

# Analysis on Beijing Urban Underground Railway Operation

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**Abstract.** With the acceleration of urbanization in China, large cities, especially mega cities like Beijing, are facing serious traffic congestion problems. As a key tool to alleviate urban traffic pressure and improve urban operational efficiency, the construction and operation of the Beijing subway have received widespread attention. This study adopts comparative analysis and case study methods to explore in-depth coverage and expansion of Beijing's subway network, passenger experience and service quality, safety management and emergency response, and compares with the operation of other international metropolises. Research has found that the Beijing subway has made significant achievements in improving transportation capacity, passenger experience, and safety, while also revealing issues such as congestion during peak hours, insufficient equipment updates, and the need for improved service qualities. In response to these issues, this study proposes corresponding countermeasures, such as improving transportation capacity during peak hours, accelerating equipment updates and maintenance, improving service levels to meet passenger needs, etc., aiming to provide reference for the optimization and sustainable development of Beijing Metro and even the national urban rail transit system.

**Keywords:** Beijing Metro, transportation capacity, passenger experience, security management, sustainable development.

## 1. Introduction

In recent years, with the rapid advancement of urbanization, major cities in China are facing serious traffic congestion problems, especially in super large cities like Beijing. According to the China Statistical Yearbook 2023, the permanent resident population of Beijing has exceeded 21.5 million, and the urbanization rate has reached 87.5% [1]. In this context, an effective public transportation system has become the key to alleviating urban traffic pressure and improving urban operational efficiency. The "Management Measures for Urban Rail Transit Planning and Construction" (revised in 2022) jointly issued by the National Development and Reform Commission and the Ministry of Transport clearly states that accelerating the development of urban rail transit is one of the important measures to achieve sustainable urban development. As the capital city, Beijing's urban underground railway construction and operation have received high attention and support from national policies, aiming to expand the subway network, improve transportation capacity, reduce carbon emissions, and achieve green development.

For the Beijing urban underground railway, although its network scale has rapidly expanded and operational efficiency has continuously improved in recent years, it still faces many challenges and problems. For example, with the increase of lines and the extension of operating time, the maintenance and operating costs of underground railways have sharply increased. In terms of passenger experience, issues such as congestion, aging facilities, and service quality during peak hours are becoming increasingly prominent. Meanwhile, how to effectively utilize modern technologies such as big data and artificial intelligence to improve operational efficiency and passenger experience is also an important issue faced by Beijing Metro. Therefore, in-depth research on the operational status, challenges, and countermeasures of Beijing's urban underground railway is of great theoretical and practical significance for optimizing its operational management mode, improving the level of public transportation services, and promoting the healthy development of Beijing and even the national urban public transportation system.

## **2. Operation of Beijing Metro**

### **2.1 Network Coverage and Expansion**

As one of the largest urban rail transit systems in the world, Beijing Metro has opened 23 subway lines with a total length of over 700 kilometers as of 2023. The layout of the Beijing subway network is a combination of radial and circular shapes, effectively connecting the city center and suburban areas, greatly alleviating urban traffic pressure and improving people's travel efficiency [2]. Especially in recent years, with the construction and development of Beijing's urban sub center, the addition of new subway lines has not only promoted the rational layout of urban space, but also further improved the transportation network of the entire city. For example, the opening of Metro Line 19 has greatly shortened the east-west transportation time of the city, becoming an important transportation network connecting the main business and residential areas of the city.

### **2.2 Passenger Experience and Service Quality**

Beijing Metro continues to make efforts to improve passenger experience, not only focusing on comfort and safety in carriage design, but also constantly innovating in service facilities. All stations are equipped with accessible facilities, providing convenience for the elderly, children, and people with disabilities. Moreover, by introducing advanced electronic payment systems, such as scanning QR codes on mobile phones for transportation, the convenience of entering and exiting the station has been greatly improved [3]. In addition, Beijing Metro actively utilizes big data and intelligent technology to update and share real-time information inside and outside the station. Passengers can use mobile applications to query real-time information such as vehicle arrival time and congestion, effectively plan their travel routes, and significantly improve efficiency and satisfaction.

### **2.3 Safety Management and Emergency Response**

Safety is the primary task of Beijing subway operation. In recent years, Beijing Metro has taken a series of innovative measures to ensure passenger safety, including but not limited to the comprehensive deployment of high-definition monitoring systems and strengthening safety inspections inside stations and carriages. At the same time, in response to extreme weather, emergencies, and other situations, Beijing Metro has established a comprehensive emergency response mechanism, which can activate emergency plans in a timely manner to ensure passenger safety. For example, when encountering heavy rainfall or foggy weather, subway operators will promptly release operational adjustment information through various media to guide passengers to adjust their travel plans reasonably. In addition, emergency facilities and professional first aid personnel are equipped inside and outside the subway station to ensure timely and effective rescue in case of emergency medical situations.

## **3. Beijing Metro vs. Metros in Other International Metropolises**

### **3.1 Operational Efficiency and On-time Rate**

Beijing Metro has shown outstanding performance in operational efficiency and punctuality, particularly in terms of departure frequency during peak hours and a punctuality rate of over 99%, thanks to advanced signal systems and strict time management [4]. Even during peak commuting periods with huge passenger flow, the Beijing subway can maintain a 2-minute departure interval, effectively alleviating passenger waiting time. In addition, the intelligent dispatch system adopted by Beijing Metro can monitor the real-time operation status of trains, adjust operation strategies in a timely manner to ensure punctuality and ensure passenger travel efficiency.

Compared to the efficient operation of the Beijing subway, New York Subway often experiences train delays due to aging infrastructure and insufficient maintenance, resulting in a significant difference in punctuality compared to the Beijing subway [5]. The problems with New York Subway

mainly stem from insufficient funds and outdated signal systems, making it difficult to maintain high-frequency departures during peak hours, which affects the travel experience of passengers [6]. Although London Underground has undergone large-scale infrastructure upgrades in recent years, including signal system upgrades, to improve punctuality and operational efficiency, there are still challenges in responding to extreme weather and emergencies, especially in maintaining punctuality during peak hours, which is still a certain gap compared to the Beijing Metro.

### **3.2 Technology Application and Innovation**

The technological application and innovation of Beijing Metro are mainly reflected in mobile payments and real-time information services, which provide great convenience for passengers. For example, Beijing Metro has achieved a convenient way of scanning QR codes to enter and exit the station through cooperation with major mobile payment platforms. Passengers do not need to queue up to purchase tickets, effectively reducing entry time. At the same time, with the help of big data and cloud computing technology, Beijing Metro can update train operation information and station passenger flow information in real-time, helping passengers make more reasonable travel choices, thereby optimizing the operational efficiency of the entire subway network and passenger travel experience.

Tokyo Metro has also spared no effort in technological innovation, especially in improving punctuality, passenger service, and safety. Tokyo Metro adopts meticulous time management and strict employee training to ensure a high level of service quality and safety. In addition, the Tokyo Metro utilizes advanced Information and Communication Technology (ICT) to provide passengers with various convenient services, including station navigation, real-time train location tracking, and more [7]. However, despite Tokyo Metro's outstanding performance in technology application, Beijing Metro's practice in integrating the latest payment technology and providing real-time information services is more extensive, demonstrating progressiveness in the context of smart city construction.

### **3.3 Safety and Emergency Response**

Beijing Metro attaches great importance to the safety and emergency response capabilities of passengers, ensuring their safety through a series of comprehensive measures. This includes high-definition monitoring systems installed at all stations, regular safety drills, and fast and effective emergency response mechanisms. Especially when dealing with emergencies such as fires and emergency medical situations in subway carriages, Beijing Metro can quickly activate emergency plans, guide passengers, and minimize injuries and losses. In addition, the safety inspection system of the Beijing subway is also very strict, and all passengers must undergo safety inspections when entering the station. Although this measure increases the entry time, it greatly improves the safety of boarding.

In contrast, Paris Metro has faced more complex security challenges in recent years, including threats of terrorist attacks and rising urban crime rates. To this end, Paris Metro has strengthened its police deployment and video surveillance, while also increasing its promotion of public safety awareness [8]. Nevertheless, there is still room for improvement in the emergency response mechanism and passenger safety education of Paris Metro. Beijing Metro's approach in this regard is more comprehensive and systematic, focusing not only on pre safety inspections, but also on emergency response during the event and risk assessment and management after the event.

### **3.4 Environmental Friendliness and Sustainable Development**

Beijing Metro has taken positive measures to promote environmental friendliness and sustainable development. By using energy-saving lighting systems, adopting energy-saving materials and technologies, and recovering the energy generated during train braking, Beijing Metro has made efforts to reduce its impact on the environment. The greening project and air quality management system inside the station also provide passengers with a healthier and more comfortable riding

environment. In addition, the design and construction process of the Beijing subway strictly follows the standards of green buildings, reducing energy consumption and carbon emissions from the source, reflecting a high commitment to sustainable development.

In contrast, London Underground faces the challenge of implementing environmentally friendly measures in old infrastructure. Although London Underground is striving to reduce energy consumption and improve energy efficiency in station renovations and train upgrades, its long-standing lines and facilities limit the possibility of wider application of modern environmental technologies [9]. Although the efforts of the London Metro in reducing carbon emissions and improving environmental friendliness have achieved certain results, compared with the Beijing Metro, the latter has demonstrated a more comprehensive environmental protection concept and practice in overall planning and new technology application. These practices of the Beijing subway not only improve the environmental impact of urban transportation, but also provide a reference for sustainable development for other subway systems around the world.

## **4. Problems and Suggestions for Beijing Metro Operation**

### **4.1 Problems**

#### **4.1.1. Severe congestion during peak hours**

Despite the high operational efficiency and frequent train services of the Beijing subway, the congestion caused by the large number of passengers during peak hours in the morning and evening is still a difficult problem to solve. Especially on some busy lines and major transfer stations, such as Jianguomen Station on Metro Line 2, Lishuiqiao Station on Metro Line 13 and Metro Line 5, congestion is particularly prominent. During the morning rush hour, passengers need to queue up for multiple train services to successfully board the train [4]. The carriages are crowded to the point where it is difficult to move, and in some extreme cases, passenger pressure can cause discomfort for some elderly, weak, sick, and disabled passengers. This high-density flow of people not only brings great inconvenience to the travel experience of passengers, but also puts higher requirements on the safety of subway operation.

#### **4.1.2. Frequent failures caused by insufficient maintenance and updates**

With the rapid expansion of the Beijing subway system, the maintenance and updating of some old lines and equipment are facing enormous challenges. Some lines, especially the early constructed subway lines 1 and 2, often experience equipment aging and malfunctions due to long-term operation. For example, problems such as signal system failures and train door malfunctions often occur, which not only affect the normal operation of the train, cause delays, but may also endanger passenger safety. In addition, maintenance and updates often need to be carried out at night, with limited available time, which puts considerable pressure on timely troubleshooting and repairing faults. Therefore, how to accelerate the updating and replacement of old equipment while ensuring the safe and stable operation of the subway system is a major problem faced by Beijing Metro.

#### **4.1.3. The gap between service level and passenger expectations**

Although Beijing Metro has made many efforts to improve passenger experience, there is still a gap between service level and passenger expectations. On the one hand, with the increasing demand for travel quality from passengers, the demand for personalized and comfortable subway services is also growing day by day. However, there is still room for improvement in the comfort of train carriages, clarity of station signage, and response speed of customer service in the current Beijing subway system [3]. On the other hand, especially in some old stations, due to space limitations and differences in design standards, there is insufficient accessibility facilities, which are not convenient for the elderly, weak, sick, and disabled groups to use. In addition, passengers' dissatisfaction with train congestion during peak hours and concerns about subway safety also reflect a certain difference between service level and passenger expectations.

#### **4.1.4. Insufficient communication between information services and passengers**

Although Beijing Metro utilizes big data and intelligent technology to provide real-time information services, in emergency situations such as equipment failures or emergencies, information transmission and communication with passengers are still insufficient. In these situations, passengers often feel information is missing or unclear, leading to unnecessary panic or confusion. For example, when a fault occurs on a certain route causing delay, the lack of timely and detailed information updates may affect passengers to re-plan their itinerary. In addition, the lack of smooth passenger feedback channels also affects the rapid response of subway management to passenger needs and issues, thereby reducing overall service satisfaction.

### **4.2 Suggestions**

#### **4.2.1. Improve transportation capacity during peak hours**

To solve the problem of congestion during peak hours, improving transportation capacity during peak hours has become crucial. This requires comprehensive measures such as increasing train schedules, optimizing train composition length, and improving platform evacuation efficiency. Through scientific scheduling, increase the frequency of departure during peak hours, and adjust the length of train formations in a timely manner based on passenger flow data to maximize carrying capacity. In addition, improve the measures for pedestrian flow diversion within platforms and stations, such as optimizing the layout of platform entrances and exits, adding signage, and improving evacuation efficiency.

Based on the actual situation of Beijing Metro, it is recommended to introduce a more advanced train scheduling system, use big data analysis to predict passenger flow during peak hours, and dynamically adjust train operation plans. For particularly congested routes and stations, it is possible to consider using large capacity carriages or adding specialized express services to directly reach major transfer stations or busy nodes, reducing midway stops to alleviate the pressure on some routes. At the same time, it is necessary to strengthen guidance and information dissemination for passengers, such as providing real-time congestion situations and suggested travel routes through subway apps, guiding passengers to plan their travel time and routes reasonably.

#### **4.2.2. Accelerate device updates and maintenance**

Accelerating equipment updates and maintenance is the fundamental solution to the problem of aging and frequent failures of equipment. This includes regular maintenance and upgrading of old equipment, introduction of more advanced technical equipment, and improvement of the overall reliability and safety of the subway system. At the same time, it is necessary to establish a more comprehensive equipment monitoring system to achieve real-time monitoring and early warning of equipment status, to timely detect problems and carry out maintenance, and reduce operational interruptions caused by equipment failures [4].

For Beijing Metro, priority should be given to updating and upgrading key equipment such as signal systems and vehicle door control systems, especially on old lines with long operating hours and severe facility aging. It is suggested to draw on the experience of advanced international subway systems and adopt more intelligent and automated maintenance technologies, such as using robots for tunnel inspections and applying Internet of Things technology for equipment status monitoring. At the same time, Beijing Metro needs to increase funding investment, improve the frequency and quality of maintenance and updates, and ensure the efficient and stable operation of the subway system.

#### **4.2.3. Improve service quality to meet passenger needs**

To narrow the gap between service quality and passenger expectations, it is necessary to improve service level to better meet the diverse needs of passengers. This involves improving the comfort of carriages and stations, strengthening the training of customer service teams, and providing more humane services. By modernizing the station, measures considered are improving the coverage and

quality of accessible facilities, and improving the professional level and service quality of service personnel, so that comprehensive optimization of passenger services can be achieved [10].

Specifically, for the Beijing subway, it is recommended to increase air conditioning efficiency inside the carriages, provide free Wi-Fi services, optimize seat layout, and other measures to improve ride comfort. In stations with high-foot traffic, more customer service points and self-service equipment can be added to provide faster consultation and rescue services. In addition, the transportation needs of special groups such as the elderly, weak, sick, and disabled should be met through measures such as increasing accessibility facilities and providing special assistance. Through these specific measures, not only can the riding experience of passengers be improved, but also the overall satisfaction of the public with Beijing subway services can be enhanced.

#### **4.2.4. Strengthen information dissemination and passenger interaction in emergency situations**

In response to the insufficient communication between information services and passengers, it is recommended that Beijing Metro strengthen the information release system in emergency situations to ensure that passengers can timely and accurately obtain all information that affects their itinerary. This can be achieved by upgrading the official subway app and integrating more real-time information publishing functions, including emergency notifications such as train delays and station closures. At the same time, a more effective passenger feedback mechanism should be established, such as setting up a 24-hour customer service hotline and adding online interactive platforms, so that passengers can provide timely feedback and answers to their questions. In addition, more electronic display screens should be installed inside subway stations to update train operation status and emergency information in real time, helping passengers make more reasonable travel choices, thereby improving their sense of safety and satisfaction.

## **5. Conclusion**

This article comprehensively analyzes the development, operational status, and main challenges faced by the Beijing subway in the process of rapid urbanization, and compares it with the subway operation situation in other international metropolises. Through this analysis, it is clear that Beijing Metro has made significant achievements in expanding its network coverage, improving passenger experience, ensuring operational safety, and promoting environmentally friendly and sustainable development. At the same time, in response to the problems of congestion during peak hours, insufficient equipment maintenance and updates, and the gap between service level and passenger expectations, this article also proposes specific countermeasures, aiming to further optimize the operation and management mode of Beijing Metro, improve the level of public transportation services, and support the healthy development of Beijing and even the national urban public transportation system.

Although this article strives to provide comprehensive analysis and constructive suggestions, due to limitations in data acquisition and analytical perspectives, further exploration of Beijing Metro's operation is still needed. Future research can make more use of real-time data and advanced analytical technologies such as artificial intelligence and machine learning to deepen understanding of subway operation efficiency, passenger behavior, and service optimization. In addition, considering that the urban public transportation system is a complex socio-economic system, future research should also comprehensively consider various factors such as urban planning, transportation policies, environmental protection, etc., to propose more comprehensive and in-depth countermeasures and suggestions to promote the sustainable development of Beijing Metro and even the global urban rail transit system.

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