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Resilience Management of Urban Public Transportation Under Public Health Emergencies

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Abstract: Public health emergencies often have a huge impact on conventional urban traffic management strategies. With the requirements of dynamic response and control under public health emergencies, urban public transportation not only serves as the main field for pandemic prevention but also the safeguard of economic recovery. By discussing the possibility of introducing resilient urban governance into management of public transportation operation, this paper proposes to improve urban transportation governance in several aspects: objectives, method, subjects, techniques, etc. Finally, the paper puts forward a three-step governance framework including response strategies, system capabilities, and practical tools for resilient governance of urban public transportation so as to achieve rapid response to public health emergencies. **DOI:** 10.13813/j.cn11-5141/u.2020.0044-en

Keywords: public health emergencies; dynamic prevention and control; resilience governance; public transportation

0 Introduction

With China's prevention and control of Coronavirus Disease 2019 (COVID-19) continue to improve, the main mission has changed from pandemic prevention and control to economic and social recovery. The requirement of prevention and control has also switched from static isolation to dynamic prevention and control. In this situation, Shanghai, as a megacity that serves comprehensive functions of economy, finance, international shipping and trade, and scientific innovation, is facing challenges to both defense and recovery.

As expected, with the continuous growth of economic activities, the transportation system serves as the veins of the city and will face real challenges. One of the challenges is the transition of public transportation from a low-activity state under the strict prevention and control to a dual role of "main battlefield" for epidemic prevention and "security line" for economic recovery. However, this dual role corresponds to opposite requirements of organization and management, such as stagnation versus activeness, as well as isolation versus connectivity. How to effectively coordinate these contradictory management strategies has become a difficult problem for urban public transportation.

The COVID-19 pandemic once again brought metropolitan areas into a high-risk situation with "substantial diversity and complication leading to increasing vulnerability"[1]. The demand for prosperity as well as security has become a common development baseline and a significant challenge for cities. With the great uncertainty, it is difficult to build an effective risk control "dam" by developing preventive measures and increasing redundancy under a conventional strategy. Therefore, the concept of resilient urban governance and related practices are gradually implemented to address the vulnerability of urban mega-systems, improve the ability of cities to cope with external challenges, and accelerate cities' ability of adaptive adjustment. Inspired by this resilient concept, it is helpful during the control period of the pandemic to solve the dilemma of current and future operation and guide the management of the public transportation through resilient urban governance.

1 The dual role of public transportation during the pandemic

1.1 "Main battlefield" of pandemic prevention and control

The characteristics of activities define the major role of public transportation during the economic recovery and pandemic control. With one-day travel activities of citizens as the example, the risk of virus transmission in public transit services is relatively high in the following types of space: residence, office, and social place and transportation.

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The epidemic dynamics model is $R_0 = n\beta_0 \frac{1}{\gamma} S_0$, where R_0 is the basic reproduction number, representing the number of infected persons by a patient during an average period of illness in the initial stage of disease outbreak; n is the number of contacts between any infected person and susceptible persons in unit time; β_0 is the probability of infection after contact between susceptible and infected persons (i.e., effective contact rate in percentage); $\frac{1}{\gamma}$ is the recovery rate per unit time (i.e., the average duration of disease /d); S_0 is the initial number of susceptible persons in a compartment model [2]. The crowd using public transit has high density and mobility, so n and β_0 are both higher than the other two types of space. In addition, due to the long incubation period of COVID-19 infection and the large number of patients with mild symptoms, some asymptomatic infected patients may travel normally; n and β_0 in the model will increase again as a result. Compared with residence under quarantine or office spaces with restrictions, public transportation spaces have greater potential of virus transmission.

Once a virus infection event occurs, compared with those in community and office spaces under lock-down or partial lock-down, travel trajectories and contact population involved in public transportation are more difficult to track in the pandemic investigation. Moreover, different from the management of fixed locations, the control of virus spread by managing a few stations in public transportation is very difficult, given that activities of confirmed cases may distribute through a network of transit.

1.2 "Security line" for economic recovery

With the increasing pace of reopening, the use of public transportation will inevitably present accelerated growth and serve as the "security line" for economic recovery. As a a national demonstration city for public transportation, Shanghai had an average daily transit volume of 17.822 million passengers in 2018. Rail transit (including maglev train), transit buses, and taxis account for 57.0%, 32.3%, and 9.8%, respectively [3] in public transportation. At the same time, the peak-hour congestion index of expressways continues to increase. The expressways in the central urban area operate at near capacity during peak hours. Once the pandemic prevention changes from static isolation to dynamic prevention and control, public transportation will become critical in urban commuting and business activities. Therefore, meeting the rigid needs of commuting and providing safe and reliable urban public transit services are necessary to ensure the accelerated recovery of economic and social activities as well as the enhanced public's confidence in urban governance.

2 Connotation of public transportation management in the context of resilient urban governance

With growing globalization and urbanization, the size and mobility of urban population continue to rise, and the consequences of various types of potential crises become increasingly serious and unpredictable. To address the risk of urban disasters, the United Nations launched the "Making Cities Resilient Campaign" in 2010 and further identified "Resilient City" as an innovative content of the *New Urban Agenda* at the Third United Nations Conference on Housing and Urban Sustainable Development in October, 2016[4]. Some cities have also initiated relevant practices of resilience strategy, such as the Rockefeller Foundation's "100 Resilient Cities Centennial Challenge," the New York's "Plan of Stronger and More Resilient Cities," and London's "Strategic Plan to Enhance Urban Resilience" [5]. Research institutions and scholars have also conducted a large amount of research on urban resilience, developing multiple increasingly rich definitions of concepts and analyses of connotations [6]. For example, Rockefeller Foundation believes that urban resilience refers to the ability of individuals, communities, institutions, enterprises, and systems in a city to survive, adapt, and grow under chronic and acute pressure [7]. On the basis of complex adaptation, resilient cities refer to those that can absorb the impact and pressure of future uncertainties on their society, economy, technological systems, and infrastructure, while maintaining their basic functions, structures, systems, and characteristics [8–9]. Although the interpretation of resilient cities in various fields has different characteristics, there are still certain general rules to identify. Linked to the field of urban public transportation and compared with the traditional operation modes, the connotation of resilience governance reflects the following four types of transitions:

1) In terms of meeting goals, resilience governance changes focus from restoring the old steady state to forming a new stable state.

With the concept of resilience governance, urban public transportation system has different stable states at different stages of external impact. Before the impact, the system is in an initial stable state. If the impact is within a tolerable range, the system tends to accommodate the impact and maintain a relatively stable state as much as possible through auxiliary measures; after the impact, the original stable state can be restored as soon as possible. However, if the impact is beyond the bearable range and the cost of maintaining the original steady state is too high, the system tends to move towards a new steady state through self-adjustment and improvement. In addition, after the adjustment, if the adaptive system has improved the ability to cope with the impact and optimize the operation efficiency, it will give up the original steady state and enter a new steady state. The target setting should be

more flexible in resilience governance to address infectious diseases with high diffusion capacity. The actual effect and input-output of restoring the old steady state should be considered, and a new steady state should also be included in the framework of target selection.

2) With regard to developing strategies, resilience governance gradually transfers from defensive response only to a combination of defense and adaptive adjustment.

In resilient governance, strengthening defense against unexpected disasters or external shocks is not the only choice. On the one hand, enhancing defense capacity cannot avoid high risk events; on the other hand, complete defensive response may result in a long term reduction or even a termination of service, which is harmful to economic activities. Therefore, in response to the impact, the system should incorporate adaptive adjustments at different stages of interference; such adjustments particularly include the absorption of the impact and an active transformation of the system itself. When the disturbance is small, the impact absorption can help ensure an independent balanced state and basic functions of the system; when the disturbance is large, it is necessary to modify the operation organization mode to address the vulnerable components and further maintain a new equilibrium state of the system.

3) As regards organizational management, resilience governance emphasizes the transition from top-down single system scheduling to improved self-organization efficiency.

Resilient cities, as organisms, emphasize self-organization and coordination. The units of different sizes within a city have the ability of self-support or mutual rescue in the process of coping with disasters. For example, New York's resilient city plan puts special focuses on developing community building capacity, promoting the participation of residents, non-profit organizations, and enterprises in emergency planning and exploring social cohesion as a strategy to enhance urban resilience [10]. In response to the external impact, public transportation system should offer opportunities for possible social organizations and enterprises to participate and maximize the governance benefits by expanding the operation subjects and reforming the industry management.

4) In regard to coping measures, resilience governance focuses on the transition from safety redundancy only to a combination of redundancy and diversity.

Resilient governance highlights the redundancy reserved in infrastructure; however, excessive security redundancy is not recommended. In an urban public transportation system, it is necessary to reserve parallel backup and self-repairing safety redundancy in rail transit, bus transit, and other transportation modes to cope with the external impact. It is also necessary to consider the overall cross-modal resource allocation and alternative measures, so that functional systems can jointly resist multiple risks and ensure basic travel needs of citizens under disturbance of external factors.

3 Resilience management framework of public transportation under public health emergencies

Since January 2020, public transportation systems in many cities have continuously adjusted prevention and control measures against COVID-19, implemented innovative approaches, and made substantial progress in improving the accuracy and effectiveness of pandemic prevention and control. For example, the approaches in Shanghai's subway system include measuring travelers' temperature at all station entrances, increasing the frequency of vehicle disinfection, publishing passenger flow information, adjusting capacity in a dynamic manner, and guiding some passengers to off-peak periods. In Shenzhen Metro, a real-name riding system has been implemented to tracking all passengers and efficiently identify the close contacts with suspected patients. In Jinan City, customized public transportation services have been offered to support business reopening with 215 special transit lines operated through online booking. These strict regulation and refined protection measures have suggested typical features of residence governance in public transportation. With reference to the experience in these cities, this paper summarizes the response path for urban resilience governance of public transportation under the demand of dynamic pandemic prevention and control (see Fig. 1).

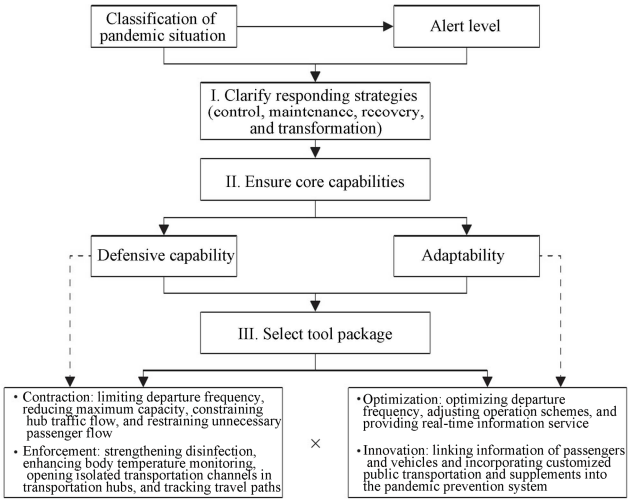

Fig. 1 Resilience governance framework of urban public transportation

1) Dynamic changes in pandemic risk levels should be taken as the basis to accurately identify transmission risk and develop response strategies.

Based on the alert level of virus transmission and the prevention process, the urban public transportation system needs to identify transmission risks and formulate response strategies under different pandemic risk levels. When the situation is at a high risk, the strategy for a resilient city should focus on preventing the virus from spreading within

the city, restricting export of infectious cases, and enforcing management and control [10]. The public transportation system should be quickly adjusted to constrain passenger flow. Regional traffic control or even termination of transit operation under legal enforcement should be implemented as needed. At the same time, high risk events can be eliminated or reduced through strict hygiene inspection and enhanced disinfection. In the medium risk stage, a key implementation strategy is to prevent the external infectious cases from entering the city and the virus from spreading within the city [11]. The public transportation system should incorporate a maintenance strategy to quickly adjust and form a systematic service plan matching the demand of prevention and control, ensure safe distance (at least 1 m) among passengers, and effectively reduce the capacity by shortening departure intervals and monitoring passengers flow on key transit lines. At important transportation hubs, enhancing trajectory tracking, isolating entry and exit channels, and transferring within a close loop can help reduce potential contact for vulnerable groups. When the pandemic transfers into the low risk state, the key strategy should focus on preventing impact from external infectious cases [11]. The public transportation system can gradually restore to providing basic services and reducing risk of travelers gathering through reservation and information sharing. After the pandemic, the public transportation system needs to identify and correct its vulnerability and improve its normal service plan.

2) Based on strategies at different stages of the pandemic, core capabilities of public transportation system should be identified.

Different from the traditional prevention and control, the strategies under resilient governance focus on the flexibility of coping resources, the diversity of coping tools, and the self-organization of participants. The system needs to maintain its basic operation under external shocks and address its vulnerability exposed in the event. The core competence under resilience governance mainly includes two aspects: One is the ability to defend against external shocks in terms of minimizing the possibility of occurrence risk and reducing disaster losses; the other is the ability to adapt to the external attack through maintaining basic service capabilities as much as possible and achieving a new balance in a short period of time. According to changes in classification of pandemic situation, the above two kinds of capabilities should be combined in a flexible manner.

3) After the stage-specific core competence is defined, the public transportation system needs to equip with appropriate response tools.

Through the application of policies and management tools associated with the defensive and adaptive capabilities, the interference of external shocks can be minimized and the dynamic evolution from the old steady state to a new steady state can be eventually realized. In general, mobilization of the rigid defense should be focused when the risk is high; in contrast, flexible adaptability should be enhanced when the risk is low.

With specific response tools, the defense capabilities are largely dependent on the contraction and enforcement strategies. Contraction strategies mainly coordinate with the overall defense strategy in high risk areas to restrain unnecessary passenger flow by appropriately reducing departure frequency, limiting capacity, and controlling flow at key transportation hubs. Enforcement strategies aim at effectively preventing import of external cases and reducing likelihood of contact and infection by strict disinfection procedures, enhanced body temperature inspection, and isolation of traffic at key transportation hubs. In addition, when the pandemic is in the widespread stage, public transportation services need to be terminated to effectively prevent the virus transmission.

Adaptability is primarily reflected in optimization and innovation strategies. Optimization strategies reduce passenger flow and density as well as transit transfer in through optimizing departure frequency (e.g., high frequency of platooning), operation (e.g., multi-routing operation and supplement of rail transit in high density section with bus transit), information service (e.g., pushing real-time capacity warning and booking bus service during peak time). Innovation strategies provide diversified options for the regular travel demand in the stage of pandemic prevention and recovery through innovative logos (e.g., real-name tracking system associated with transit cabin code), customized cooperation mode of public transportation (e.g., increasing the access to bus booking and enhancing information-sharing and cooperation with bus rental enterprises), and support of co-management in public transportation (e.g., providing disinfection procedures and health assistance for shared bicycles and online car rental platform). Meanwhile, the above strategies can also help to develop improvement ideas for the public transportation system to boost operation efficiency and mitigate congestion in the post-pandemic normal operation of economy and society.

4 Conclusion

Coordinated actions and close cooperation of all departments and organizations in an urban system are required to address the COVID-19 pandemic. This paper summarizes measures of the public transportation system in pursuit of resilient governance under pandemic prevention and control, considering the special role of urban public transportation system as the “main battlefield” of pandemic prevention and control as well as the “safeguard” of economic recovery. With the evolvement of the pandemic prevention and control and various challenges of health risks faced by the cities in the future, it is necessary to continue to understand the development pattern of public health emergencies, refine risk categories, and enrich professional means to improve flexibility of response plans. Addressing these issues will ensure that the urban public transportation system can actively adjust its structure to cope with complex risks and safeguard and energized cities under resilient development.

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