PAPER • **OPEN ACCESS**

Research on BIM-Based highway tunnel design, construction and maintenance management platform

To cite this article: Lijuan Chen *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **218** 012124

Research on BIM-Based highway tunnel design, construction and maintenance management platform

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Abstract. Currently, the construction scale of the highway tunnel in China is in rapid development. As tunnel shop drawings are generated separately and independent by different professions. Highly professional skill is required to ensure effective design review, construction coordination and operation guarantee due to the scattered information. In view of these problems, BIM is introduced in this study to prevent from information islands and improve information interoperability during the whole life cycle for highway tunnel. Based on a mountain tunnel project in Zhejiang Province, this paper presents a BIM-based highway tunnel design, construction and maintenance(DCM) management platform, illustrates data flow and transmission during the whole life cycle for seamless information integration of and the lightweight delivery in operation and maintenance management.

1. Background

With the rapid development of the economy and the increasing social demand, the construction scale of highway tunnels in China has expanded rapidly in recent years. According to the statistics of the Ministry of Transport, as of the end of 2017, there were 16,229 highway tunnels in China and 1,528.1 kilometers. Highway tunnel management are challenged with long service life, poor operating environment and serious consequences when failed. At present, the design, construction and maintenance management of most highway tunnel projects in China are facing following problems: the design process is highly rely on personal engineering analogy and experience, understanding of the design intention varies due to poor presentation[1-4]; Also, the traditional way of processing documents (paper or electronic version, text or drawings) requires manual operation file by file, which might lead to design errors and change orders[1-4]; Lack of overall evaluation, preventive maintenance and management countermeasures for long-term performance of tunnels, so that potential safety hazards have not been discovered in time[6]; Also, difficulty in locating fault equipment often result in processing delay[7]; Risks of poor efficiency in operation and maintenance management is the result of lacking whole life cycle view.

In order to ensure safe operation of the tunnel in the long term, a more scientific and efficient management platform is needed. It has been 15 years since the concept of BIM was first proposed and officially introduced into the engineering construction industry[8]. BIM is a digital representation of the physical and functional characteristics of the facility and help provide a reliable basis for decision making[8]. BIM has the potential to facilitate whole life cycle tunnel management.

2. Literature review

In view of the problems of current tunnel engineering practice, researchers have done a lot of research on tunnel data modeling. Christian Kocha et al. [11]developed an integrated model which can provide results from numerical driving simulations using structural models mapping in space and time. Li Xiaojun et al. [12]proposed the development of a network-based information system for managing,

visualizing and analyzing shield tunnel construction data to improve efficiency. Hu et al. [10]proposed that BIM technology and data visualization technology combine on the basis of multi-source spatiotemporal data. The artificial intelligence method provides the basis for tunnel environmental monitoring and control decision-making. TAsakura et al. [10]analyzed the typical maintenance techniques of Japanese tunnels and specified the importance to conduct maintenance works to maintain the function of the tunnels. R yu M, Nakai T, Koyama T et al. [14]developed a three-dimensional underground space information management system to integrate and manage tunnel construction and operation and maintenance information, and integrated heterogeneous, discrete and spatially complex operation and maintenance information. a 4D-BIM-based construction resource dynamic management and cost implementation monitoring system is designed to achieve dynamic control of resources during the construction phase, thus achieving real-time cost monitoring[14]. Hu et al. [10]studied the management method of BIM-based operation tunnel maintenance health monitoring, and integrate operation and maintenance information in the initial stage of tunnel construction.

However, most construction companies in China still use traditional AutoCAD (Aomputer-Aided Design) technology for graphic design, instead of integrated BIM technology[10]. The research results of Weihong Zhou and Haiyang Qin et al. [17]show that the BIM technology in domestic tunnel engineering is mainly applied in the design stage, and application of BIM in the whole life cycle of tunnel engineering is still in its infancy[18]. A practice of such implementation is of great value for tunnel life cycle management.

3. Tunnel information modeling method for tunnel life cycle management

In order to developed a life-cycle management framework, the tunnel model that provides essential information must be carefully built to establish a seamless interaction between design, construction and operation phrase. The parametric 3D design model is built with tunnel tube, tunnel support, tunnel service models with design parameters digitally and visually, taking the lighting system as an example, the detailed level of model information is shown in Table 1. The tunnel components volume, material, size, as well as construction schedule, cost, quality, safety and other information are structured and stored in the SQL database, and the data is linked with the 3D component in the BIM model. Then, operation and maintenance related information is simplified, and the volume of information reduced for better efficiency.

Table 1. Lighting electrical system model fineness standard

Kind	Device	Bridge trough	Pipeline
Parameter	Geometric information (family, name of the size) Technical information (suppliers, manufacturers, etc.)	Geometric information (specific routing, support hanger installation) Product information (suppliers, manufacturers, etc.)	Geometric information (specific routing, pipeline) Technical information (material and material information, system properties) Product information (suppliers, manufacturers, etc.)

4. Framework of design, construction and operation management of highway tunnel based on BIM

Through tunnel information modeling mentioned above, related information is integrated and utilized in construction and maintenance phrase.

4.1 Tunnel information modeling

The tunnel structure model is consisted of five tunnel sections corresponding to different surrounding rock grades, as shown in Figure 1, as well as pedestrian passage and emergency stop. Each of the cross section is tunnel is the combination of tunnel components, in Figure 2：

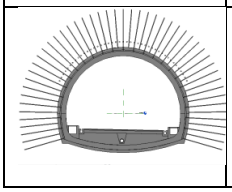
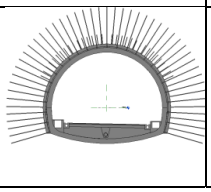
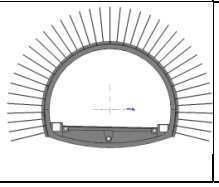
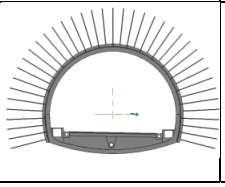
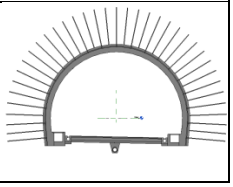
Surrounding rock of Category-V		Surrounding rock of Category-IV		
SA5a	SA5b	SA4a	SA4b	SA4c
				

Figure 1. Tunnel cross section of surrounding rock lining

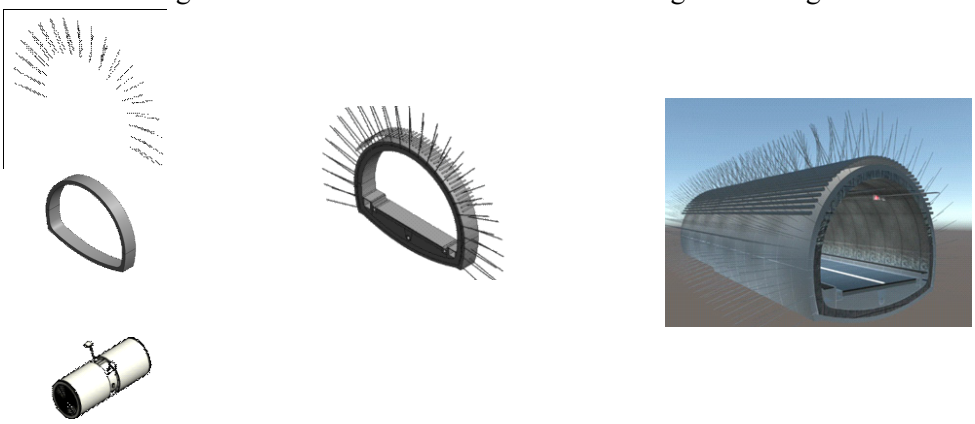


Figure 2. Tunnel model integration process

The virtualized model would facilitate the coordination of work between different professions. Tunnel service model including ventilation, lighting and etc. The relevant information for each equipment is listed as in Figure 3：

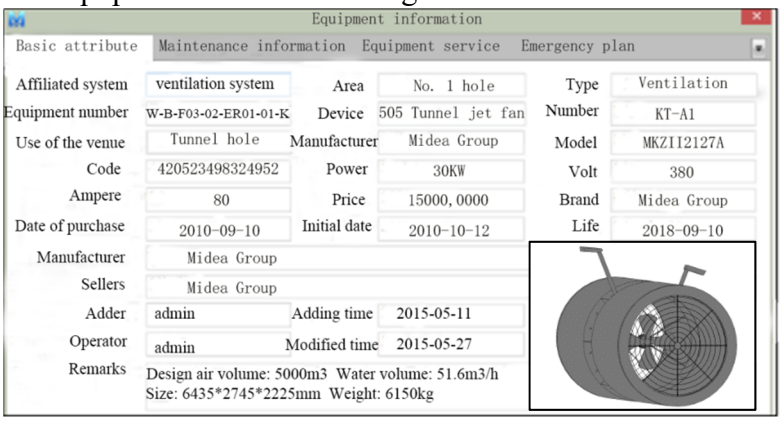


Figure 3. Tunnel service information of a ventilation equipment

4.2 BIM-based construction schedule and cost management

The model displays various uncertainties and randomness in the construction process, as well as resource utilization and site conditions for simulation and prediction of the construction process. As quantity is attached with individual component, cost could be generated dynamically with schedule. This process involves the management of the BIM plan. As shown in Figure 4. Based on the data analysis and numerical simulation, the simulation results are compared, construction resource allocation and site layout is optimized, resource and site utilization efficiency improved, and the goal of construction schedule and cost is met.

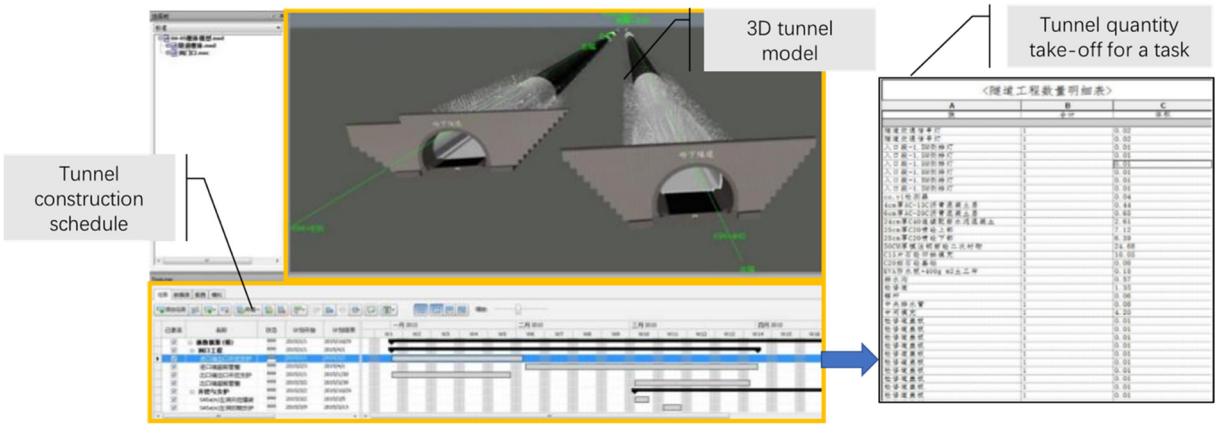


Figure 4. BIM-based schedule plan and corresponding tasks engineering quantity take-off list

4.3 BIM-based highway tunnel maintenance management platform

As assets information is digitalized in the tunnel BIM-MEP system. Information of tunnel structure (such as drainage, pavement, roof, etc.) and equipment (such as lighting, ventilation, etc.) is then simplified and utilized for operational phrase.

With the integration of BIM and information that collected and filtered during project delivery, specific information can be efficiently located in the platform instead of looking up in piles of paper documents. The system provides a standard workflow and document management with a closed loop for each task using the same set of visualized data.

The interface of the platform is shown in Figure 5, tunnel 3D model is linked with facility management information below for each component. Inspection and maintenance plans are then developed according to the type of entities based on specifications. The alerts for each task are incorporated based on the interval of maintenance with information of date, staff, location, requirements and etc.

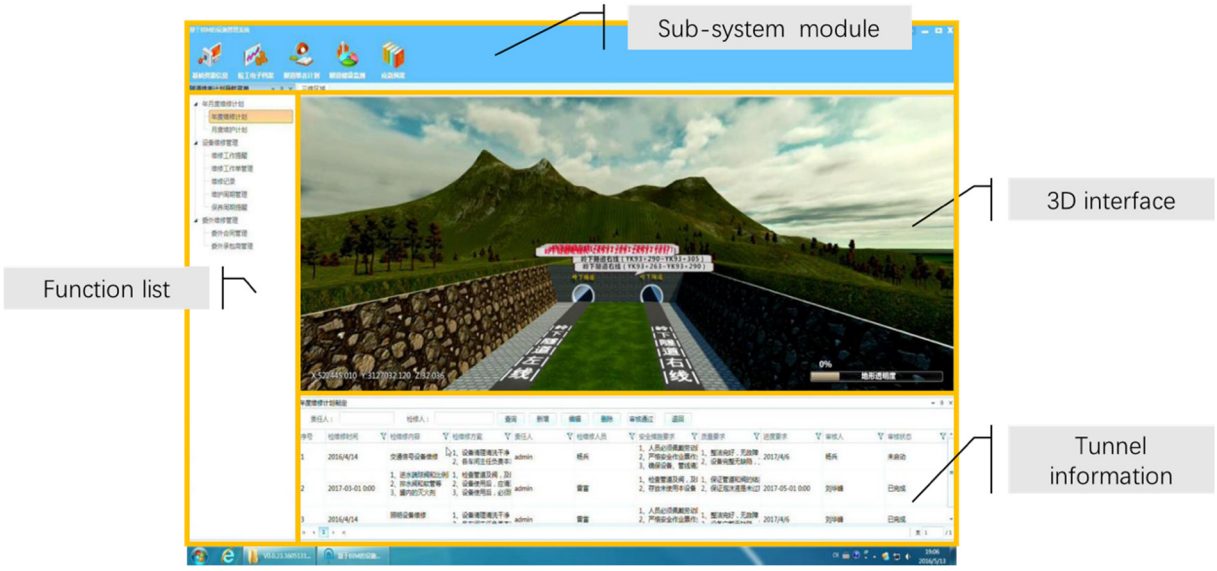


Figure 5. Interface of tunnel maintenance platform

5.Conclusion

Based on the tunnel project in Zhejiang Province, this study developed a BIM-based highway tunnel design, construction and maintenance management platform, which can realize the information management of the whole process of the tunnel life cycle.

At present, the application of BIM technology in tunnel engineering is still in the exploration stage. The BIM research carried out in this research project is a good demonstration for other tunnel projects, which will help accelerate the industrialization and information development of tunnel engineering.

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