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Innovation and Practice of BIM Full-Life Cycle Application in the Building of Shenshan Station

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SUMMARY: *This paper will introduce the entire life cycle applications of BIM in the Shenshan Station Building project. It is a big railway station and integrated transport hub project. It is a large-scale building, has an elaborate structure, many professional interfaces, and the construction environment is near the existing railway lines. In light of the common problems in railway BIM application, such as inconsistent modeling standards, lack of model detail and absence of a unified collaboration platform, a technical route was formed in the project based on four tasks: one set of standards, one group of high-precision models, one collaborative platform and multiple uses of one model. The paper introduces the standard system, the construction of architectural, structural, MEP and bridge models, and the application of BIM at different stages of design, construction and operation. MaaS platform is used to share model viewing, document management, WBS linkage, issue management, asset information transfer, etc. According to the actual application results, 188 MEP coordination and clearance problems have been discovered in the project; 56 reserved-opening and prefabricated equipment-room drawings have been produced; up to 150 complex beam-column reinforcement joints have been supported; and the BIM+GIS earthwork checking error is still less than 3%. Based on the above practices, it can be concluded that to achieve the value transfer of BIM from design to construction and operation, a unified data standard, a high-precision model and a controlled platform are needed. It is also a typical case of the digital construction of a large railway station building.*

KEYWORDS: *BIM full-lifecycle application; railway station building; MaaS platform; BIM application standard; digital management; intelligent construction*

1 Introduction

Construction and Support for the Integrated Transport Hub of Shenshan Station are in the Shenzhen-Shanwei Special Cooperation Zone. The total building area of the integrated hub is about 448,000 m², and the area of the main station building is around 48,000 m². There is one underground floor and four upper floors for the station building. The engineering objects are the station building, the transfer space, the elevated mezzanine, the municipal connection, the MEP system and the station-related bridge works. For this kind of high-speed railway station building, the function of BIM is not only 3D display. It is to ensure that the information structure of the model remains stable in Design, Construction, Operation, Maintenance and other phases. Recently, research on the digital twins of railway stations has also shown that the assets of the stations need to be carried by a BIM-based information carrier for operation and management, so that people can view spaces, equipment, maintenance records, etc., in

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one place [1].

Three problems existed in the actual work process of the first project. The first was the inconsistency of model standards. The different disciplines and project parties have used different naming habits, family libraries, model precision rules and information fields. When the model was passed from one stage to the next, some of the object information was lost or could not be recognised. The second contradiction is that there is a lack of details in the geometric information. Some models in the ordinary project are suitable for the needs of visual display but do not meet the requirements of reinforcement inspection, prefabrication, accurate quantity takeoff and operation hand over. The third contradiction is that there is no unified collaborative platform. The Design Model, Construction Model, documents, issue records and equipment data were distributed in different software and at different organisations. Only a small number of professional users could use the model, and thus BIM was not widely used in management.

Therefore, there was only one visualisation problem for BIM in the Shenshan Station project. The whole construction system of the project was built. The original idea was to build a single standard system, create one set of high-precision models, develop a single MaaS platform and use that model in all the stages of various projects. Common data environment research points out that the information delivery should not only be a model file, but also need to have a controlled status, role authorization, review workflow and structured delivery logic [2]. According to research on the performance value of a common data environment, platform value is related to project governance and project performance; it is not only about file storage [3]. Therefore, this paper will change the project description from a simple application report to an engineering paper that can be verified. The revised text adds project tables, calculation formulas, numbered figure references and a result comparison section so that the logic of the project can be understood by design, construction and operation reviewers.

The subject of this paper is the BIM application process of Shenshan Station Building. The research materials are in accordance with the BIM standards for this project, and the model creation work, coordination records, construction application records, operation and handover requirements, MaaS platform functions, etc., are included. The paper does not put forward a new BIM theory. Repeated applications of the BIM scheme have been made to connect model accuracy, information needs, platform management and engineering indices for railway stations. The new English work is still in a translation style. It keeps the facts and engineering data from the original manuscript, but normalises the figure numbers, table numbers, formulas and references.

The scale of the project and the vertical organisation of the station are shown in the technical route before the BIM requirement, as they are directly related to the station level, transfer space and underground interface. Figure 1 is the English-labelled floor diagram instead of the original Chinese-labelled one.

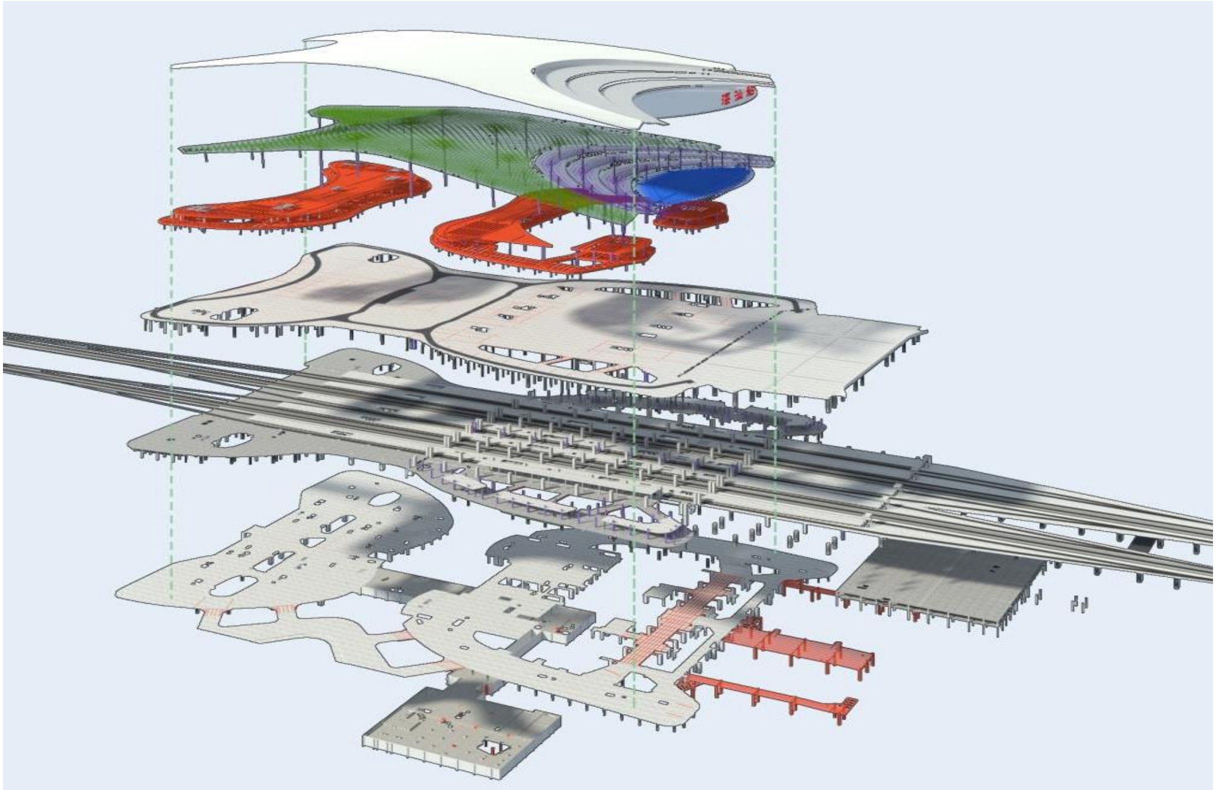


Figure 1: Shenshan Station Floor-by-Floor Schematic Diagram

Figure 1 shows that the station is not a single building block. The underground transfer and parking level, the entrance level, the platform connection, the commercial mezzanine and the roof service zone are all in different layers. Therefore, the arrangement of model objects should include both spatial index information and stage information. A component can only be added after its discipline, floor, zone and axis relationship have been specified together.

2 Project Scope and BIM Full-Life Cycle Goals

The BIM goal of the project has been set in line with the management needs of the high-speed railway station building. The goal was not to create individual models for every person. The goal of the general-purpose data warehouse is to support various work in Design Verification and Construction Simulation, Quantity Control, Quality Traceability, Operations Management, etc. A model is not to be a fixed shape, but rather a data interface in the research on the combination of BIM and digital twins [4]. Based on the above analysis, the four realisation goals of the Shenshan Station project are a unified standard system, a high-precision model group, a collaborative platform and multiple applications of one model.

First, we need to construct a typical system at the project level. Standard Model Structure, Data Exchange Format, LOD, LOI, Naming Rules, Attribute Templates and Delivery Requirements. The second goal is to build high-precision models of the architecture and structure of the building, Mechanical and Electrical systems (MEP), etc. The third is to construct a general data area for MaaS. A small amount of model information can be shown here, tasks assigned, documents managed, model reviews conducted and data linked in this platform. The fourth goal was to use the same database for Design, Construction, Completion and Operation. A new model has been added along this route, and finally, it will be put into service.

Table 1: Project Overview and Scope of BIM Application.

Item	Project information	BIM implication
Project location	Shenzhen-Shanwei Special Cooperation Zone	The site connects railway, municipal transport and urban service space.
Total integrated hub area	about 448,000 m²	Large model capacity and cross-discipline data management are required.
Main station building area	about 48,000 m²	Station building model must support space, structure, MEP and equipment management.
Building levels	one underground level and four above-ground levels	Floor, zone and axis coding must be included in model object names.
Key interfaces	station building, bridge, municipal network, MEP and operation systems	A single platform is needed to coordinate model, drawing, issue and asset information.

Table 1 is the engineering boundary of this paper. Add a table to avoid having only a descriptive text of the project. According to the scale data, the model does not have to be displayed in only one design-stage mode. Given the size of this hub, the model needs to be an index for storing and retrieving data later on.

Four calculation formulas were added to make the application of the model quantifiable. They are employed to assess the consistency of the model, clash closure, quantity deviation and schedule deviation. The formula is simple, but it links BIM work to project management indicators. They can also be checked by a reviewer.

$$C_m = \frac{N_{\text{consistent}}}{N_{\text{checked}}} \times 100\% \tag{1}$$

where C_m is the model consistency rate, $N_{\text{consistent}}$ is the number of checked components whose model information is consistent with drawings or field records, and N_{checked} is the total number of checked components.

$$R_c = \frac{N_{\text{closed}}}{N_{\text{detected}}} \times 100\% \tag{2}$$

where R_c is the clash or issue closure rate, N_{closed} is the number of closed issues, and N_{detected} is the total number of detected issues in model coordination.

$$E_q = \frac{|Q_{\text{BIM}} - Q_{\text{field}}|}{Q_{\text{field}}} \times 100\% \tag{3}$$

where E_q is the quantity deviation, Q_{BIM} is the quantity extracted from the BIM model, and Q_{field} is the field-checked or contract-confirmed quantity.

$$D_s = \frac{|T_{\text{plan}} - T_{\text{sim}}|}{T_{\text{plan}}} \times 100\% \tag{4}$$

where D_s is the simulated schedule deviation, T_{plan} is the planned duration of a work package, and T_{sim} is the duration checked by 4D construction simulation.

3 Standard System Compilation

The project standard was compiled by the owner in conjunction with the design, construction, consulting and operation parties. It is not one of the national or general building codes. It was developed for the multiple disciplines and large quantities of railway hub buildings. The standard system comprises the design application standard, the construction deepening application standard and the operation handover application standard. With the development of BIM-GIS technology and research on the digitalisation of the built environment, cross-scale data integration now requires standardised object classification, exchange rules, spatial references, etc. [5] Therefore, the project standard first set up the common data environment, the exchange format and the object-level information requirements.

IFC was the main open exchange format of the project. The reasons are that different people have used different modelling software, such as Revit, Tekla and Bentley. Due to the absence of a fixed exchange format, some objects and parameters were lost during the model conversion and it could not be used for a long time. IFC Delivery did not remove the native model files. It has been used to store and manage the progress of a construction project. Therefore, there is no need for one software environment; the MaaS platform will be able to collect models from all areas.

A regular rule for the name, object index and information attribute definition has been formed in this project. The component name consists of discipline code, object type, material and spatial location information. A Spatial Index was constructed based on the Zone, Floor and Axis information. Therefore, the object name is used as the management index. The LOD and LOI requirements were set at the same time. LOD is for the geometry; LOI is for other attributes. Research on the Digital Twin framework for the built environment shows that after construction, geometry, sensor data, operating records, management workflows, etc., need to be connected so that the model can be used [6]. Therefore, the project had different LOI fields for Design, Construction and Operation Handover.

Table 2: BIM Standards and Information Requirements at Different Stages of a Project.

Stage	Model precision	Information requirement	Main output
Feasibility and preliminary design	LOD100-LOD200	project scope, function, main spatial relation and conceptual quantities	scheme comparison model and preliminary quantity data
Construction drawing design	LOD300	material, specification, component size, system route and professional interface	discipline model, clash report and drawing check record
Construction deepening	LOD400	manufacturer, batch, processing parameter, installation date and inspection status	deepening model, fabrication list and construction simulation
Completion handover	LOD500	asset code, warranty information, maintenance cycle, manual link and operation record	as-built model, asset data package and O&M model

Table 2 is the revised stage boundary. The main change is that the information requirement is now written with the model precision. Therefore, one should not think that a high-precision BIM model only has to be more detailed in shape. The model will only be able to operate after the object has been completed and possesses an asset code, warranty, maintenance cycle, etc.

Standard attribute templates have also been set up for the general component types of station buildings. The Template Reduced Subjective Input for the Modelers. When the modeler called a family from the project library, the preset information fields were already there. The Modeller only filled in the specific values. The above manner of dealing with information is more organised and consistent, thus laying a good foundation for the next stage of extraction and analysis. Research on Facility Management based on BIM and GIS has also found that, to achieve good Facility Management, model objects, spatial units and maintenance records need to be linked in an integrated framework [7].

4 Construction of High-Precision BIM Models

4.1 Standardized and Parametric Family Library

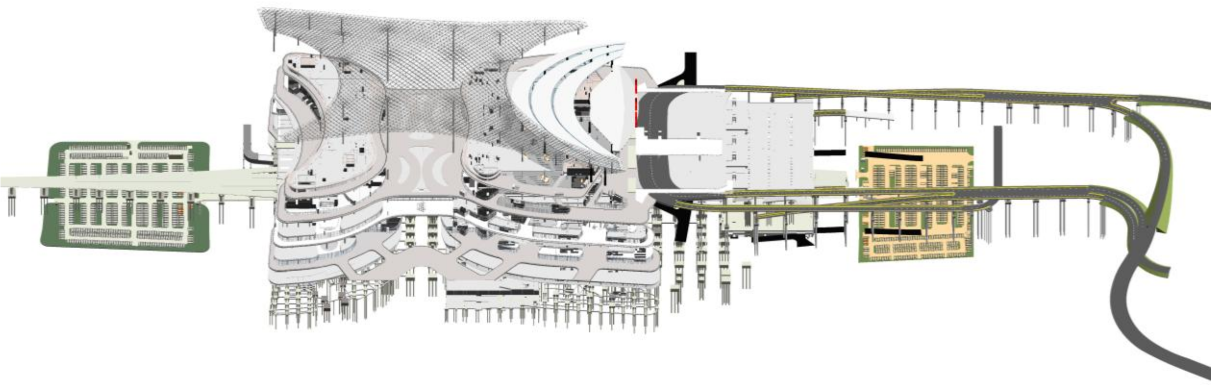
The Family Library was the base of model accuracy. A BIM family library for Shenshan Station has been built in the project, and it includes architecture, structure, MEP, railway-related works, equipment objects, etc. The four rules of the family library. First, the key size and material were parametrised to be updated with the design. Second, each family had the same attribute fields as in the project EIR list. Third, the geometry was in line with the LOD400-LOD500 requirements for the object when it would be used in fabrication, installation or operation. Fourthly, all the family files have been stored, organised and versioned on the MaaS platform. The Model User should be in the newest approved family. Fewer variations and non-standard parts were in the original work.

The family library was not used for the purpose of modelling. It will organize the data. Steel structures, MEP equipment and other reinforcement will be added to the list of quantities and fabrication arrangements. The family parameters of the station-room area are based on statistics of the area and its operating zones. The family parameters of railway bridge and municipal connection objects are based on their space and construction order. Thus, the family library has become the first level of BIM standard application.

4.2 Architecture Model

To make a 3D model of the building, I used Revit. It showed the overall massing, organisation of circulation, division of space and internal finishing of the station building. The model has the roof structure, curtain wall grid, panel division, partition walls, fire walls, decorative layers, fixed furniture and signage system, etc. Parts that cannot be shown in the two-dimensional drawing, such as the arrangement of parking charging piles and special-function rooms, can be presented in a 3D model of BIM, and the layout can be optimised before construction.

The BIM model of the building is shown in Figure 2. The figure is a combination of the original project model images and adds English subfigure captions to allow people to understand the model hierarchy and interior details in order.



(a) General Model of Shenshan Station

(b) Interior Decoration Model of the Shenshan Station Building

Figure 2: BIM Model of Shenshan Station

As shown in Figure 2, the architectural model is not only an external visual model. The whole of the massing, platform connection and interior finishing are in the same model set. Therefore, this model can be employed to conduct a circulation review and space check, and then the operating areas will be divided. The figure also solves the original problem that the subfigure order was incomplete and only part of the image had a clear English caption.

4.3 Structural Model

The structure of the model was the most difficult part of the project. The columns of the station building are steel-reinforced concrete, the frame system is prestressed reinforced concrete beams, and there are also steel beams and columns for the elevated mezzanine. The Floor is relatively high, and there are many embedded steel profiles in the beam-column joint. If it is only at the stage of general Design for the structure, reinforcement conflicts and construction directions cannot be identified. Therefore, the project has been divided into three parts: the concrete structure, the reinforcement model and the steel structure model. Research on BIM-GIS disaster management has also found that, in order to carry out risk assessment and emergency response, a model that can present the structure and space of large buildings reasonably well needs to be created [8].

Figure 3 is the general structure model before the detailed reinforcement and steel-structure application. The figure is kept from the original manuscript because it shows the structure of the station directly.

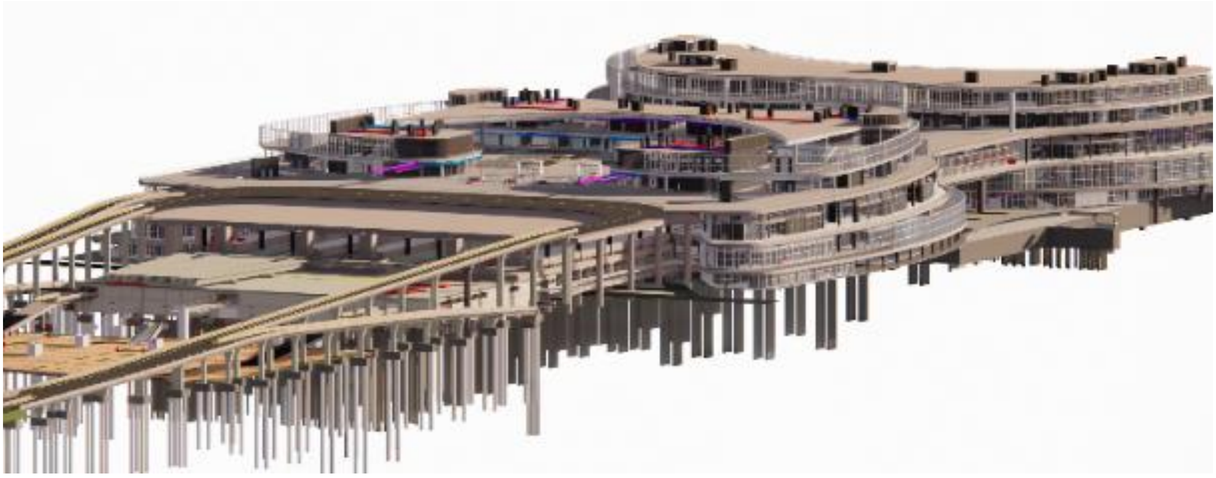


Figure 3: Overall Structure of Shenshan Station

As shown in Figure 3, the structure of the BIM work should include pile foundations, steel-reinforced concrete columns, prestressed beams, slabs, large-span members, etc. The whole structure has been completed to the present day; it will be examined in collaboration with others and counted.

A Model of the concrete Structure was created in Revit. It is a pile foundation, steel-reinforced concrete column, prestressed beam, slab, excavation boundary, cushion layer and water collecting pit. Program logic was employed to handle the deduction at the overlapping part of the beam-column. The above measure has increased the accuracy of the concrete quantity take-off. The model could also be used to find the geometric basis of formwork and support schemes.

Tekla Structures has been used to model the complex nodes of the reinforcement model. A total of 150 complex joints were constructed and reinforced to 1mm in the project. A reinforcement model is used for quantity statistics, reinforcement collision checking, generation and processing of bar cutting lists, etc. A QR code can be used to link to the site of 3D technical information disclosure. In accordance with the research results of Scan-to-BIM and 3D-GIS mapping, accurate geometric information for the model needs to be acquired so that it can function as an as-built record and a basis for space query [9]. Based on the previous situation, the detailed strengthening plan for the Shenshan Station project has been updated.

The model of the reinforcement for complex beam-columns is as follows in Figure 4. Add English subscript captions to the revised figure and keep the original detailed model images for engineering accuracy.

(a) Reinforcement arrangement

(b) Joint collision review

Figure 4: Reinforcement Model of Complex Beam-Column Joints

Figure 4 is the reason we need to use a high-precision reinforcement model. The steel profile and the dense bars are in the same joint area, so this risk will not be included in the general two-dimensional inspection. A reinforcement layout, collision points and cutting lists have been prepared for the model before the start of the field installation.

The raised mezzanine of Shenshan Station is to be used as the commercial area for passengers. It is primarily a steel-structure area, which is quite large, has many types of steel members, and local column-on-beam conditions exist. The combination forms are too complicated. The member geometry, connection relationships, weld positions and fabrication information of the steel-structure BIM model were expressed. Factory CNC cutting, component processing, virtual pre-assembly and site welding organisation are all applications.

The application of steel structure is shown in Figure 5 after the reinforcement model because both parts are related to deepening design and fabrication control.

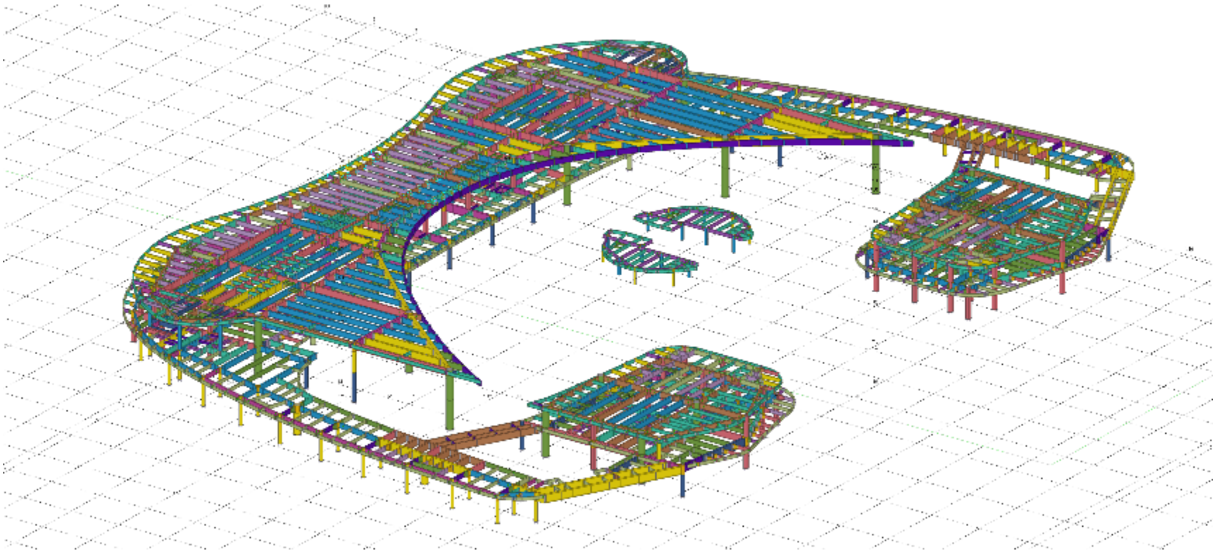


Figure 5: Overall Model of the Steel Structure for the Elevated Mezzanine

Figure 5 shows that the steel mezzanine model met the requirements of space organisation and fabrication management. According to the geometry and processing data of the members, this model has reduced the number of times steel-structure drawings need to be interpreted and has helped factory-site coordination.

4.4 MEP and Bridge Models

The Municipal Engineering Department Area will also be established here. The goal was to solve the problem of internal MEP collision and also address the issue of the interface between station equipment pipelines and external municipal networks. There is no clearance in the model; there is a pipe collision, and it conflicts with the municipal network and underground foundation. A good Plan for the Construction was developed through cooperation among various disciplines. Interoperability research of BIM-FM based on open standards has shown that, if the data is to be used repeatedly for facility management, then equipment and facility data need to be organised at the time of design and construction [10].

The whole MEP coordination model is as follows: Figure 6. The figure is placed at the beginning of the construction phase due to MEP coordination producing direct Design and Construction Outputs.

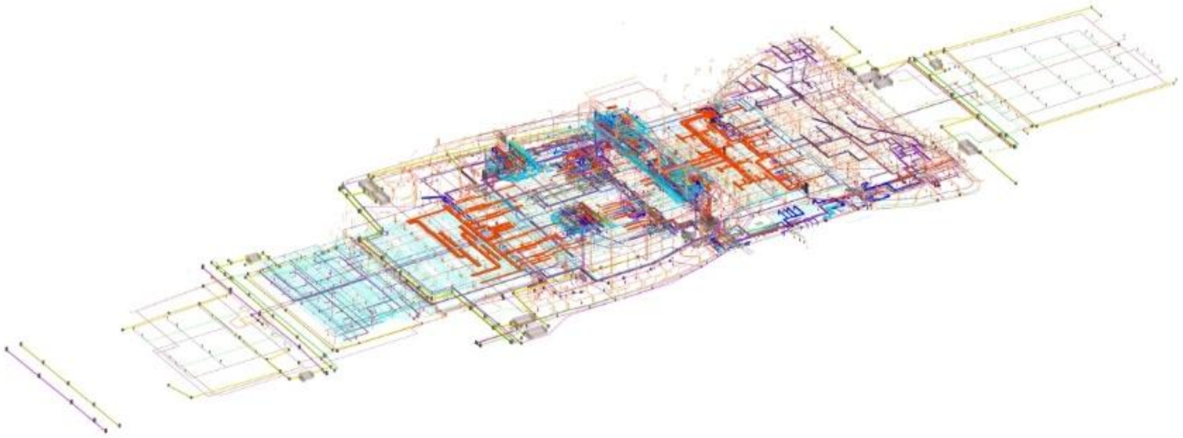
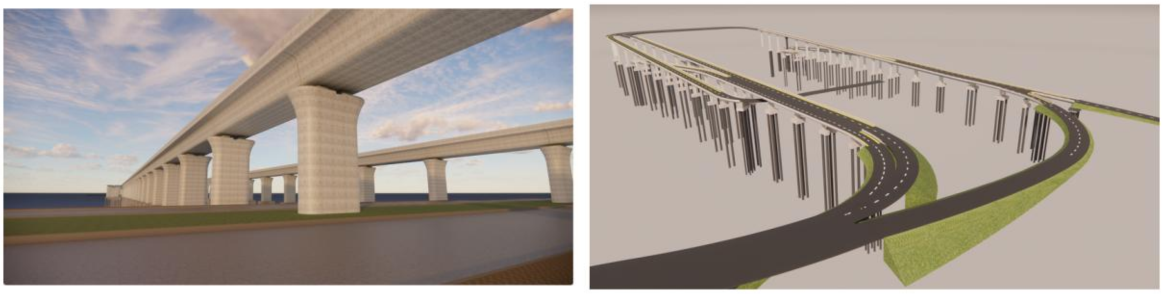


Figure 6: Comprehensive MEP Coordination Model of Shenshan Station

Figure 6 is the connection of the station equipment pipelines, municipal pipelines and underground structures. According to the project record, there were 188 collision and clearance problems in the BIM model. A model has been established to produce 56 reserved-opening drawings and prefabricated equipment-room drawings. The numbers will be used to analyse the results later.

Bentley software was used to build the bridge model for the main railway bridge in the station area and the municipal bridges that connect to and leave the station. The model shows the substructure, superstructure, bridge deck system, contact-network foundation, track slab and lane marking of the municipal bridge deck. The location and dimensions, as well as the reinforcement binding for curved and variable-width beams in the template design have been added in the BIM model. This part joined the model of the station building with the models of railways and municipalities.

The model of the railway and municipal bridge is shown in Figure 7. The original manuscript repeated the number of Figure 6 for this figure. The revised manuscript has corrected the order and given the bridge model its own figure number.



(a) Railway bridge model

(b) Municipal bridge connection model

Figure 7: Railway and Municipal Bridge Model of Shenshan Station

Figure 7 shows the change from station building BIM to infrastructure BIM. Railway bridge and municipal bridge elements are different from building elements in object classification and spatial reference. Use different numbers for the figures to make the sequence clearer and avoid confusion with MEP coordination and bridge models.

5 BIM Application in the Design Stage

BIM application at the Design stage of Shenshan Station was not only used for converting 2D drawings. It was employed for the comparison of schemes, professional coordination, quantity estimation and forward-design drawing output. The decision-maker has used a picture model to compare the exterior, interior and street layout of the buildings. The design of the architecture, structure and MEP can be conducted together on one platform to check models from different parties and address any conflicts early on. Therefore, the design coordination is now in the stage of process management.

The model can also help with the amount estimation in the detailed Design. The amount of the main material can be determined from the model and checked against the cost-control requirement. It did not replace the formal bill of quantities, but it did alert us to the large-quantity deviation early on. In some places, the project has started BIM-based forward drawing. A Customised drawing template and view rule are used to generate the plans and sections of the model. According to the research on the application of digital twins, if model data and project decisions cannot be linked, the value of the model will be reduced [11]. Shenshan Station will use the model verification and output drawing process to avoid drawing errors in the design stage.

Figure 8 is the connection between BIM 3D model and 2D drawing output. The revised figure number is in accordance with the bridge figure and has removed the earlier sequence disorder.

(a) 3D BIM model

(b) 2D drawing generated from the model

Figure 8: BIM 3D Model and 2D Design Drawings

As shown in Figure 8, BIM forward drawing is possible in the local area. The 2D drawings produced by the model had a higher correlation with the model than drawings drawn separately. An update to the model object will also update the related view. It helped to achieve the goal of drawing-model consistency, but the project did not state that BIM drawings had completely replaced all two-dimensional construction drawings.

6 BIM Application at the Construction Stage

The Construction Stage was the time when BIM realised its full potential. The construction technology and management of the project are based on BIM. The first is BIM+GIS Macro-site Management. Oblique photography of UAVs is used to get a high-precision model of the construction site and its surrounding environment in reality. The GIS data and the station BIM model are in the same coordinate system and are in the real scene. Research on the current application of BIM-GIS has also suggested that, in order to present engineering objects in the context of terrain, surrounding facilities and maintenance conditions, etc., one could combine BIM and GIS [12].

The combined Model of GIS and BIM is shown in Figure 9. The figure is moved after the design-stage figure because it is related to construction-site management.

Figure 9: GIS and BIM Integrated Model of Shenshan Station.

Figure 9 shows that the BIM model was not separated from the construction site. Together, the two models have been used to solve problems such as changes in the site layout, control of earthwork quantity, simulation of slope excavation and construction boundary inspection, etc. The error rate of earthwork checking in the project has been reduced to 3%, and it is now suitable for field management and can serve as a model.

The second is 4D Construction Schedule Simulation and Resource Control. The Construction Schedule has been linked to the BIM model. A 4D model can show the development process of a picture with time and help us find abnormal sequences or resource conflicts. At that time, there were also some dangerous construction operations, such as excavation of deep foundation pits, lifting and supporting large-span steel structures, high-formwork support, etc. Visual-technical disclosure can help the workers better learn about the construction method and safety requirements. Research on the digital twin of infrastructure has been able to collect and utilise the time, resources and construction sites of a building during construction [13]. The road of the 4D application in this project has been the same.

The Construction Simulation Model is as follows in Figure 10. The original manuscript had the wrong English figure number for this figure. The corrected manuscript has been submitted, and the figure will be placed after the BIM+GIS site model.

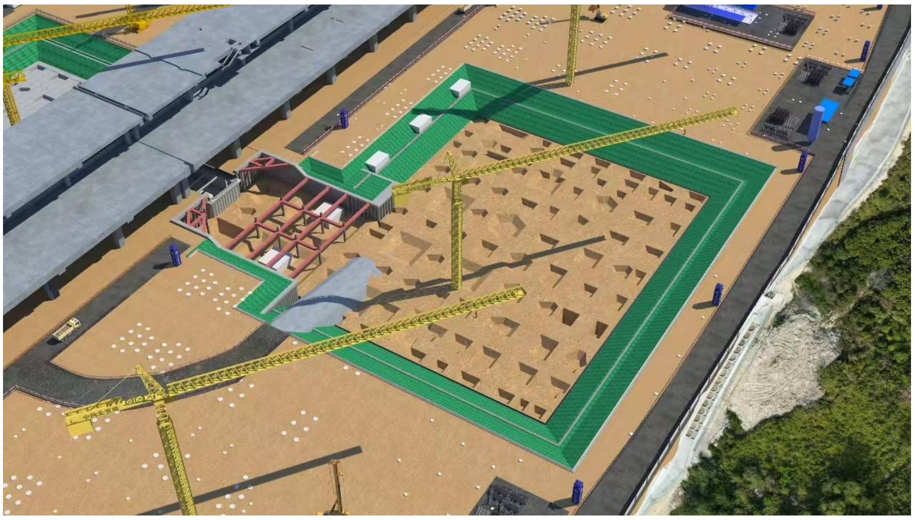


Figure 10: BIM Model for Construction Simulation

Figure 10 is the Construction Sequence and Temporary Organisation Information. The model had resource competition and process problems before the start of construction. It was also used to base the technical disclosure and was required in the construction of large-span steel structures, high formwork and deep foundation pits.

The third reason is Digital Processing and Prefabrication. A bar list containing the size, shape and quantity of the bars has been generated according to the high-precision reinforcement BIM model. Data can be used in the reinforcement processing equipment of CNC machines. Thus, there will be less waste of materials and labour errors. BIM modelling was used to model the cutting and processing of factory parts and virtual pre-assembly of steel structures. Literature on the construction digital twin also shows that, for the prefabrication and industrialisation of construction, a stable digital thread needs to be created from the model to fabrication [14].

The fourth is Construction Attribute Attachment. At the same time, some necessary process data have also been added to the corresponding BIM model via the MaaS platform. The contents of these records are pile hole information, concrete pouring time, steel weld inspection report, equipment acceptance sheet, etc. Therefore, the model has been a construction log. When there is a quality problem, one can trace back the model object, related document, responsible work package and inspection record. The gathered data have been arranged in preparation for the operation handover.

7 BIM Application in the Operation and Maintenance Stage

The operating stage is the time after construction for the BIM model. Shenshan Station has developed an intelligent O\&M (operation and maintenance) management application on the MaaS platform based on the delivered LOD500 operation BIM model and lifecycle data. Research on the operational value of digital twins in construction has shown that this value is based on the connection of as-built models, equipment data, real-time monitoring and maintenance workflows [15]. Therefore, the focus of the application of Shenshan Station O&M was on asset management, equipment monitoring and inspection, emergency response, structural health monitoring, etc.

BIM models have been linked with asset codes, purchase information, warranty contracts and maintenance records for the management of assets and spaces. Find the position, attributes, suppliers and maintenance records of the equipment quickly. The area of the station building was also included in the statistics, leasing management and energy zoning. The Model of Equipment Monitoring is based on data from the building automation and energy management system. The state of the air-conditioning unit, pump, transformer, etc., in the model environment can also be shown. Set the failure warning and energy abnormality analysis threshold of the system.

Standard inspection routes and points for the inspection and maintenance management have been set in the BIM model. Inspection Tasks were moved to the Mobile Terminal. The inspector can scan the code at the site, record the status information, and then return the record to the platform. The Data are attached to the model object. In case of an emergency, the operator can find the location of the fire, water leakage or equipment failure in the model. They can check the surrounding area, close the relevant valve, find an evacuation path and start the response process. Model objects for the stress, deformation and vibration data of the long-span steel roof and other main structures can be established by means of sensors. Research on the combination of BIM and GIS for infrastructure has also found that, in the current model of infrastructure, facilities management can be achieved by linking space and asset information [16].

The O&M Application is as follows: Figure 11 The original screenshot had Chinese interface text. Replace it with an English dashboard-style figure in the revised manuscript to meet the requirements of the English manuscript.

Figure 11: Application of Equipment Operation-State Management in the O&M Stage

Figure 11 shows the working principle of the O&M model. Asset records, inspection closure, energy exception and structural monitoring are not separate data tables. They are associated with model elements, warning rules and work orders. It will help us visualise the queries and maintenance records.

8 MaaS Collaborative Management Platform

BIM application should be supported across all links of life. All kinds of software need to be stored, files and problems need to be organised, structured data needs to be analysed, and service can be provided to people without using a separate modelling tool. The Shenshan Station project has constructed a MaaS platform, which is to speak of a Model as a Service, and this will serve as the common data environment for all station construction projects of Guangzhou Railway Group. The purpose of the construction of the platform is to create an orderly, stable and efficient single source of project information. One source can meet the purpose of owner governance, prompt decision-making and provide trustworthy lifecycle information. Research on point clouds and scan-to-BIM has also found that the model data is more useful when it can be compared with, verified and updated according to the actual project data [17].

The Seven Functions of the MaaS Platform. The first was BIM collaboration and model management. A platform has been established to provide Models, Aggregation, Visualisation, Coordination and Data Analysis for the Models. Model objects can be linked to work packages, deliverables, issues and cost items. Second, there is a Cloud Document Management. All the project documents, drawings and models have been saved with version control and status management. The third was the management of work breakdown structures.

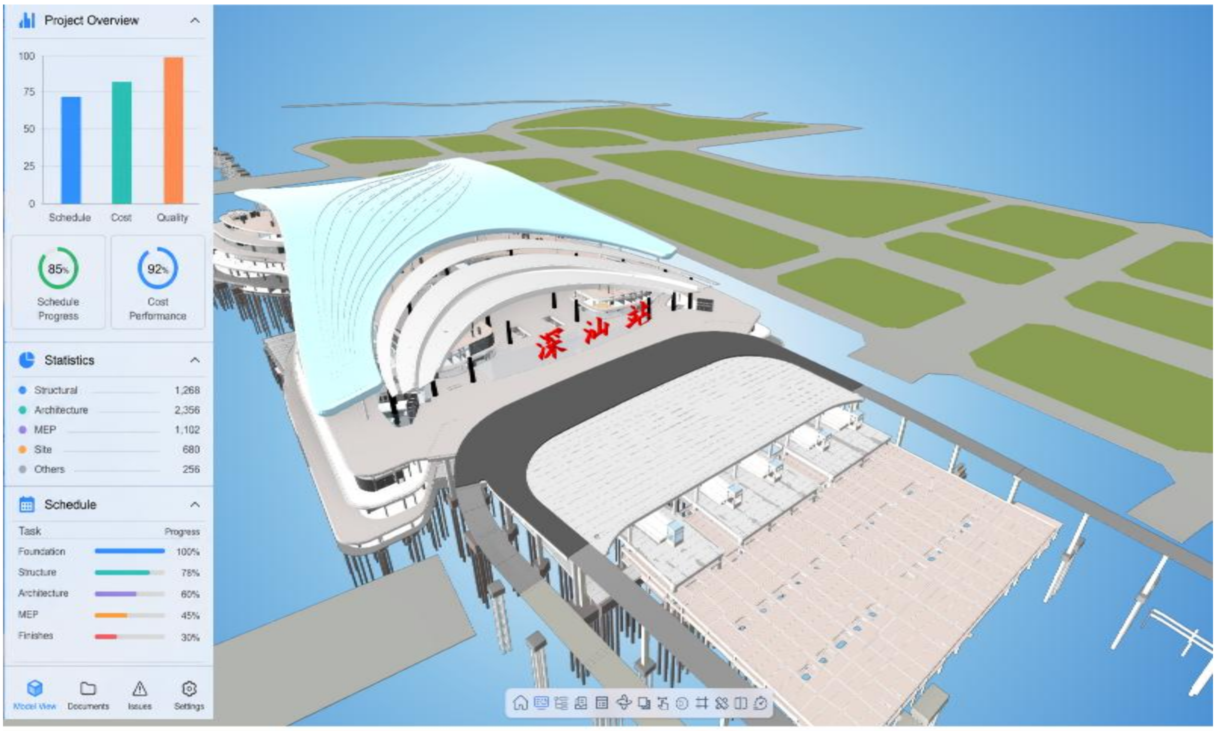
Work Packages are associated with Deliverables and BIM model assets. The fourth was Workflow and Status Automation. The fifth was Issues and Risk Management. The sixth is a project control dashboard. The seventh is openness by Application Programming Interface.

Table 3: Maas Platform Functions and Data Links

Function module	Managed data	Engineering use
Model management	IFC model, native model, object ID and discipline filter	Online review, lightweight browsing and model comparison
Document management	drawing, specification, report, approval state and version	controlled release and lifecycle archiving
WBS association	work package, deliverable, model object and cost item	scope control and progress-cost linkage
Issue management	clash, clearance issue, risk item and responsible party	assignment, closure tracking and review evidence
O&M data link	asset code, warranty, manual, inspection and sensor data	operation handover, maintenance query and warning analysis

Table 3 has been modified to show the data-link table instead of only a list of functions. It can be seen that the data in each module is managed and what kinds of engineering applications can be realised with that data. It is also in line with the paper's argument that MaaS is not merely a display platform but a governance carrier for model, document, issue and asset data.

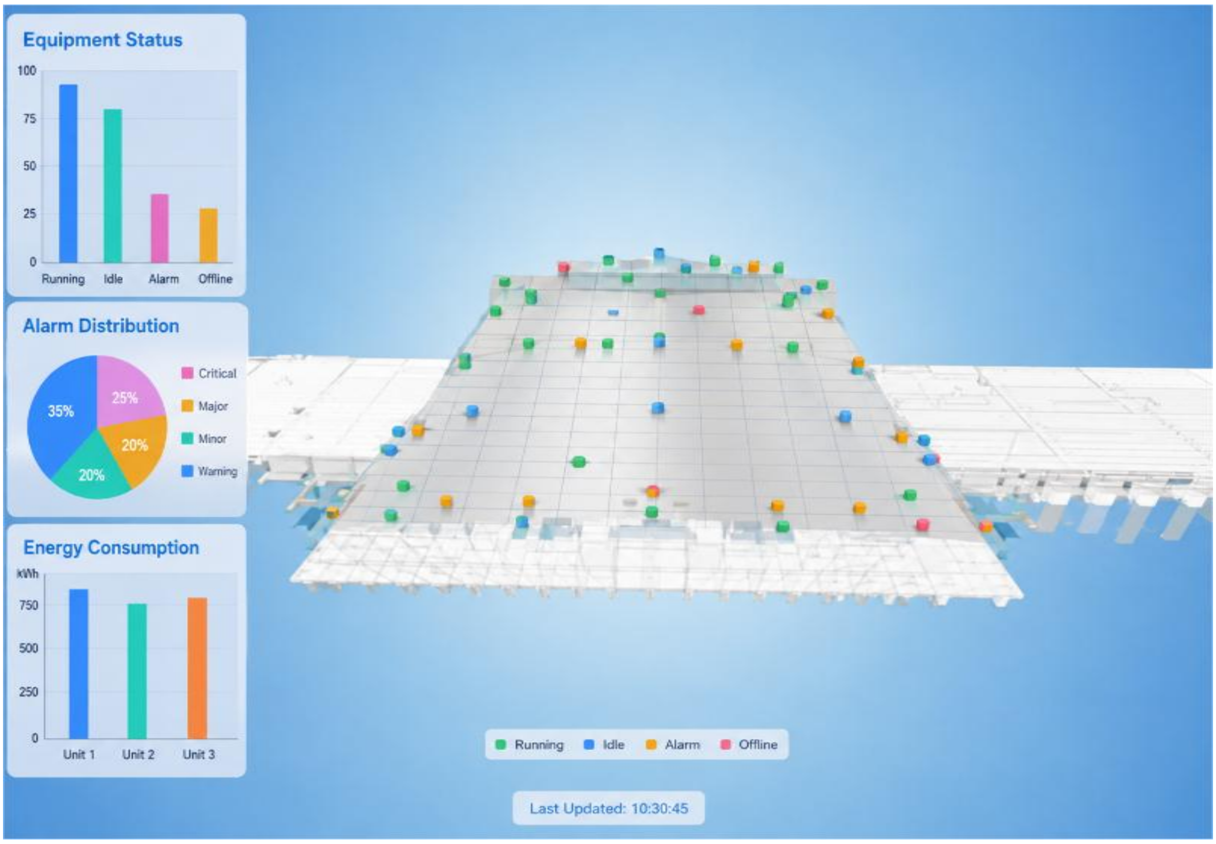
The MaaS interface is as follows in Figure 12. The first figure is a screenshot of the Chinese interface. The new figure is an English schematic dashboard, and it still has the two parts of model display and monitoring management.



Structural	1,268
Architecture	2,356
MEP	1,102
Site	680
Others	256

Task	Progress
Foundation	100%
Structure	78%
Architecture	60%
MEP	45%
Finishes	30%

(a) Demonstration of the MaaS Platform Model



(b) Application of Monitoring Steel Space Frames with the MaaS Platform

Figure 12: User Interface and Management Dashboard of MaaS Platform

As shown in Figure 12, the MaaS platform links model display, issue coordination, WBS, document status, asset link and progress dashboard. It is a technical link that can be applied to several parts of the model. The figure also corrects the original spelling error of "Mass platform" and uses the unified term "MaaS platform".

9 Result Analysis and Discussion

The four indicators of the results of the project are modelling, coordination efficiency, construction support and operation handover. The comparison object was the traditional workflow of storing drawings, models, issue records and operating documents separately. BIM is not a complete solution to all the problems in construction management. It shows what changed after the model, standard and platform were used together. Research on Digital Twins for Sustainable Construction also believes that the value of a Digital Twin is data continuity, lifecycle use and decision support; it is not a single model display [18].

Table 4: Application Indicators and Comparison with the Old Way.

Application item	Conventional workflow	Revised BIM-based workflow	Observed result
MEP coordination	Collision and clearance problems are found mainly by drawing review and site adjustment.	MEP model integrates station pipelines and surrounding municipal network in advance.	188 collision or clearance problems were identified and coordinated.
Reserved openings and equipment rooms	Reserved openings depend on manual drawing checking and are easy to miss.	Model is used to generate reserved-opening drawings and prefabricated equipment-room drawings.	56 drawings were generated from the model for later construction guidance.
Complex reinforcement joints	Dense bars and embedded steel profiles are difficult to review in 2D.	Tekla model creates millimeter-level reinforcement layout for complex joints.	150 complex beam-column joints were modeled and checked.
BIM+GIS earthwork control	Earthwork checking depends on field measurement and separate terrain data.	UAV real-scene GIS data and BIM model are integrated in one coordinate system.	Earthwork checking error was controlled within 3%.
Operation handover	As-built documents and equipment records are separated from model objects.	LOD500 model links asset code, warranty, inspection and monitoring information.	O&M model supports asset query, inspection and equipment warning.

Table 4 is the list of indicators in the project. The strongest data are the 188 coordination problems, 56 generated drawings, 150 complex joints and the earthwork error of 3%. From the above data, it can be seen that the application results of BIM are verifiable. The results are not to be considered a generalisation that BIM can improve efficiency; instead, each item can be traced back to a particular project task.

According to Formula (2), if all 188 detected coordination problems could be assigned and closed before the corresponding construction operation, the issue closure rate R_c would be 100%. If there were still some problems, based on the number of closed issues, the platform could calculate the closure rate. The next reports will be published each month. It can be seen whether the BIM issue list is merely a record or an actual management tool.

Using Formula (3), the BIM+GIS earthwork checking error was controlled within 3%. This means that $|Q_{\mathrm{BIM}} - Q_{\mathrm{field}}| / Q_{\mathrm{field}} \times 100\% \leq 3\%$ for the checked earthwork package. This result gives a quantitative boundary to the BIM+GIS application. It does not mean that all quantities in the project reached the same error level. It means the combined model was sufficiently accurate for macro site and earthwork control in the checked scope.

The 56 drawings of the reserved-opening and prefabricated equipment rooms are model-based, and they have been used to produce the downstream construction documents. The meaning of the above results is not just a number of drawings. It can be concluded that the MEP model has sufficient detail and consistency for issuing construction instructions. Model drawings used at the construction site should be updated after modifications to the Design. Otherwise, there will be no advantage in the output of model-based drawing. Therefore, the platform also needs to manage the version of the model and the status of documents at the same time.

Based on the 150 complex reinforcement joints, it can be concluded that the project has chosen to model the high-risk joint areas in detail and not all components at the same level of detail. It is a practice. If there is a large amount of technical risk or a large volume of production, high precision should be used. The regular parts can meet the requirements of Stage 2 in Table 2. To reduce the amount of modelling work and keep only the essential engineering content, a lower-precision method will be employed.

The limitation of the current project is that some operation-stage indicators have not been observed for a long time. For example, after the station goes online, we need to collect equipment fault response time, inspection completion rate, annual maintenance cost and energy consumption reduction, etc. In the future, the same MaaS platform will be used to collect the O&M indicators in this way and compare them with the baseline period. Only then can we fully evaluate the long-term operating value of the BIM model.

10 Conclusion

Shenshan Station is a good case that has shown the application of BIM in railways and stations to model reuse, platform construction, life-cycle management, etc. The existing general-purpose BIM system for traditional works is used in the station building construction. It specified the model precision, information precision, naming rule, attribute template and exchange format. It has solved the problem of various data sources in multi-party BIM cooperation for railways.

A high-precision model has been used in the Design and Construction Management of the project. Architectural, Structural, MEP and Bridge Models were developed according to the engineering requirements. The reinforcement model for the 150 complex joints, the steel-structure model of the elevated mezzanine, the MEP coordination model and the BIM+GIS site model all directly supported collision checking, fabrication, simulation and quantity control, etc.

A MaaS Platform has formed a Data Environment covering all stages of the life cycle of applications. A model object is associated with a document, WBS, issue, cost item and operating data. The platform has lowered the bar for non-modelers and now uses BIM in project management; it is no longer for professional modelers only. Figure 12 and Table 3 in the revised English manuscript can be used to clarify this platform role.

The construction had been carried out satisfactorily. The BIM model has identified 188 collisions and clearances, 56 reserved-opening and prefabricated equipment-room drawings have been generated, detailed modelling of 150 complex beam-column joints has been supported, and the number of BIM+GIS earthwork checking errors in the checked area is now less than 3%. As shown by the above indicators, the application of BIM has achieved certain results in coordination, construction and site management.

In the future, the standard system for all disciplines of the railway-station project should be further optimized in all respects to support construction-deepening design and operation handover. Indicative indicators of the O&M period must be continuously collected after the station goes into service. The development of domestic BIM platforms and tools needs to be further promoted in order to solve the problems of light model viewing, open data exchange, asset-data linkage and long-term digital archiving.

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