Hindawi
Wireless Communications and Mobile Computing
Volume 2022, Article ID 4326437, 15 pages
https://doi.org/10.1155/2022/4326437

Research Article

Visualization of Railway Transportation Engineering Management Using BIM Technology under the Application of Internet of Things Edge Computing

Sihan Wu and Xue Zhang

College of Business Administration, Liaoning Technical University, No. 188, Longwannan Street, Huludao, Liaoning 125105, China

Correspondence should be addressed to Xue Zhang; zhangxue@lntu.edu.cn

Received 29 November 2021; Revised 7 January 2022; Accepted 20 January 2022; Published 28 February 2022

Academic Editor: Haibin Lv

In the past, railway line planning usually required engineers to design based on their own experience after a series of field visits, leading to heavy workload and low efficiency. Moreover, operation and maintenance management is more complicated due to an abundance of railway station equipment. Based on the above problems, this paper first puts forward the railway transportation line planning and design method based on Building Information Modeling (BIM) technology. Besides, LocaSpace Viewer realizes the three-dimensional (3D) visual scene modeling of the railway environment to improve the efficiency of railway line planning and design. Secondly, the railway station's visual operation and maintenance management system is constructed via BIM Technology. Besides, the Internet of Things (IoT) is combined with edge computing and deep learning technology to build a 3D model of station equipment, collect data in real time, and analyze data efficiently. Finally, the design effect of the model, the performance of the visual management system, and the test results of network transmission delay are displayed and analyzed. The results show that BIM can construct the 3D visualization model with high fidelity for the railway environment. This model can get a reasonable line planning scheme and analyze its feasibility, provide a reliable basis for engineers to plan railway transportation lines, and improve design efficiency. In addition, the GPU occupation rate, CPU occupation rate, and memory occupation rate of the operation and maintenance management system in different operating environments are within the standard range; when multiple clients access the system, the system data access delay is 100% less than 8 ms, which has good performance. Furthermore, the performance of the IoT transmission data real-time scheduling model and the edge computing optimization algorithm applied to this system is better than other popular methods, which can significantly improve the operation efficiency of the system. This study aims to enhance the efficiency of railway transportation line planning and station operation and maintenance management with the help of digital technologies.

1. Introduction

In recent decades, with the development of the railway industry, railway traffic has become a quite familiar and indispensable part of people's lives. Railway transportation uses trains to transport passengers and goods, which is characterized by large transport volume, fast speed, low cost, and invulnerability to climate [1]. The passenger transport function of the railway provides great convenience for people's travel, and its freight function plays a crucial role in China's social material production and economic development [2]. At present, the railway cannot be replaced by other modes of transport (e.g., highways, waterways, or flight lines). China has invested substantial human and material resources in railway construction, bringing the railway construction into the stage of rapid development [3]. In addition, the line planning and design of railway transportation is a vitally fundamental link in railway engineering, directly affecting the general operation of railway transportation [4]. Furthermore, the operation and maintenance management of railway stations is a vital link in railway transportation engineering, which is related to the convenient travel and even safety of passengers [5]. Therefore, it is of great practical significance to strengthen the line planning of railway transportation and station operation and maintenance management.

There are still various problems in the process of railway construction. Firstly, railway lines usually span a large area and face complex topographic and geological conditions, resulting in difficulty in the planning and design of railway transportation lines. Secondly, railway transportation engineering covers an extensive range of disciplines, and it is hard to smoothly carry out the collaborative work between various departments. Thirdly, the transportation flow increases year by year, hampering the operation and maintenance of railway stations [6]. Recently, with the popularization of computer and information technology, railway construction is gradually developing in the direction of globalization, intelligence, and virtualization [7]. Specifically, Building Information Modeling (BIM) is the primary technology widely used in this process, which has brought new opportunities for the development of railway construction [8]. Neves et al. analyzed the application of BIM Technology in track repair research. The authors used various BIM-based tools to create three-dimensional (3D) and 4D BIM models to realize the spatial and parameter representation of track and the simulation of main construction tasks. They emphasized the feasibility and necessity of applying BIM technology in railway track repair through practical case analysis [9]. Lee et al. constructed an automatic 3D modeling system of railway bridges based on BIM Technology. They proposed a method of developing 3D solid modeling and placement module of transportation infrastructure. Then, they verified the applicability of this method by developing the user interface of the integrated 3D model assembled by these modules 10. Choi et al. proposed a way to automatically create a BIM model in tunnel design without converting 2D drawings. This method allowed engineers to use BIM for tunnel design, make maximum use of linear information, and modify the BIM model timely when linear information changed [11]. From the above existing research results, BIM Technology can build 3D models of railway track, bridge, tunnel, and other infrastructure to assist the efficient development of railway track repair and architectural design, and dramatically improve work efficiency.

In the past, engineers had to spend considerable time in on-site investigation for line planning during railway construction, usually resulting in heavy workload and low efficiency. Meanwhile, the management system of railway stations generally only provides information related to the storage and dispatching of the vehicle and passenger movement and cannot monitor each piece of equipment in the station, so it needs to be maintained manually. Based on this, the railway transportation line planning and design method is proposed based on BIM Technology. Then, the visual operation and maintenance management system for railway stations is constructed based on BIM technology. Besides, the deep learning technology implements the real-time scheduling of Internet of Things (IoT) data and optimizes edge computing. Finally, the design effect of the model, the performance of the visual management system, and the test results of network transmission delay are displayed and analyzed. This paper innovatively applies BIM technology to railway line planning and design and station equipment operation and maintenance management, significantly improving railway construction and management efficiency and quality. However, due to the short research period, the indicators set up here for the system performance test are not perfect. This study aims to improve the efficiency of railway transportation line planning and station operation and maintenance management with the help of digital technologies.

2. Railway Line Planning Method and Establishment of Station Operation and Maintenance Management System

2.1. Analysis on Key Technologies

2.1.1. IoT Edge Computing Principle. With the advent of the era of big data, Internet technologies are increasingly improving. Among them, the development of IoT has made the connection between things and things a reality. It primarily collects the required information in time through various sensing devices, and realizes the connection between things and things, things and humans, and things and networks through the Internet, to facilitate identification, management, and control [12]. However, with the increasing number of terminal devices in the EC environment such as intelligent monitor units and sensors, an enormous magnitude of data will generate at the edge of the network. If massive data are all processed and transmitted in the cloud, it will bring huge congestion pressure and high delay to the network [13]. Therefore, EC technology came into being [14]. EC refers to an open platform integrating network, computing, storage, and application core capabilities on one side of the object or data source to furnish the nearest end service [15]. It aims to disperse the things that need to be processed in the core node to each edge node close to the end-user for processing, to realize the purpose of an efficient data processing system. The edge of EC refers to any computing and network resources between the data source and the path of the cloud computing center [16]. Figure 1 reveals the EC architecture.

At present, EC has been popularized in many fields around the world. Lv et al. proposed a collaborative computing method to alleviate the huge computing pressure brought by the single mobile edge server computing mode with the increase of data volume, which further improved the computing performance of the mobile EC system [17]. Lv developed the Max-PSN-cache algorithm to meet the increasing social demand for the IoT and reduce the risk of data leakage in the IoT system. They found that the max-PSN-Cache algorithm was superior to other algorithms in the hit ratio and average response speed of centralized and distributed fiber optic gyroscope systems with edge nodes, indicating the effectiveness of this cache algorithm [18].

2.1.2. BIM Technology. BIM Technology is a data-based tool applied to engineering design, construction, and management. It can construct the visual 3D of building engineering via digital technology to provide the model with a building engineering information database including geometric

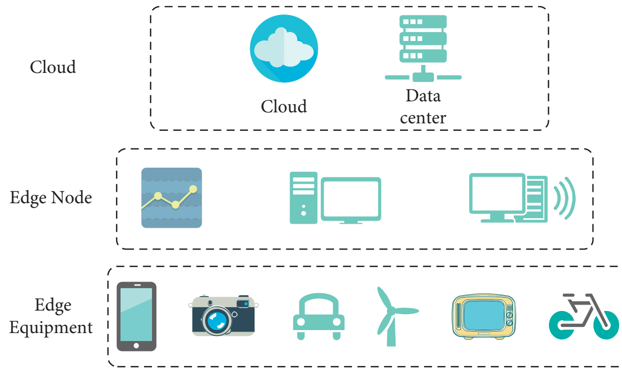


Figure 1: EC architecture.

information, professional attributes, and state information of building components [19]. The primary goal of employing BIM technology is to integrate all information in the whole project process from architectural design, construction, operation, to the end of the whole life cycle of the building into a 3D model information base. This operation can realize the integration, transmission, and sharing of architectural information [20]; enable engineers and technicians to correctly understand and effectively respond to various building information; and lay the foundation for the cooperation of the design team, construction organization, facility operation department, and other participants [21]. BIM has a powerful analysis function, which can adjust, judge, and analyze different design schemes to determine the best design scheme, conducive for the profound acquaintance with the work amount and estimating the cost by technicians [22]. BIM Technology plays a vital role in improving production efficiency, saving cost, and shortening construction period [23]. To sum up, the BIM Technology has conspicuous values and advantages, as presented in Figure 2.

Compared with the traditional two-dimensional (2D) design method, the 3D model established by BIM technology not only maintains the accuracy of the 2D model but also results in a remarkably intuitive effect [24]. Each component in the BIM information model carries digital information. When the information in a component in the model is modified, the BIM technology will present the changed results to ensure the accuracy of modification [25].

3. Analysis of the Line Planning and Design Railway of Transportation Based on BIM

An intuitive and real 3D railway visualization scene covers diverse essential elements, including artificial features, mountains, and rivers. However, there are many mountainous areas in China, forming a complex geographical environment, which requires a considerable amount and varieties of data, so an integrated platform is needed as a support [26]. InfraWorks is a mainstream BIM software. Firstly, it can quickly create a wide-range 3D visualization scene with high fidelity, and realize the design scheme in a more intuitive and clearer way under the existing scenes. Secondly, after completing the design work, InfraWorks can analyze the feasibility of the design results. Finally, the design model can be rendered by InfraWorks to record realistic line roaming video and realize the dynamic demonstration of the design scheme [9].

3.1. Railway 3D Visual Scene Modeling via InfraWorks Platform

3.1.1. Data Acquisition and Import. The LocaSpace Viewer is taken as a source of geographic information data here. LocaSpace Viewer is a digital Earth software that supports various online maps (such as Google Maps) loading, image elevation data download, three-dimensional geographic information data browsing, measurement and annotation, adding data in multiple formats, and other functions [27]. The terrain and images of a certain area are downloaded from LocaSpace Viewer and imported into InfraWorks for modeling.

3.1.2. 3D Scene Modeling Based on the Collaborative Design through InfraWorks and Civil 3D. Civil 3D is also a mainstream BIM software. Its main function is to create 3D visual and digital terrain through different sources of data such as geographic information system (GIS) and point files, and manage and analyze the terrain to improve the accuracy of terrain modeling [28]. The most reliable raw measurement point data, i.e., the point file, is selected to carry out terrain modeling. The measurement point data can be expressed in the form of Civil 3D points in the graphics, and can also record the external text files [29]. The terrain is created by generating points in Civil 3D and adding point editing.

The terrain jointly created by InfraWorks and Civil 3D is more standardized and closer to the real terrain in practice. InfraWorks and Civil 3D have good data exchange ability, and can effectively integrate models and scenarios in different data formats, to make the line planning scheme of railway transportation more reliable. The general direction of railway lines can be preliminarily obtained by constructing the 3D railway model, but many details need to be further optimized by using the horizontal, vertical, and cross dynamic functions in InfraWorks.

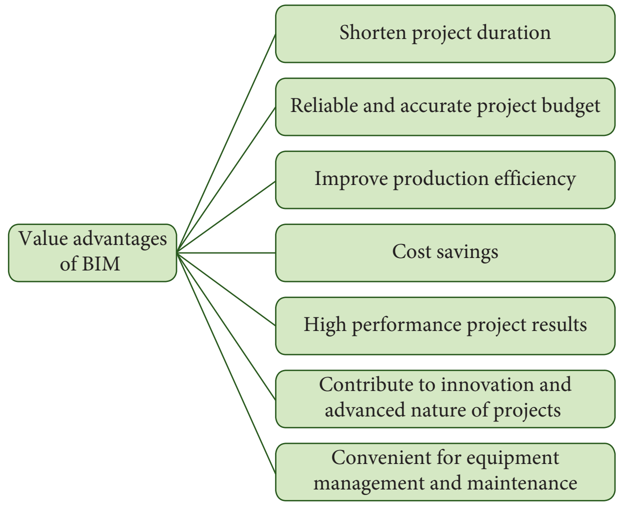


FIGURE 2: Significance of the BIM technology.

3.2. Line Planning and Design Method for Railway Transportation Based on InfraWorks

3.2.1. Line Plane Design. To ensure the security and smoothness of the train track, it is necessary to reasonably select the basic plane alignment (straight line, circular curve, and transition curve) of the line in combination with the actual situation of different sections. It is also essential to ensure that the curvature and change of the line are continuous. Through InfraWorks, the user can select the line creation tool and directly drag the line horizontal manipulator to design the line segment. Besides, the designer can use the shortcut context menu to add a horizontal curve to the selected line tangent, and change the horizontal curve radius through the curve intersection or curve radius manipulator. In addition, the user can click the curve radius control grip of the curve and expand convert geometry to set the spiral.

3.2.2. Line Vertical Profile Design. The road vertical profile is the unfolded surface after the road is cut vertically along the center line. The spatial position of the road can be accurately judged by combining the longitudinal section map and the plane map of the road. The vertical profile of the railway transportation line is composed of two parts, namely, the slope section and the vertical curve connecting the adjacent slope sections. In the design process of the vertical profile of the railway line, it is necessary to comprehensively consider the plane conditions and geological conditions of the line. InfraWorks has the preliminary design and optimization functions of line profile.

3.2.3. Line Cross Section Design. The road section along the normal direction is called the road cross section map, which is mainly composed of the cross section design line and the ground line. InfraWorks provides underground tunnels with rectangular and horseshoe cross sections.

3.2.4. Route Selection Scheme Roaming Display. After the completion of the line design, the storyboard function of InfraWorks can be employed to make a dynamic demonstration of line roaming according to the previous design scheme. The scene around the line can be adjusted to the optimal visual effect by setting the parameters such as time, wind direction, and cloud amount. The production of storyboard dynamic demonstration is mainly realized by connecting a series of snapshot views into animation.

4. Construction of the Railway Station Visual Operation and Maintenance Management System Based on BIM Technology

4.1. Construction of Visual Operation and Maintenance Management System for the Railway Station. The operation process of the railway station visual operation and maintenance management system based on BIM technology can be described as follows. First, geometric information, professional attributes, and status information of all components in the railway station are collected by networked base stations, surveillance cameras, and sensors, and transmitted to the IoT information platform for system scheduling. Information collection plays a critical role in the decision-making and analysis of the operation and maintenance process, and it is also the foundation of the normal operation of the system. After the information is collected, artificial intelligence technology is used to analyze and process the information to realize the real-time and dynamic management of resources and information in the operation of the station. Figure 3 displays the architecture of the railway station visual operation and maintenance management system based on BIM technology.

4.2. Real-Time Scheduling Model for IoT Transmission Data Based on Deep Reinforcement Learning (DRL)

4.2.1. IoT Data Security Discrimination. The IoT transmission data model should be constructed first to realize the

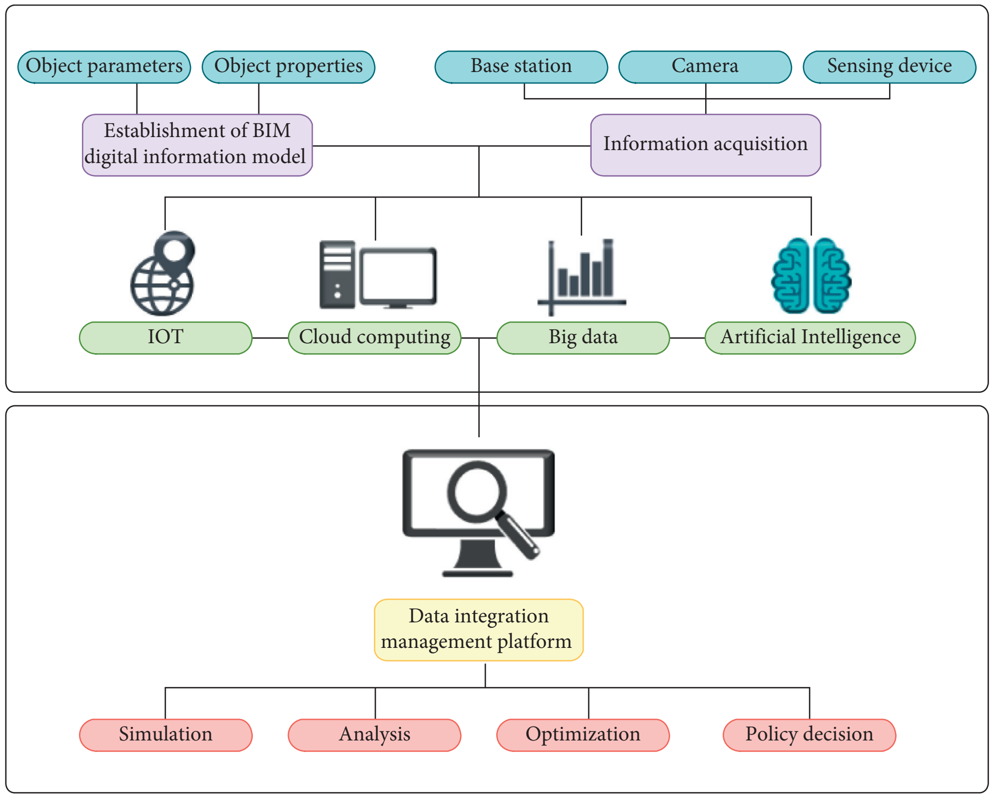


FIGURE 3: Architecture of the railway station visual operation and maintenance management system based on BIM.

real-time scheduling of information in the IoT under a safe network environment. The characteristic samples C_T of the IoT transmission data scheduling should be collected based on the time period node T. The acquisition process can be expressed as follows:

$$C_T = \frac{x' X_V (M + N)}{T}. \tag{1}$$

In equation (1), x' indicates the bit sequence of data transmitted by the IoT, T denotes the transmission period, and X_V signifies the distributed sequence of data transmitted by the IoT. Besides, M and N represent the maximum and minimum bytes of data transfer. The real-time characteristic quantity of transmitted data can be calculated by equation (1).

In the real-time scheduling process of IoT transmission data, the maximum number of feature distribution collected by data information needs to meet the adaptive analysis amount of scheduling information, which is calculated according as follows:

$$s_m(t) = \frac{c_i C_T x'}{V}. \tag{2}$$

In equation (2), $s_m(t)$ refers to the adaptive analytic quantity, V stands for the real-time consumption of data information acquisition in IoT data transmission, and c_i denotes the transmission rate coefficient.

According to the scheduling algorithm of the shortest information transmitted in the IoT, the information with the shortest real-time running time in the system is preferentially scheduled. The frequency domain time balance control model A_m of real-time scheduling of IoT transmission data is described as follows:

$$A_m = \frac{u_{(i,d)} + z_{(i,d)} + x_{(i,d)}}{C_R}. \tag{3}$$

In equation (3), $u_{(i,d)}$ represents the information transmission compensation coefficient; $z_{(i,d)}$ denotes the rate modulation coefficient; $x_{(i,d)}$ refers to the transmission frequency coefficient; C_R represents the maximum capacity of information balancing for real-time scheduling of IoT data transmission.

$s_m(t)$ is combined with the real-time equalization control optimization method to construct a feedback equalization model F_z, according to which the security of network transmission data can be judged. The model can be written as follows:

$$F_z = \frac{A_m s_m(t)}{n_i}. \tag{4}$$

In equation (4), n_i signifies the random transmission of data information.

The security judgment method of network transmitted data is as follows. If $F_z < C_T n_i$, the transmitted data cannot achieve feedback balance, and then, it is judged as unsafe data. On the contrary, if $F_z > C_T n_i$, the transmitted data is safe, and real-time scheduling can be carried out in the IoT.

4.2.2. Construction of the Real-Time Scheduling Model for IoT Transmission Data. The packet loss rate is a key factor to be considered in IoT data transmission. It is the ratio of the number of lost packets to the sent data set. Here, DRL technology is adopted to implement signal transmission, which plays an important role in promoting the receiving node to receive effective data amount and receiving time. The minimum packet loss rate in IoT data transmission is taken as the research objective, and a big data scheduling model based on DRL technology is constructed. The data allocation method of scheduling target is as follows.

Firstly, the Transmission Control Protocol-friendly Rate Control (TFRC) algorithm is used to calculate the broadband $B(m,t)$ of the m-th transmitting node at time t to determine the online broadband. Then, $S(m,t)$ is determined to minimize F_t, as shown in equations (5) and (6).

$$F_t = \sum_{m=1}^{n} L(m,t)S(m,t), \tag{5}$$

$$S_{\text{req}}(t) = B(m,t)\sum_{m=1}^{n} S(m,t). \tag{6}$$

Among equations (5) and (6), F_t signifies the bus transmission rate, $L(m,\ t)$ and $S(m,t)$ represent the packet loss rate and sending rate of the sending node m in time $(t, t+\Delta t)$, $S_{\text{req}}(t)$ indicates the normal data transfer rate of the node, and $B(m,t)$ refers to the bandwidth upper limit at the moment t of the m-th transmission node in the IoT network.

Taking the minimum packet loss rate as the research objective can promote the receiving node to make full use of the effective transmission broadband of the sending node. This can not only cause some nodes with high transmission rates to continuously transmit data but also greatly increase the load. Moreover, other nodes cannot participate in data transmission effectively. Based on this, the contribution thinking of DRL technology is introduced into the model, as described below.

The contribution factor $a(m,t)$ is implanted to all sending nodes, which is mainly used to describe the ratio between the contribution amount $C(m,t)$ of node m from the initial entry into the system to time t to the sum of all nodes' contributions. The contribution $C(m,t)$ of node m is the difference between the upload amount of node m and the download amount from other nodes, which is calculated as follows:

$$C(m,t) = \int_0^t f(\beta)\mathrm{d}\beta. \tag{7}$$

In equation (7), β stands for the element rate. In practical applications, the download of node m can be regarded as its upload quantity, which can be expressed as follows:

$$C(m,t)' = \sum_{j=1}^{N}\sum_{j=1}^{N} t\left(D_j - D_m\right). \tag{8}$$

In equation (8), j and m represent the number of uploaded node sequences, and D signifies the lock frequency. Therefore, the contribution factor $a(m,t)$ can be expressed as follows: .

$$a(m,t) = \frac{C(m,t)}{kC(m,t)'}. \tag{9}$$

In equation (9), k denotes the number of data transmission cycles. It is essential to select as many edge nodes as possible, to reduce the time delay and loss in network data transmission. The sum of squares of each period after a node enters the system and can be used as the online duration. The online duration U can be written as follows:

$$U = \sum_{m=1}^{n} m\left(t_e - t_s\right)_o^2. \tag{10}$$

In equation (10), t_s indicates the time when a node enters the system, t_e denotes the time when the node is pushed out of the system, and o represents the number of system entries.

In summary, the real-time scheduling model based on IoT transmission data can be expressed as follows:

$$\begin{aligned} F(t)' &= \sum_{m=1}^{n} \frac{S(m,t)L(m,t)a(m,t)}{\sum_{j=1}^{i}\left(t_e - t_s\right)_j^2}, \\ S_{\text{req}}(t)'' &= U\sum_{m=1}^{n} S(m,t). \end{aligned} \tag{11}$$

4.3. EC Optimization Algorithm of IoT Based on DRL. DRL technology has been used above to optimize the efficiency and security of real-time scheduling of data transmitted in the IoT. However, not only data scheduling but also data processing efficiency in the era of big data should be considered to improve the overall efficiency of the operation and maintenance system. The specific content of the EC optimization algorithm of the IoT is as follows.

4.3.1. Settings of the Execution Process of IoT EC. The execution process of EC is as follows.

The work index set in the network is set as $A = \{0, 1, \ldots, a, \ldots, A\}$. For the local computing part $(1-\alpha_i)a_i$ of the IoT, $(1-\alpha_i)a_i$ is set as the delay of local execution, and u_i^t is set as the frequency of the central processing unit (CPU) during calculation. Then, the execution delay z_i^t is calculated according to

$$z_i^t = \frac{(1-\alpha_i)a_i d_i}{u_i^t}, \tag{12}$$

In equation (12), d_i denotes the communication channel length. Denote d_i as the energy consumption generated when executed locally, as shown in the following equation:

$$y_i^t = p_i\left(u_i^t\right)(1-\alpha_i)a_i d_i, \tag{13}$$

In equation (13), p_i refers to the energy density in the IoT.

Set the overall computing time as σ_i^t, and the local computing CPU frequency u_i^t can be calculated by

$$u_i^t = \min\left\{\frac{(1-\alpha_i)a_i d_i}{\sigma_i^t}, u_i^{t\max}\right\}. \quad (14)$$

Equation (15) describes the data transmission rate s_i of the IoT.

$$s_i = \frac{W}{\beta(t)} + \frac{b(t) f_i}{X^2}. \quad (15)$$

In equation (15), W denotes the wireless bandwidth in the IoT, and $\beta(t)$ refers to the accumulated energy value of the IoT in the calculation period. Besides, f_i signifies the transmission power of user data in the IoT, and X^2 indicates the variance of Gaussian white noise.

The delay time t_i^0 of the calculation process is calculated based on equation (15), as shown in the following equation:

$$t_i^0 = \frac{a_i}{\sigma_i^t}. \quad (16)$$

4.3.2. Allocation of Computing Resources at the Edge of the IoT. In the present work, the Convolutional Neural Network (CNN) model is adopted to allocate the computing resources at the edge of the IoT. Specific methods are as follows:

The convolution result $r(n)$ of the two signals are expressed in discrete form, as shown in the following equation:

$$r(n) = j(n) * l(n) = \sum_{m=-\infty}^{\infty} j(m) l(n-m). \quad (17)$$

In equation (17), n and m represent the length of sequences; $l(n)$, $j(m)$, and $j(n)$ represent discrete sequences in resource allocation, and $h(n-1)$ denotes a signal in EC.

The weights and biases in the process of resource allocation are set according to the parameter characteristics of CNN model, which are taken as the connection number. Then, the parameter number U in the calculation can be expressed as follows:

$$U = N_k * (m_c * s_k * q_k) + 1. \quad (18)$$

In equation (18), m_c signifies the number of channels in EC, and s_k and q_k stand for the width and height of the convolution kernel, respectively. Then, the reasonable allocation of the calculated quantity $m_c * s_k * q_k$ can be expressed as follows:

$$p_i^a(t) = \frac{m_c * s_k * q_k}{r(n)}. \quad (19)$$

5. Experiment and Test Methods

5.1. Data Sources. In the experiment of railway line planning, this paper takes the Hohhot West Railway Station as the research object. This area includes 15 tracks of Tanghu up and down lines, Beijing Baotou passenger dedicated line, and station yard, with complex railway equipment, poor on-site inter-visibility conditions, and great difficulty in surveying and mapping. It takes two months to measure according to the traditional method. In this paper, LocaSpace Viewer obtains the 3D geographic information of the area, and BIM establishes the 3D model. Moreover, MATLAB 7.0 programming software simulates the system and algorithm proposed here and carries out relevant test experiments.

5.2. Development Environment of the Visual Operation and Maintenance Management System for Railway Station. This system is developed in Windows 10 system. The configuration of running equipment is suggested to be more than the Central Processing Unit (CPU) i3, a graphics card over GTX1060, a 100 MBIT/s network port, and a Cluster Communication Port, namely, a COM serial port, a Universal Serial Bus (USB) serial port, more than 4 GB of memory, and a hard disk more than 500 G.

5.3. Test Method for Overall Performance of the Visual Operation and Maintenance Management System for Railway Station. The visual operation and maintenance management system for railway stations must have good performance in the operation process to prevent the network transmission delay, card frame, and even collapse when the system continues extensive data reading operations. This test mainly uses the resource monitor of the Win 10 system, and takes the CPU occupancy rate, Graphics Processing Unit (GPU) occupancy rate, and computer memory usage as indicators to investigate the overall performance of the system under different environments and conditions. In general, CPU occupancy rate is below 90% by standard, and computer memory usage is less than 80%.

5.4. Network Transmission Delay Test Method of the Visual Operation and Maintenance Management System for the Railway Station. In the network transmission delay test, 1, 2, 4, 8, and 16 clients are used to access the server, respectively. The total network delay and single network delay are calculated through the time difference between the system client and the server. In the local area network, the delay less than 5 milliseconds proves that the system has good performance.

5.5. Test of the Real-Time Scheduling Model for IoT Transmission Data. In the present work, the traditional real-time scheduling method of IoT transmission data is compared with the model reported here, and the scheduling time and data integrity of the two models under different transmission data bandwidths are tested.

5.6. Test of the IoT EC Optimization Algorithm. Here, the popular improved cat swarm algorithm [30] and edge-cloud cooperation algorithm [31] are selected for comparison. Moreover, the server occupied time and computing waiting time are taken as the test indexes to compare with the IoT EC optimization algorithm based on DRL reported here.

6. Experimental Results and Design Effect

6.1. Construction Results of the 3D Railway Visual Model. The core of high-fidelity 3D railway visual scene model is describing and analyzing the spatial objects in a certain area. Figure 4 displays the 3D railway visual model constructed based on InfraWorks and Civil 3D in this report.

As shown in Figure 4, the 3D visual model based on InfraWorks and Civil 3D has the outline of primary elements such as mountains, trees, and railway tracks. This model can show the spatial position, geometric shape, and route direction of all objects in the region in a quite intuitive way, with strong authenticity and vitality. The 3D railway visual model designed here provides an important basis for engineers and technicians to accurately understand the regional terrain and carry out the planning and design of railway transportation lines.

7. Design Results of Comprehensive Route Selection Scheme for Railway Transportation

Figure 5 describes the design scheme of the comprehensive route selection for railway transportation based on InfraWorks.

From Figure 5, the geological conditions, river trend, and mountain distribution in this area are complex, so the above factors must be comprehensively considered in the planning and design of railway lines. InfraWorks can create different route planning schemes within the same model and analyze the feasibility of different schemes based on the actual situation. The black lines in Figure 5 indicate several reasonable line schemes with different directions but the same destination through InfraWorks in BIM. The engineer can analyze these schemes according to his or her own experience and conduct line planning after comprehensive consideration combined with the analysis results output by InfraWorks. This method can support technicians to quickly decide the best route scheme of railway transportation, saving massive time and cost.

Figure 6 provides the roaming demonstration.

After the basic direction of the railway transportation line is preliminarily determined, it is also necessary to use the storyboard function of InfraWorks to record the roaming dynamic demonstration of the design scheme. Technicians can elaborately analyze and judge the selected scheme through the roaming demonstration with high fidelity. From the roaming dynamic demonstration of the railway route selection design scheme in Figure 6, the 3D railway model is optimized by the horizontal, vertical, and horizontal dynamic functions in InfraWorks. After a series of rendering by the storyboard, the railway track, train, sky, house, cloud layer, and other elements are refined, with high fidelity. Consequently, technicians can conduct in-depth discussion, analysis, and scheme optimization of the design scheme based on the roaming dynamic demonstration together with other department personnel. This model provides a basis for the collaborative work of the design team, the construction unit, the facility operation department, and other participants.

8. Construction Results of the 3D Visual Model for the Railway Station

Figure 7 illustrates the 3D roaming dynamic demonstration screen of the 3D visual model for the railway station established based on BIM technology in this report.

As shown in Figure 7, the spatial position and geometric shape of all people, components, and devices in the 3D scenes of the railway station are visually presented. For example, the spatial position and distance of elevator relative to the platform or column are demonstrated in the scene, as well as the positioning of people in the station space. People can accurately understand the spatial layout and scale of the whole station and timely adjust unreasonable places through the 3D model. Meanwhile, the visual operation and maintenance management system for the railway station reported here can monitor all activities like equipment operation status in real time, and make timely response to avoid accidents.

9. Performance Test Results of the Visual Operation and Maintenance Management System for the Railway Station

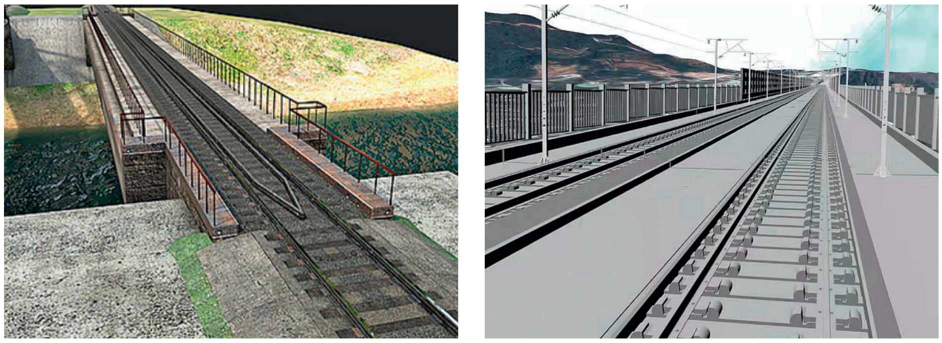
Using the resource monitor of the Win 10 system, the overall performance of the visual operation and maintenance management system for the railway station is tested with the GPU occupancy rate, CPU occupancy rate, and computer memory usage as test indicators. The test results are presented in Figure 8.

According to Figure 8, the performance of this system varies under different environments and conditions. The average GPU occupancy rate of the system is about 63.2%, the lowest is 40.02% after start-up, and the highest is 88.56% when the system alarms. The average CPU occupancy rate of the system is about 8.4%, the lowest is 1.23% at normal operation, and the highest is 18.34% at alarm. The average memory usage of the system is about 38.3%, the lowest is 33.41% after start-up, and the highest is 41.29% when the system alarms. In summary, the three indicators of the system in operation are the highest when the system alarms but also within the standard range. Therefore, the overall performance of the system is excellent, in line with the standard.

10. Network Transmission Delay Test Results of the Visual Operation and Maintenance Management System for the Railway Station

Figure 9 indicates the network transmission delay test results of the visual operation and maintenance management system for the railway station.

As shown in Figure 9, as clients increase, the number of Queries Per Second (QPS) responded by the system is enlarging, from 6,529 QPS responding to one client to 69,079 QPS responding to 16 clients. In the test results, the average ratio of data access delay less than 1 millisecond is about 99.95%, the average proportion of less than 2 milliseconds is



(a) (b)

Figure 4: 3D terrain model of railways. (a) Railway bridge. (b) Railway track.

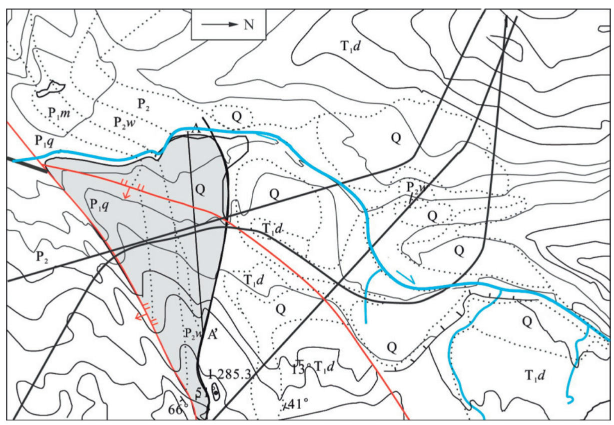
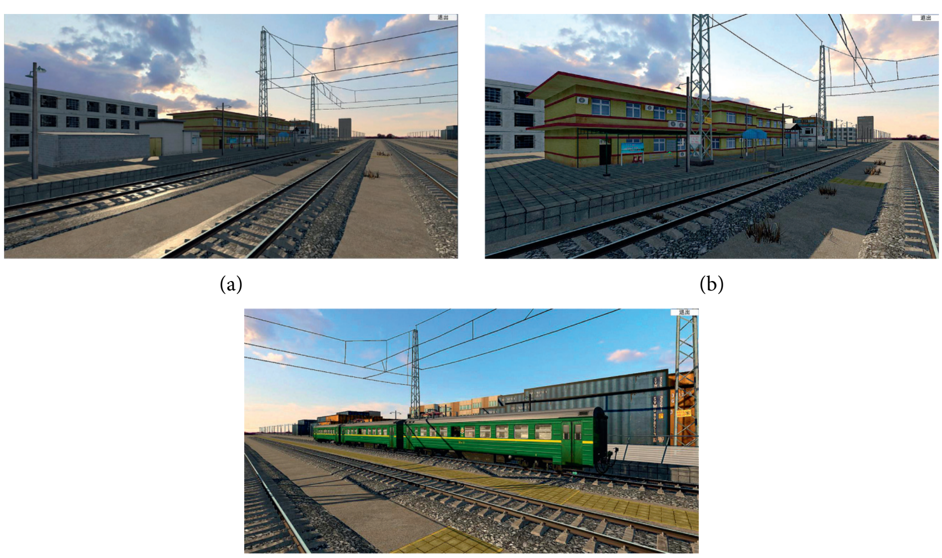


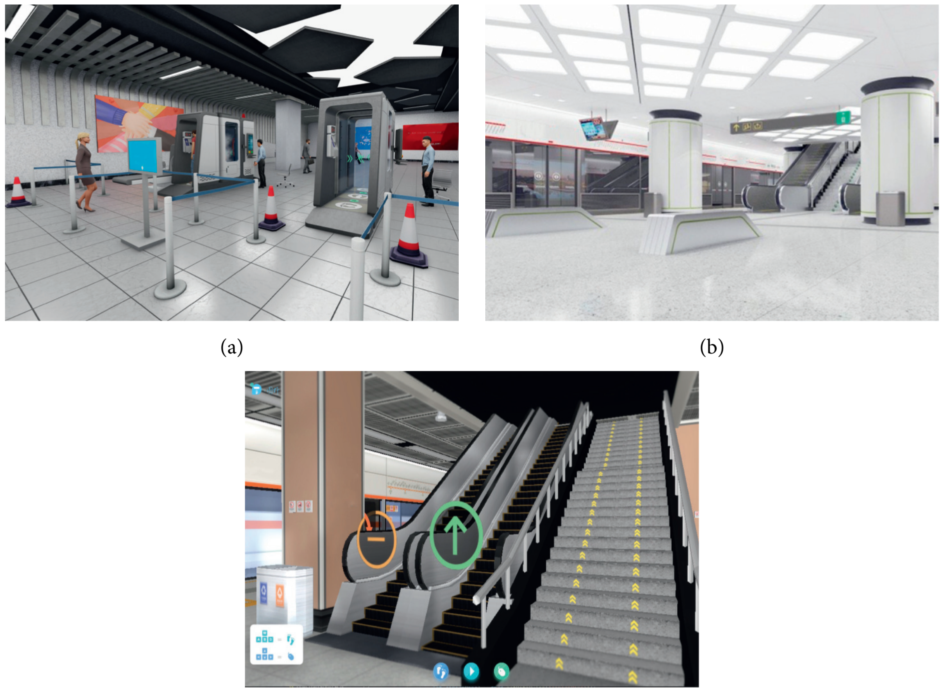
Figure 5: Design scheme of the comprehensive route selection for railway transportation.



(a) (b)

(c)

Figure 6: Roaming demonstration of the design scheme of integrated route selection for railway transportation. (a) 3D railway model prospect; (b) 3D model of rail and house; (c) 3D model of the transportation train.



(a) (b)

(c)

Figure 7: 3D scene displays of the railway station. (a) 3D scene of the railway station security hall; (b) 3D scene of the waiting hall; (c) 3D scene of the elevator and staircase.

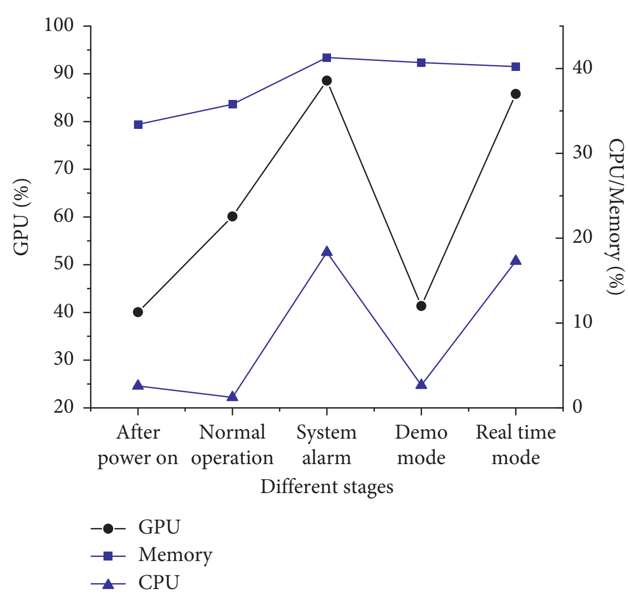


Figure 8: Performance test results of the visual operation and maintenance management system for the railway station.

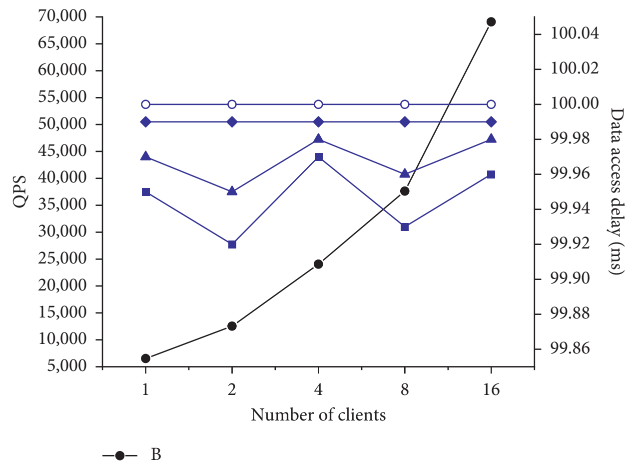


Figure 9: Network transmission delay test results of the visual operation and maintenance management system for the railway station.

around 99.97%, and the proportion of less than 4 milliseconds reaches 99.99%. In summary, the visual operation and maintenance management system for the railway station has good real-time performance and runs smoothly with high fluency when multiple clients access.

11. Test Results of the Real-Time Scheduling Model for IoT Transmission Data

11.1. Test Results of Data Scheduling Time. Figure 10 illustrates the test results of data scheduling time of the real-time scheduling model for IoT transmission data based on DRL designed here and the traditional real-time scheduling method.

From Figure 10, when the traditional method schedules IoT transmission data, the scheduling time shows an obvious upward trend with the increase in transmission data bandwidth, proving that the traditional method cannot complete real-time data scheduling. When the model designed here allocates the IoT transmission data, the scheduling time is generally controlled within 10 seconds. Besides, when the transmission bandwidth of data is greater than 0.6 Mb/s, the scheduling time shows an obvious downward trend, which can realize the real-time scheduling of the IoT transmission data.

11.2. Test Results of Data Integrity. The test results of IoT transmission data integrity of the two data scheduling models are shown in Figure 11.

Through Figure 11, in the experimental process, the integrity rate of the IoT transmission data scheduled by the traditional method is between 47% and 53%, with an average of 49.73%, generally at a low level. The data integrity rate of the model reported here ranges from 84% to 96%, with an average of 91%. This result is significantly higher than that of the traditional method, which can ensure data integrity in the process of scheduling IoT transmission data.

12. Test Results of the IoT EC Optimization Algorithm

12.1. Test Results of Server Occupancy Time. Figure 12 provides the test results of server occupancy time of the improved cat swarm algorithm, edge-cloud cooperation algorithm, and the optimization algorithm reported here in the IoT EC.

According to Figure 12, the average server occupancy time after optimization by the improved cat swarm algorithm is about 65 seconds; the average occupancy time after optimization using the edge-cloud cooperation algorithm is 56.9 seconds; and the average occupancy time after optimization through this algorithm is about 17.3 seconds. Therefore, all three algorithms reduce the server occupancy time in the process of IoT EC, but the optimization method of IoT EC based on DRL proposed here achieves a significantly better performance than the other two methods.

12.2. Test Results of the Calculation Waiting Time. The test results of the calculation waiting time of the three algorithms at the edge of the IoT are presented in Figure 13.

Figure 13 shows that the average calculation waiting time of the improved cat swarm algorithm is about 99.9 milliseconds; the average waiting time of the edge-cloud cooperation algorithm is 81.1 milliseconds; and the average waiting time of DRL algorithm is 27.4 milliseconds. It can be concluded that under the condition of the same number of tasks, the computation waiting time of the DRL algorithm designed here is significantly lower than that of the other two algorithms.

13. Result Discussion

A railway transportation line planning and design method is developed based on BIM technology. Besides, LocaSpace Viewer is taken as the source of 3D geographic information

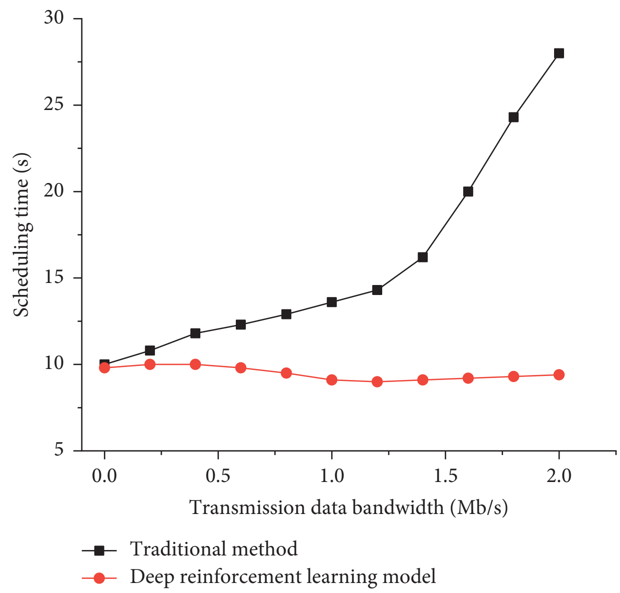


Figure 10: Test results of data scheduling time.

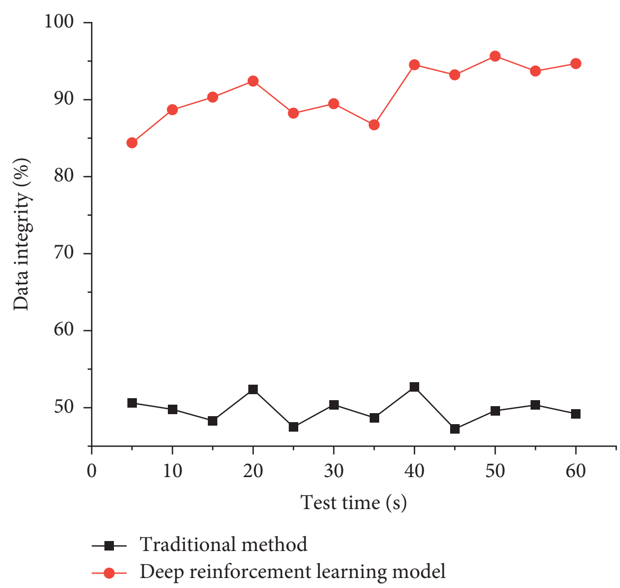


Figure 11: Test results of data integrity.

data. The mainstream software in BIM is used to establish and optimize the 3D visualization scene and generate the railway line planning scheme. Finally, the Hohhot West Railway Station is the research object for the railway line planning and design experiment. The results demonstrate that BIM technology can build the 3D visualization model of the railway environment of high fidelity. This is mainly due to the collaborative work of InfraWorks and Civil 3D, making the railway 3D visualization scene more standardized and closer to the actual natural terrain. Meanwhile, InfraWorks can also obtain a practical line planning scheme and analyze its feasibility to provide a reliable basis for engineers to plan railway transportation lines and improve design efficiency.

Furthermore, this paper constructs a visual operation and maintenance management system of railway stations based on BIM technology and puts forward the IoT data transmission real-time scheduling model based on DRL technology and the IoT edge computing optimization algorithm. The MATLAB 7.0 programming software simulates the Hohhot West Railway Station to carry out the relevant test experiments. The results indicate that the GPU occupation rate, CPU occupation rate, and memory occupation rate in different operating environments are within the standard range; when multiple clients access the system, the system data access delay is 100% less than 8 ms, which has good performance. Meanwhile, when scheduling the IoT transmission data, the scheduling time is generally

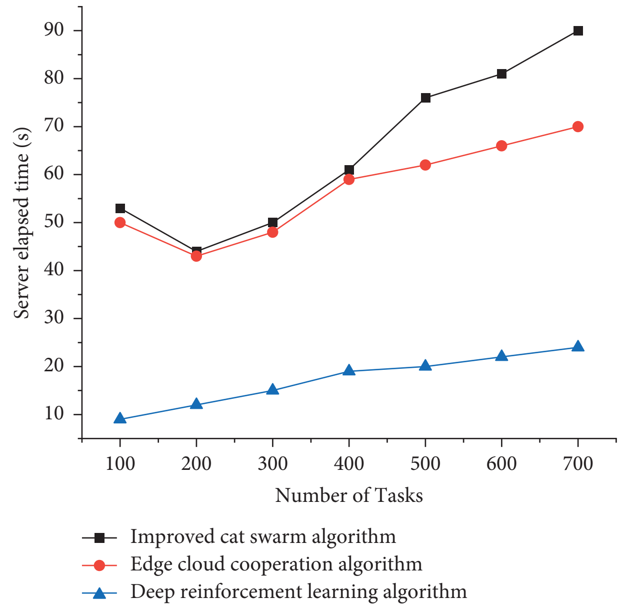


Figure 12: Test results of server occupancy time.

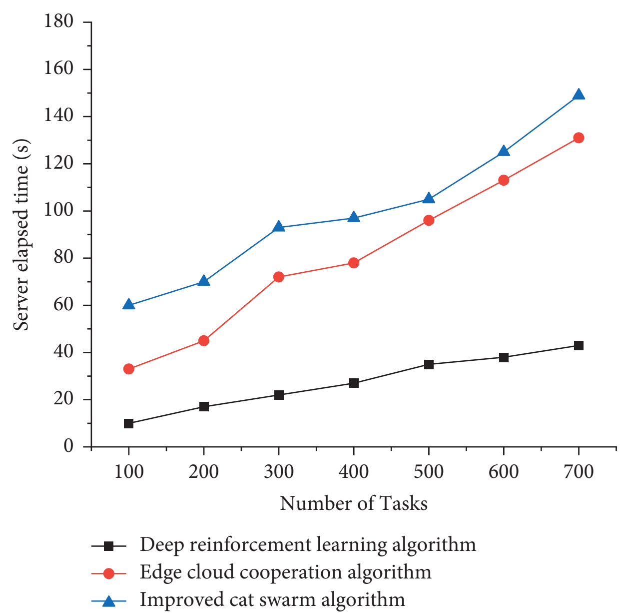


Figure 13: Test results of the calculation of waiting time.

controlled within 10 s, realizing the real-time IoT data scheduling. Moreover, the integrity rate of scheduling data is between 84% and 96%, with an average of 91%, significantly higher than traditional methods. Therefore, the performance of the real-time IoT transmission data scheduling model based on DRL is much higher than that of conventional methods in scheduling time and data integrity, which can be applied to the visual operation and maintenance management system of railway stations. In addition, the average server occupancy time of the IoT edge computing optimization algorithm is about 17.3 s, and the average computing waiting time is 27.4 ms, which is much lower than the optimization method proposed by Kumar and Singh [30] and Wu et al. [31]. Therefore, the IoT edge computing optimization algorithm based on DRL can significantly reduce the computing cost and time. This scheme is feasible to the railway station visual operation and maintenance management system and can effectively improve its overall efficiency.

14. Conclusions

With the advancement of society, railway transportation has become an indispensable part of people's travel, social material production, and even Chinese national economic development. However, there are some problems in the process of railway construction, such as difficult line planning and design, and challenging station operation and maintenance management. Based on the above background, this paper puts forward the planning and design method of railway transportation line based on BIM technology. Secondly, the railway station visual operation and maintenance management system is constructed based on BIM technology. Then, the real-time IoT data scheduling and the optimization of edge computing are realized via deep learning technology. Finally, the design effect of the model, the performance of the visual management system, and the test results of network transmission delay are demonstrated and analyzed. The results suggest that the 3D visualization model of railway environments with high fidelity can be established by BIM. In addition, a reasonable line planning scheme can be obtained and feasibility analysis can be carried out for engineers to provide a reliable basis for railway transport line planning and improving design efficiency. The GPU usage, CPU usage, and memory usage of the management system in different operating environments are all within the standard range. When multiple clients access the system, the system data access delay is less than 8 ms, providing excellent performance. The real-time scheduling model of IoT transmission data and IoT edge computing optimization algorithm applied to the system are superior to other popular methods in performance, which can significantly improve the operating efficiency of the system. This paper innovatively applies BIM technology to railway line planning and design and station equipment operation and maintenance management, enhancing the efficiency and quality of railway construction and management. However, due to the time limitation, the indexes set up here for system performance testing are not perfect. Future research should extend related test indexes to improve the system performance. This paper aims to optimize the railway transportation line planning and station operation and maintenance management efficiency via digital technologies.

Data Availability

The EC architecture data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] A. A. Shirov, "Assessment of interregional economic interactions using statistics of freight railway transportation," *Studies on Russian Economic Development*, vol. 31, no. 2, pp. 153–161, 2020.

[2] C. Wu, N. Zhang, and L. Xu, "Travelers on the railway: an economic growth model of the effects of railway transportation infrastructure on consumption and sustainable economic growth," *Sustainability*, vol. 13, no. 12, p. 6863, 2021.

[3] H. Chen, H. Li, Y. Wang, and B. Cheng, "A comprehensive assessment approach for water-soil environmental risk during railway construction in ecological fragile region based on AHP and MEA," *Sustainability*, vol. 12, no. 19, p. 7910, 2020.

[4] R. M. Lusby, J. Larsen, and S. Bull, "A survey on robustness in railway planning," *European Journal of Operational Research*, vol. 266, no. 1, pp. 1–15, 2018.

[5] C. J. Fourie and N. T. Zhuwaki, "A modelling framework for railway infrastructure reliability analysis," *South African Journal of Industrial Engineering*, vol. 28, no. 4, pp. 150–160, 2017.

[6] W. Pan, Z. Gao, C. Zheng, and Z. Gong, "Analysis on the influence of cross tunnel construction on the deformation of the existing high-speed railway tunnel," *Geotechnical & Geological Engineering*, vol. 36, no. 6, pp. 4001–4013, 2018.

[7] C. Lu, J. Liu, Y. Liu, and Y. Liu, "Intelligent construction technology of railway engineering in China," *Frontiers of Engineering Management*, vol. 6, no. 4, pp. 503–516, 2019.

[8] Y. Pan, L. Zhang, and M. J. Skibniewski, "Clustering of designers based on building information modeling event logs," *Computer-Aided Civil and Infrastructure Engineering*, vol. 35, no. 7, pp. 701–718, 2020.

[9] J. Neves, Z. Sampaio, and M. Vilela, "A case study of BIM implementation in rail track rehabilitation," *Infrastructure*, vol. 4, no. 1, p. 8, 2019.

[10] H.-M. Lee, H.-S. Kim, and I.-S. Lee, "Development of automated 3D modeling system to construct BIM for railway bridge," *Journal of the Computational Structural Engineering Institute of Korea*, vol. 31, no. 5, pp. 267–274, 2018.

[11] H. L. Choi, K. S. Jang, and H. Kim, "Algorithm-based railway tunnel BIM design considering railway alignment," *Journal of KIBIM*, vol. 9, no. 1, pp. 1–10, 2019.

[12] M. S. Ali, M. Vecchio, M. Pincheira, K. Dolui, F. Antonelli, and M. H. Rehmani, "Applications of blockchains in the internet of things: a comprehensive survey," *IEEE Communications Surveys & Tutorials*, vol. 21, no. 2, pp. 1676–1717, 2018.

[13] G. Liu, B. Chen, Z. Gao et al., "Calculation of joint return period for connected edge data," *Water*, vol. 11, no. 2, p. 300, 2019.

[14] J. Chen and X. Ran, "Deep learning with edge computing: a review," *Proceedings of the IEEE*, vol. 107, no. 8, pp. 1655–1674, 2019.

[15] Y. Xiao, Y. Jia, C. Liu, X. Cheng, J. Yu, and W. Lv, "Edge computing security: state of the art and challenges," *Proceedings of the IEEE*, vol. 107, no. 8, pp. 1608–1631, 2019.

[16] G. Premsankar, M. Di Francesco, and T. Taleb, "Edge computing for the Internet of Things: a case study," *IEEE Internet of Things Journal*, vol. 5, no. 2, pp. 1275–1284, 2018.

[17] Z. Lv, D. Chen, R. Lou, and Q. Wang, "Intelligent edge computing based on machine learning for smart city," *Future Generation Computer Systems*, vol. 115, pp. 90–99, 2021.

[18] Z. Lv, "Security of internet of things edge devices," *Software: Practice and Experience*, vol. 51, no. 12, pp. 2446–2456, 2020.

[19] X. Qin, Y. Shi, K. Lyu, and Y. Mo, "Using a TAM-TOE model to explore factors of Building Information Modelling (BIM) adoption in the construction industry," *Journal of Civil Engineering and Management*, vol. 26, no. 3, pp. 259–277, 2020.

[20] Z. Liu, Q. Wang, V. J. L. Gan, and L. Peh, "Envelope thermal performance analysis based on building information model (BIM) cloud platform-proposed green mark collaboration environment," *Energies*, vol. 13, no. 3, p. 586, 2020.

[21] H. Son, C. Kim, and Y. Kwon Cho, "Automated schedule updates using as-built data and a 4D building information

model," *Journal of Management in Engineering*, vol. 33, no. 4, Article ID 04017012, 2017.

[22] M. H. Elnabawi and N. Hamza, "Investigating building information model (BIM) to building energy simulation (BES): interoperability and simulation results," *IOP Conference Series: Earth and Environmental Science*, vol. 397, no. 1, Article ID 012013, 2019.

[23] W. Zhou, H. Qin, J. Qiu et al., "Building information modelling review with potential applications in tunnel engineering of China," *Royal Society Open Science*, vol. 4, no. 8, Article ID 170174, 2017.

[24] Z. Liu, L. Jiang, M. Osmani, and P. Demian, "Building information management (BIM) and blockchain (BC) for sustainable building design information management framework," *Electronics*, vol. 8, no. 7, p. 724, 2019.

[25] W.-F. Cheung, T.-H. Lin, and Y.-C. Lin, "A real-time construction safety monitoring system for hazardous gas integrating wireless sensor network and building information modeling technologies," *Sensors*, vol. 18, no. 2, p. 436, 2018.

[26] H. Zhang, J. Zhu, Q. Zhu et al., "A template-based knowledge reuse method for generating multitype 3D railway scenes," *International Journal of Digital Earth*, vol. 11, no. 2, pp. 179–194, 2018.

[27] Z. Zheng, "The application research of oblique photogrammetry technology in road planning. IOP conference series: earth and environmental science," *IOP Publishing*, vol. 192, no. 1, Article ID 012071, 2018.

[28] F. A. N. Yali, P. Jiawei, and X. Fengrong, "Application of AutoCAD Civil3D in quantity estimation of an abandoned mine rehabilitation project," *Soil Engineering and Foundation*, vol. 35, no. 3, p. 260, 2021.

[29] M. Kosijer, M. Ivić, I. Belošević, N. Pavlović, and M. Opricović, "Fuzzy multicriteria decision-making in railway infrastructure planning and design," *Građevinar*, vol. 72, no. 4, pp. 323–334, 2020.

[30] Y. Kumar and P. K. Singh, "Improved cat swarm optimization algorithm for solving global optimization problems and its application to clustering," *Applied Intelligence*, vol. 48, no. 9, pp. 2681–2697, 2018.

[31] H. Wu, K. Wolter, and P. Jiao, "EEDTO: an energy-efficient dynamic task offloading algorithm for blockchain-enabled IoT-edge-cloud orchestrated computing," *IEEE Internet of Things Journal*, vol. 8, no. 4, pp. 2163–2176, 2020.