement, and data management promotes the digital development of highway projects in mountainous areas.

5.2.1 Highway Construction Process and Analysis

(1) BIM implementation plans and standards

First, by establishing high-precision models of roads, bridges, tunnels, etc., the specific implementation process is shown in the figure. Secondly, perform EBS coding on important nodes such as bridges, tunnels, and high slopes along the entire line, and formulate unified BIM modeling and delivery standards to standardize the behavior of all participants and ensure the uniqueness, inheritance, and sharing of BIM models and information. Finally, it was imported into the Chengyi Construction Management Cloud Platform, where the owner company, design unit, construction unit supervision unit, etc. work collaboratively on the construction management platform.

Figure 5.6 Software usage framework (Xiang et al. 2021)

(2) Secondary research and development

In order to improve modeling efficiency, a batch placement tool for retaining walls was developed based on OpenRoads Designer. This tool can import the retaining wall paragraph table and place different types of retaining walls based on the road center line or edge line to improve modeling efficiency. The station number query tool is developed to facilitate modelers to check and locate the design station number at any time; the coordinate query tool is developed to facilitate modelers to query the coordinates of key parts in batches, verify drawings, and facilitate on-site personnel to query model coordinates for construction stakeout and positioning. Through research and development tools, you can improve modeling efficiency and complete modeling tasks on time.

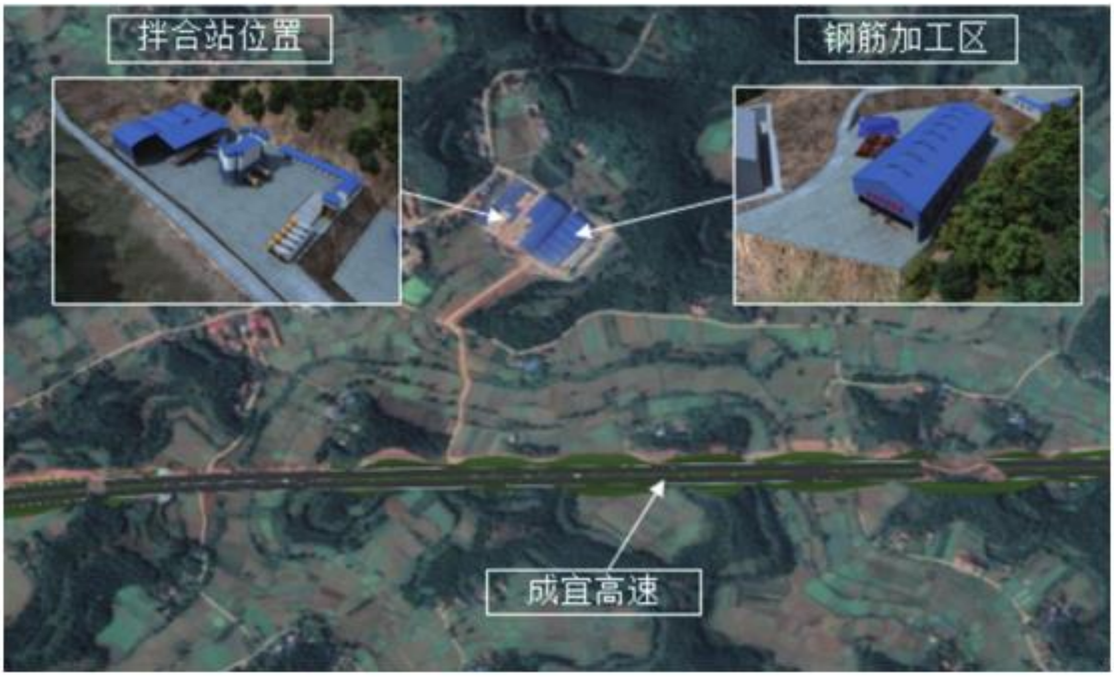


Figure 5.7 Construction site selection (Xiang et al. 2021)

(3) Construction site layout

The digital simulation method is used to optimize the location of the project department construction, as shown in the figure. Compared with the traditional method, it can more truly reflect the local geography and geological environment, and then implement scientific and reasonable planning. Establish a large number of temporary facility models to optimize the locations of mixing stations, prefabrication sites, and work area residents. BIM software is used to simulate the construction conditions at each construction stage, and management personnel continuously optimize the site layout plan by roaming the virtual site, effectively improving site utilization and reducing the cost of secondary relocation.

(4) Construction management cloud platform

In view of the characteristics of the Chengdu-Yi Expressway, such as long lines, tight construction schedules, and difficult construction management, a BIM construction management cloud platform based on cloud technology, GIS technology, and Internet of Things technology was developed to facilitate management.

(5) Project quality management

The expressway project mainly consists of roads, bridges, tunnels, traffic safety facilities, etc. Due to the complex geology and landforms of the mountainous area, construction management is difficult. BIM technology can greatly improve project management and improve management quality. In the quality management process, BIM components automatically match the acceptance construction process and work bench according to their own type attributes, making the process more standardized; the management platform can use GPS positioning technology to record the inspection location of the inspection applicant, and all marked The self-inspection information of the section is stored in the BIM model for easy reference, while ensuring that responsibilities are assigned to the person; ensuring that process data is traced, hidden dangers are dealt with in a timely manner, quality is reliably guaranteed, and management efficiency and quality acceptance pass rate are improved.

On the other hand, quality inspection can also be carried out through the mobile APP, which improves the self-inspection efficiency of the construction unit and makes the quality inspection process more standardized; the "pusket method" is used to associate on-site quality and safety issues with the platform model, and dynamically adjust the on-site quality according to the 2. Regularly summarize the frequency of safety problems, and strengthen management of key areas and work points; at the same time, they are divided into different levels according to the severity of quality and safety problems, and are automatically sent to relevant handlers and persons in charge, and relevant records are checked and saved in a timely manner.

(6) Cost control

In highway construction projects, how to reduce construction costs while meeting construction quality has always been the most concerned thing for the construction side. In the Chengdu to Yibin expressway project, BIM technology was introduced to achieve effective cost control. The project leader used the virtual construction function of BIM technology to detect unreasonable situations in the design plan in advance; The engineering coordinates, elevation, dimensions, steel bars, signs and signs, etc. were reviewed as drawings to avoid later changes and rework, as shown in the figure. Corrections were made in the preliminary work to effectively control costs.

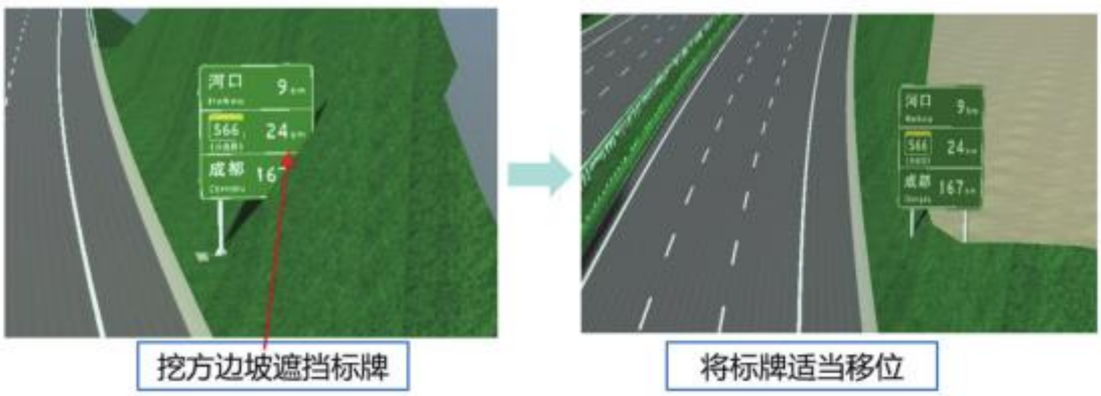


Figure 5.8 Model collision check (Xiang et al. 2021)

(7) Construction progress management

Construction progress management is one of the main contents of project management. The application of BIM technology in this project can shorten the construction period and improve the construction progress to a great extent. The management cloud platform will automatically convert the quality inspection results into progress data and display the project progress through visualization.

The construction progress data comes from quality acceptance, which not only ensures the uniqueness and inheritance of the data, but also forms a refined construction management system based on daily construction and weekly construction progress as the key points. At the same time, different users can also use the summary capabilities of BIM to summarize the information received regularly by the system, and then organize it into different reports, so that the relevant persons in charge can understand the construction progress in a timely manner. The most important job of the relevant management person in charge is to use BIM technology to understand the work progress in the project. Based on the comparison between the actual progress and the planned progress, if problems such as delays occur, they only need to analyze the causes of these problems and propose reasonable measures to ensure Effective control of construction progress.

(8) Material procurement

During the construction stage of the expressway, there are many types of materials and equipment involved, and the quantities required at different stages are not uniform, making management difficult. By selecting different conditions for the established BIM model, the basic management platform can export the model's concrete volume, slope protection engineering quantity, etc. according to the structure tree. The quantity information is then submitted to the purchasing department for use, and these data can also be summarized and counted, and used again in subsequent material procurement management work.

(9) Data management

In terms of data management, each participating party is responsible for uploading and downloading data within their respective scopes based on the construction management cloud platform, ensuring timely and accurate updates, and realizing internal sharing of data. Establish project approval processes such as seal approval and decentralization of contact orders, and standardize process management. It realizes the combination of online and offline office and improves office efficiency. At the same time, the tree structure management of design drawing files and technical data forms the basis for digital file delivery.

5.2.2 Summary

The Chengdu-Yibin expressway project uses BIM technology to solve the pain points in the construction phase of mountainous expressways and has achieved good results. It has strong reference significance for similar types of expressway projects and has certain promotion and application value.

In summary, the application of BIM technology in mountainous highway projects can optimize site layout to a great extent, improve project quality, reduce construction costs, improve management efficiency, improve the office efficiency of all participating parties, and realize the integration of data from all parties. Unique, timely and shareable, the digital assets accumulated through this project provide support for applications such as data analysis and data services on mountainous highways.

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