Scholar Publishing Group
International Journal of Big Data Intelligent Technology
https://doi.org/10.38007/IJBDIT.2024.050124
ISSN 2790-0932 Vol. 5, Issue 1: 230-238

Application of BIM in Visual Management of Metro Projects

Haidong Jiang*

Institute of Resources and Environmental Engineering, Guizhou Institute of Technology, Guiyang 550003, Guizhou, China
jianghaidong888@163.com
**Corresponding author*

Keywords: BIM technology, subway project, visual management, construction progress

Abstract: The urbanization process has led to an increase in the complexity of subway construction projects, while traditional management methods face various problems such as coordination difficulties. Based on the technical characteristics of Building Information Modeling (BIM) technology, such as its ability to integrate various types of information, improve collaborative efficiency, reduce costs, and shorten cycles, this study explores the application effect of BIM technology in the visualization management of subway projects and analyzes its role in improving project management efficiency, quality control, and risk warning. The study first establishes a BIM model for the subway project, builds a three-dimensional visualization platform based on the constructed model, and dynamically monitors the construction progress, cost, quality management and safety risks. Then, through real-time data collection and comparison, combined with schedule planning and cost budgeting, BIM is used for real-time monitoring and adjustment. BIM technology has significantly improved project management efficiency and shortened construction periods. Specific data show that the application of BIM has increased project construction progress by up to 3%, shortened the feedback cycle of quality issues by up to 60%, and reduced project costs by an average of 8%. The conclusion is that BIM technology has significant advantages in the visual management of subway projects, which can improve the efficiency of information transmission, reduce delays and errors, optimize resource allocation, and enhance project benefits. It is recommended to widely use BIM in future subway projects to promote the modernization and intelligence of project management.

1. Introduction

With the continuous acceleration of urbanization, subway construction projects, as a core component of modern urban transportation, are becoming increasingly large in scale and complexity. Traditional subway project management methods face many challenges, such as delayed information transmission, coordination difficulties, construction delays and cost overruns, and cannot effectively meet the needs of modern subway construction. In order to solve these problems, Building Information Modeling (BIM) technology has gradually been introduced into engineering project management, especially in the visual management of subway projects. BIM technology can provide accurate data support and three-dimensional visualization platform, greatly improving the collaborative efficiency and transparency of the project. With the deepening of the application of BIM technology, more and more research has begun to focus on its specific application effects and practical value in subway projects.

This paper aims to explore the application of BIM technology in the visualization management of subway projects, and evaluate the actual benefits of BIM technology in subway projects by analyzing its role in project management efficiency, quality control and risk warning. This paper analyzes the actual case of a subway construction project, constructs a three-dimensional visualization management platform based on BIM, and applies it to construction progress monitoring, cost control, quality management, and safety risk assessment. Studies have shown that the application of BIM technology has significantly improved project management efficiency, reduced construction period, reduced costs, and played an important role in quality control and risk warning.

This paper first introduces the basic concepts and development history of BIM technology, and explains its application background in engineering project management; then it describes the research methods and case analysis in detail, focusing on the establishment of BIM models, data collection and management processes; then it presents and analyzes the research results, and evaluates the actual effect of BIM technology in combination with project data; finally, it summarizes the entire article, puts forward research conclusions and future prospects, and provides relevant suggestions for the application of BIM technology in subway project management.

2. Related Work

In recent years, subway construction has developed rapidly around the world, and various countries have conducted extensive research on issues such as the safety, environmental impact, and sustainability of subway construction. The following literature reviews relevant research results and their contributions. Zhang S et al. studied the safety factors of China's subway construction projects and explored how to reduce the accident rate [1]. Ghanbaripour et al. identified the critical success factors of Iranian subway projects through focus group discussions and project manager surveys [2]. Liu et al. proposed a projection pursuit model (PPM) based on quantum particle swarm optimization (QPSO) to evaluate the resilience of subway stations to waterlogging[3]. Zhou et al. proposed a BIM-based automatic identification framework for environmental risks in the subway design stage[4]. Wu et al. proposed an emission reduction path to provide a basis for green development and carbon neutrality goals[5]. Fang et al. analyzed the construction process of the Tsinghua University Tunnel of the Beijing-Zhangjiakou High-speed Railway underpassing Beijing Subway Line 10[6]. Saeedi et al. evaluated the health risks of PM emissions from construction sites in Tehran Metro, Iran. The results showed that PM emissions from construction sites had significant impacts on health and that stricter control measures were needed [7]. Zhang et al. evaluated the greenhouse gas emission potential of different subway earthwork recycling scenarios using an LCA model and found that recycling ESR significantly reduced emissions. They also proposed recycling options with significant economic benefits [8]. Mao et al. analyzed subway development patterns and building material inventories in metro cities around the world, revealing the rapid expansion of China’ s subway system and its greenhouse gas emissions, and emphasized the importance of evaluating the spatiotemporal characteristics of material inventories for sustainable subway planning[9]. Wang et al. studied the dynamic response of the underground structure of a new subway station combined with an overpass in China under earthquake action and found that lateral seismic excitation is more dangerous, emphasizing the inhibitory effect of bridge loads on the deformation of underground structures [10]. However, these studies still face some challenges in practical applications, such as data incompleteness, model limitations and cross-national differences. The innovation lies in the construction of a three-dimensional visualization management platform based on BIM, which comprehensively improves the efficiency of construction progress monitoring, cost control, quality management and safety risk assessment, and provides a new direction for the digital and intelligent management of future subway projects.

3. Methods

3.1 BIM Model Establishment and Data Collection

This study constructed a BIM (three-dimensional building information model) model [11] for a subway construction project, covering the integration of various professional modules such as architecture, structure, and electromechanical. By integrating the project's design drawings, construction plans and technical specifications, the comprehensiveness and consistency of the data are ensured. The architectural module constructs the spatial layout and structure of the subway station by inputting information such as building plans and elevations[12]; the structural module includes detailed information such as the station’ s supporting structure and infrastructure; and the electromechanical module covers the equipment and layout of systems such as power, ventilation, and fire protection. These modules realize information sharing and communication between different disciplines through the BIM platform, ensuring that various data of design, construction and operation can be seamlessly connected. In order to achieve real-time updating and dynamic management of data, the research team introduced the Internet of Things (IoT) technology[13] and deployed sensors at key locations on the construction site to collect real-time data such as material usage, worker progress, and safety status. These real-time data are transmitted to the BIM platform through the Internet of Things, ensuring the timeliness, accuracy and comprehensiveness of the data. The combination of the Internet of Things and BIM makes the project data management more intelligent, effectively supporting subsequent progress control, cost management, quality monitoring and risk warning. Through this data integration platform, the research team can track construction progress, monitor cost budgets, analyze quality control in real time, predict potential risks through data analysis, and take countermeasures in advance. The deep integration of BIM and IoT makes project management more accurate and efficient, and provides scientific technical support for the full life cycle management of subway construction projects. Figure 1 is a BIM model framework diagram.

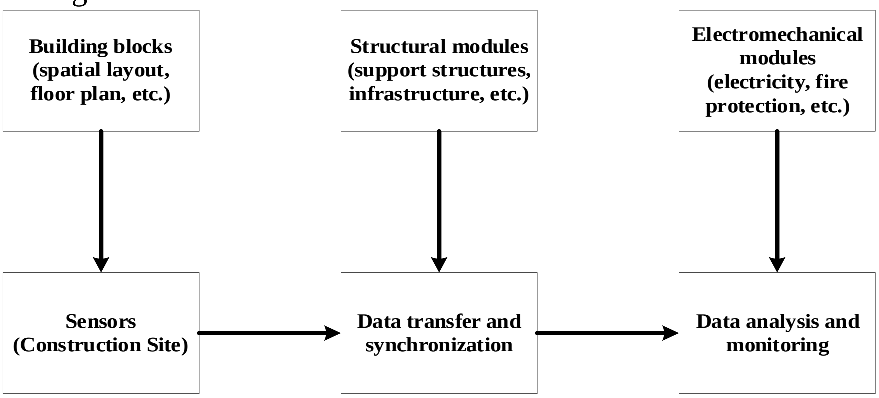

Figure 1. BIM model framework diagram

3.2 Application of BIM Technology in Construction Progress and Cost Management

This study improves the accuracy of construction progress and cost management through the dynamic simulation and progress planning tools of BIM technology. In terms of progress management, the BIM platform allows the project team to set detailed time nodes for each construction phase and compare them with the actual progress, update progress information in real time, promptly identify deviations and adjust plans to ensure that the project proceeds on time. BIM's 3D model can also dynamically display construction progress[14], enhance visual management, and reduce communication lags and information asymmetry in traditional management. In terms of cost management, the BIM system integrates information such as construction budget, material procurement and equipment usage, reflects resource usage in real time, helps the team dynamically monitor budget execution, identify potential overspending risks, and take measures in advance to control costs. BIM also supports the comparison of budget and actual costs, which helps to accurately predict funding needs and optimize cash flow. Through BIM technology, construction progress and cost management are more intelligent and refined, providing effective project control and guarantee. Table 1 shows the progress and cost management of subway construction projects.

Table 1. Progress and cost management of subway construction projects

Project Phase	Planned Progress (%)	Actual Progress (%)	Deviation (%)	Budgeted Cost (10,000 CNY)	Actual Cost (10,000 CNY)	Cost Deviation (10,000 CNY)	Remarks
Foundation Construction	20	18	-2	50	52	+2	Delay due to rain, construction interrupted
Station Main Structure	30	32	+2	100	95	-5	Completed ahead of schedule, saved resources
Mechanical and Electrical Installations	40	38	-2	80	85	+5	Material supply delay
Completion and Acceptance	10	12	+2	20	18	-2	Early acceptance, reduced delays

This table shows the progress and cost management of subway construction projects at various stages. In terms of progress, there were delays in foundation construction and electromechanical equipment installation, resulting in actual progress being lower than planned; the station main structure construction and completion and acceptance were completed ahead of schedule, reflecting resource conservation and efficient use. In terms of cost, the foundation construction and electromechanical equipment installation phases were overspent mainly due to weather factors and delayed material supply, while the main structure construction of the station saved costs and the overall budget control was relatively effective. This table provides a basis for project management to control progress and costs.

3.3 Implementation Process of Quality Management and Risk Monitoring

In order to achieve efficient quality management and risk monitoring[15], this study used information technology to track the construction quality throughout the entire process and provide feedback on problems. The quality inspection results of all construction activities are entered into the BIM platform in real time through mobile devices. The platform automatically compares them with the design standards and construction specifications to promptly identify any quality issues that do not meet the requirements and provide feedback to the relevant person in charge. BIM technology is closely integrated with the safety monitoring system of the construction site to collect monitoring risk data from sensors in real time. By combining the dynamic management and information integration of BIM technology, the project team can maintain a high level of construction quality and safety management while ensuring progress and cost control.

4. Results and Discussion

4.1 The Role of BIM in Improving Project Management Efficiency

The information transmission delay and poor communication problems of traditional construction management lead to progress deviation and project delays, while the real-time data and 3D modeling provided by BIM technology solve these problems. Data shows that after adopting BIM, the construction progress has increased by up to 3%. BIM also promotes cross-departmental collaboration, ensures real-time information transmission, reduces communication lags, and thus improves work efficiency. In summary, BIM technology not only optimizes construction progress management, but also enhances team collaboration, reduces the risk of delays and overspending, and ensures the smooth progress of the project. Figure 2 shows the comparison between the planned progress and the actual progress.

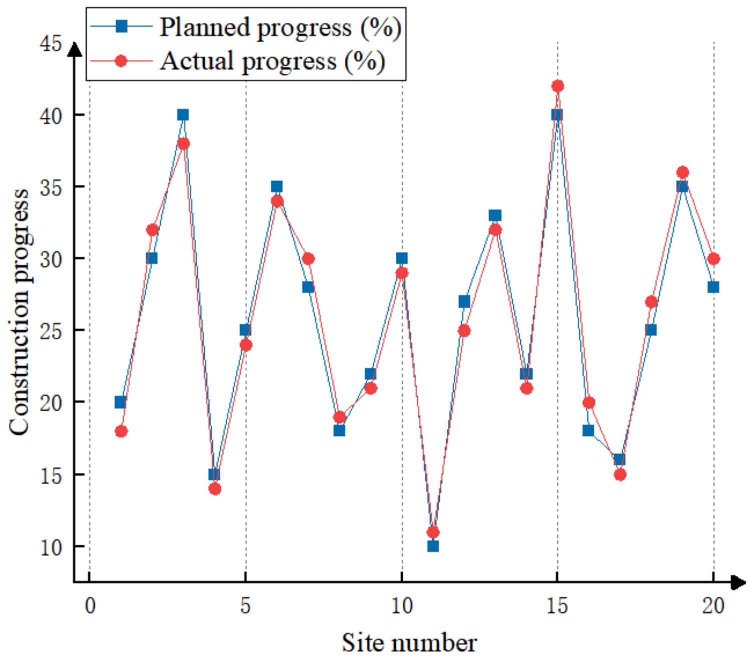

Figure 2. Comparison of planned progress and actual progress

By comparing the planned and actual progress of 20 different construction sites, BIM technology has effectively improved construction efficiency and progress control in multiple projects. The data shows that the actual progress of multiple construction sites (such as 2, 15, 16 in the figure) exceeded the planned progress, with an increase of between 2% and 3%, indicating that BIM has optimized progress and resource scheduling. Although the progress of a few construction sites (such as 1 and 3 in the figure) is slightly lower than the plan, the deviation is small and can be compensated by later adjustments. Overall, BIM technology has significantly improved the construction progress, reduced delays caused by information lag and poor communication, and enhanced the efficiency and accuracy of construction management.

4.2 BIM's Role in Promoting Quality Control and Risk Early Warning

BIM technology plays an important role in quality control and risk early warning, especially in discovering potential design defects and construction problems. By integrating on-site construction data with design drawings, BIM can identify and resolve potential problems in real time, thus avoiding the information gap between design and construction in traditional methods. Research shows that the application of BIM technology has significantly shortened the feedback cycle of quality issues by 60%. This change not only improves the speed of problem response but also effectively reduces rework and delays caused by construction problems. BIM technology also plays a key role in risk management. By real-time monitoring of the safety status of the construction site, BIM can promptly identify potential safety hazards and issue early warnings, greatly enhancing the safety of the construction process. BIM's functions in quality control and risk early warning not only improve the efficiency of construction management but also provide a solid guarantee for the smooth implementation of the project. Figure 3 shows the feedback cycle of quality issues.

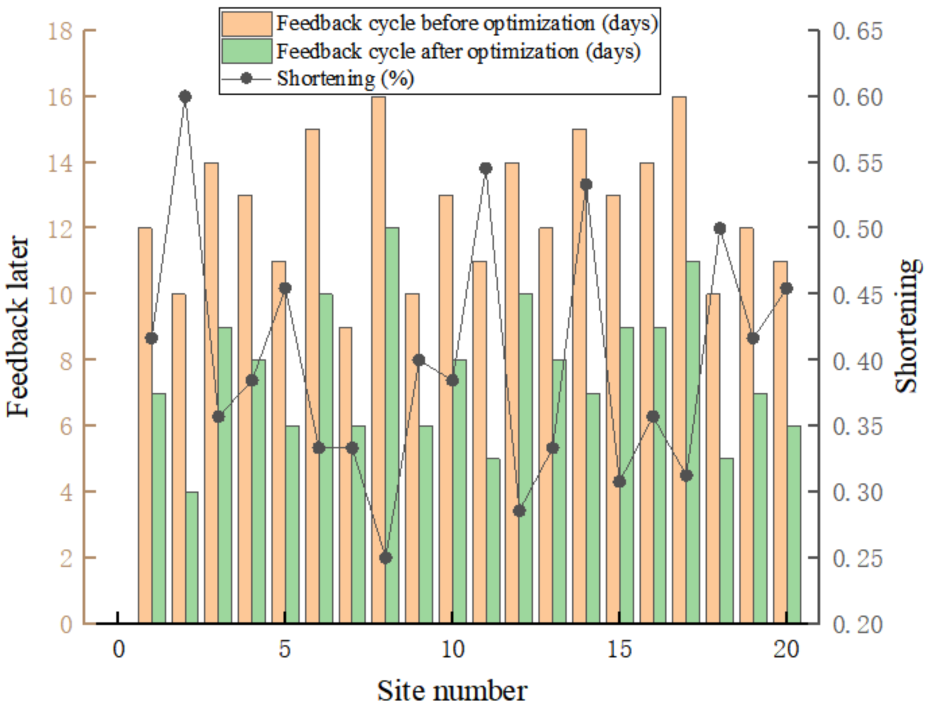

Figure 3. Quality issue feedback cycle

From the data analysis, we can see that BIM technology has effectively shortened the feedback cycle of quality issues at each construction site. The feedback cycle of most construction sites has been shortened by 3 to 7 days, and the longest has been shortened to 8 days. This is particularly evident in construction sites 2, 14, and 18. Through real-time data updates and feedback, the project team can respond to quality issues more quickly to reduce delays and additional costs caused by quality defects. Therefore, BIM technology not only improves the accuracy of quality management but also provides strong support for safety monitoring and risk warnings at the construction site.

4.3 BIM's Contribution to Cost Control and Resource Optimization

By applying BIM technology, the project team can more accurately forecast costs and control budgets, thus avoiding unnecessary waste and unreasonable resource allocation. In terms of cost control, BIM technology can accurately prepare budgets for materials, labor, equipment and other resources before construction, and make timely budget adjustments through real-time monitoring of changes in various cost data during the construction process. The research results show that BIM technology reduces project costs by an average of about 8% compared to traditional methods. This reduction significantly improves the overall economic benefits of the project, optimizes the efficiency of resource use, and provides strong support for project management. Figure 4 shows the cost control data comparison.

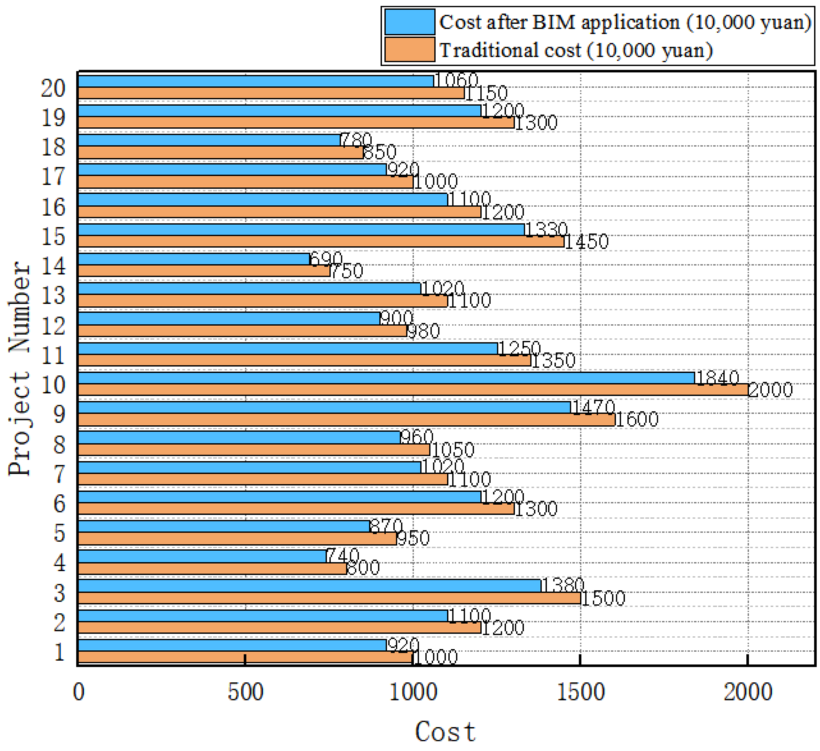

Figure 4. Cost control data comparison

As can be seen from the figure, after applying BIM technology, the costs of all projects have been reduced, and the cost reduction of most projects is between 7.5% and 8.57%. By optimizing resource allocation and adjusting budgets in real time through BIM technology, project costs have been effectively controlled, saving a lot of expenses. Especially in larger-scale projects, the application of BIM can better control material procurement, labor costs and equipment usage, avoiding waste of resources. In general, the introduction of BIM technology makes project management more efficient, which not only improves resource utilization efficiency but also provides strong support for the optimization of power material management and other projects.

5. Conclusion

This study explored the application of BIM technology in the visualization management of subway projects and achieved remarkable results. Studies have found that BIM can improve project management efficiency and optimize construction progress, cost and quality control. By establishing a BIM three-dimensional visualization platform, the project team can monitor the construction progress in real time, dynamically adjust resource allocation, promptly identify quality issues and take measures, thereby improving construction efficiency, reducing the feedback cycle of quality issues, and effectively controlling costs. Specific data shows that the application of BIM has increased the construction progress by up to 3%, shortened the feedback cycle of quality issues by up to 60%, and reduced the project cost by an average of 8%. These results verify the significant advantages of BIM technology in subway projects. The contribution of this paper is that it demonstrates the actual application effect of BIM technology in subway construction through case analysis, and provides valuable experience for the management and technical application of similar projects. In practical terms, this study promotes the popularization of BIM in subway construction and reflects its important role in improving project management efficiency and visual management. The limitation of the study is that only a certain subway project is used as a case, and BIM is only applied in some management links, lacking a systematic analysis of its comprehensive application. Future research can expand the sample scope and explore the application of BIM in other subway projects, especially in the design stage and later operation. It can also combine technologies such as big data and artificial intelligence to further improve the intelligent management level of subway projects, and study the role of BIM in cross-departmental collaboration to optimize information sharing and collaborative work.

Funding

This work was supported by the Research on the application of BIM in the whole life cycle of Urban Rail Transit (Foundation of Guizhou science and technology cooperation [2019] No. 1420) .The special projects for promoting the development of big data of Guizhou Institute of Technology. And that also funded by Geological Resources and Geological Engineering, Guizhou Provincial Key Disciplines,China(ZDXK[2018]001).

References

[1]Zhang S, Sunindijo R Y, Loosemore M, et al. Identifying critical factors influencing the safety of Chinese subway construction projects[J]. Engineering, Construction and Architectural Management, 2021, 28(7): 1863-1886.

[2]Ghanbaripour A N, Sher W, Yousefi A. Critical success factors for subway construction projects–main contractors' perspectives[J]. International Journal of Construction Management, 2020, 20(3): 177-195.

[3]Liu L, Wu H, Wang J, et al. Research on the evaluation of the resilience of subway station projects to waterlogging disasters based on the projection pursuit model[J]. Mathematical biosciences and engineering, 2020, 17(6): 7302-7331.

[4]Zhou M, Tang Y, Jin H, et al. A BIM-based identification and classification method of environmental risks in the design of Beijing subway[J]. Journal of Civil Engineering and Management, 2021, 27(7): 500-514.

[5]Wu H, Yang K, Chen K, et al. GHG emission quantification and reduction pathway of subway shield tunnel engineering: a case study on Guangzhou Metro, China[J]. Environmental Science and Pollution Research, 2024, 31(42): 54768-54784.

[6]Fang Q, Du J, Li J, et al. Settlement characteristics of large-diameter shield excavation below existing subway in close vicinity[J]. Journal of Central South University, 2021, 28(3): 882-897.
[7]Saeedi R, Khani Jazani R, Khaloo S S, et al. Risk assessment of occupational and public exposures to airborne particulate matter arising from a subway construction site in Tehran, Iran[J]. Air Quality, Atmosphere & Health, 2021, 14(6): 855-862.
[8]Zhang N, Zhang H, Schiller G, et al. Unraveling the global warming mitigation potential from recycling subway‐related excavated soil and rock in China via life cycle assessment[J]. Integrated Environmental Assessment and Management, 2021, 17(3): 639-650.
[9]Mao R, Bao Y, Duan H, et al. Global urban subway development, construction material stocks, and embodied carbon emissions[J]. Humanities and Social Sciences Communications, 2021, 8(1): 1-11.
[10]Wang Q, Geng P, Guo X, et al. Case study on the seismic response of a subway station combined with a flyover[J]. Underground Space, 2021, 6(6): 665-677.
[11]Pan Y, Zhang L. Integrating BIM and AI for smart construction management: Current status and future directions[J]. Archives of Computational Methods in Engineering, 2023, 30(2): 1081-1110.
[12]Sy K T L, Martinez M E, Rader B, et al. Socioeconomic disparities in subway use and COVID-19 outcomes in New York City[J]. American Journal of Epidemiology, 2021, 190(7): 1234-1242.
[13]Sadeeq M M, Abdulkareem N M, Zeebaree S R M, et al. IoT and Cloud computing issues, challenges and opportunities: A review[J]. Qubahan Academic Journal, 2021, 1(2): 1-7.
[14]Mnasri S, Nasri N, Alrashidi M, et al. IoT networks 3D deployment using hybrid many-objective optimization algorithms[J]. Journal of Heuristics, 2020, 26(5): 663-709.
[15]Sun D, Wang H, Lall U, et al. Subway travel risk evaluation during flood events based on smart card data[J]. Geomatics, Natural Hazards and Risk, 2022, 13(1): 2796-2818.