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Research Article

Metro Engineering Project Schedule Optimization Based on Wireless Network Communication and BIM Model Algorithm

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BIM (Building Information Modeling) is to create models based on various related information in construction projects and use simulation virtual technology to model actual building information. It is not only the integration of digital information but also the application of digital information in engineering construction. Digital models can be used to plan and simulate the whole process of construction projects scientifically and accurately. In the process of project construction, wireless network communication technology can provide a good basis for collaboration, which is essential for the control of project progress, task scheduling, and systematic communication between all parties. This article introduces the LTE wireless network communication technology and network coverage plan, summarizes the cost and schedule control principles of construction projects, analyzes the factors that affect the construction schedule in subway construction, and introduces the application of BIM technology in subway construction schedule control. Taking the construction of Section XX of Line 1 of City A as an example, a simulation experiment was carried out, and the optimization effect was evaluated with SPI and CPI indicators. The final experimental results show that it is meaningful to use the BIM model algorithm to optimize the subway project. In the simulation experiment, the corresponding construction period saving rate after completion of the project is 6.94%.

1. Introduction

1.1. Background. Urban rail transit projects are difficult to construct, have high technical requirements, and have huge investments. They are the key investment directions for urbanization. If there is a lack of effective management of engineering projects, it will cause huge economic waste, especially the control of progress. The construction of urban rail transit was originally designed to relieve the pressure of urban traffic, but the construction process will take up a lot of valuable surface transportation lines. If the progress is not effectively controlled, it will aggravate urban traffic congestion. At the same time, due to the large construction area of the subway project, the complex location, and the different signal receiving environments in different places, it is necessary to implement different communication signals laying according to different conditions to meet the full coverage of the signal in the construction area. Therefore, it is necessary to conduct special research on the progress control in the process of urban rail transit construction to reduce the impact on urban traffic to the lowest level.

1.2. Significance. Schedule management has an important position in project management. The quality of subway project schedule control will directly affect the industrial competitiveness of construction companies and their own profitability. Strengthening the control of the construction process is the key to rapid and high-quality construction of subway projects. Therefore, research on the construction period control of shield construction of subway projects has important practical guiding significance. In the construction, the quality and management level can be improved by using wireless network communication technology and BIM technology, and the good implementation of the construction project can be realized. Supported by wireless network information technology and BIM model algorithms, a high degree of information sharing is realized in a collaborative platform, which reduced the ambiguity and prevarication of the parties involved, and improved the efficiency of the parties involved in obtaining schedule information in the construction of subway stations and provided support for schedule control decision-making.

1.3. Relating Work. Ansari has developed a hybrid modeling and algorithm framework to analyze the mutual influence of multiple sources of uncertainty on the quality and robustness of the construction schedule. This model combines variable neighborhood search (VNS) with an event-driven simulation framework. The simulation experiment adopted a dual-objective optimization model to minimize the project completion time and maximize a new agent robustness function at the same time [1]. The sustainability calculation algorithm is indeed very effective in optimizing the project completion time, but generally, such research will ignore the control of project quality and cost, which will lead to the two extremes of the project, either the quality is not good enough, or the cost is high. Most construction simulation tools require an integrated platform to combine with optimization techniques. In order to alleviate these limitations, Salimi et al. developed a simulation-based integrated optimization framework on a high-performance computing (HPC) platform and analyzed its performance through a case, using a master-slave (or global) parallel genetic algorithm (GA) to reduce calculation time and effectively use all capacity [2]. The advantage of the algorithm is that the hardware environment required for the construction of the integrated platform is not high, but the algorithm model has not been used in practical applications, and its true performance is unknown. Houssein et al. proposed a framework that combines building information modeling (BIM) with least squares support vector machine (LSSVM) and nondominated sorting genetic algorithm II (NSGA-II) to study the influence of building envelope structure parameters on building energy consumption and find the best schedule design plan [3]. The combination of the BIM model and the deep learning framework has become a research hot pot because with the help of deep learning models, not only can an adaptive schedule optimization control model be constructed, but also the cost of various human learning and manipulation can be simplified. Hwang et al. compare two sets of projects (implemented BIM and nonimplemented BIM) to assess and compare the current status of rework, as well as the scale and impact of rework divided by project type and source of rework. He also proposed a set of practical strategies to help prevent rework in projects that use fuzzy set theory-based models to implement BIM and greatly improve the efficiency of project construction [4]. According to research, rework is indeed an important factor affecting the construction progress of construction projects. The research is of great significance to the progress control of construction projects, but its model is not well applicable to all types of construction projects. Ajewole et al. studied the performance of Orthogonal Frequency Division Multiplexing (OFDM) free-space optical communication systems under gamma-gamma turbulence channels. Various fluctuations in irradiance and atmospheric turbulence hinder the performance of the system. OFDM-FSO channel adopts two traditional modulation schemes, namely, binary phase-shift keying (BPSK) and M-ary quadrature amplitude modulation (QAM) to reduce the influence of channel damage [5]. The research is mainly aimed at solving the problem of channel damage in signal propagation, and no further solutions are proposed for how to better solve signal interference and improve network throughput. Ma and Liu designed a project schedule control algorithm based on communication strategy and communication strategy and combined the algorithm with BIM to provide a visual overlap planning and dynamic control platform framework. This research is valuable to practitioners because it provides a dynamic overlapping plan [6]. This is a comprehensive plan to control the project process, including communication strategy optimization and BIM model technology, but it is only a plan proposed and not used for empirical analysis.

1.4. Innovation. Construction projects are increasingly developing in the direction of complexity and scale, higher requirements are put forward for the progress control of engineering projects, and the continuous updating of information technology methods creates prerequisites for them. In this paper, the innovations of the research on the schedule optimization of subway projects based on wireless networks and BIM model algorithms are as follows. First is the introduction of LTE wireless network technology and RFID radio frequency identification technology to improve the efficiency of project construction collaboration and the tracking efficiency of building products. The second is to use a series of network congestion control algorithms to solve the signal interference and network congestion problems. The third is to propose a schedule optimization plan that combines communication strategies and project schedule control strategies, and its optimization effect has been confirmed in the article.

2. Metro Project Schedule Optimization Based on Wireless Network Communication and BIM Model Algorithm

2.1. Wireless Network Communication Technology. Wireless network communication refers to a way to achieve communication through wireless protocols, including various fixed, mobile, and portable applications, such as cellular networks, WiFi, and mobile satellite communications that are now widely used [7–9]. For a large-scale project such as subway construction, its engineering control and task scheduling are inseparable from a wireless communication system with strong anti-interference ability and high signal connectivity. The wireless network communication technology involved in this research is introduced below [10, 11].

From a performance point of view, WLAN, EUHT, and LTE can all meet the needs of rail transit vehicle-ground wireless communication. WLAN technology will have a relatively large control information overhead. The application of EUHT technology is advancing, and the technological development is not comprehensive and not stable enough. The application of LTE wireless technology is feasible.

2.1.1. LTE Technology. The principle of LTE technology is mainly based on OFDM and MIMO as the core for wireless communication, which can improve the information transmission rate and spectrum efficiency, and can also allocate spectrum flexibly, which can ensure low communication delay of the system and improve the anti-interference characteristics of the system. The LTE system uses a three-level architecture, namely, the core network, base station, and user equipment. Among them, EPC is the core network part, responsible for UE control and bearer establishment. The network structure of LTE is shown in Figure 1.

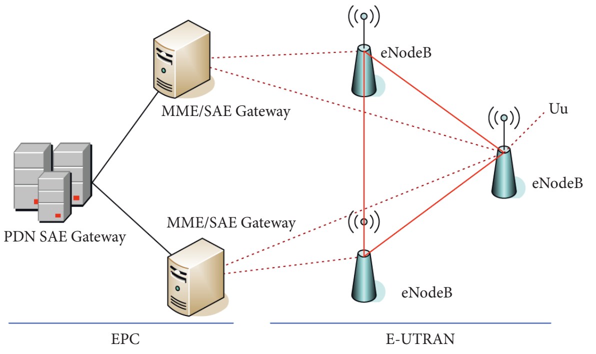


Figure 1: LTE network system structure.

3GPP defines two methods for the LTE system, namely, Frequency Division Duplex (FDD-LTE) and Time Division Duplex (TDD-LTE). The comparison between the two is shown in Table 1.

Table 1: Comparison between FDD-LTE and TDD-LTE

	FDD-LTE	TDD-LTE
Working principle	Frequency division duplex	` duplex
Uplink rate	150 Mbps	40 Mbps
Downlink rate	100 Mbps	50 Mbps
Frame structure	10 subframes*2	5 ms half-frames*2
Asymmetric service support	Poor	Preferably

(1) LTE Network Protocol. There are two LTE wireless interface protocols, namely, control plane protocol and user plane protocol. According to the trend of data flow and signaling flow, the LTE protocol structure is composed of four parts: UE, eNodeB, MME, and S-GW. The LTE system architecture is divided into two parts: the evolved core network EPC (MME/S-GW) and the evolved access network E-UTRAN. The evolved system only has the packet switching domain. The LTE access network is only composed of evolved NodeB (evolved NodeB), which provides the termination point of the E-UTRA control plane and user plane protocol to the UE. The LTE network protocol stack is shown in Figure 2.

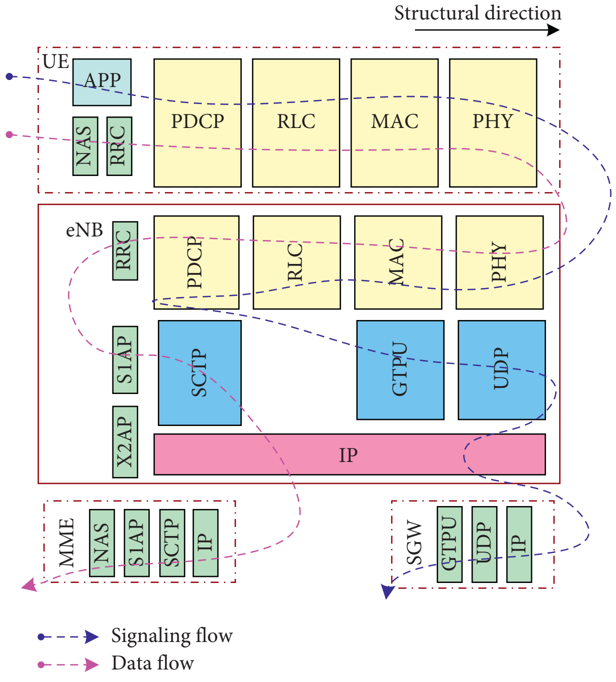


Figure 2: LTE network protocol stack architecture diagram.

(2) OFDM Technology. OFDM uses orthogonality between carriers for data transmission. Compared with the technology used in 3G, it can improve spectrum utilization and save half of the spectrum. OFDM divides the signal source into N subsignal sources and modulates these subsignal sources on N orthogonal subcarriers. In this way, higher spectrum utilization is achieved. OFMD can also solve the problem of multipath fading [12, 13]. OFDM has the following advantages: (1) high spectral efficiency, (2) strong bandwidth expansion, (3) anti-multipath fading, (4) frequency domain scheduling and self-adaptation, and (5) being relatively simple to implement MIMO technology. LTE uses DFT-S-OFDM as the uplink multiple access method, and its schematic diagram is shown in Figure 3.

(3) MIMO Technology. MIMO technology is a multiantenna transmission technology: the base station transmitter transmits multiple data through multiple antennas at the same time, and the receiving section uses multiple antennas to simultaneously receive multiple data streams, and according to the spatial characteristics of each parallel data stream, using demodulation technology, the original data stream is finally restored. Multiple antennas are used at the transceiver end. Compared with the single-transmit-single-receive link of the same bandwidth, the channel resources of

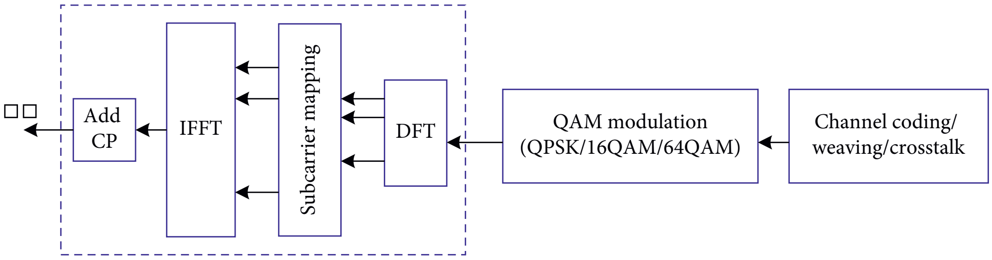


Figure 3: Schematic diagram of LTE uplink multiple access mode.

MIMO are doubled [14]. The form of the MIMO smart antenna is shown in Figure 4.

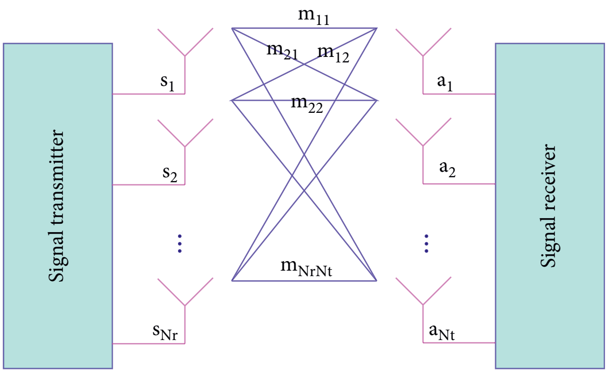


Figure 4: The form of MIMO smart antenna.

MIMO technology essentially provides the system with spatial multiplexing gain and spatial diversity gain. Spatial multiplexing technology can greatly increase channel capacity, while spatial diversity can improve channel reliability and reduce the channel error rate. The manifestation of the wireless signal received by the MIMO system is expressed as a mathematical model:

$$E = M * L + A,$$

$$M = \begin{bmatrix} e_1 \\ e_2 \\ \dots \\ e_{N_r} \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & \dots & m_{1N_t} \\ m_{12} & m_{22} & \dots & m_{2N_t} \\ \dots & \dots & \dots & \dots \\ m_{N_r 1} & m_{N_r 2} & \dots & m_{N_r N_t} \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ \dots \\ s_{N_r} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ \dots \\ a_{N_t} \end{bmatrix}. \quad (1)$$

Among them, A is the additive white noise, M is the transmission channel matrix, L is the transmitted signal, and E is the received signal. The transmitter end is equipped with N_t transmitting antennas, and the receiving end is equipped with N_r receiving antennas. s_i represents the signal transmitted by the i-th transmitting antenna, a_j represents the signal received by the j-th receiving antenna, and m_{ij} represents the signal fading coefficient.

2.1.2. Radio Frequency Identification Technology (RFID). Radio frequency identification technology (RFID) is a short-range wireless communication system. It recognizes specific targets through wireless communication signals, does not require mechanical or optical contact with the target, collects corresponding data, and can be applied to the identification and tracking of construction products [15, 16]. RFID technology consists of four parts: RFID tags, RFID readers, supporting software, and RFID application software systems, as shown in Figure 5.

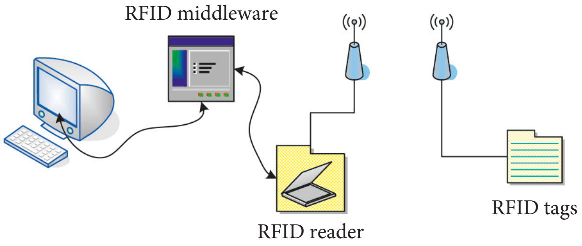


Figure 5: RFID identification system.

The technical principle is as follows: the electronic tag receives the radio frequency signal sent by the reader in the magnetic field, the energy is obtained by the induced current, and the reader collects relevant information stored in the internal chip of the electronic tag. The reader sends the collected information to the central processing unit for the processing to deal with.

In more complex and large-scale construction projects, RFID technology can be used to establish a material management tracking system model to track the material storage location and dispatch method of the construction site and improve construction efficiency. In the system supported by information tools, the workload is greatly reduced, saving labor costs for enterprises, and bringing great convenience to construction enterprises.

2.1.3. Wireless Network Congestion Control Algorithm. A major problem of wireless networks is channel interference [17–19]. Excessive channel interference will reduce the quality of network transmission and aggravate the congestion of each transmission node, which is also causing network congestion. In addition to channel interference, node load and link load are also factors that cause network congestion. Considering dividing the degree of congestion from the above three aspects:

$$CCM = \omega_1 \sum LN_i + \omega_2 \sum LL_i + \omega_3 \sum LC_i. \quad (2)$$

LC_i, LL_i, and LN_i, respectively, indicate the degree of channel interference, link load degree, and node load degree. ω_1, ω_2, and ω_3 are the weights of network congestion caused by node load, link load, and channel interference, and their sum is 1.

According to the transmission rate of the node in the wireless network, the expected transmission time (ETT) and the expected number of transmissions (ETX), the load degree of the node, the load degree of the link, and the interference degree of the channel can be quantified.

In the wireless network transmission queue, the load of any node is associated with its previous-hop node and next-hop node. The load degree of node i can be represented by the length of the transmission queue of the node. The congestion degree of all nodes on each transmission path is

$$LN_i = ETX_i * \frac{Q_i + \sum r_j \cdot ETT_j - \alpha \sum r_n \cdot ETT_n}{r_i}. \tag{3}$$

Q_i represents the length of the waiting transmission queue of node i. r_j is the receiving rate of node i. r_n is the potential receiving rate of the next node of node i. α is the latent factor, and the value is 0 or 1. r_i is the sending rate of node i.

There are different limit rates for the sending rate of nodes. Assuming that the node's limit sending rate is R_i, then the limit formula is

$$\lim_{\substack{r_i \longrightarrow R_i \\ \sum r_j \cdot ETT_{j \longrightarrow N}}} \frac{Q_i + \sum r_j \cdot ETT_j - \alpha \sum r_n \cdot ETT_n}{r_i} * ETT_n = M. \tag{4}$$

When the rate of node i approaches the limit rate, because the load value N from the previous node is too large, the limit approaches a value M much larger than $\mathrm{ETT_i}$. At this time, no matter how to adjust the sending rate or the potential factor, it will cause congestion.

When $\alpha = 0$, transmission at normal speed r_i can meet the time:

$$\begin{gathered} \frac{Q_0 - Q_i + \sum r_j \cdot ETT_j}{r_i} = ETT_i, \\ Q_0 = ETT_i * r_i + Q_i - \sum r_j \cdot ETT_j. \end{gathered} \tag{5}$$

At this time, the queue occupancy rate is

$$P_0 = \frac{Q_0}{Q}. \tag{6}$$

When $\alpha = 0$, transmission at the limit rate R_i can meet the time:

$$\begin{gathered} \frac{Q_1 - Q_i + \sum r_j \cdot ETT_j}{R_i} = ETT_i, \\ Q_1 = ETT_j * R_i + Q_i - \sum r_j \cdot ETT_j. \end{gathered} \tag{7}$$

At this time, the queue occupancy rate is

$$P_1 = \frac{Q_1}{Q}. \tag{8}$$

When $\alpha = 1$, transmission at the limit rate R_i can meet the time:

$$\begin{gathered} \frac{Q_2 - Q_i + \sum r_j \cdot ETT_j - \alpha \sum r_n \cdot ETT_n}{R_i} = ETT_i, \\ Q_2 = ETT_i * R_i + Q_i - \sum r_j \cdot ETT_j + \alpha \sum r_n \cdot ETT_n. \end{gathered} \tag{9}$$

At this time, the queue occupancy rate is

$$P_2 = \frac{Q_2}{Q}. \tag{10}$$

When $P_i < P_0$, it means that the node has a good transmission status. When $P_0 < P_i < P_1$, it means that the transmission rate can be adjusted appropriately to ensure transmission. When $P_1 < P_i < P_2$, it means that the potential next node needs to be scheduled to ensure transmission quality. When $P_i > P_2$, it means that the node is heavily congested and the routing link needs to be reselected.

The link load level LL_i can be measured by the load transmission capacity of the link:

$$\begin{gathered} LL_i = \frac{Q_{ij}}{R_i - M} * ETX_{ij}, \\ M = \sum_{k \in N_i} R_{ik}. \end{gathered} \tag{11}$$

$$R_i - M = 2R_0 \tag{12}$$

R_i represents the total transmission rate. R_{ik} represents the actual shunt rate. Q_{ij} represents the total amount of information to be transmitted from node i to j. ETX_{ij} represents the expected number of transmissions from i to j. N_i is the next node of node i. When the value of M keeps increasing, it will cause congestion. In order to avoid this problem, it can be stipulated that when in the state of formula (12), congestion handling must be adopted, and R_0 is the minimum transmission rate of node i.

The channel interference level LC_i can be expressed as

$$\begin{gathered} LC_i = CST_i + \underset{k \in N_k}{MAX} \left\{ \frac{\gamma}{d_k} * LCIT_k \right\}, \\ LCIT_k = \sum_{k \in N_k} ETTk. \end{gathered} \tag{13}$$

γ is the channel interference factor. d_k is the interference distance of each interfering link. $LCIT_k$ is the link channel interference time. CST_i is the channel switching time. When LC_i increases, excessive channel interference will cause serious network congestion. Therefore, a limit value must be set. When the channel interference is close to the limit value, congestion processing must be adopted.

2.2. Comprehensive Target Forecast Model of Engineering Project Progress

2.2.1. Statistical Forecasting Method. The influencing factors of the project schedule should be regarded as random variables, and each activity factor obeys its own probability distribution. Project management personnel can carry out risk analysis and effective control close to the actual project schedule, time, resources, and costs. The reliability method of the construction schedule is to regard the various variables that affect the construction schedule as random variables, such as human factors, material supply, capital supply, technical level, management level, construction conditions and environment, design changes, and risk factors. And the laws of these complex variables can be studied by probability and statistics methods [20]. In actual engineering, the impact of construction schedule is a complex issue, and actual schedule prediction may involve a variety of complex probability distribution methods, such as normal distribution, logarithmic distribution, and exponential distribution. The probability density curve and function curve of the standard normal distribution are shown in Figure 6.

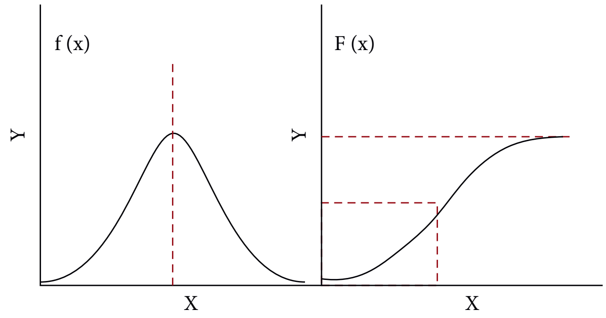


Figure 6: Standard normal distribution probability density curve and function curve.

2.2.2. Basic Relational Model. For engineering projects, under certain constraint conditions, consider the interrelationship between the goals, establish a multiobjective collaborative optimization model, effectively implement project goal control, and achieve the shortest schedule, the lowest cost, the highest quality, and other goals and the best overall system. The overall structure is shown in Figure 7.

(1) Cost-Schedule Relationship Model. Costs include direct costs and indirect costs. The direct cost is the sum of the direct cost required to complete the various activities of the project; the indirect cost includes the salary of the management staff, office expenses, etc. Direct costs increase with the shortening of the schedule, and indirect costs increase with the continuous increase of activities. The relationship between cost and schedule is the superposition of the above two relationships, and the graph is shown in Figure 7(a).

(2) Quality-Schedule Relationship Model. In the construction of engineering projects, as the duration is compressed, the quality of activities is affected, and different completion times result in different degrees of quality. The activity corresponds to the normal construction quality (z_{i0}) under the normal duration x_{i0} and corresponds to the accelerated construction quality (z_{im}) under the limit time x_{im}. The quality-schedule change curve of the activity is obtained, as shown in Figure 7(b).

2.3. BIM Model Engineering Project Schedule Forecast Integrated System. The BIM model can realize the digital information and visual expression of the physical and functional characteristics of the project. In the implementation of BIM technology, various model information is shared through the data information resource platform. And the application of BIM technology runs through the entire life cycle of decision-making, design, construction, operation and maintenance, and collaborative work and management. The computer-integrated architecture of BIM and construction schedule prediction model is shown in Figure 8.

The application of BIM in the preparation of the schedule is essentially the addition of a four-dimensional construction simulation function on the basis of the three-dimensional model. Relevant tasks decomposed by the project schedule can be automatically associated with BIM software, and engineering simulations can also be carried out before construction. The visualization of the project schedule information and construction process helps to predict and judge possible problems in advance, thereby improving the schedule plan. The introduction of BIM technology has a major impact on the schedule optimization of engineering projects, which is mainly reflected in the visualization of schedule control, abundant information, improving schedule management efficiency, and optimizing process control.

2.4. Construction Schedule Optimization Model Based on Wireless Network Communication and BIM Model Algorithm. The BIM schedule optimization management first requires the preparation of the overall schedule plan, including design models, statistical engineering quantities, determination of the construction period, and start and completion time to form a BIM 4D model. The second is the preparation of the secondary schedule plan, using WBS work structure analysis, defining the working space, linking the construction drawing budget and the associated list model, determining the schedule-cost model, and obtaining the consumption of labor, materials, machinery and equipment, and funds. Then, the weekly schedule is prepared with LPS (LPS is a final planning system that can provide refined management and lean operation solutions and decompose tasks according to the contract duration) as the core, and the heads of each group will work together to refine and decompose the tasks, reasonably carry out BIM construction simulation, determine the important and difficult points of the project, and carry out prefabrication to ensure the implementation of the plan. The last is the formulation of daily work, including material supply, quality acceptance, daily work report, problem-solving, and adjustment [21, 22].

Considering that the subway construction is more complicated and the amount of work is compared with the traditional building construction, and the traditional schedule control system is difficult to adapt to the construction of the subway project, this paper chooses the modular construction mode. A construction schedule optimization model based on wireless network communication technology and the BIM model algorithm is established for

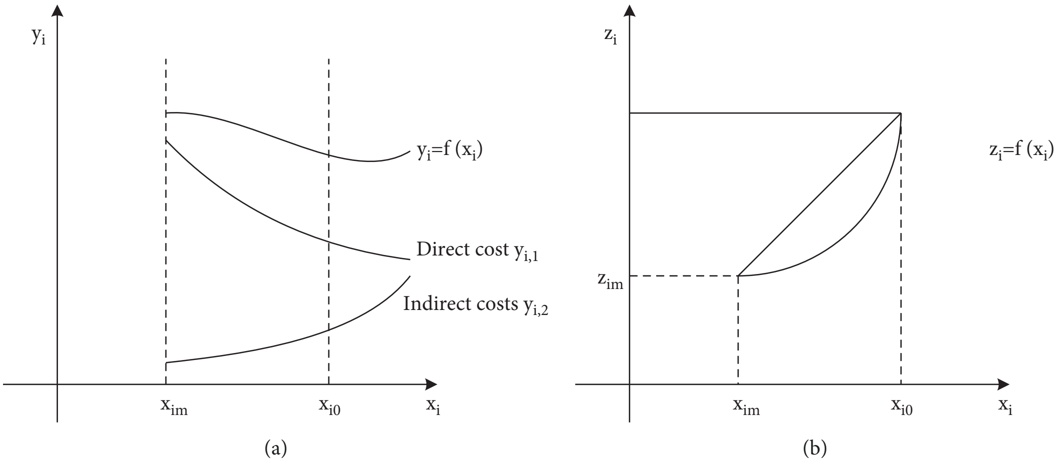


Figure 7: Basic relational model.

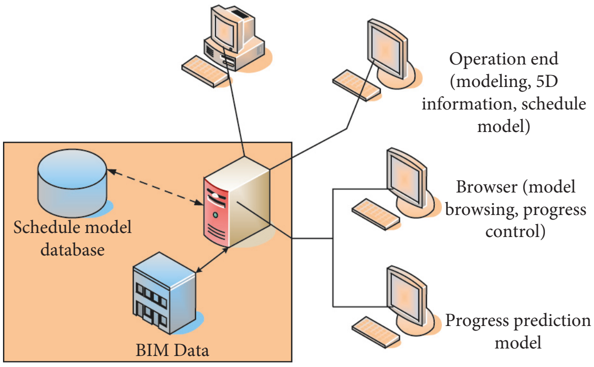


Figure 8: BIM project schedule prediction model.

the three aspects of the optimization of information acquisition quality, the optimization of personnel task scheduling, and the optimization of quality control in the modular construction of subway stations. The specific physical model is shown in Figure 9.

The introduction of the BIM collaboration platform can predict possible problems in the project in advance through virtual construction simulation and reduce conflicts and collisions and help professional engineers to optimize the design plan. LTE wireless network communication technology can ensure the communication environment of the project and improve various tasks' coordination of progress. RFID can collect construction progress information in time and transmit it to the BIM platform and then show the deviation between actual progress and planned progress in the BIM model.

3. Metro Engineering Project Schedule Optimization Model Test and Scheme Verification Based on Wireless Network Communication and BIM Model Algorithm

3.1. A Summary of the Subway Traffic Engineering Project of Line 1 in City A. Metro Line 1 of City A is the only circular metro line with the longest line and the most cross-transfer metro lines in the metro line planning of the city where it is located. The total length is 38 km, all of which are underground lines. There are a total of 25 stations, including 4 transfer stations, all of which are located in the main urban area of city A. Take the XX depot as an example. The depot is responsible for parking, cleaning, daily inspections, technical management, and crew work of the attached vehicles. The main engineering content of the vehicle scope includes earthwork engineering, foundation treatment engineering, track engineering, power lighting, fire-fighting drainage, and ventilation engineering. The main project quantity table is shown in Table 2. The major and difficult points of the construction of this project are as follows: it involves many professional fields, strong professionalism, and high requirements on the construction ability of the construction unit, and the construction procedures are easy to affect each other and slow down the progress. The project volume is relatively large, and there are many topics involved. It is necessary to scientifically and rationally plan the procedures of various professional projects and strengthen on-site coordination within the specified construction period.

3.2. Simulation Application of LTE Wireless Network Communication in Schedule Optimization of Subway Engineering Projects

3.2.1. Wireless Network Design

(1) Wireless Coverage Design. Design the wireless communication coverage during the construction process of the A city subway Line 1 project. Setting up base station equipment and radio frequency units in the constructed stations, the radio frequency units are deployed in the track tunnel near the leaky cable, and the base station equipment is deployed in the station of the communication equipment room, which can guarantee the coverage of wireless signals to the greatest extent.

(2) Link Budget Design. In the urban subway transportation wireless communication system, a dual-network structure of 5 Mhz for A network and 15 Mhz for B network is generally adopted. When adapting to radio frequency units with the

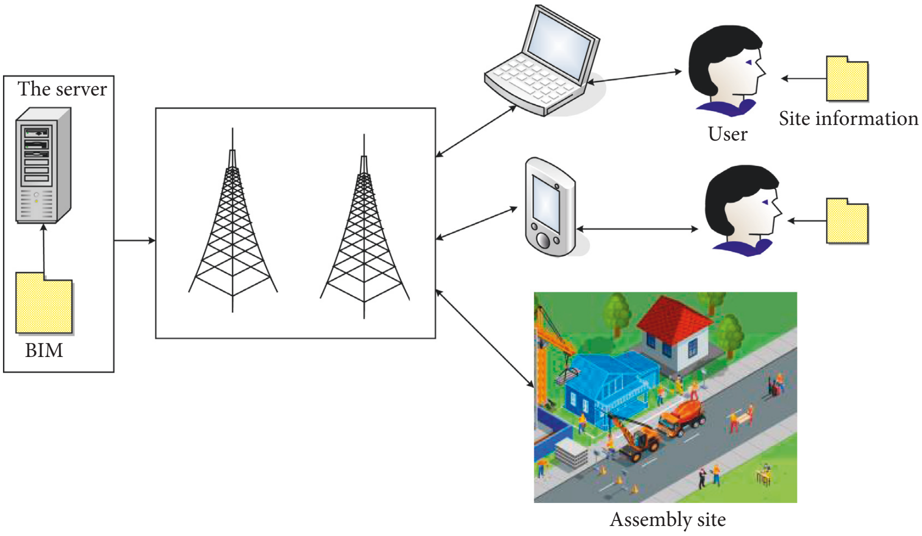


Figure 9: Physical model of construction schedule optimization.

Table 2: Number of main projects.

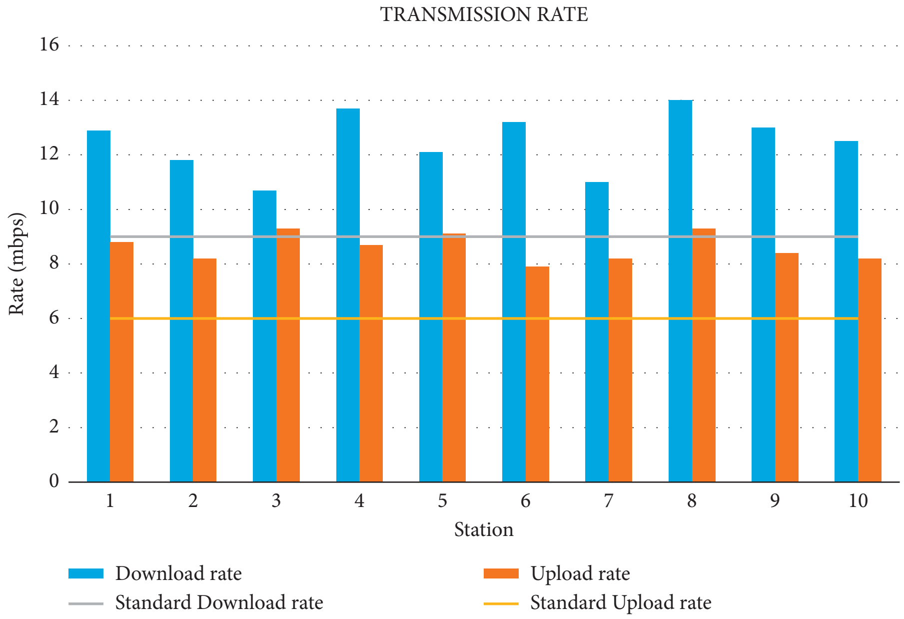
	Engineering	Unit	Quantity
Earthwork engineering	Excavation	m^3	612977
	Fill		835820
	Desilt		698211
	Subgrade earthwork		931880
Foundation treatment engineering	Precast concrete pipe pile	m	105523
	Track jet grouting pile		138480
Track engineering	Track laying	km	7.9
	Lay a railway track	Group	28
	Integral track bed	m^3	964
	Gravel track bed	m^3	12869
—	Dynamic lighting	m^2	156800
	Fire-fighting		
	Drainage		
	Ventilation works		

Table 3: Link calculation table within the construction section of LTE subway project.

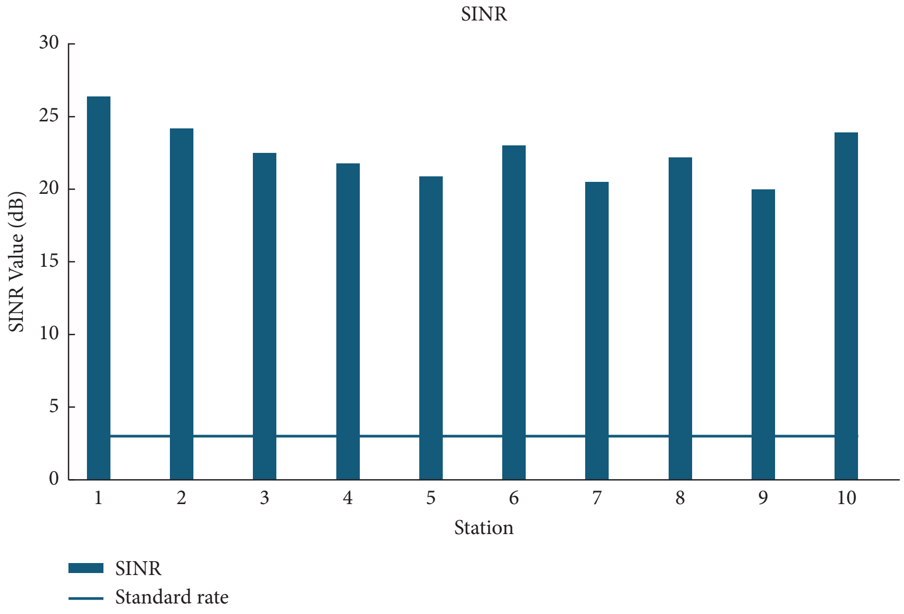
Channel type	A uplink	A downlink	B uplink	B downlink
System broadband (MHZ)	6		15	
MIMO	1*2	2*2SFBC	1*2	2*2SFBC
Maximum total transmit power (DBM)	26	52	25	52
Subcarrier transmission power (DBM)	−1.2	23.4	−6.63	18.82
Feeder loss (DB)	0	6	0	6

same power, network A is larger than network B with regard to the transmission power of subcarriers, and the coverage of the network with higher transmission power is also relatively larger. When performing link calculations, network B should be used as a reference. The calculation of wireless links in the tunnel scenario can be shown in Table 3. The use of this link design scheme is reasonable and can reduce the number of equipment in the station section and reduce costs.

(3) Anti-Interference Design. The anti-interference system of the wireless communication network will mainly be applied to the network congestion control algorithm mentioned above. Since the subway LTE system used is closer to the frequency band of the civil mobile communication system, the design of the same frequency anti-interference solution and the solution to the multipath interference problem are more important [23, 24]. When designing the corresponding scheme, the last part of the OFDM symbol can be copied and inserted into the starting position. At this time, certain continuous orthogonality can be maintained between the subcarriers, which will avoid interference to a greater extent. Because this is equivalent to adding a cyclic prefix, if the cyclic prefix is always longer than the service signal delay, continuous orthogonality can be guaranteed.

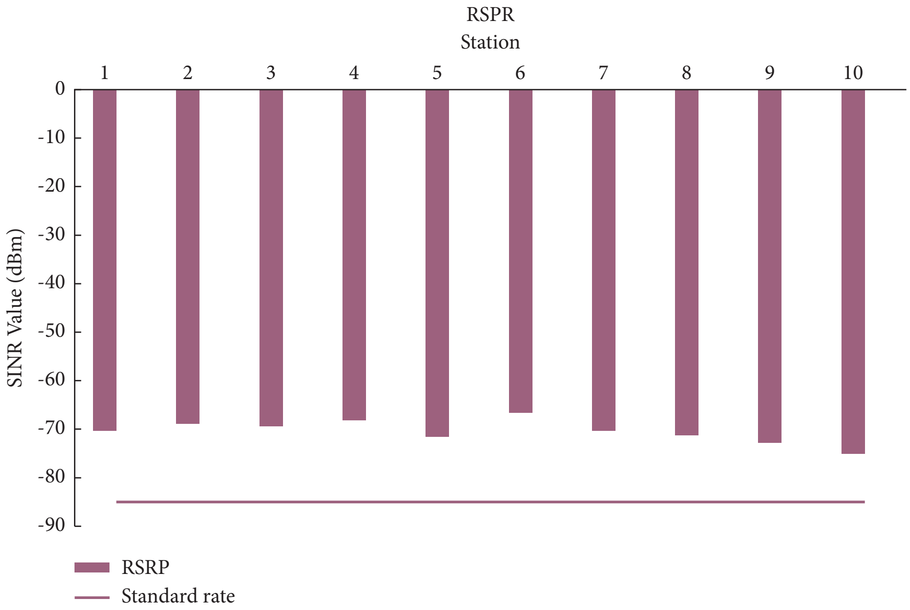


(a)



(b)

Figure 10: Continued.



(c)

Figure 10: Wireless communication test results. (a) Transmission rate. (b) SINR. (c) RSPR.

3.2.2. Wireless Communication Result Test. The wireless communication network system of this project was tested, and 10 station construction points on Line 1 of City A were randomly selected and numbered 1~10. The test indicators include the download rate, upload rate, SINR value, and RSRP value of each station construction module. SINR refers to the ratio of the strength of the received useful signal to the strength of the received interference signal (noise and interference); it can be simply understood as the “signal-to-noise ratio”. RSRP is the reference signal received power, which can represent the signal strength, and is the average value of the signal power received on all REs (resource particles) that carry the reference signal in a certain symbol in the LTE network. The test result is shown in Figure 10. The qualified values have been marked with horizontal lines in the figure, and the index evaluation values are RSRP > −85 dBm, SINR > 3 dB, download rate > 9 Mbps, and upload rate > 6 Mbps. It can be concluded that the test results of various index values are greater than expected values, and the signal conversion between 10 stations is normal. The data obtained from this test proves that the application of LTE to the wireless communication of subway project construction can meet the system requirements.

3.3. The Application Benefit of BIM in XX Road Section Construction Schedule Optimization. First carry out temporary site layout, civil engineering, and electromechanical modeling of the project, import the deepened model into the BIM application platform, then import the construction schedule into the platform, and associate the construction model to simulate and analyze the construction process. In addition, it is necessary to import a budget file, associate the three-dimensional model with it according to the project quantity, check the compatibility of the list and the schedule plan, and realize the collaborative management of the construction schedule and cost. According to the overall construction schedule plan, determine the key routes and work, comprehensively consider the resource constraints, formulate hierarchical monthly schedules and weekly schedules, and arrange daily work schedules to achieve effective control of the construction schedule and refined construction management to improve project profit and industry informatization level [25, 26]. Autodesk Autocad and Autodesk Revit 2016 are used for temporary site layout, civil engineering, and electromechanical modeling; Fuzor, Lumion, and Naviswork are used for roaming, construction simulation, and construction animation production. The evaluation of the schedule optimization of a subway project cannot only rely on the index of how much the schedule has been optimized but also comprehensively analyze the cost index of the method. Therefore, this article uses the schedule performance index SPI and the cost performance index CPI to evaluate the level of the project’s use of BIM technology management to optimize the construction schedule.

The progress performance index SPI represents the ratio of earned value to planned value, that is, the ratio of the completed work budget to the planned work budget. When SPI is greater than 1, the progress is advanced, and less than 1 is the delay. The cost performance index CPI is the ratio of the budget cost of the completed work to the actual cost of the completed work (total of direct and indirect costs). A CPI value less than 1 indicates that the actual cost exceeds the budget, and a CPI value greater than 1 indicates that the actual cost is lower than the budget. The actual value can be obtained by directly selecting the time point on the BIM platform, and the earned value can be obtained by multiplying the percentage value of the project completion

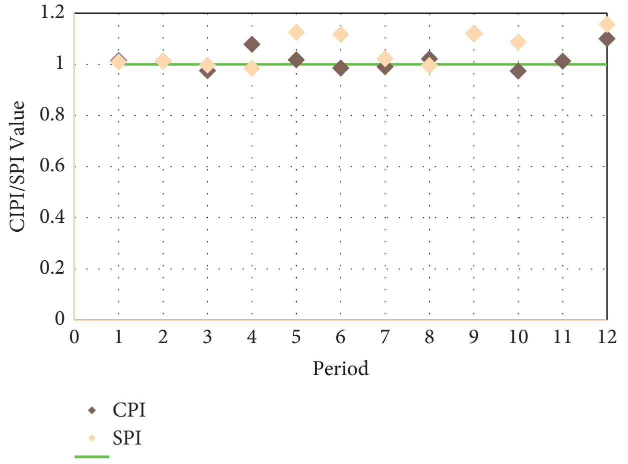


Figure 11: Cost and schedule performance indicator statistics.

amount by the completion budget. It took 24 months from the actual start to completion of the XX section of the project. The actual completion time of the project was divided into 12 cycles, two months as a cycle, and the CPI and SPI values were counted. The results are shown in Figure 11. It can be seen that the CPI value and SPI value of most cycles are greater than 1, indicating that the project has been optimized in terms of cost and time.

The XX section subway station project lasted 24 months in total. After the completion of the project, it was concluded that the construction period was shortened by 50 days, the construction period saving rate was 6.94%, and the engineering cost-saving rate was 1.63%, indicating that the project goal was completed ahead of schedule and not exceeded according to the original plan original budget. And from the perspective of overall quality and safety management, the project can reasonably control the progress, organize the work in an orderly manner, maximize the use of resources, strictly control the quality links, and meet the acceptance standards.

4. Discussion

This paper takes the optimization of the subway project schedule as the main research object, takes LTE wireless network communication technology and BIM model technology as the main technical support, and takes the cost control and schedule control theory of construction engineering as the theoretical support. It deeply studies the modular construction of subway stations' schedule optimization problem of modular construction. The article first summarizes the relevant research background and research significance of the development background of BIM technology and the role of wireless network information technology in the construction of engineering projects and summarizes the research results of predecessors on project schedule optimization and the significance of their research to the realization of this paper. Secondly, some professional theoretical knowledge and methodology that the article may or should be involved in are elaborated, such as LTE wireless network communication technology and its key technologies (MIMO technology and OFMD technology). Some solutions are proposed for the interference and congestion problems that may occur in the communication process. We introduce the comprehensive predictive control models of engineering projects, such as statistical forecasting methods, cost-schedule and quality-schedule relationship models, and description of the BIM model engineering project schedule forecast integrated system. The construction schedule optimization model based on the wireless communication network and BIM model algorithm is designed in this paper. Finally, it is the simulation test part of the scheme. With the subway traffic engineering project of Line 1 in City A as the main test object, a specific wireless coverage scheme for the thread project is designed and tested. The results verify that the scheme has a good effect. The anti-interference ability and the ability to deal with network congestion have good real-time performance, which can fully meet the task scheduling and communication needs during the construction period. Using SPI and CPI as performance indicators, the construction status of the XX section of Line 1 in City A was evaluated. Under this plan, the simulation experiment results showed that the introduction of the BIM model can save the construction period and the cost did not exceed expectations.

5. Conclusions

Based on the foundation of BIM technology and wireless network communication technology, this paper proposes an integrated system for predicting and optimizing the utilization of subway project construction schedule and explores the integration method between subway project construction schedule prediction model and construction management system in BIM technology. This method can identify the factors that affect the completion schedule of any subway project, predict the schedule, quantitatively analyze the actual completion prediction, automatically modify the actual completion schedule in the BIM technology foundation, analyze the deviation from the schedule, and modify the subsequent schedule plan. Wireless network communication technology plays an important role in improving the collaboration and real-time and scientific nature of the construction of engineering projects. The technology application research in BIM has been expanded and deepened, thereby improving the scientific accuracy of predicting short-term progress and general risks, and improving refined management and scientific management of engineering projects has been achieved. Judging from the results of the simulation experiment, the scheme proposed in this paper is not excellent in cost-saving, but there is still some research progress in schedule optimization. However, because of the limited research content of this article, the application analysis of BIM in various aspects of schedule control, such as cost and quality control, is still limited. In the future, BIM technology will be further combined with modern advanced information technology.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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