An Intelligent Algorithm of Operation and Maintenance Cost Based on BIM of the Utility Tunnel

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Abstract. Through analyzing the relationship among the utility tunnel components, disaster risks and cost and the importance of BIM technology to integrated component information, disaster risk information and cost information, a component-disaster-cost data model based on BIM technology is built to realize dynamic recording of operation and maintenance cost and structured storage of operation and maintenance cost data. Based on the cost data model, the data flow of operation and maintenance cost analysis is established, artificial intelligence algorithm is introduced, deep learning, data analysis iteration is carried out, decision-making is assisted, and the healthy development of intelligent pipe gallery construction is promoted.

Keywords. BIM, utility tunnel, operation and maintenance, cost, AI.

1. Introduction

In recent years, with the continuous promotion of the construction of the utility tunnel, a large number of integrated pipe corridors have been introduced, and many problems have emerged in the later period of operation and maintenance, and the cost management of operation and maintenance is one of them. It is of great significance to establish a high-performing operation and maintenance cost management mechanism for insuring the steady functioning of the utility tunnel, improving the return on economic investment and promoting the sustainable development of the integrated pipe gallery. However, the prime data of pipe gallery operation and maintenance are widely derived, including the operation units (for the operation and maintenance) of pipe gallery body and ancillary facilities and the entry units for (the operation and maintenance of) the respective pipelines. The lack of structured storage data is also difficult to be effectively used. In addition, since there are many pipelines inside the utility tunnel, in which the main body locates in a complex underground environment, once the pipe gallery disasters occur, it will often lead to coupling disaster, which will lead to the difficult problem of cost power and responsibility division. The problems mentioned above hinder the development of operation and maintenance cost management.

BIM technology provides an information solution for the problems. BIM is characteristic for its strengths of visualization, coordination and simulation. It can not only visualize three-dimensional model, reasonably divide the main body of responsibility and responsibility of pipe gallery cost according to the model, but also carry rich data information and realize structured operation and maintenance data storage based on components. Therefore, the establishment of integrated management corridor operation and maintenance cost analysis model based on BIM technology, integrating component information, disaster information and cost information, can provide scientific...
A BIM-based utility tunnel operation and maintenance cost analysis model is proposed to provide decision basis for pipe gallery operation and maintenance cost management. Firstly, the pipe gallery body and its ancillary facilities, pipelines and equipment are split and the information of the main body of component authority and responsibility is added to the model to produce the component data set. The disaster data set and the cost data set are then simultaneously established according to the literature and expert opinions. Secondly, the existing risk sorting algorithm of the team is used to realize the connection between the BIM model component and the disaster. According to the cost composition and the actual situation of the project, the connection between the disaster and the cost is realized to contribute to the component-disaster-cost data model. Finally, according to the above data logic, the data flow of cost analysis of integrated pipe gallery is established, and the occurrence of operation and maintenance disaster and the corresponding operation and maintenance expenditure are recorded dynamically.

2. Research Status

2.1. Current Situation of the Utility Tunnel Operation and Maintenance Based on BIM Technology

Although the structure of the integrated pipe gallery is simple, the environment is complex and the operation and maintenance is difficult. BIM technology is widely applied in the operation and maintenance of the utility tunnel because of its visualization and information ability. Xu et al. [1] studied and designed the operation mode, architecture and function module of the management platform based on BIM are, which provides the theoretical basis and technology for the management platform. Yang et al. [2] combined GIS, BIM, the Internet of things, big data, cloud computing and other technologies to established the integrated management corridor intelligent operation and maintenance management system. Li et al. [3] put forward the concrete method and idea of constructing the cooperative platform of the utility tunnel operation and maintenance management based on BIM as the core. Song et al. [4] purposed the design idea of visual operation and maintenance management integrating platform with BIM technology as the core, through systematic analysis of the application of "BIM+" technology in the operation and maintenance stage of the utility tunnel. Zhou et al. [5] designed the intelligent management platform of the utility tunnel and realized by means of SOA architecture, comprehensive application of BIM (building information model), GIS, intelligent control and so on.

It is not hard to see that the existing research focuses on the BIM management platform of pipe gallery operation and maintenance and the platform functional framework and data layer logic have begun to take shape [6-9]. However, there is a lack of platform data docking and later data-based operation and maintenance management related research, while the operation and maintenance cost or disaster related research is relatively lacking. Under the framework of the current mature operation and maintenance management platform, the effective docking of operation and maintenance cost and disaster data can further improve the current management mode and improve the management efficiency.

2.2. Current Situation of Operation and Maintenance Cost of the Utility Tunnel

At present, there are the problems of massive investment, high cost of operation and maintenance and low return on investment. Therefore, in December 2015, the State Development and Reform Commission and the Ministry of Housing Urban-Rural Development issued the "Guidance on the Implementation of the System of Paid Use of Urban Underground Integrated Management Pipelines" (hereinafter referred to as "the Opinions"). The opinion points out that the paid use fee should include the entrance fee and the daily maintenance fee and emphasizes that the price mechanism formed by the market should be established to promote the construction and development of the urban underground integrated pipe corridor. Under the guidance, the states, Guangzhou, Xiamen, Zhuhai and other places attempted to explore the operation and maintenance cost calculation method of the pipe gallery, using
the space ratio and the use intensity as the basis of the cost calculation. Additionally, aiming to improve the rationality and scientific nature of cost calculation, some scholars have investigated the operation and maintenance cost calculation method. In order to improve the enthusiasm of pipeline units, Meng et al. [10] improved proportional allocation method, group decision method and the combination of various cost allocation methods based on the deviation leveling method are put forward. Jing et al. analyzed [11] The advantages and disadvantages and applicability of the current cost sharing model, and put forward the selection principles and suggestions of the model, which provides a reference for the selection of the daily maintenance fee allocation model of the utility tunnel project. According to the importance of each factor, Zhang et al. [12] distinguished the cost sharing factor and the annual operation and maintenance cost sharing factor, and constructed the cost sharing factor model and pricing model. According to the principle of "user payment", Qiao et al. [13] constructed the model of charging and pricing to each pipeline unit.

From the point of view of theory and application, the existing research has carried out a thorough research on the pipe gallery operation and maintenance charge calculation rule question and obtained the stage result. This charging method sets the main body of fee as the operating unit and sets the main body of the payment as the corridor unit of each pipeline, which can not calculate the total cost of the actual operation and maintenance expenditure based on the operation and maintenance of the pipe gallery itself. In fact, the frequency of risk and disaster for different types of pipelines and equipment as well as the corresponding means of maintenance is different. The dynamic cost expenditure caused by disaster has the significance for followed data guidance. Therefore, it is the future direction to reasonably structure the total cost data of operation and maintenance of storage pipe gallery and realize data oriented cost management.

3. Data Model of Operation and Maintenance Cost of the Utility Tunnel

3.1. Integrated Management Corridor Operation and Maintenance Cost Data Logic

Based on the case study of the project of the utility tunnel and municipal road (phase I) in the core area of Tianfu New District of Chengdu, the length of the pipe gallery is about 8 km, and its trunk integrated pipe corridor is the primary channel of the main municipal engineering pipeline.

Based on the actual situation of the project, this study analyses the relationship among the components, disaster risk and cost of the utility tunnel, and establishes the component-disaster-cost data logic, which provides the basis for dynamic and quantitative calculation of operation and maintenance costs and structured storage cost data. According to Zhou Wenyong [9] Building component data sets, including civil engineering, ancillary works and public pipelines; establishing disaster data sets, including natural disasters, man-made disasters and technical disasters, based on the study of common operation and maintenance disasters by Guo Jiaqi et al.; establishing cost data sets according to the total cost composition of operation and maintenance of the utility tunnel, including daily maintenance costs, emergency disposal costs, personnel costs, professional testing costs, major and medium repair costs and operating costs. Then, the mapping relationship between component and disaster is built based on the existing risk sorting algorithm of the research team, which is expressed as "connected_with", and the mapping relationship between disaster and cost is built according to the relevant unit materials and expert opinions of the project. Finally, the component-disaster-cost data logic is established, as shown in figure 1.
According to the data logic, the dynamic record of operation and maintenance cost of the utility tunnel can be realized. Take the disaster of pipeline short circuit as an example, as shown in figure 2: when pipeline short circuit disaster occurs during operation, on the one hand, the cost expenditure caused by pipeline short circuit can be quickly obtained in the data model, that is, large and medium repair cost.

3.2. Integrated Management Corridor Operation and Maintenance Cost Data Docking
In this study, the operation and maintenance data of the utility tunnel are combed to realize the effective docking between the operation and maintenance data of the utility tunnel and the operation and maintenance cost data logic. The operation and maintenance cost data model of the utility tunnel is built, as shown in figure 3. The operation and maintenance data of the utility tunnel include pre-design, construction stage information and operation and maintenance stage information. The design and construction stage information is integrated into the completed BIM model and the operation and maintenance BIM model is established by adding the attribute information of the main body of the component authority and responsibility, which provides the component geometry data and the non-geometric data associated with the component, and the structured storage is the component data set. The operation and maintenance phase information is composed of daily operation data and maintenance data, in which the daily operation data includes monitoring and monitoring data, manual inspection data, and maintenance data include disaster data, maintenance data and cost data.
According to the data characteristics, the monitoring data, manual inspection data and disaster data are stored as disaster data sets, and the maintenance data and cost data are stored as cost data sets. Finally, the structured storage of operation and maintenance cost data can be realized, and the data can be queried quickly and the connection between data can be obtained.

![Figure 3. Operation and maintenance cost data docking diagram](image)

4. Cost Management of the Utility Tunnel Operation and Maintenance Based on BIM

According to the operation and maintenance cost data model of the utility tunnel in section 3, the data flow of operation and maintenance cost analysis based on BIM is built, and the processing, storage, integration and data application logic of operation and maintenance disaster and cost data between data layer, platform layer and application layer are built to realize the effective utilization of the utility tunnel operation and maintenance data. As shown in figure 4, data has different roles and properties in the data layer, platform layer and application layer.
Figure 4. BIM based utility tunnel operation and maintenance data flow

The platform layer data logic is built as the information exchange carrier. The operation and maintenance cost data model of pipe gallery builds component-disaster-cost data logic, and realizes the integration of operation and maintenance disaster information and BIM lightweight model information through the association of component information with BIM components, and then presupposes operation inspection information based on BIM model information. The data logic built by the management corridor operation and maintenance cost data model is used as the data storage framework to build the operation and maintenance cost database to ensure the structured storage of massive operation and maintenance data and to automatically establish the relationship between the data. Finally, the data layer is built. At the same time, artificial intelligence algorithm is introduced to analyse the data to provide data decision assistance for field operations.

Data flow is divided into two parts, data storage and data application. In the aspect of data storage, according to the pre-set history maintenance information storage framework, the field operators can input the complicated operation cost information into the platform for the operation and maintenance managers to view. Meanwhile, according to the operation and maintenance cost data storage framework, the historical maintenance information is further processed and entered according to the description of cost data set and disaster data set, and finally the operation and maintenance cost database of pipe gallery is built. In the aspect of data application, combined with artificial intelligence algorithms such as knowledge reasoning, the operation and maintenance cost data in the database can be analysed, and the operation inspection information can be continuously updated. Assist field operators to improve operation and maintenance efficiency and quality. In addition, the data analysis of the operation and maintenance cost of the utility tunnel can be realized based on the database, which provides the basis for the customization and cost allocation of the cost mechanism of the subsequent pipe gallery.
5. Conclusion
With the acceleration of urbanization in China, the construction of intelligent city has become the mainstream direction of urban development. As an important part of underground space development, the utility tunnel reflects the management ability and service level of the city. In this paper, according to the requirements of operation and maintenance cost management of the utility tunnel, the operation and maintenance cost of the utility tunnel is related to components and disasters, and the operation and maintenance cost analysis model is built to provide data support for operation and maintenance cost analysis. A real-time recording of cost and disease data in BIM model is proposed. The accumulation of structured cost data provides the basis for operation and maintenance decision. The introduction of artificial intelligence algorithm promotes the construction of urban the utility tunnel to develop in the direction of wisdom.

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