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Epidemic Prevention Strategy of Shanghai Rail Transit System: Taking the COVID-19 Pandemic as an Example

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Abstract: The outbreak of Coronavirus Disease 2019 (COVID-19) poses a great challenge to urban rail transit system. Several cities take measures such as line outage, in and out station control, and operation diagram adjustment to cope with the sharp drop of passenger flow as well as epidemic prevention and evacuation demand. With the gradual restoration of social order and the increase in the traffic volume brought by the resumption of work and school, urban rail transit system is faced with the changing travel demand as well as long-term and sustained epidemic prevention demand. This paper analyzes the impact of the pandemic on passenger flow of Shanghai rail transit and the huge challenge it faces. According to travel demand in different periods, the paper provides suggestions on epidemic prevention and control in several aspects: further implementing epidemic prevention and control measures, strengthening passenger flow early-warning and passenger management, dynamic analysis and scientific allocation of transportation capacity, refining the management and control of full load rates at stations and carriages. Aiming at recovery of operation resilience of urban rail transit, effective measures for epidemic prevention and control are of great significance to the modernization of the governance system and management capacity of transportation industry. **DOI:** 10.13813/j.cn11-5141/u.2020.0303-en

Keywords: rail transit; modern governance; COVID-19; megacities; coping strategies; Shanghai

0 Introduction

Coronavirus Disease 2019 (COVID-19) has been spreading rapidly across China since it broke out in Wuhan. COVID-19 is very similar to the Severe Acute Respiratory Syndrome (SARS) that broke out in 2003, but it impacts more widely and spreads faster. The passenger and freight volumes have declined sharply in a very short period. From January to February 2020, the freight volume was 4.51 billion tons, with a decrease of 19.7% year on year, and the public transit passenger volume of 36 central cities was 4.76 billion passengers, with a decrease of 49.3% year on year. Urban rail transit, which is the backbone of the urban public transit system and connects the main passenger distribution centers of a city, has a year-on-year decrease of 46.6% [1]. The decrease in passenger and freight volumes seriously impacts the development of politics, economy, culture, education, science and technology in a city.

During an epidemic, the transportation industry plays a key role in transporting epidemic prevention materials, moving medical staff, and blocking routes for disease transmission. Some research has studied how to prevent and control epidemics in the field of transportation. Considering the challenges faced by the transportation industry in an epidemic, Reference [2] learned from the resilience theory in the transportation system from multiple countries. It suggested that the epidemic prevention and control should be carried out along with the emergency response of the passenger and freight transportation system. This research provided a strong support to the construction of a high-quality three-dimensional transportation network that is modern and comprehensive. With the US pandemic influenza as an example, Reference [3] analyzed the influenza prevention and control measures taken by the US Department of Transportation and their positive effects. It provided enlightenment on China's epidemic prevention and control. Reference [4] focused on the impact of the epidemic on China's transportation industry from several aspects, such as passenger and freight transportation, port production, and fixed-asset investment in transportation. It made constructive suggestions on how to strengthen the epidemic prevention and control and how to reduce the impact of the epidemic. Reference [5] compared and analyzed the passenger and freight turnover volumes of railway, highway and civil aviation during SARS and COVID-19. Based on the similarities and differences of the two pandemics, this research put forward the key points that the transportation industry should control during epidemic prevention and control and proposed that the prevention and

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control mechanism should be improved further. Reference [6] established a transmission model of infectious diseases that spread across regions. These diseases' impact on the transportation network was verified through the network topology analysis in this research. Based on the comparison of SARS and COVID-19, Reference [7] analyzed the problems exposed by COVID-19 from five aspects: macro-economy, meso-industry, micro-industry, capital market and national governance. This research also proposed long-term and short-term industrial reform measures. Reference [8] pointed out that the COVID-19 pandemic had a huge impact on the civil aviation industry in China: The flight execution rate of key domestic air routes is less than 30% and more than 50 small and medium-sized airports have been suspended. This research then predicted the development of China's civil aviation market in 2020.

With urban rail transit as the research topic, this paper analyzes the spread of COVID-19 in China and its impact on the passenger volume of Shanghai rail transit. It discusses the severe challenges faced by the transportation industry in the modernization of the governance system and capacity and makes suggestions on the epidemic prevention and control of rail transit.

1 Changes in passenger demand of urban rail transit

The COVID-19 pandemic has spread across the nation and the resumption of work and school has been delayed, which led to the changes in the passenger volume of urban rail transit. As of April 6, 2020, the weekday passenger volume of the 16 rail transit lines under the jurisdiction of Beijing Subway is 3.119 million passengers per day, about 30% of the value before the pandemic; the weekend passenger volume is about 1.40 million passengers per day. The total passenger volume of the Guangzhou rail transit network is 5.194 million passengers per day on weekdays and less than 3.1 million passengers per day on weekends, about 50% of the value before the pandemic. The weekday passenger volume of the 10 lines under the jurisdiction of Nanjing Rail Transit is 1.993 million passengers per day, and the weekend passenger volume is about 1.3 million passengers per day, with passengers mainly concentrated on Line 1, Line 2 and Line 3. Compared with the passenger volume of urban rail transit during the peak of the pandemic, the current passenger volume is gradually recovering in the 41 cities that have resumed urban rail transit service.

Under normal circumstances, the daily passenger volume of Shanghai rail transit is 12 million passengers per day on weekdays and 8 million passengers per day on weekends. However, it exceeded 1 million only once between February 1 and 9, 2020. The average weekday passenger volume of each week from February 10 to April 3, 2020 is shown in Table 1.

Tab. 1 Weekly changes of average daily passenger volume of Shanghai rail transit

Week	Average weekday passenger volume/(10^4 passengers·d^{-1})	Increase from last week /(10^4 passengers·d^{-1})
February 10–14	120.7	
February 17–21	166.3	45.6
February 24–28	280.4	114.1
March 2–6	396.1	115.7
March 9–13	478.6	82.5
March 16–20	573.5	94.9
March 23–27	635.4	61.9
March 30–April 3	692.8	57.4

Source: the official Weibo page of Shanghai Shentong Metro Group Co., Ltd.

Fig. 1 shows that early January 2020 was the incubation period of COVID-19, and the passenger volume was basically stable. The COVID-19 was spreading between middle and late January to middle and late February, and the passenger volume plunged sharply from more than 10 million passengers per day to less than 1 million passengers per day, with a drop of 90%. The situation has been effectively controlled since March. The passenger volume gradually picked up and the average daily passenger volume recovered to half of the pre-pandemic level at the end of March. However, the resumption of work and school has brought new challenges to the operation of urban rail transit.

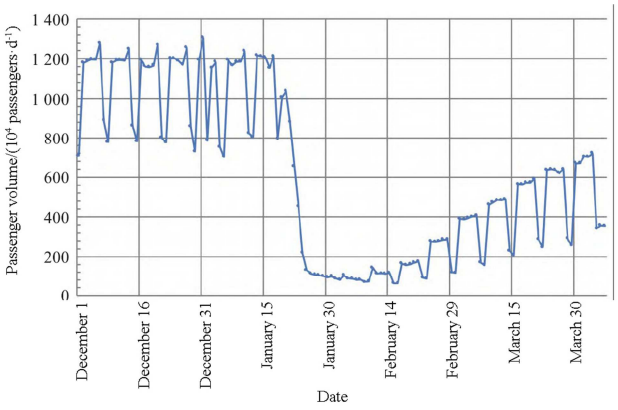

Fig. 1 Trend of daily passenger volume of Shanghai rail transit

Source: the official Weibo page of Shanghai Shentong Metro Group Co., Ltd.

2 Challenges to urban rail transit

As an important component of urban public transportation, urban rail transit should take the lead in achieving a breakthrough in modern epidemic prevention and control and accumulate experience to promote epidemic prevention and control for other modes of transportation. In the face of the sharp recovery of passenger demand brought by the resumption of work and the upcoming resumption of school, the rail

transit operation departments in Nanjing, Hangzhou and some other cities have made preliminary adjustments. As an international metropolis with a population of more than 24 million, Shanghai is facing more pressure to recover the operation of urban rail transit.

1) Epidemic prevention and control

To effectively prevent and control the COVID-19 pandemic in Shanghai and to serve the passengers who return after the Spring Festival or after the resumption of work, Shanghai required all people to properly wear masks in public places. On February 3, 2020, Shanghai started to screen passengers' temperatures before they enter the station at nine rail transit stations. The number of rail transit stations where temperature screening is required increased to 106 on February 8, 2020 and reached 354 as of February 11, 2020. The main problems of temperature screening include the long queue of people waiting at the entrance of a station, the long waiting time to enter a station, and the heavy workload on staff responsible for temperature measurement.

On February 28, 2020, Shanghai started "registering rail transit passengers by scanning codes." This measure allows relevant departments to contact and trace the close contacts in time after receiving the notification of confirmed infections. Due to the lack of prominent signs at the entrance and in the subway, many passengers have not realized this measure and failed to cooperate proactively. Therefore, this measure faces new challenges in terms of increasing publicity and education, raising the public's awareness, and strengthening cooperation and guidance by working with relevant departments.

2) Recovery of passenger demand due to the resumption of work

On the first day of the resumption of work (February 10, 2020), the rail transit passenger volume was 1.451 million passengers per day, less than 12% of the normal volume. As more and more people returned to Shanghai after the Spring Festival, the average daily passenger volume of rail transit reached 2.804 million passengers per day in the second week after the resumption of work. With more businesses reopened, the passenger volume increased faster. In the third week after the resumption of work, the average daily passenger volume of rail transit reached 3.961 million passengers per day, and the load factor of morning-peak trains on some lines, such as Line 6 and Line 8, rose rapidly and exceeded 50%.

During the COVID-19 pandemic, the spatial distribution of passengers in railway carriages was unbalanced on some rail lines. The passenger volume in some middle carriages increased temporarily, which resulted in congestion; while the first and the last carriages were not congested. Therefore, the main challenges brought by the increasing passenger volume include the heavy operation load of hub stations, the passenger demand control in areas with high load factors, the potential risk of cross infection among passengers, and the high work pressure on station security inspectors.

3) Large passenger volume during the peak period after the resumption of school

When this paper is drafted, the Ministry of Education of China has not announced the exact date to resume all levels of schools. Urban rail transit is the main transportation mode for parents and students when they travel to schools. Therefore, the resumption of school has a tremendous impact on urban rail transit, especially in the morning and evening peak periods.

Line 9 of Shanghai rail transit is taken as an example. This line passes through Songjiang District, Minhang District, Xuhui District, Huangpu District and Pudong New Area. It connects many important areas and passenger distribution centers, such as Songjiang University Town, Songjiang New Town, Lujiazui Finance and Trade Zone, and Century Avenue Hub, where passengers travel mainly for work or school. Once colleges and universities resume operations, the vast majority of students of the seven colleges and universities in Songjiang University Town would choose to travel by rail transit, and the peak hour passenger volume would be as high as 12,000 passengers per hour. In addition, the start time for elementary and middle schools concentrates at 7:00–9:00 and the end time at 16:00–18:00, and stations with large passenger volume gather around schools, such as Sijing Station, Jiuting Station, and Sheshan Station [9]. The sketch map to show the operation of eastbound Line 9 and the distribution of its top five stations with the largest passenger volume is shown in Fig. 2.

After the resumption of work and with the upcoming resumption of school, the main challenges faced by the Shanghai rail transit system are the prevention of emergencies caused by stranded passengers, the avoidance of large passenger volume and the formulation of relevant policies in advance.

4) Operation recovery and adjustment

During the COVID-19 pandemic, many cities closed some of their rail transit stations, lines or even the whole rail transit network. On January 26, 2020, Shanghai suspended the rail transit operation between Huaqiao Station and Anting Station on Line 11. Starting from February 22, 2020, Shanghai rail transit Lines 2, 5, 7, 8 and 16 stopped operation earlier at 21:00. Since March 13, 2020, Shanghai rail transit had extended the hours of operation for Line 10 and cancelled the extended operation for Lines 1, 2, 7, 8, 9 and 13 on Fridays and Saturdays in order to ensure sufficient cleaning and disinfection time at night after the end of rail transit operation.

One of the challenges faced by the operation recovery of Shanghai rail transit is the temporary adjustment and recovery of the operation sections, hours and intervals of relevant rail transit lines. Another challenge is to improve the organization, analysis and evaluation system of large passenger flow and enhance the linkage mechanism of management, control and communication. It is also a challenge to comprehensively planning and balancing the passenger flow organization at the point, line and network levels in epidemic

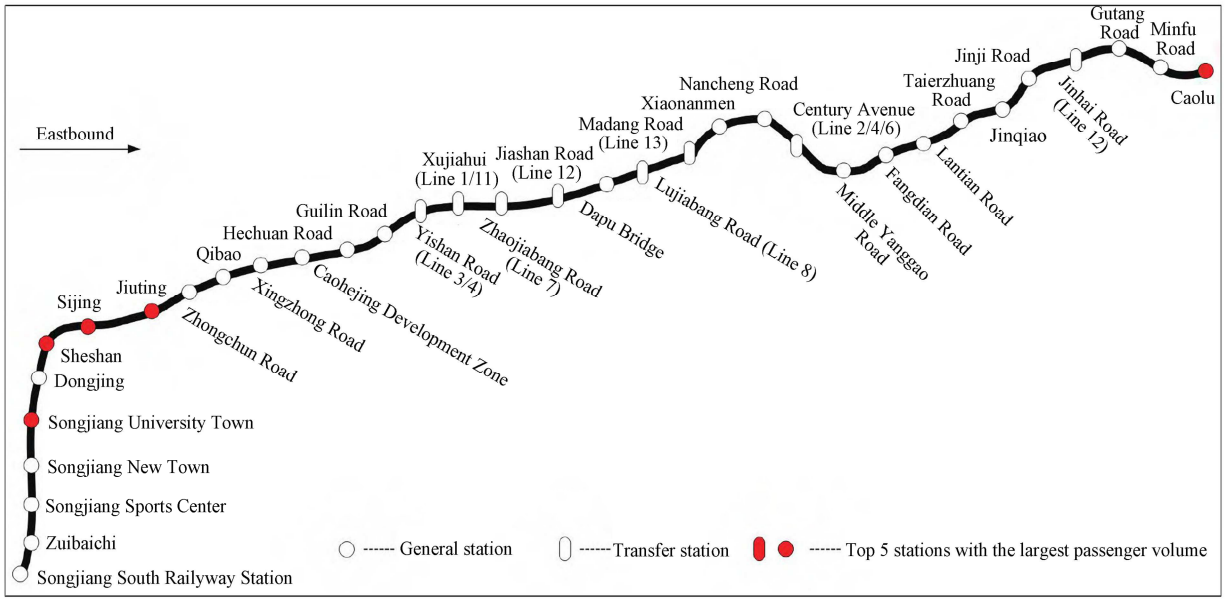

Fig. 2 Upward operation of Shanghai rail transit Line 9 and distribution of top passenger stations

Source: Reference [9].

prevention and control and in the management and control of large passenger flow.

3 Measures to mitigate the impact of passenger flow recovery

To resume operations safely and effectively, rail transit enterprises should cooperate with municipal departments and pay attention to epidemic prevention and control while resuming work. Efforts should be taken to minimize the impact of passenger flow recovery on rail transit operation in the post-pandemic period.

1) Further implementing epidemic prevention and control measures

According to *the Notice of Shanghai on Further Strengthening the Requirements of Environmental Cleaning and Disinfection of Rail Transit Stations and Vehicles*, it is suggested to strengthen the management and control of each station, enhance the management of rail transit staff, and reinforce cleaning and disinfection. The specific measures include prolonging the ventilation time of trains, stations, tunnels and workplaces and cleaning and disinfecting public areas regularly and more frequently, such as railings, seats and facilities inside trains and stations. The measures also include setting isolation areas in advance at each station to prevent and control the epidemic in time, promoting the education of epidemic prevention and control and enhancing passengers' awareness.

It is suggested to continue the requirement for passengers to scan the QR codes on railway carriages for registration, further strengthen and implement the health protection of rail transit staff, and minimize the unnecessary relocation of frontline staff. Staff at the key positions, such as drivers, dispatchers and station attendants, must be screened by checking their temperatures before their shifts. Frontline staff must wear masks when they are on duty.

2) Strengthening the early warning of large passenger volume and enhancing the organization and management of passenger flow

After the resumption of work, the passenger volume of the Shanghai rail transit system has recovered to 50% of the pre-pandemic level. It is necessary to actively respond to the growth trend of the passenger flow, pay close attention to its temporal and spatial distribution, and strengthen the guidance at the stations near universities, middle schools and elementary schools. It is also necessary to further improve the early warning mechanism of large passenger volume and make efforts to prevent the large passenger volume. Once it is found that the increase in passenger flow is beyond the predicted range and the station operation capacity, the early warning of large passenger volume should be issued immediately. In the meantime, passengers should be guided through various means, such as broadcasting, to choose other transportation modes.

Each passenger transportation department should arrange trainings from top to bottom for the early warning of large passenger volume as well as the epidemic prevention and control, so as to achieve the goal that "everyone knows and fulfills his/her responsibility." According to the situations and the unique attributes of each station and each rail line (for example, whether the station is a transfer station or an important transportation hub), it is suggested to adjust the number of working gates and escalators, lengthen the

walking time, avoid temporary passenger gatherings, and relieve the passenger flow pressure. It is also suggested to further improve the supporting infrastructure for passenger transportation, shorten the maintenance interval, and improve safety and comfortableness.

3) Carrying out dynamic analysis and scientifically allocating transportation capacity

The passenger flow situations should be summarized and analyzed every day after the daily operation is over, and the classification of stations should be refined based on the total daily passenger volume. It is suggested to strengthen the monitoring of on-site passenger flow, timely learn the public opinion of passengers, and implement dynamic management and accurate passenger flow restriction at each station of the rail transit network. It is also suggested to adjust the organization of trains and passengers flexibly so that the density of passenger flow and the load factor can be controlled. In terms of the organization of trains, the load factor of railway carriages should be controlled dynamically to implement epidemic prevention and control effectively. Various methods can be used, such as adjusting departure intervals and the dwell time at stations, dispatching more trains, and regulating the operational segments.

In addition to allocating transportation capacity according to the adjusted operation diagram, it is necessary to adjust transportation capacity dynamically based on the growth of the regional passenger flow. In the peak period, transportation capacity should be allocated based on the degree of passenger gathering at different stations so that the passenger flow intensity can be controlled at three different levels: station, line and network. Various methods can be used to allocate transportation capacity, such as skipping certain stations on a line.

4) Refining the management of the load factor of stations and carriages

It is suggested to meet the demand of large passenger flow in transportation hubs, accommodate commute and school travel during peak hours, and implement epidemic prevention. In addition, the emphasis is on strengthening the control of train load factors and reducing the risk of cross infection caused by the accumulation of stranded passengers. Once the load factor of carriages is too high, dynamic passenger-flow-limiting measures should be taken to strictly control the flow density of stations and carriages.

The recovery of passenger flow results in travel peaks in some areas. Some carriages might be crowded for a short time over certain rail transit line segments while the whole train is not crowded. Therefore, it is necessary to strengthen the guidance, suggest passengers to use different carriages, balance the passenger load, and encourage passengers to take initiative to keep a certain distance.

4 Conclusion

This paper analyzes the impact of the COVID-19 pandemic on the Shanghai rail transit system and summarizes the challenges faced by urban rail transit in the progress of modernization. The paper then proposes measures to restore urban rail transit operation in an orderly manner and prevent the surge of passenger flow when the pandemic is dissolving and passengers are returning to Shanghai due to the resumption of work and school. The COVID-19 pandemic has not ended completely yet in China, and its impact on urban rail transit still exists. It is still necessary to continue adhering to the principle of “avoiding being slack due to the downgrade of the alert level, being remiss in staying vigilant for the pandemic and loosening requirements on epidemic prevention and control.” A scientific, standardized and effective prevention mechanism should be built, and it can support the operation management department to make better decisions on epidemic prevention and control and modern governance.

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