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Cloud control platform of intelligent and networked public transport based on BIM technology

Xitong Xia**

Information Perception and Data Analysis Engineering Laboratory of Intelligent Transportation of Jiangsu, Nanjing University of Science and Technology, Nanjing, Jiangsu 210094, China

Abstract: To ensure the efficiency and safety of citizens' travel while enhancing the management level of urban public transportation, this paper constructs an intelligent bus control platform deployed on the Internet, leveraging Building Information Modeling (BIM) technology. Two systems, "Comprehensive Monitoring" and "Operation and Maintenance Management," have been established. The platform achieves three-dimensional visualization and controllability for functions such as "Active Safety" and "Intelligent Scheduling" on the Internet. The research outcomes facilitate the integration and sharing of information among "people," "vehicles," "roads," and "environment," as well as the whole-life health monitoring of related facilities and equipment. It provides a comprehensive operation and maintenance management platform with robust functional practicability, an excellent level of intelligent decision-making, and high visualization for the management departments of urban public transportation at all levels.

Keywords: Traffic engineering; BIM; ITS; Urban public transportation; Operation; maintenance management

1 Introduction

In recent years, with the rapid development of communication technology and autonomous driving technology. Traditional cars are gradually being updated and iterated to intelligent network-connected vehicles. While strengthening their own sensing ability, the powerful and time-efficient, and stable communication ability of intelligent network-connected vehicles is also changing people's travel mode by osmosis. Intelligent networked vehicles are not only able to monitor the vehicle operating status, the environment inside and outside the vehicle, as well as energy consumption, passenger flow, and other data in real-time, but also have the functions of path planning and decision-making, cooperative control, etc. Through V2X technology, it solves the difficulties of vehicle-vehicle communication and vehicle-road cooperation, provides a safer, more efficient, more energy-efficient, and more comfortable way of travel for transportation participants, and is also the recognized future development of transportation in the world. It is also recognized as the future direction of transportation in the world.

The outstanding advantage of intelligent networked vehicles is that each vehicle is a road traffic environment information collector, roadside RSU real-time collection of massive information from the running intelligent networked vehicles, through the background or roadside edge calculation, and then the corresponding emergencies, weather conditions, road body stability and other information feedback to other vehicles in the road network, for the road section and even the efficient operation of the entire road network provides a strong database and planning capabilities.

With the rapid progress of 5G technology at this stage and the layout plan of 6G technology in the future, the communication between car and car, car and road, and car and people will be more timely, and will further promote the safety and reliability of future self-driving vehicles.

With the continuous improvement of the urban road network and the continuous development of the public transport system, the use of information technology to solve the city bus waiting for difficult, crowded, congested, uncontrollable, and other problems have become an urgent need of bus operating companies, traffic management departments.

The application of BIM(Building Information Modeling) technology in urban public transport, especially in the intelligent networked bus system due to its digital, parametric, visualization, and other characteristics, will effectively improve the quality of system construction, can provide the intelligently networked bus popularization and the upgrade of the operation and maintenance management platform of the digital twin way with strong reality mapping, high information traceability and the digital base for carrying information [1].

Based on the project "Solution+, the flagship project of sustainable intelligent transportation demonstration" jointly declared by Nanjing University of Technology, T-Systems International GmbH, Germany, and the European Intelligent Transportation Association in 2019, this paper creates a set of cloud control platforms for intelligent networked public transport with high practicality, high informatization, and excellent 3D visualization. The innovation is the first time to create a cloud control platform based

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** *Corresponding author*: 22022244@njust.edu.cn
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on BIM technology for intelligently networked transit, using the model parameterization features of BIM technology and the rendering capability of UNITY, integrating key technologies such as multi-dimensional perception and analysis of intelligently networked transit, system control, etc., strengthening the whole chain of perception-analysis-control intelligent networked transit control technology and realizing efficient, safe and low-carbon digital management of urban transit. The system is a digital management system for efficient, safe, and low-carbon urban public transportation. It solves the lack of digital twin capability of the intelligent Internet-connected bus system and lays the foundation for intelligent urban management in the future autonomous driving environment. In addition, the Twinmotion plug-in is also used to solve the prominent problem of material loss during format conversion in the BIM industry, laying a foundation for further expansion and application of BIM.

2 Current status of domestic and international research

2.1 Research status of BIM technology

Combined with the interpretation given by the Ministry of Housing and Construction, BIM is an information modeling technology that can realize the planning and design of the project, and also the operation and maintenance management of the project after the project is delivered.

In 2007, the National Institute of Building Science released the first BIM technology application specification "BIM application standard based on IFC standard". In 2011, the UK introduced the "Government Construction Strategy" and released some documents on the application of BIM technology. In 2014, the Japanese Ministry of Land, Infrastructure, and Transport issued the BIM application guidelines and introduced a series of policies to promote the application of BIM technology in the country. BIM technology started late in China, but during the "Eleventh Five-Year Plan", it was included in the national science and technology support program, and currently, all provinces have released BIM-related policy documents [2].

Regarding the development and application of BIM technology, Ding et al. systematically discussed the *n*D BIM model framework, which supports the use of high-dimensional BIM models in actual construction site work [3]. Lee et al. believe that high-dimensional BIM models involve both technical and cultural aspects and will lead to interdisciplinary research in the future [4]. Hamid combines 3D laser scanning, wireless radio frequency, and BIM technology to achieve efficient aggregation of various data on construction sites, assisting in information management and scientific decision-making of engineering projects [5]. El Mekawy et al. combined GIS (Geographic Information System) with BIM to achieve applications in building analysis, construction planning, urban planning, and other fields [6]. Most of the relevant research abroad focuses on the exploration of BIM modeling technology, while there are many applications of BIM technology in China, resulting in a large number of digital twin platforms targeting various industries. Shu Xin optimized the design scheme of the parking complex building of Nantong Government Center through BIM technology and studied the application value of BIM technology throughout the entire lifecycle of the project [7]. Huashe Design Group uses BIM technology to carry out high-precision modeling of Wufengshan Yangtze River Bridge and Nanjing Fifth Yangtze River Bridge and serve as the data base of the digital twin system, realizing the three-dimensional digital operation and maintenance management of the project.

2.2 Status of development of intelligent networked public transport system

The rapid development of Internet of Things technology has led to rapid changes in the transportation industry, and in the context of the "Internet+ transportation" era, people's travel patterns are also undergoing profound changes.

Intelligent networked public transport is one of the important development directions of urban public transport, dedicated to the mobile Internet, Internet of Things, big data, cloud computing, and other new generation of information technology applied to urban public transport operations, services, management, and other aspects, to create a safe, efficient, reliable and comfortable urban public transport information service system to improve the level of urban public transport intelligence.

The U.S. Urban Public Transport Administration has carried out an intelligent bus system project to build functional modules for dynamic monitoring of bus vehicles, satellite positioning and wireless communication, and command and control. Europe through signal priority, dedicated right-of-way, and other initiatives to achieve intelligent scheduling and monitoring of the bus system. Japan has achieved improvements and upgrades in management systems through technologies such as passenger count statistics, vehicle operation monitoring and control, and progress information release. Numerous cities in China have also continued to optimize their urban bus scheduling and management systems through technologies such as vehicle-road collaboration and 5G Telematics. To date, most first-tier cities have carried out the intelligent design of public transportation.

However, many existing bus control systems or platforms only solve the problems of data statistics and real-time monitoring for operation and maintenance management and traffic management to a certain extent, but there is more room for improvement in terms of system intuitiveness and system intelligence. After literature review and survey visits, there is no domestic intelligent cloud control system that can simultaneously serve multiple participants such as bus vehicles, dispatching command centers, and passengers, and there is no BIM technology introduced into the field of public transport operation and maintenance management platform. There are key technical points worth breaking through in terms of data transmission, bearing methods, information invocation, intelligent decision-making, etc.

In summary, both BIM technology and intelligent networked bus system have certain successful application cases, however, no BIM-based intelligent networked bus cloud control platform has been seen in relevant research results at home and abroad. This paper will explore the innovative application of BIM in the platform to help create an innovative intelligent networked bus digital twin control platform with three-dimensional panoramic visualization, efficient command and dispatch, all-day safety and security, and low-carbon environmental protection and green.

3 BIM-based intelligent network connected bus cloud control platform functional design

This paper proposes a cloud control platform for intelligent Internet-connected public transportation mainly for the pain and difficulty of data synchronization, lagging response to traffic events, and difficulty of accident warning generated by public transportation companies in the process of operation and maintenance management, as well as for the poor travel experience of passengers in the process of travel, such as the difficulty of waiting for a bus and the degree of congestion. Through information perception and edge computing devices to build a comprehensive intelligent perception of people, vehicles, roads, and stations, the establishment of a seven-layer system framework, including the security layer, perception layer, data layer, analysis layer, decision-making layer, control layer, display layer, forming a closed-loop system based on BIM technology to support the intelligent networked bus cooperative control. As in Fig. 1 [8-10].

The BIM parametric model of intelligent bus lines and road net-

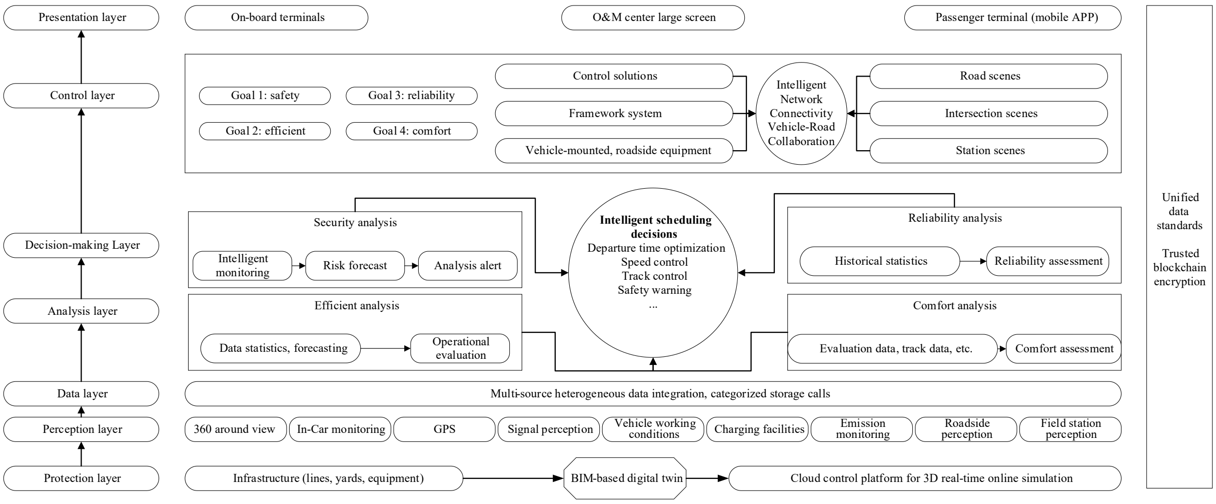

Fig. 1 Overall platform architecture.

works within a certain range is used as the digital base of the digital twin cloud control platform, which integrates multi-source heterogeneous data from vehicles, roadsides, stations, and operation and maintenance management centers on the model to achieve three-dimensional visualization browsing and invocation. The data are analyzed by the platform to the four modules of safety, efficiency, reliability, and comfort to form intelligent scheduling decision plans such as departure time optimization, speed control, trajectory control, and safety warning, and control commands are issued through relevant control modules and information release devices. The vehicle terminal, operation, and maintenance management center, and passenger cell phone terminal system show the relevant operation and operation status and the prediction and analysis results in a subsequent period of time in real-time for managers, drivers, and passengers to plan and form in advance to improve the line operation and passenger travel efficiency and guarantee traffic safety [11-13].

In terms of functions, as in Fig. 2, the platform develops and ar-

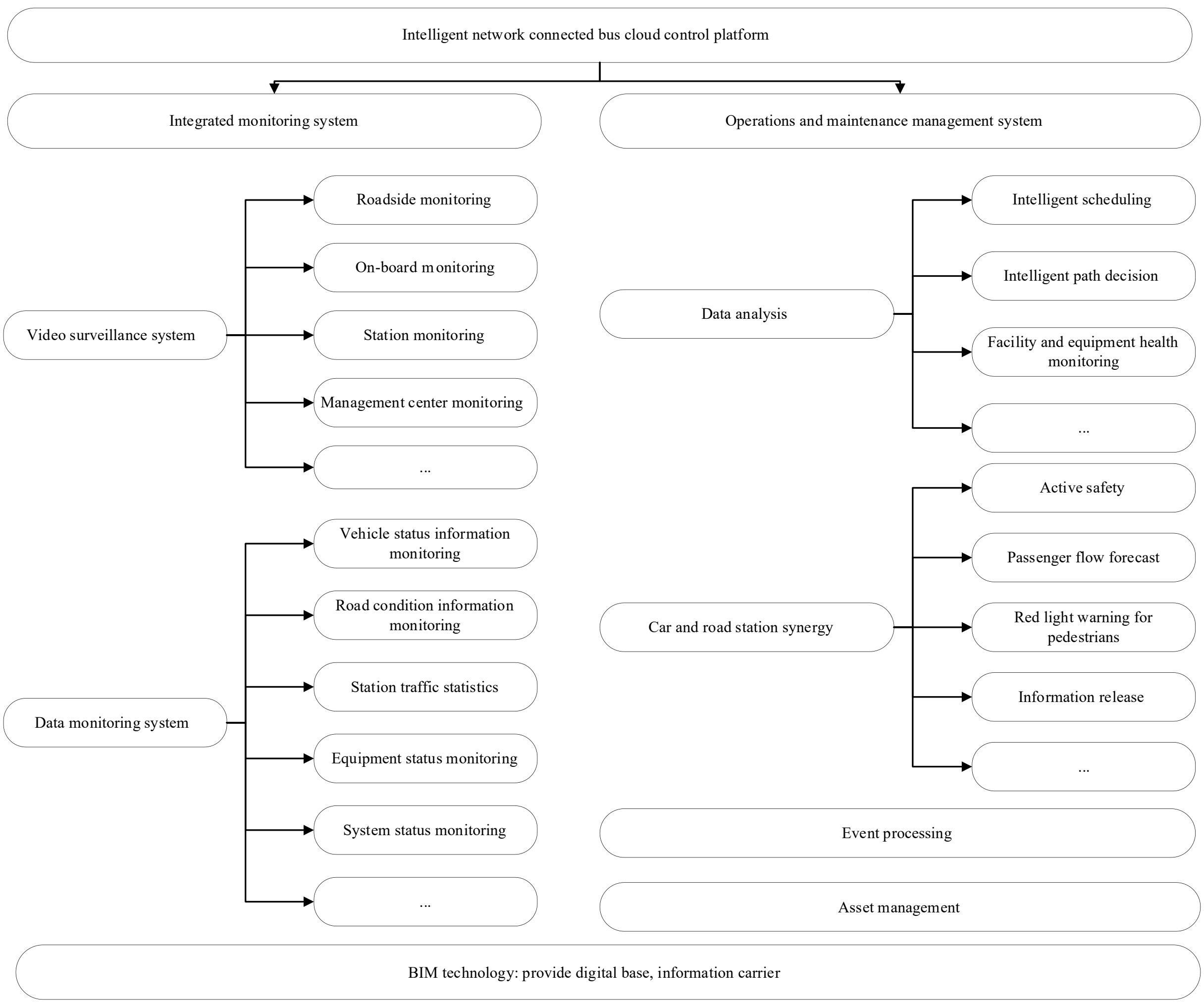

Fig. 2 Platform features.

ranges a number of typical application scenarios around the two functional modules of a comprehensive monitoring system and operation and maintenance management system.

3.1 Integrated monitoring system

The comprehensive monitoring system of the platform includes a video monitoring system and a data monitoring system, as in Fig. 3. The video monitoring system includes roadside monitoring, vehicle monitoring, station monitoring, management center monitoring, etc.; the data monitoring includes vehicle status information monitoring, road condition information monitoring, station traffic statistics, equipment status monitoring, and system status monitoring, etc.

Fig. 3 Screenshot of the platform-integrated monitoring system.

While the integrated monitoring system performs daily monitoring, the video, image, radar, and other data information collected by monitoring equipment, roadside RSU equipment, etc. will also provide data support for active safety, passenger flow prediction, energy consumption monitoring, red light warning, and other functions.

BIM technology-based intelligent network connected bus cloud control platform integrates a large number of intelligent products with wide data classification, high integration of application functions, and complex system linkage. The platform builds a centralized and unified data collection system, which is responsible for collecting real-time status data of various intelligent devices and monitoring whether the operation status of maintenance objects is normal. These data support the workflow of facility resource management, centralized monitoring management, and maintenance process management on the basis of the BIM model, and are also the basis for efficient supervision by staff.

According to the different regulatory needs, when viewing the equipment parameter information, it can be displayed in the form of a data list superimposed on the BIM model. When viewing the temperature of the equipment room, it can be displayed in the form of a heat map; when viewing the information released on the station display, it can directly display the information released on the model; when checking the road monitoring information, it can click on the facility model to pop up the real-time monitoring screen and other forms of multi-style, multi-factor integration display to improve the efficiency and means of comprehensive control.

Video data is mainly through the front-end control platform by clicking on the corresponding stake location camera BIM lightweight model, associated with the corresponding link video data is immediately pop-up monitoring window. Based on the parametric information display achieved in the modeling stage, click the camera BIM model in the platform, you can achieve the camera name, state, location, model, pixel parameters, and other dynamic and static information of the unified display, but also in the platform interface to provide direct application of camera rotation, zoom, and other functions. Facilitates the operation of supervisors, and provides technical support for rapid response to traffic events.

3.2 Operation and maintenance management system

While creating a comprehensive monitoring system based on BIM technology, the platform will also create an operation and maintenance management system for the urgent needs of the operation and maintenance management department, such as comprehensive public transport control and big data decision-making for public transport.

The operation and maintenance management system will also be based on BIM technology, with a 3D parametric BIM model as a digital base to achieve four core functions: data analysis, vehicle-road-station collaboration, event processing, and asset management. Based on each functional module, it will simultaneously optimize functional sub-modules such as intelligent dispatching, active safety, red light warning, conflict warning for vulnerable traffic participants, path deviation warning, event warning, and passenger flow prediction.

In terms of data analysis, the system makes intelligent decisions based on various types of data collected by roadside equipment. According to the traffic evaluation of the road network, it intelligently optimizes the path decision of vehicles in non-stationed road sections. According to the health monitoring data of roadside and vehicle facilities and equipment, it optimizes the attendance efficiency of maintenance operation staff and intelligently identifies hidden dangers.

In vehicle-road-station cooperation, roadside equipment interacts with vehicles and stations in real-time, and when a pedestrian runs a red light and the vehicle is within the danger range, the vehicle cab realizes sound and light alarm to ensure travel safety. In case of abnormal driving status vehicles, the system will also automatically alarm and prompt the region’s bus vehicles to pay attention to avoid. The station will also display real-time bus arrival information to optimize the passenger waiting experience.

In terms of incident handling, the system will determine the severity of the incident based on the video image information collected by the relevant equipment, save the relevant data while automatically sending alerts to the appropriate departments to achieve a rapid response to the incident and take emergency measures at the first time.

In terms of asset management, the system will automatically inventory all kinds of asset information, and automatically prompt the replacement of consumables and maintenance plans to ensure the smooth operation of the bus system.

Combined with the BIM lightweight model, the O&M management system can visually show the real-time mapping of the digital twin road signals and traffic distribution on the platform and also realize the list of all vehicles, roads, and stations information statistical display. By clicking on the station BIM lightweight model in the system, you can also view the information of the scheduling scheme under preset different traffic and meteorological conditions, including the information on departure density, path decision information, and regular intelligence information, which can realize the virtual display of intelligence display system functions. It provides a visualization basis for supervisors to quickly select equipment for information release and choose appropriate release contents [14].

4 BIM technology support

4.1 Build a parametric 3D model of traffic engineering

Unlike the design and management of highways and bridges, the design and operation, and maintenance of facilities and equipment along traffic engineering are more about the extensive perception of the state of the roadway and the accurate management of dynamic data, so the establishment of a parametric digital model of traffic engineering is of great significance for building a complete virtual world of intelligent networked public transport so as to enhance the digital level of the operation and management of the public transport system and help the application effect of intelligent networked public transport.

The use of BIM technology to achieve the restoration of traffic engineering facilities and equipment, not only to achieve the virtual presentation of the model itself but also to achieve the application of equipment-related functions and digital display, taking into account the later refinement of equipment management, the platform traffic engineering and ancillary facilities and equipment models in accordance with the model fineness LOD (Levels of Detail) 300 (component-level model units) to carry out modeling. In the modeling process, the key dimensions of equipment components are parameterized and associated. Take the road model as an example, the lane width, the number of lanes, and other dimensions are parameterized and associated with good component relationships to achieve rapid adjustment to adapt to different roadbed widths and lane conditions. The use of parametric modeling ideas to build facilities and equipment models containing monitoring systems, pre-buried projects, intelligent networked public transport systems, and other professional, effective integration of the main engineering model to achieve the construction of a virtual digital world of all elements.

As shown in Fig. 4, in the BIM software Revit, the lighting status of the bus station, information board release content, advertising space content, vehicle arrival status, and other attributes are parameterized, which will provide data support for subsequent platform applications. It can realize the efficient management of management personnel in the operation and maintenance process.

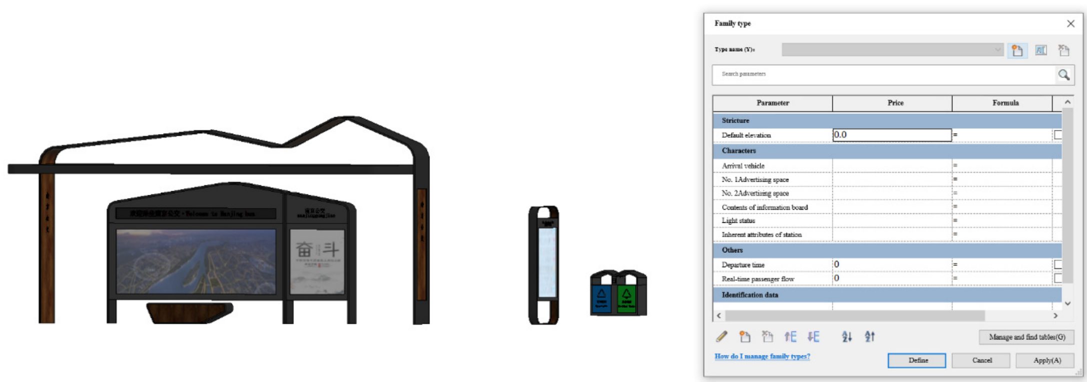

Fig. 4 Parametric modeling of bus stops.

4.2 Build CIM city information model

At this stage, many government management departments and enterprises are actively building intelligent cloud control platforms for each profession. The number of platforms is huge, the functions overlap, and the intelligent functions are realized while wasting huge social resources. Cloud control platforms with similar professions are in urgent need of unification. In this paper, while fully considering the future development direction of the cloud control platform, in order to enrich the platform presentation effect, the CIM city information model will be built around the target road section.

The platform constructs a perfect regional city information model around the demonstration site of Nanjing Baixia Hi-tech Zone of intelligent network connected bus. The detailed structural features of real buildings are restored with high precision. The building models all come with engineering information such as construction unit and completion time, while information interfaces such as architectural drawings and management units are reserved to fully prepare for the future unification of the CIM platform. At the same time, the platform is also based on BIM technology to create a three-dimensional model of the construction site in the region and will be used in the future to synchronize the construction progress and enrich the function and presentation effect of the cloud control platform.

As shown in Fig. 5, we have parameterized and customized the floor area, resident personnel, affiliated units, building name, building nature, the contact information of the property manager, and other contents in the building model. In addition, we can reserve more information that may be needed in the future CIM platform. Adding building information to the BIM model will greatly improve the utilization rate of model information, and also improve the efficiency in the process of platform development.

4.3 File format conversion and material comparison test

In the practical work application of BIM technology, it is usu-

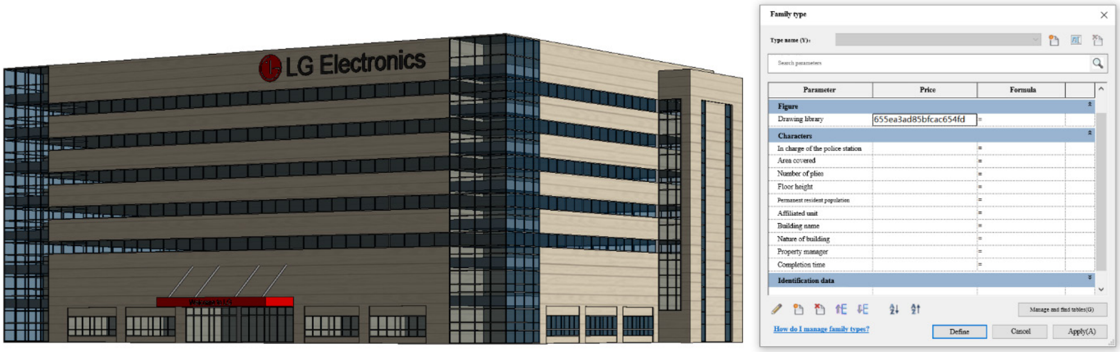

Fig. 5 Parametric BIM model of buildings.

ally necessary to export the 3D model created by the BIM software Revit to the back-end developers to realize the display and related applications at the platform end. the file-saving type of Revit is divided into family and project, which are .rfa and .rvt files respectively. And these two file formats cannot be read by the back-end software. At present, the common solution is to export .fbx or .glb format, and then re-edit the material through SketchUp or 3DMAX software to restore the simulation effect in Revit. Twinmotion plug-in can realize the export of Revit model with texture material to .fbx format, but it cannot save the effect of Revit self-editing transparency and bump. The scheme comparison is shown in Fig. 6.

As shown in Fig. 7. In this paper, while BIM modeling, we continuously carry out material comparison experiments, and import the model built by Revit into the Unity platform after exporting .fbx format through the Twinmotion plug-in to verify the presentation effect of materials among different platforms.

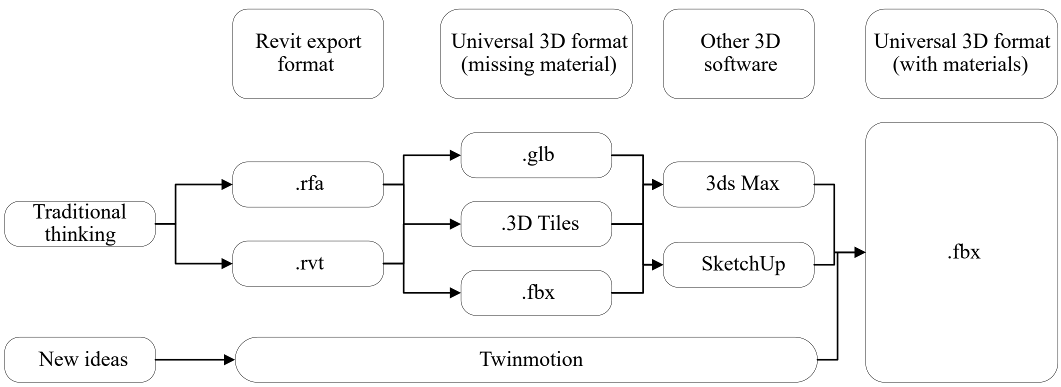

Fig. 6 Flow chart of format conversion.

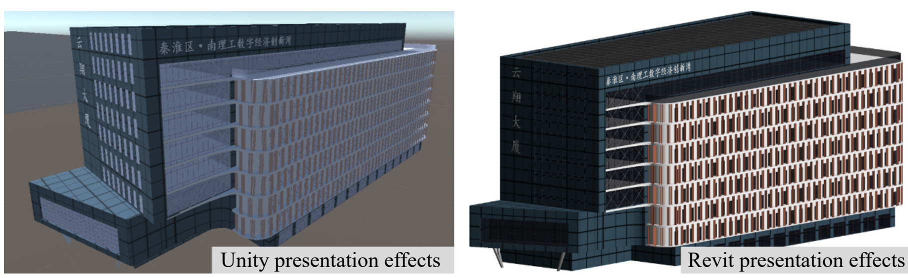

Fig. 7 Comparison of display effects between Revit and Unity.

The test results show that the .fbx files converted by the Twinmotion plugin show well when imported into the Unity platform.

5 Conclusion

In order to fill the gap between BIM technology and an intelligent network-linked bus management system, this study takes Nanjing Baixia High-tech Zone as an example and establishes an intelligent network-linked bus cloud control platform based on BIM technology. First, BIM structural models of all landmark buildings in the scope and roadside facilities and equipment models were established through Revit software. The 3D models were lightened through the Twinmotion plug-in. Highly integrated vehicle-road coordination and other forward-looking, innovative technologies, through intelligent, comprehensive solutions to provide strong support for the intelligence of urban public transport, a comprehensive improvement in the ability to respond to unexpected situations, road network traffic information services, road safety index, and road environmental performance, and actively explored the morphological characteristics of the intelligent network-linked bus cloud control platform, drawing the platform system framework and clarifying the platform construction The platform system framework has been drawn and the platform construction model has been clarified, and the application of BIM technology in the intelligent network connected bus cloud control platform has been completed.

The intelligent network connected bus cloud control platform established in this research has achieved some of the functions of CIM smart city and completed the construction of a bus cloud control system based on BIM technology, though. However, with the popularity of automatic driving technology, several functions of the automatic driving management system should also be integrated in the future. With the further development of computer technology, the future should also have the management and user-oriented use of AR, and VR mode scenarios.

In the face of the above outlook, the research of BIM series software and each rendering platform should be further strengthened in the future, while actively exploring the interaction between the autonomous driving system and the dynamic and static models to build a comprehensive cloud control platform for the future.

Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article.

Data Availability Statement

Some or all Data, models, or code that support the findings of available from the corresponding author upon reasonable request.

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