



Risk Characteristics of Accidents Occurred in the Metro Construction: A Case Study in Guangzhou

Huidong Zhang¹, Haifeng Huang¹, Yubing Yang^{2*}, Xingbin Chen² and Jiechun Sun²

¹Guangzhou Metro Engineering Consulting Co., LTD, Guangzhou, 510180, Guangdong, China

²College of Water Conservancy and Civil Engineering, South China University of Agricultural University, Guangzhou, 510642, Guangdong, China

*yubingyang@scau.edu.cn

Abstract. The metro construction projects are typically high-risk, thus nearly all of them will be covered by Contractors' All Risks Insurance. The spatial and temporal characteristic of 138 metro construction accidents occurred in Guangzhou City, China from 2012 to 2022, was analyzed from the perspective of property insurance. The results indicate a pronounced temporal clustering of accidents, with peaks observed during 8:00–10:00 AM and 4:00–6:00 PM. The annual indemnity payment exhibited an oscillatory ascending trend, reaching a peak in 2019, which was consistent with intensified construction activities during this period. In terms of loss types, over 90% of total indemnity payments was attributed to the damage involving main structural works, and third-party buildings or facilities. Spatial analysis further revealed that Panyu, Tianhe, and Huangpu districts were the most critical areas for the metro construction of Guangzhou City. Some risk prevention strategies were suggested to be implemented during the high-risk time and the above three high-risk regions. These insights offer practical guidance for improving safety risk management in urban metro construction projects.

Keywords: Accidents of metro construction, Indemnity payment, Type of loss, High-risk time and region.

1 Introduction

Urban metro projects pose particularly high risks due to the unpredictable geological conditions, complex construction sites employing a variety of construction methods, and surrounding construction conditions. A lot of research show an increasing number of accidents occurred in the metro construction process of China[1-2].

A lot of work has been done in the field of risk management of urban metro construction projects, such as identification of safety risk Factors[3], pre-control method in safety risk management[4], web-based system for safety risk early warning[5], and risk management plan to technical risks[6]. Recently, A temporal qualitative comparative analysis has been presented to explore the safety risk factors temporal combination path of metro construction projects in China[7].

Most of studies have predominantly focused on the pre-construction risk identification and risk warning in construction. In fact, the retrospective analysis of accidents occurred in the metro construction is demonstrated an effective method to explore the laws between risk factors and risk event, as demonstrated by Wu et al.[7]. Hence, this study collected and analyzed the 138 insurance claim data occurred in the metro construction of Guangzhou City, China, covering about 10 years from 2012 to 2022, aiming to real the spatial and temporal characteristic of risk events. The empirical support and strategic recommendations are expected to realize from the perspective of property insurance.

2 Data Source and Research methodology

The data adopted in this study were obtained from several metro lines built mainly during 2012 to 2022 in Guangzhou City, China. The data-set comprises 138 settled insurance claim cases. The total settled indemnity payments reached approximately to 364.19 million RMB. All data were derived from official insurance claim records.

A multi-dimensional analysis was conducted based on above data. Five dimensions are taken into consideration: type of accidents, time of occurrence, annual indemnity payment, damaged objects or type of losses, and geographical locations. It is expected to enable a detailed exploration of the spatial-temporal patterns of accidents and the associated economic loss characteristics during metro construction in Guangzhou City, China.

3 Results of Data Analysis

3.1 Type of Accidents

All of 138 insurance claims were mainly categorized into two types: natural disasters (I), and accidental events (II). Several sub types can be further classified. The number of each sub type of accident and the corresponding proportion of total settled cases were presented in Table 1 and Figure 1.

For the natural disasters, the majority of cases was induced by the rainstorm and typhoon, accounting for 10.9% and 8.9% of total settled cases, as shown in Table 1 and Figure 1. For the accidental events, 65 incidents related to the vibration, displacement, or weakened of structural support, with a highest proportion of 47.1% of total settled cases. It should be noted that incidents related to the vibration, displacement, or weakened of structural support are a collection of a large category of accidents. For example, shield tunneling/excavation of underground metro station-induced soil deformation may lead to excessive settlement and crack of the road surface, gas pipeline, nearby bridge piles and buildings. The blasting construction of the tunnels and vibration during pile foundation construction may also result in damage of nearby buildings. Other accidental event and personal injury accident should not be ignored in terms of the number of accidents, as they ranked second and third in the category of accidental events. The insurance claims related to flood and collapse of pit excavation in the metro construc-

tion of Guangzhou City have a extremely low proportion of 0.7% of total settled cases, which may indicates these two sub types of accident were well controlled in 10 years from 2012 to 2022. Thus, risk control measures should be focused on the following five sub types of accidents: the incidents related to the vibration, displacement, or weakened of structural support; accidents induced by rainstorm and typhoon; other kind of accidental event; and personal injury accident.

Table 1. The detailed classification of 138 insurance claims in Guangzhou City, China

Type of Accident	Sub Type of Accident	Settled Cases	Proportion of Total settled Cases
Natural Disasters(I)	Rainstorm	15	10.9%
	Typhoon	12	8.7%
	Flood	1	0.7%
Accidental Events (II)	Incident related to Vibration/ displacement/weakened structural support	65	47.1%
	Other accidental event	13	9.4%
	Personal injury accident	11	8.0%
	Water/mud/sand inrush	9	6.5%
	External pipeline cut off	8	5.8%
	External pipelines leakage	3	2.2%
	Collapse of pit excavation	1	0.7%
Total		138	100%

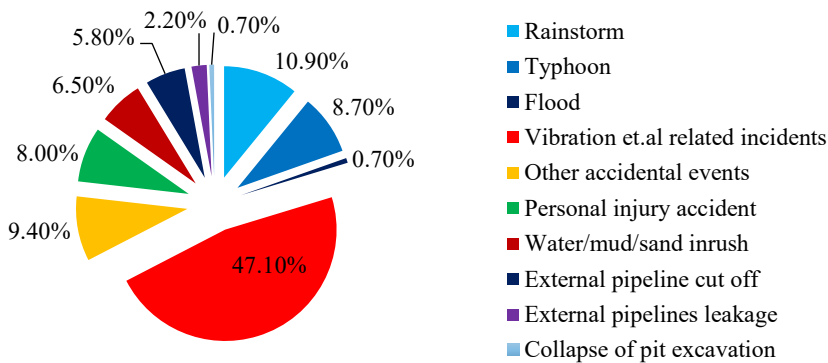


Fig. 1. The pie chart for the classification of 138 insurance claims in Guangzhou City, China.

3.2 Time of Occurrence for Accidents

The cumulative indemnity payment was a integrated index considering both frequency and severity of accidents. Hence, it was statistically analyzed by a interval of 2 hours in one day, as depicted in Figure 2.

It can be seen that the indemnity payments across different time periods was apparently uneven. The highest cumulative payments occurred during the 8:00–10:00 AM with a value of 127.8 million RMB, accounting for 35.1% of the total indemnity payments of about 10 years. It was followed by the 4:00–6:00 PM period with value of 68.39 million RMB. Notably, the above two peak periods corresponded to the beginning and end of the typical construction workday respectively. Besides, the indemnity payments ranked third at 10:00–12:00 AM. The cumulative indemnity payment was 49.15 million RMB, with a percentage of 13.95% of total payments. The summation of payments for above three time periods was 245.34 million RMB, accounting for 67.34% of total indemnity payments. It might be concluded that safety incidents are more likely to occur at the time when the when a large number of construction activities were carried out in the morning (8:00–12:00 AM) the worker’s fatigue reached to a limit state in the end of afternoon(4:00–6:00 PM). A relatively low indemnity payment was obtained at the time of lunch break and shift changes during 12:00~14:00. This might be attributed to the staggered work hours and pre-shift safety briefings.

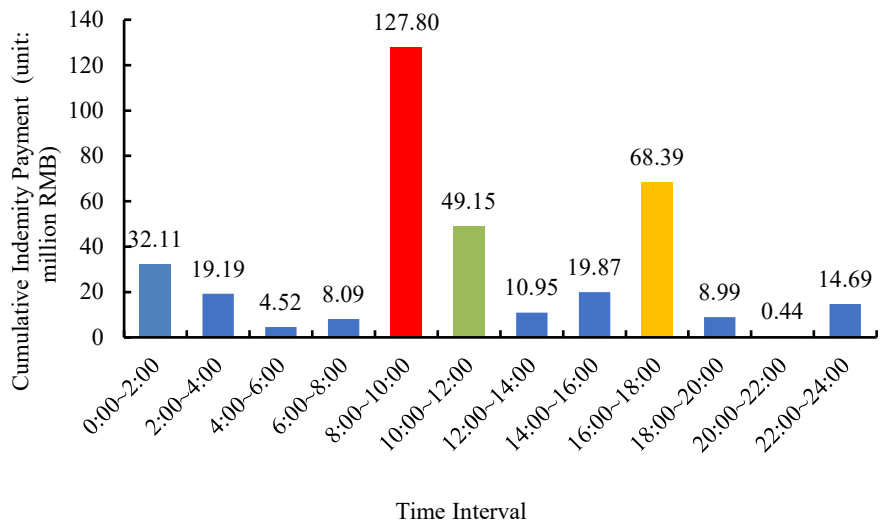


Fig. 2. The cumulative indemnity payment at different time intervals in one day

3.3 The Annual Indemnity Payment

The annual indemnity payment of metro construction accidents during 2012 to 2022 in Guangzhou City was plotted in Figure 3.

It is clear that the annual indemnity payments rose and fell like waves, with three peaks obtained in the years of 2013, 2017, and 2019. The peak value of 2017 increased by 32.7%, compared with 34. 63 million RMB of 2013. Notably, in 2019 a highest annual indemnity payment of 115.97 million RMB was recorded. It increased by 1.52 times compared with the peak value 45.96 million RMB obtained in 2017, and ac-

counted for 31.9% of the total indemnity payment from 2012 to 2022. Detailed investigation is needed to explore the reason.

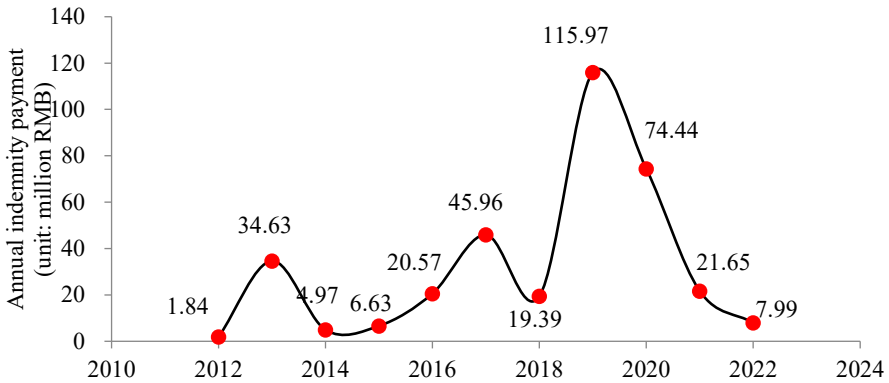


Fig. 3. Annual indemnity payment during January, 2012 to February, 2022

The newly added operating mileage of Guangzhou Metro from 2011 to 2021 was depicted in Figure 4. Considering the lag in insurance case closure and compensation, a relatively large amount of accident compensation in 2019 can be matched with the significant increase in new operating mileage in 2017 and 2018.

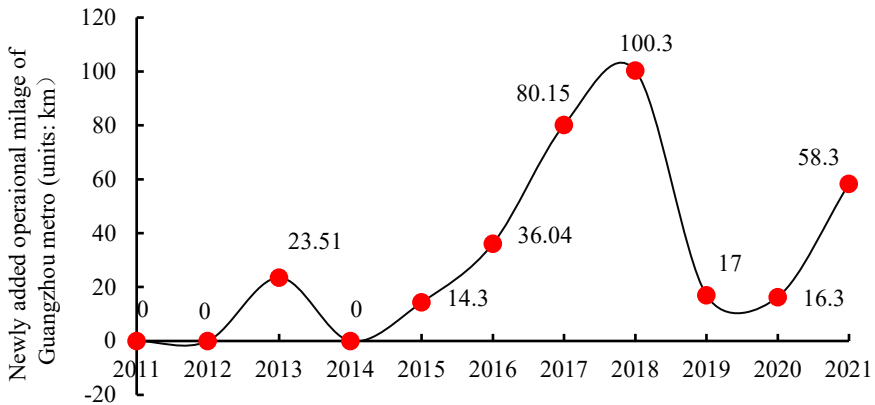


Fig. 4. Newly operational mileage of Guangzhou metro per year during 2011 to 2021

3.4 Type of Losses

The type of losses refers to the object which suffered a direct damage in a accident and arise a liability for compensation. The physical space affected by the accidents might be revealed by the statistical analysis of directly damaged objects. It is also helpful for identifying the hazard-affected body of construction risks. All the directly damaged

objects were classified as seven types of losses as show in Figure 5. The cumulative indemnity payment of each type of losses was calculated as well.

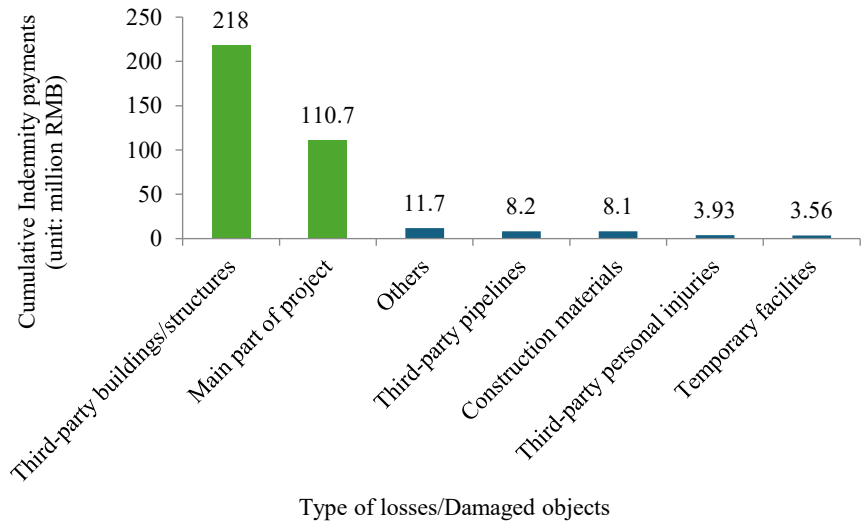


Fig. 5. The affected objects by accidents and the cumulative indemnity payments

It is found that third-party buildings/structures were the predominantly damaged objects induced by the metro construction in Guangzhou, because a maximum value of cumulative indemnity payments 218 million RMB was obtained in this type of losses, accounting for approximately 60% of total indemnity payments. Main part of project ranked second with a cumulative indemnity payment of 110.7 million RMB, which is about 30% of the total indemnity payments.

The metro system typically constructed in the densely built-up urban areas, surrounded by residential buildings, road infrastructure and underground pipelines. Any instability in retaining structures and sudden changes in underground excavation may cause structural damage to adjacent third-party assets, especially the costly buildings and structures with the features of vulnerability and great difficulty in repair. The proximity of these accidents to the damaged buildings/structures varied from a few meters to tens even hundreds of meters, so it is very hard to establish safer buffer zones between the construction sites and the damaged buildings/structures for the future urban rail transit planning. The reason lies in the variability and unpredictability of surrounding hydrological and geological conditions for underground works in a metro line. The third-party pipelines were demonstrated to be frequently damaged by the metro construction, while the economic loss was not as high as the buildings and structures.

The damage of main part of projects was usually accompanied by accidents like shield-arrival, water/mud/sand inrush, collapse of pit excavation, etc. The reason might be the complexity of construction method, the sensitivity of surrounding hydrological and engineering geological environment, and improper operation of workers during construction.

3.5 Location of Accidents

To further clarify the spatial characteristic of accidents, the indemnity payments of eleven administrative region were counted, as illustrated in Figure 6.

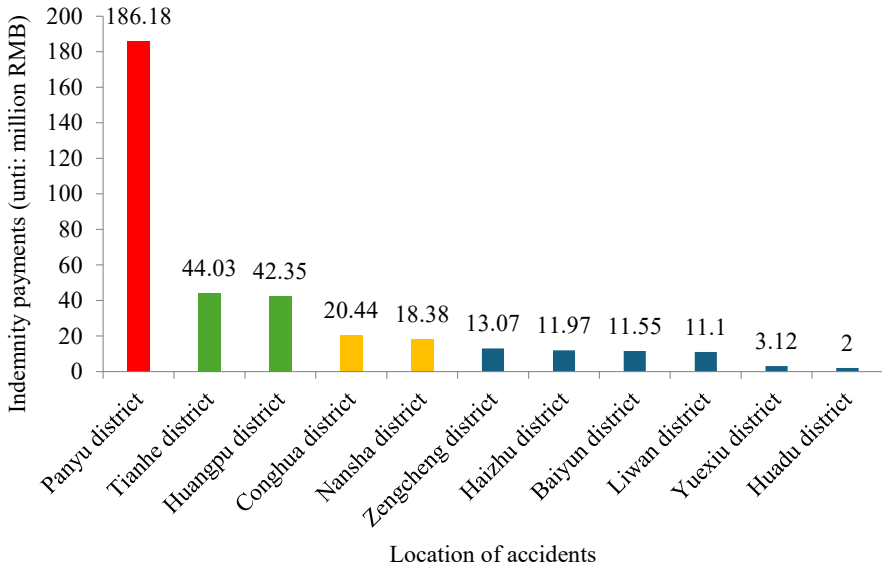


Fig. 6. The indemnity payments of different locations of accidents

It can be seen that Panyu district reported the highest indemnity payment, reaching 186.18 million RMB and accounting for 51.1% of the total indemnity payments, making it the most risky area for metro construction. It was followed by Tianhe district and Huangpu district, with a indemnity payment of 44.03 million RMB (12.1%) and 42.35 million RMB (11.6%) respectively. The summation of indemnity payments of above top three administrative districts was as high as 272.56 million RMB, with a proportion of 74.8% of total indemnity payments.

Panyu District has been a major location of metro line construction in recent years. Its complex geological conditions—characterized by dense water networks, soft soils, and water-rich strata—make it particularly susceptible to high-risk events such as retaining structure leakage, piping, ground settlement, and displacement of adjacent buildings/structures. These factors likely contribute to its high indemnity payments. Tianhe District, as the urban core of Guangzhou, features a dense built environment and is surrounded by high-rise buildings. Construction mishandling in this area can easily cause damage to nearby building/structures and lead a high loss of third-party property. In general, the spatial distribution of metro construction accidents in Guangzhou reveals a typical pattern of “high in the south, low in the north” or “concentrated in the central zone, and scattered in the periphery.”

4 Comparsion With Incidents Across China

1584 settled insurance claims related to metro construction accidents from across China between 2012 and 2022 were analyzed in reference [8]. The Guangzhou findings in above section can be compared with findings all over China as follows:

(1) In terms of natural disasters, the Guangzhou Metro was significantly affected by typhoons and heavy rain, while the national metro was mainly affected by heavy rain. In terms of accidents, the top three types of accidents in the national metro system are external pipeline cut off, incident related to vibration/displacement/ weakened structural support, and water/mud/sand inrush. The Guangzhou Metro is mainly affected by incident related to vibration/displacement/ weakened structural support.

(2) In terms of the amount of compensation, an average annual compensation of 32.185 million RMB In Guangzhou metro was obtained, but the average compensation amount per accident was only 978,000 RMB in the national metro system. It can be seen that the average compensation amount for each accident in Guangzhou Metro is much higher than that of metro systems across China.

(3) In terms of type of losses, the losses with the highest compensation amounts for Guangzhou Metro accidents were third-party buildings/structures (59.9%) and main projects (30.4%). For the national metro system, the top two were the main project (59.10%) and third-party buildings/structures (24.26%). It is observed that in Guangzhou third-party buildings/structures are more vulnerable during metro construction. This might be contributed to complexity of the geological environment. Guangzhou is known as a geological museum.

5 Conclusion

Based on 138 settled insurance claims related to Guangzhou Metro construction accidents between 2012 and 2022, this study conducted a comprehensive statistical analysis from five dimensions in terms of number of accidents or indemnity payment: type of accidents, time of occurrence, annual indemnity payment, type of losses, and location of accidents. The main conclusions can be drawn as follows:

(1) Rainstorm and typhoon are the most frequently encountered natural disasters in the metro construction of Guangzhou City. In the category of accidental events, there are 65 incidents related to the vibration/displacement/weakened of structural support, accounting for 47.1% of total settled cases. Hence, this type of accident is regarded as the key target of risk prevention and control from the perspective of property insurance.

(2) The safety incidents are more likely to occur at the time when the when a large number of construction activities were carried out in the morning (8:00–12:00 AM) the worker's fatigue reached to a limit state in the end of afternoon (4:00–6:00 PM), as the indemnity payments summarized for above time periods reached two-thirds of the total indemnity payments. The mandatory inspection was suggested to be established during the 4:00–6:00 PM fatigue window, in order to let the workers who have reached a certain degree of fatigue rest.

(3)The annual indemnity payments rose and fell like waves, with three peaks obtained in the years of 2013, 2017, and 2019. In 2019, a highest annual indemnity payment of 115.97 million RMB was recorded, which accounted for 31.9% of the total indemnity payment from 2012 to 2022. Detailed investigation is needed to explore the reason.

(4)The third-party buildings/structures were the predominantly damaged objects induced by the metro construction in Guangzhou. Main part of project ranked second with a cumulative indemnity payment of 110.7 million RMB, which is about 30% of the total indemnity payments.

(5)The spatial distribution of metro construction accidents in Guangzhou reveals a typical pattern of “high in the south, low in the north” or “concentrated in the central zone, and scattered in the periphery.” The summation of indemnity payments of Panyu, Tianhe and Huangpu districts was as high as 272.56 million RMB, with a proportion of 74.8% of total indemnity payments.

Acknowledgments

This study was funded by Guangzhou Metro Engineering Consulting Co., LTD (grant number JS-B-2025-015).

Disclosure of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Yu, Q. Z., Ding, L.Y., Zhou, C., Luo, H.B. Analysis of factors influencing safety management for metro construction in China. *Accident Analysis and Prevention*. 68, 131–138(2014).
2. Li, H., Li, Q., Lu, Y.. Statistical analysis on regularity of subway construction accidents from 2002 to 2016 in China. *Urban Rapid Rail Transit*, 30: 12–19(2017)(in Chinese).
3. Tang, C.; Shen, C.; Zhang, J.;Guo, Z. Identification of Safety Risk Factors in Metro Shield Construction. *Buildings*, 14, 492(2024).
4. Liu, P., Shang, Y. T., Jin, X. Q. A pre-control method in safety risk management of metro construction, *Journal of Asian Architectural and Building Engineering*, 24(2), 816–834(2025).
5. Ding,L.Y., Zhou, C. Development of web-based system for safety risk early warning in urban metro construction. *Automation in Construction*. 34: 45-55(2013).
6. Zhang, Y. Application of risk management plan to technical risks in metro construction: Case study of the Grand Paris Express project. *Tunnelling and Underground Space Technology*. 147: 105716(2024).

7. Wu, X., Dong, S., Li, Y. Exploring safety risk factors temporal combination path of metro construction projects: A temporal qualitative comparative analysis in China. *Work*. 81(1): 2148–2160(2025).
8. Ping An Property & Casualty Insurance Company of China, Ltd., Risk and Insurance Research Branch of China Civil Engineering Society and Tongji University, et al. *Blue book of metro risk management and insurance in China*. Tongji University Press(2018).

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

