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Research on the Strategy of Preventing COVID-19in Urban Rail Transit in the Yangtze River Delta

HongzhiLi
School of Management, Shanghai University, Shanghai

ABSTRACT: *In the context of China's Yangtze River Delta integration policy, urban rail transit must not only prevent and control the* COVID-19 *epidemic, but also ensure the normal commuting needs of people under the construction of integrated transportation. It is a huge challenge to the urban rail transit operation emergency management system and emergency response capabilities. In addition to conventional disinfection, wearing masks and other epidemic prevention measures, it is also necessary to put forward targeted epidemic prevention strategies for practical problems. This article takes the urban rail transit in Shanghai as a case study to analyze the three major problems of the evacuation of large passenger flow at the current stage of urban rail transit, the easy spread of viruses in confined spaces, and the incomplete informationization of passengers. And for each problem, the passenger evacuation strategy, the confined space ventilation strategy, and the establishment of information sharing platform strategy suggestions were proposed to provide a reference for the construction of the urban rail transit epidemic prevention and control system in the Yangtze River Delta region.*

KEY WORD*: Yangtze River Delta, Urban Rail Transit, Virus Transmission, Epidemic Prevention and Control*

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I. INTRODUCTION

Since the 1990s, the world has gradually shown a trend of economic globalization and regional economic integration. At present, from the perspective of market integration development of the three major urban agglomerations in the Yangtze River Economic Belt in China, the Yangtze River Delta urban agglomeration has strong economic strength, high transportation accessibility, and developed information networks, and has now ranked among the six world-class urban agglomerations in the world. The Yangtze River Delta region is the traditional economic center of gravity, and advanced manufacturing industries such as biomedical science, integrated circuits, and high-end equipment are in a leading position in China. The industrial linkage between cities in the region is a development trend that enhances the comprehensive competitiveness of the region, which will inevitably induce large-scale personnel flows between cities in the region. Therefore, accelerating the construction of a modern comprehensive transportation system is the only way for the high-quality economic development of the Yangtze River Delta region. As a leader in the development of the Yangtze River Delta, Shanghai will accelerate the creation of an "excellent global city". Shanghai's urban rail transit is also actively and quickly connecting neighboring cities to help people circulate quickly. For example, Suzhou Metro S7 will seamlessly connect with Shanghai Metro Line 17, and rail transit line 11 will connect to Suzhou S1 line, and the rail transit connection will be realized from Putuo to Suzhou.

However, COVID-19 is still raging around the world at this stage. According to information on the official website of the Chinese Health Commission, as of 24:00 on May 18, 2020, 31 provinces (autonomous regions, municipalities) have 85 confirmed cases (including 10 severe cases). There were 4634 deaths, 82960 confirmed cases, 740428 close contacts, and 5054 close contacts under medical observation. And according to Professor Zhang Wenhong's prediction, the virus will not end due to high temperatures in the summer of 2020, and a new peak of the epidemic may be triggered in November. After the outbreak of the epidemic in December 2019, in order to avoid the gathering of people and cross-regional movement, the Chinese government has decisively adopted powerful control measures such as closing the city in the hardest-hit area, cutting off all public transportation, extending the Spring Festival holiday, and quarantining at home. However, since February 2020, the resumption of work and production and school has fully activated the comprehensive transportation network in the Yangtze River Delta. In the next few months, the transportation network with Shanghai as its core is bound to usher in a new round of passenger flow peaks, which will once again face severe challenges in the prevention and control of the epidemic in cities in the Yangtze River Delta and even across the country.

Urban rail transit is the main way for people to travel. The passenger traffic of London, New York, Paris, and Tokyo respectively account for 40%, 60%, 70% and 80% of the total urban passenger traffic. Shanghai urban rail transit accounts for about 54% of the passenger flow of public transportation, and it has the characteristics of multiple stations, long routes, dense passenger flow, and closed space. It is a passenger transportation mode with a high risk of virus transmission. Under the requirements of transportation integration in the Yangtze River Delta, in the face of the COVID-19epidemic, urban rail transit operations need to effectively block the spread of the epidemic while ensuring people's rigid travel needs. How to effectively cope with multiple pressures such as the recent resumption of work and production, students returning to school, and normal commuting to create a safe and secure travel environment for the general public is a major problem that the rail transit management department needs to solve. This research aims to take Shanghai's rail transit status and problems as a starting point under the background of the integration of the Yangtze River Delta, learn from the effective rail transit epidemic prevention experience of other cities, and propose an urban rail transit epidemic prevention strategy in the Yangtze River Delta based on the theory of transportation integration.

II. LITERATURE REVIEW

Research results onCOVID-19 are mainly concentrated in the fields of epidemiology, virology, and medicine. In addition to these three areas, research on infectious diseases in transportation networks has also achieved more results. The focus is mainly divided into research on the complex relationship between infectious diseases and transportation networks, and research on prevention and control strategies for traffic epidemics.

In the field of research on the relationship between infectious diseases and transportation networks, Cooley divides subway passengers into commuters, shoppers, and various travelers. Through the SEIR disease model, he found that the proportion of subway passengers infected between 4% and 5%[1]. By referring to reports of infectious diseases spreading infections on airplanes, Hertzberg found that passengers sitting in two rows of infected individuals have a 6% risk, and passengers sitting two rows of infected individuals have a 2% risk [2]. Zhang Yu built a dynamic spread model of infectious diseases in a complex social transportation network based on the Markov chain model. The experimental results found that the results of calculating the spread of infectious diseases are positively correlated with actual case data [3]. Li Zhengguang established an infectious disease dynamics model that relies on the migration rate of traffic flow, and found that population movement will make cities with more developed traffic have more infected people, and it is easier to promote disease outbreaks [4]. Dai Xiaoxu took the analysis of the similarity between the spread of air traffic congestion and the spread of infectious diseases as a starting point, and referred to the SIR model of infectious diseases, established an air traffic congestion transmission model, and explained the influence of congestion transmission influence factors and dissipation factors on the congestion transmission process[5].

In terms of public transportation epidemic prevention and control, research on COVID-19 involves many fields such as buses, rail transit, shipping, and water transportation. Aiming at the bus traffic during the recovery period of the epidemic, Liu Haiping proposed coping strategies from reducing the number of susceptible people in the car, preventing the occurrence of infections in the car, shortening the exposure time in the car, and optimizing ventilation conditions [6]. Feng Xujie analyzed the impact of the COVID-19 epidemic on the operation of urban rail transit from three aspects: transportation services, business operations, and emergency response, and put forward countermeasures [7]. Shen Yingying analyzed the epidemic prevention and control measures of various urban rail transit operating companies by comparing the time for the first reported epidemic prevention and control of urban rail transit operating companies in various regions with the first-level response time of major public health emergencies in various provinces and cities [8]. Zhou Jibiao and others proposed that the urban public transportation system should adopt a combined epidemic prevention strategy based on local actual conditions and risk assessment levels[9]. Zuo Qi and others systematically put forward response strategies from the aspects of urban traffic supply, demand, dynamic and static management, etc., to provide reference for traffic management and decision-making in Wuhan during special periods [10].

At present, there are many research results on the complex relationship between infectious diseases and transportation networks and the prevention and control of public transportation epidemics, but there are no articles on emergency management strategies for rail transit in the linkage area. In the face of the epidemic, an efficient rail transit system plays an important supporting role in the prevention and control of the epidemic in the Yangtze River Delta. Faced with multiple pressures such as the resumption of work and production, students returning to school and normal commuting, rail transit management departments need to formulate unusual emergency traffic management strategies in addition to regular traffic organization and control measures. This study takes the current situation and problems of Shanghai rail transit epidemic prevention under the integration of the Yangtze River Delta as the starting point, refers to the emergency prevention strategies proposed in the existing literature, and proposes the urban rail transit epidemic prevention strategy under the COVID-19epidemic in Shanghai based on the theory of transportation integration.

III. PROBLEM DESCRIPTION

Since the outbreak of the epidemic, the rail transit department has adopted a variety of epidemic prevention measures. For example, subway cleaning and disinfection is adjusted from once a day at night to deep cleaning and spraying disinfection every time the train enters the warehouse. However, in general, the Yangtze River

Delta Rail Transit still faces the following problems in the three stages of preventing the source of infection, blocking the spread of the virus in the station, and tracing suspicious cases in the integrated epidemic prevention process.

(1) Evacuation of large passenger flows on the return journey is a great challenge. Controlling the spread of the epidemic requires controlling the source of infection and the number of susceptible people at the source. Faced with the contradiction of high housing prices in Shanghai but with more job opportunities, non-Shanghai residents working in Shanghai and buying properties in surrounding areas have become an important form of alleviating this pressure. The daily commuting between Shanghai and surrounding cities has undoubtedly greatly increased the transportation pressure of rail transit. The space of rail transit stations is limited, and the evacuation of passenger flows can only rely on the exit population, transfer channels and the carrying capacity of the train itself. When the local passenger flow is crowded and the passenger flow is accumulated and the rapid evacuation is not possible, a large passenger flow phenomenon will occur [11]. With the resumption of work and production and school, a large amount of travel demand will cause the passenger flow in the subway section to continue to peak. The subway must ensure sufficient transportation capacity and effectively prevent crowds from gathering to control the spread of the epidemic from the source. Therefore, how to scientifically and reasonably evacuate the coming large passenger flow is a major problem faced during the epidemic.

(2) Virus spreads more easily in confined spaces. The Chinese Health Commission pointed out three ways of transmission of the new coronavirus: direct transmission, aerosol transmission, and contact transmission. The transmission characteristics of ordinary contact infectious diseases are single-dimensional linear, while when the new coronavirus spreads through aerosols, it will show three-dimensional diffusion, that is, without external interference, the virus spreads to the surrounding area until the concentration reaches a dynamic equilibrium. [12]. The rail transit compartment space is relatively closed, and air can circulate freely only during the time period when the car doors are opened when arriving at the station. Such a confined space undoubtedly increases the risk of virus infection. Therefore, how to adopt a fast, effective and reliable solution to reduce the droplet concentration and block the spread of the virus is a problem worthy of study.

(3) Passenger information is not perfect. Once a suspicious case is discovered, tracing the passenger's track and passenger information is a necessary means to control the epidemic. Because the COVID-19virus has the characteristics of human-to-human transmission, the incubation period is as long as 14 days, and the asymptomatic infection is an "invisible" source of infection, which makes it difficult to know the transmission path of the source of infection. Even if the infected person has symptoms, there is no guarantee that they will report their driving tracks truthfully. Therefore, how to use the information platform to track passengers' travel information and realize the information recording, storage, query and backtracking of the entire process of passengers taking rail transit to form "early warning" data is an important responsibility of the rail transit epidemic prevention and control departments.

IV. SPECIFIC CONTROL INDICATORS FOR URBAN RAIL TRANSITN EPIDEMIC PREVENTION

According to current research findings, the main ways of transmission of the COVID-19 include respiratory droplet transmission, aerosol transmission and indirect contact transmission. Most urban rail transit stations are set underground, and the air circulation inside the carriages is slow, which is a confined space, which leads to a higher risk of droplet transmission and aerosol transmission. This study considers the analysis of the factors affecting the spread of the virus in confined spaces in the subway on the basis of exploring the mechanism of indoor transmission of infectious diseases, so as to block the spread of the COVID-19 virus in the subway to the greatest extent.Fennelly et al. [13] developed the classic Wells-Riley model into

$$P = \frac{C}{S} = 1 - \exp\left(-\frac{Ipqt\theta}{Q}\right)$$

In the formula,P is the probability of virus transmission; C is the number of newly infected persons in an outbreak; S is the total number of susceptible persons; I is the number of infections; q is the quanta of an infected person (the number of pathogens that cause a person to reach the least amount of disease) Number) production rate; p is the ventilation volume of the room; Q is the ventilation volume of the room; t is the exposure time, and θ (the value range is 0 to 1) is the permeability coefficient of the mask. When θ =1, it means that the droplet nuclei can fully penetrate into the human breathing area, and the mask does not work at all.

Analyzing the above formula, it is concluded that when the probability of spread of the virus P is certain, the number of sick people is proportional to the number of susceptible people. The virus transmission probability P is positively correlated with the number of infected people I, the amount of ventilation per person p, the quanta production rate of the infected person, the indoor exposure time t and the permeability coefficient of the mask, and there is a negative correlation with the outdoor ventilation Q. If the probability of virus transmission is certain, the total number of susceptible people can be reduced to reduce the number of new infections. If the probability of virus transmission is reduced, it can be achieved by reducing the number of infected people, reducing the amount of ventilation per person, reducing the quanta production rate of infected people, reducing indoor exposure time, reducing the permeability coefficient of masks, and increasing the room Ventilation.

Table 1: Control index

Target	Indicators
Reduce the number of infections	Reduce the number of susceptible people
Reduce the probability of spread	Reduce the number of infected people
	Reduce breathing ventilation
	Reduce the quanta production rate of infected people
	Reduce indoor exposure time
	Reduce the permeability coefficient of the mask
	Increase indoor ventilation

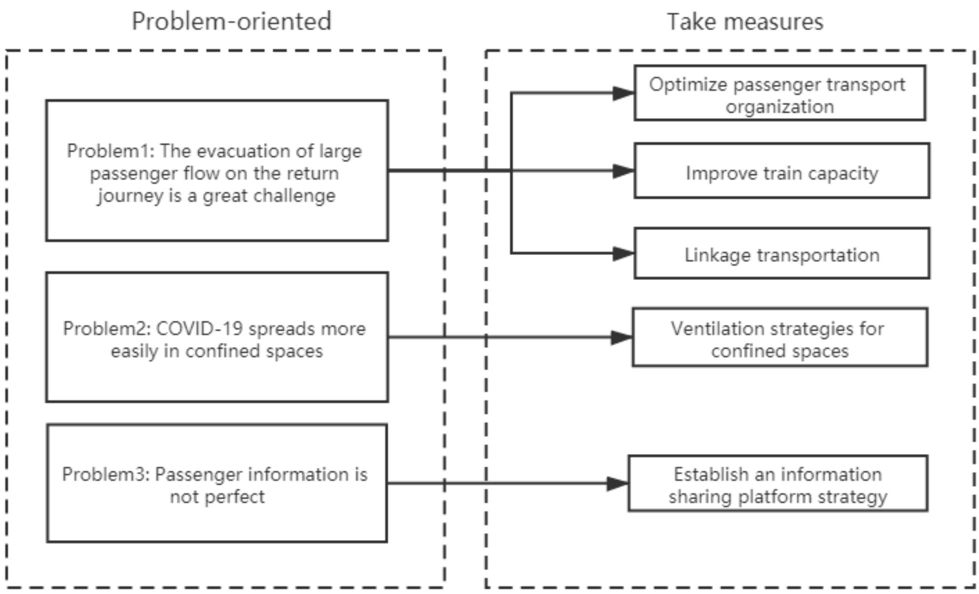
Source: Own

Reducing the permeability coefficient of a mask requires everyone to wear a mask with a higher protection coefficient to prevent droplets from spreading into the air. The information on the protection level of masks is cyclically broadcast on public screens in subway stations, calling on the public to choose higher-level protective masks. The most effective way to reduce the number of susceptible people, reduce the number of infected people, and reduce indoor exposure time is to evacuate the passenger flow as soon as possible. Reducing the amount of ventilation per person is not in line with the reality and will not be discussed. Increasing the amount of indoor ventilation requires increasing the amount of air exchange in the subway.

V. SPECIFIC EPIDEMIC PREVENTION MEASURES FOR URBAN RAIL TRANSIT

Urban transportation integration is the organic combination of different types of public transportation modes through the integration of the technology, management, policy, and information of the public transportation system to form a resource-sharing urban public transportation system. The integrated construction of rail transit should start from the comprehensive transportation network, so that the resources among the regional public transportation networks can be rationally allocated, and the operation efficiency of the entire transportation system should be improved. Based on specific control indicators for epidemic prevention, this study proposes urban rail transit epidemic prevention measures for specific issues.

Figure 1: Problem-oriented Rail Transit Epidemic Prevention Measures



Source: Own

5.1Passenger Flow Evacuation Strategy

Controlling the source of infection and the number of susceptible people at the source requires rapid evacuation of passengers gathered at densely-traveled stations. The flow of people from surrounding cities to the center of Shanghai presents a sparse-dense-sparse-dense trend. Two relatively dense areas are the connection points between Shanghai and major cities, such as the connection point between Shanghai and Suzhou-Huaqiao, and Shanghai Central areas, such as People's Square Station. The connection nodes can be opened up and people from high-density areas in the Yangtze River Delta can be quickly drained to low-density areas to alleviate the over-crowding situation. The rail transit management department should implement passenger flow evacuation strategies at densely populated sites in Shanghai, and effectively evacuate the flow of people by optimizing passenger transportation organization, increasing train carrying capacity, and linked transportation.

5.11 Optimize Passenger Transport Organization

(1) Information promotion. When the crowd gathers in the platform, the crowd may cause panic and nervousness of passengers. This requires relatively complete information propaganda and sign guidance to evacuate and guide passengers, so that passengers can realize that the subway environment is very safe, to a large extent, to reduce passengers' panic, and to improve the public's common sense of prevention. Relevant departments can guide the flow of passengers to quickly enter, leave and transfer stations by setting up guide signs, broadcast anti-epidemic videos on TV screens, LED door plaques and electronic screens at station entrances and exits, and release anti-epidemic slogans and epidemic prevention information. At the same time, posters, videos and other methods are used to show the mental outlook of medical staff, volunteers, public security police, subway workers and other front-line personnel fighting the "epidemic".

(2) Hierarchical guidance of passenger flow. When the passenger flow reaches the bottleneck node, it may be due to the cross and convection of the passenger flow that passengers cannot walk to the destination point in an orderly manner. A classification system can be established for the intensity of the passenger flow. The flow limit follows the principle of "from bottom to top, from inside to outside", and thresholds are set according to passenger flow. When the intensity of the passenger flow reaches the first level, two isolation belts can be set for the subway station with conflicting passenger flow. This isolation belt separates the stairs into three areas. The middle area is for passengers to walk in the direction of the city during the morning rush hour, and the areas on both sides are for passengers to walk in the direction of going out of the city. During the evening rush hour, the middle area is for passengers to walk out of the city, and the two areas are for passengers to walk into the city. When the intensity of the passenger flow reaches the second level, snake-shaped railings are set up at the gates to guide passengers to queue in an orderly manner. When the passenger flow intensity reaches level three, guide passengers to queue outside the station to enter the station. Since the outside of the station is an open space, and the inside of the station and the train are enclosed spaces, the flow restriction outside the station can maintain air circulation, which is not conducive to the spread of the virus.

(3) Road network transfer adjustment. As of 2017, the total number of transfer stations in Shanghai's rail transit network is 52, and the average station interval between transfer stations has been reduced to 3 to 4 stations. Transfer travel has become more and more convenient. The information technology department monitors the congested stations in the road network in real time, and calculates the optimal transfer route through optimization algorithms. The final optimization result is displayed on the public screen in the station in real time through the red for congestion and green for unobstructed labeling, so as to promptly guide and suggest passengers to choose the best route to avoid crowded areas.

5.12 Improve Train Capacity

Transport capacity is the description of the subway's ability to transport passengers. When the large passenger flow that may occur at the congested stations is predicted, the subway capacity should be increased in time. For the high full-load rate section, according to the actual situation, the overall capacity of the subway station is improved by adjusting the stop time and minutes, adding spare vehicles, shortening the departure interval, and rationally organizing the cross operation of the trains across the entire network.

5.13 Linkage Transportation

During the peak period of resumption of work and production, the public transportation management department of the Yangtze River Delta region can activate the corresponding level of passenger flow linkage transportation mode according to the actual situation of passenger flow. Cooperate with other public transportation on the ground to make a good response, and realize point-to-point barrier-free transportation in the area according to the needs of resumption of work. At present, the commonly used ground transportation emergency vehicles mainly include: buses, taxis, etc. Taxi traffic is small and the driver's subjectivity is strong, so the bus is the most suitable emergency connection vehicle. Start the public transportation connection plan, publish the location and frequency information of the connection vehicles on the shared platform in real time, and set up emergency public transportation stations near the rail transit stations. Connect passengers from the departure point to the nearest subway station, minimize the exposure time of passengers, and quickly and effectively transport passengers to the destination. In this way, the seamless connection between public transportation and rail transit is realized, and the transportation capacity of the entire public transportation network is improved. For example, within 500 meters of the Shanghai Railway Station Metro Station, there are ten bus stations including Shanghai Railway Station (North Square), Shanghai Railway Station (Zhongxing Road), Zhongxing Road Jiashan Road, Tianmu Middle Road Datong Road, and Shanghai Coach Terminal. There are 53 bus lines at ten stations, and they are divergent. Bridges extending in all directions have been built to reach the major districts of Shanghai. This diversity of public transportation provides passengers with multiple choices, and also provides conditions for rail transit departments to formulate emergency connection strategies.

5.2 Ventilation Strategies for Confined Spaces

The ventilation volume of the room can be increased by changing the location and direction of air conditioning and increasing the intensity of air supply. In his master's thesis, Ji Yichen used Fluent software to simulate the evaporation and movement of the exhaled droplets from a source of infection standing in a confined space. Research results show that higher relative humidity can significantly delay the evaporation process of droplets [14]. In addition, Wang Ruiyan found through simulation experiments that when the piston wind in the subway encounters the pillars in the platform, elevators and other facilities, it will produce a long-lasting eddy current [15]. In response to the research in the existing literature, the following epidemic prevention measures are proposed: increase the air supply of the train air conditioner, continuously monitor the relative humidity in the carriage, and ensure that the humidity is reduced through the air conditioning dehumidification function under high relative humidity conditions. At the same time, strengthen the cleaning management of the station infrastructure, and regularly use ultraviolet rays to disinfect the platform columns, escalators, straight ladders, staircase entrances and exits, corners and other areas. It is also necessary to focus on the sanitation and cleaning of the outdoor fans of the stations. The pipes of the station’s air-conditioning and ventilation systems need to be cleaned at regular intervals to ensure clean air in the compartments and to a certain extent to reduce the spread of viruses through the ventilation system.

5.3 Establish an Information Sharing Platform Strategy

The world has entered the era of artificial intelligence + big data + cloud computing, and the intelligentization of transportation is an inevitable trend. The "Outline of the Yangtze River Delta Integrated Development Plan" proposes that cities in the Yangtze River Delta should coordinate the construction of a new generation of information infrastructure, vigorously develop professional services based on the Internet of Things, big data, and artificial intelligence, and enhance the integrated development of various fields, informatization coordination and refinement management. Speed up the sharing of government affairs data resources in the Yangtze River Delta, improve the level of government public services, and jointly create a "digital Yangtze River Delta".

During the epidemic, based on the requirements for the intelligent construction of traffic information in the Yangtze River Delta, we can provide travelers with cross-regional travel routes and travel plans in the Yangtze River Delta region by mastering personal information, OD distribution, and travel trajectories of the inter-city population. The management department can establish a regional information collaboration platform for external rail transit and urban internal rail transit, forming a whole travel chain information collection + big data analysis prevention and control system. Build a comprehensive traffic information service website in the Yangtze River Delta, and provide mobile terminal information services based on smart phones and vehicle-mounted terminals. Integrate long-distance passenger line information, rail transit lines and other information, and enterprises and schools will uniformly submit employee return information to the website. The public transportation management department can customize the transportation route of bus + subway based on different passenger demand information. Implement targeted transportation strategies in the form of "shared subway" and "shared bus". For daily commuting passengers, the real-name ride system is implemented. Passengers can only scan the codes through real-name authentication methods such as Metro and Alipay. At the same time, increase train service personnel at the entrance to assist people who are not proficient in using smart phones to manually register. For each passenger, a scanning code registration system shall be implemented, and information such as subway lines, carriages, travel time, bus schedules, license plates and other information shall be reported truthfully. These data are aggregated on the information sharing platform in real time. Once a suspicious case is found, the relevant departments can quickly trace the information of the bus route, and notify the passengers in the same compartment for home isolation as soon as possible.

VI. CONCLUSION

The urban rail transit system is the stent that supports the operation of the city and the basic guarantee for people's daily commuting. The prevention and control of the COVID-19 epidemic in 2020 is a huge challenge to the emergency management system and emergency response capabilities of urban rail transit operations. In the context of the integration of transportation in the Yangtze River Delta, this paper takes Shanghai urban rail transit as an example to analyze the three major problems of urban rail transit at this stage: the evacuation of large return passenger flows, the easy spread of viruses in confined spaces, and the insufficient degree of passenger information. Driven by problem-oriented, targeted strategies and suggestions for the orderly resumption of urban rail transit operations have been put forward to provide a reference for the construction of an urban rail transit epidemic prevention and control system in the Yangtze River Delta.

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