Study on Urban Rail Transit Passenger Flow Analysis and Economic Improvement Strategy

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Abstract: This study takes the analysis of traffic passenger flow from the perspective of commuting as the research object, and selects Suzhou rail transit as a thematic research case. Based on the analysis of the "Annual Commuter Monitoring Report of China's Major Cities 2022" and the research of Suzhou rail transit, the following conclusions are drawn: First, rail construction should take the service of commuter passenger flow as the core, emphasize the fit between line direction and commuting demand, so as to improve economy. Second, Improving the leading role of rail transit and the efficiency of the whole process is the key, and attention should be paid to the improvement of the transportation mode structure and the efficiency of "door-to-door" service. Third, rail transit should guide urban development, pay attention to function matching, in particular, attention should be paid to the balance between employment and housing of rail lines and guaranteed housing for youth, so as to promote the economic development and community stability of the city. Finally, the paper puts forward some measures to improve rail commuter coverage, including the establishment of an interactive monitoring platform between rail construction and urban development, so as to support the improvement of rail commuter coverage.

Keywords: Commuting Perspective; Rail Transit; Efficiency Improvement; Urban Development; Transit-Oriented-Development

1. Introduction

At present, many big cities of our country are embarking on the planning and construction of rail transit. In the field of traffic science, the research on rail transit network planning technology is also in full swing [1,2]. Urban rail transit is an independent rail transit system, which is not affected by the ground road conditions and can operate normally according to the designed capacity, so as to transport passengers quickly, safely and comfortably [3,4]. Urban rail transit has high efficiency, no pollution, and can realize the requirements of large volume of transportation, which has good social and economic benefits.

Urban rail transit is a rail transit, and its transportation organization, function realization and safety guarantee should follow the objective law of rail transit. In transportation organization, we should implement centralized dispatching, unified command, and organize driving according to the running chart. In terms of function realization, the relevant professional such as tunnel, line, power supply, vehicle, communication, signal, station mechanical and electrical equipment and fire protection system should be ensured in good condition and normal operation; In terms of safety assurance, it mainly relies on driving organization and normal operation of equipment to ensure necessary running intervals and correct running routes [5-7].

In order to ensure the safety and on-time operation of urban rail transit trains, under the principle of centralized scheduling and unified command, running organization, equipment, vehicle maintenance, equipment operation management, and safety assurance are regulated by a series of rules and regulations. Urban rail transit is a multi-professional multi-work cooperation, around the center of safe driving and composed of orderly linkage, highly effective system. In urban rail transit, various automation equipment with electronic computer processing technology as the core has been adopted to replace manual, mechanical and electrical driving organization, equipment operation and safety assurance systems [8-10]. For example, ATC (automatic train control) system can realize automatic train driving, automatic tracking, automatic scheduling; SCADA (Power supply system Management Automation) system can achieve the main substation, traction substation, buck substation equipment system remote control, remote communication, telemetry; BAS (Environmental Monitoring System) and FAS (Fire alarm system) can realize the automation of station environmental control and fire and alarm system [10-12]. AFC (Automatic Ticket sale and Inspection system) can realize automatic ticket sale, inspection, classification and other functions. These systems form their own networks throughout the line, and all set central computers in the OCC (Control center) to implement unified command and hierarchical control [13,14].

From the perspective of the development law and demand of today's big cities and megacities, rail transit is alleviating the growing travel problems, thus forming passenger flow corridors and supporting and guiding urban space [15]. The planning, construction and operation of rail transit have changed the land characteristics and urban spatial structure along the line, attracted social and economic activities to the transportation corridor, extended the urban space, and changed the urban spatial layout [16]. With the development of rail transit network, a new urban spatial form with stations and transfer hubs as the core, lines and traffic corridors as the development axis, and rail and road networks as the coverage area has gradually taken shape [17,18].

The proportion of rail coverage and commuting emphasizes the alignment of line direction and commuting demand, reflecting the matching degree between rail transit and occupational and residential space [19]. In 2021, after the opening of Line 5, Suzhou rail station 800 meters will cover 20% of the commuter population, reaching the highest level in cities with the same population size. Suzhou rail transit has a high degree of compatibility with urban commuting demand [8]. How to enhance the leading role of rail transit and bring into play the benefits of rail construction? On the basis of the "2022 Commuter Monitoring Report of China's Major Cities" by China Academy of Urban Planning and Design, a special study on Suzhou rail transit was carried out, and the following three conclusions were reached: (1) Rail construction insists on serving commuter flow as the core; (2) Building a low-carbon transport system led by rail transit is the key; (3) Give full play to the role of rail in guiding urban development.

2. Rail Construction is Centered on Serving Commuter Passenger Flow

According to the "Commuter Monitoring Report of China's Major Cities", from December 2020 to the end of December 2021, nearly 1,700 kilometers of new subway and light rail lines have been opened across the country (700 kilometers in December 2020), and 32 of the 40 metro operating cities have added track mileage. However, the overall improvement of commuter benefit of rail coverage is limited, and the level of specific cities varies from high to low, so rail construction needs to improve the compatibility of commuter demand.

The total rail scale of the 40 metro cities in operation is nearly 9,000 kilometers, the mileage length increased by 20% year-on-year, and the average commuter proportion of 800 meters of track coverage is 17%, an increase of only 2 percentage points year-on-year, an increase of 3.4 million rail coverage commuters, and an average increase of 20,000 people for every 10 kilometers of new track lines. The overall benefit of railway construction needs to be improved.

2.1 Suzhou Rail Covers 20% of Urban Commuting, the highest in Cities of the Same Size

Suzhou's subway covers 20% of the urban commuter population, ranking 11th in the country and the highest level among cities with a population of 3-5 million. Of the 100 commuters in Suzhou, 20 live and work within 800 meters of a subway station. The high proportion of covering commuting indicates that the rail network has a high compatibility with urban occupational and residential space, and the potential passenger flow foundation is good. At present, the low passenger flow efficiency of some urban subways is precisely due to the spatial mismatch between track layout and commuting demand. As shown in Table 1 below.

In 2021, the city with the highest level of rail coverage commuting in China is Chengdu, with 650 km of track covering 34% of urban commuting, and Shanghai with 930 km of track covering 30% of urban commuting. The level of rail coverage in Hangzhou and Nanjing is lower than that in Suzhou, 19% and 16% respectively. The tracks in Wuxi and Changzhou are smaller, covering only 9% and 5% of commuters.

Table 1. Proportion of Commuter Population Covered by Typical Urban Rail Transit

city	Track scale (km)	Proportion of population covered by 800 meters of railway station (%)		
		commuting	Residential population	Employed population
Shanghai	936	30	44	56
Chengdu	652	34	52	61
Nangjing	443	16	31	42
Hangzhou	335	19	33	45
Suzhou	254	20	39	42
Wuxi	111	9	22	24

2.2 The Opening of Line 5 has Significantly Improved the Benefits of Rail Coverage Commuting

With the opening of Line 5, the proportion of Suzhou's rail coverage has increased from 15% to 20%, and the new operating mileage has increased by 40 kilometers, increasing the proportion of railway coverage commuters by 5%, and nearly 150,000 Suzhou residents have obtained the convenience of subway commuting. Line 5 has a high level of benefits for rail coverage commuting among newly opened lines in China.

Suzhou railway construction should adhere to the commuting trend to prevent the marginal benefit of rail coverage commuting with the expansion of the network scale. According to the analysis of new rail lines in 32 cities in 2020-2021: For cities with a network scale of 100-300 kilometers, the opening of new lines has a significant effect on improving commuting. On average, every additional 10 kilometers of operating mileage can increase 22,000-24,000 people for convenient rail commuting, increasing the proportion of rail coverage commuting by 0.8% to 1.0%. For cities with a scale of more than 300 kilometers, the coverage of urban trunk lines is basically formed, the proportion of peripheral extension lines in mileage increment is high, and the marginal benefit of rail construction on commuting improvement is reduced.

3. It is the Key to Improve the Whole Process Efficiency of the Leading role of Rail Transit

3.1 The Car Dominated Mode, Suzhou Commuter Traffic Carbon Emission Pressure

The carbon emission of Suzhou's one-way commuting traffic for 10,000 people is 6.5 tons, which is much higher than the average level of 5.4 tons in cities with a population of 3-5 million, and the pressure of commuter traffic carbon emission is great. The carbon emissions of a one-way commute for 10,000 people in Nanjing and Hangzhou are 4.8 tons and 5.9 tons respectively.

The car dominates the transportation mode and is the source of carbon emission pressure in Suzhou. Suzhou 1000 people car ownership of more than 400, the highest in the country. The proportion of car travel is more than 30%, which is at a relatively high level in domestic cities. Commuter transportation carbon emission is mainly determined by commuting distance, transportation mode structure and carbon emission factors per unit mileage of various vehicles. According to the "Beijing Low-carbon Travel Carbon Emission Reduction Methodology (Trial)", the per capita carbon dioxide emissions per unit mile of different transportation modes, car travel is 5 times that of ground public transport, and 10 times that of rail transit. The car-led mode of transportation will inevitably bring greater pressure of energy conservation and emission reduction, so it is necessary to pay attention to increasing the proportion of rail transit.

3.2 Suzhou Needs a High Standard of Track Leading the Full Service Efficiency

Suzhou's "door to door" bus efficiency is low, only 43% of the urban commuter population can commute within 45 minutes by bus and subway. At present, the highest level in China is Shenzhen, where 56% of the commuter population can be reached in 45 minutes by bus, and Hangzhou, Xi 'an and other cities can reach more than 45%.

To enhance the capacity of 45-minute bus commuter service, rail connection becomes the bottleneck. Chengdu, Wuhan and

Chongqing have achieved a rapid increase in the proportion of rail coverage commute, but the overall bus 45-minute commute guarantee ability has not been significantly improved, the proportion of time outside the orbital station accounted for a high proportion of the whole journey time, and the traffic connection has become the bottleneck of the overall bus service capacity improvement. According to Chengdu survey data, the comprehensive speed of the track mode is less than 15 km/h, and the station connection time accounts for more than 40% of the whole travel time.

Suzhou rail network density is low, there is no fast line, door to door rail travel speed is difficult to be higher than Chengdu. However, Suzhou peak hour road average speed can reach 22-24 km/h, car traffic efficiency in the domestic city is at a higher level. Suzhou needs a higher standard of door-to-door service efficiency to improve rail passenger flow and the competitiveness of rail transit and car modes, and shorten the full journey time of rail transit mode through the construction of express lines, operation optimization, and the integration of rail-bus-slow traffic.

4. Track Guide Urban Development Pays Attention to the Functional Matching of Tod

4.1 Rail Guide Urban Development, Pay Attention to the balance of Employment and Housing

From 2020 to 2021, the proportion of residential and employment population in the 10-kilometer circle of Suzhou city center will decrease by 1-2 percentage points, while the proportion of employment in the 15-kilometer circle will increase by 1.2 percentage points, and urban residential and employment functions will expand to the 15-kilometer circle.

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With the increase of commuting distance, the average one-way commuting distance of Suzhou in 2021 is 8.4 km, higher than the average of 7.8 km for cities of the same size, and an increase of 0.2 km from 2020. In Suzhou, 22% of the population commuted more than 10 kilometers each way, an increase of 3 percentage points from 2020, and the proportion of medium and long distance commuters showed an increasing trend.

The development of peripheral cities needs to rely on the efficiency improvement and corridor shaping under the guidance of rail transit. TOD is not only the high-intensity construction around the station, but more importantly, the urban spatial function is organized by the rail line, and the key development functions such as residence, employment and public service are determined from the perspective of balance. Shenzhen with 300 kilometers of track scale to support nearly 10 million commuters, the key lies in the balance of employment and housing, each line of residential population and employment is basically balanced, and "hub is the center" more than 50% of jobs concentrated in the rail transfer station with high accessibility.

4.2 Population Function Matching, Site Layout Youth Security Housing

Many cities are faced with the problem that the housing price is driven up by rail stations, and the population living around the stations does not match the population of rail passenger flow. According to the relevant research of the Suzhou Comprehensive Transportation System Planning in 2017, of the 1.5 million residents gathered within a 1km radius of Suzhou rail stations at that time, only 70,000 people took the subway every day.

Young people are the main body of rail transit passenger flow. In Beijing, more than 40% of the young commuters under the age of 35 live within the 800-meter radius of rail stations. According to the requirements of the Opinions on Carrying out the Pilot Construction of Youth Development-Oriented Cities issued by the relevant parts of the government, we should focus on optimizing and guaranteeing the basic housing needs of young people. From the perspective of youth development, we should focus on the distribution of affordable rental housing and common property housing and other housing security for young people around the track. Take Suzhou as an example, the more densely populated areas in Suzhou, the greater the distribution of rail passenger flow. At the same time, the rail station as the intermediate node of rail transit is also closely related to the nearby rent distribution. The closer the plate is to the station, the higher the rent is.

5. The Conclusion

In summary, this paper takes the rail passenger flow promotion strategy from the perspective of commuting as the research object, and takes Suzhou rail transit as the case to analyze the relevant aspects of rail coverage from the perspective of commuting. From the above analysis, the following measures can be taken to improve rail commuter coverage:

(1) Establish an interactive monitoring platform for rail construction and urban development. It integrates the portrait of rail transit passenger flow and the development status of land around the station, deeply explores the interactive relationship between rail passenger flow and TOD construction, and carries out TOD development and function update around the portrait of passenger flow.

(2) Strengthen the planning of low carbon transportation travel system led by rail transit. With the goal of reducing carbon in urban transportation, it focuses on the integrated development of rail, bus and slow traffic, evaluates the current situation and diagnoses problems, and forms a systematic plan from the aspects of transportation service system construction, facility space improvement, service standard determination, and policy and measure guarantee.

(3) Strengthen the research and investigation of rail transit passenger flow portrait and demand characteristics. By means of data and interview survey, we can deeply understand the service needs of rail passengers, and find out the factors that passengers choose subway and the reasons why they do not take subway. This paper focuses on mining the data characteristics of the whole journey chain of rail passengers from door to door, and the crowd portraits of rail passengers at different types of stations.

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References

[1] Zhang Yu-jie, Li Zong-ping. Subway passenger transport organization under the condition of large passenger flow. Journal of Transportation Engineering and Information, 2017, 15(2): 58-63, 70.
[2] Wang, Y. & Levinson, D. (2020). Measuring transit-oriented development in China's cities. Journal of Transport Geography, 86, 102761.
[3] Cao, X. & Yang, X. (2020). Transit ridership and neighborhood characteristics: Empirical evidence from Beijing, China. Transport Policy, 88, 69-79.
[4] Gu, J. & Li, Z. (2021). Modeling transit ridership with urban form, socioeconomic characteristics, and transit service attributes. Transportation Research Part A: Policy and Practice, 148, 60-77.
[5] Zeng Xiao-xu, Wang Lin, Luo Xian-di, et al. Application of oridinal clustering in the division of operation periods for urban rail transit. Urban Rapid Rail Transit, 2017, 30(2): 108-112.
[6] Chen Kuan-min, Yu Li-jie, Ma Chao-qun. Differentiated peak hours at urban rail transit stations in Xian. Urban Transportation of China, 2018, 16(5): 51-58, 7.
[7] Wang Wen-xian, Xiao Meng, Cheng Lin-na, et al. Classification of subway operation intervals based on affinity propagation cluster. Operation Research and Management Science, 2018,27(12): 187-192.
[8] LIANG Xuemei, FANG Xiaonong, YANG Shuo, et al. IMS technology in industry private network. Beijing: Ports & Telecom Press, 2016: 25.
[9] XU Peiwen, XIE Shuizhen, YANG Congbao. Softswitch and SIP Practical Technology M Beijing: China Machine Press, 2007: 5.
[10]WEN Yong-peng, ZHENG Xiao-ming, WU Ai-zhong, et al. Topology optimization of urban rail wheel based on BESO algorithm. Journal of Mechanical Engineering, 2020, 56(10): 191-199. (in Chinese).
[11]JU Yan-ni, LI Zhong-ping, CHEN Yu-

fan, et al. Study on node importance and failure recovery of regional rail transit system. Chinese Journal of Safety Science, 2021,31.(2): 112-119.

[12]PAN Shou-zheng, HE Jia, WANG Ying-ping, et al. On the influence of circle line on the resilience of subway network. Journal of Transportation Engineering and Information: 1-15(2021-09-16) [2022-05-07]. https://doi.org/10.19961/j.cnki. 1672-4747.2021.08.020.

[13]ZHANG Ling-tao. Research on the structure of China's high-speed railway network community based on complex network theory. Tangshan: North China University of Technology, 2021.

[14]XUE Feng, FAN Qian-li, LUO Jian. Optimization of rail transit industry chain based on multi-layer complex network. Journal of Transportation Engineering and Information, 201,19(2):65-73,83.

[15]XU Cheng-yong, TONG Xing. Research and counter-measures on metropolitan rail transit development. Modern Urban Rail Transit, 2022(3): 1-8.

[16]Ma Shibin, Yu Qiu-fu, Zhang Jing, et al. Technical research on pavement maintenance division based on ordered sample clustering. Journal of Hebei University of Technology, 2014, 43(5): 106-109.

[17]Chen Kuan-min, Yu Li-jie, Ma Chao-qun. Differentiated peak hours at urban rail transit stations in Xian. Urban Transportation of China, 2018, 16(5): 51-58, 7.

[18]Song Mei-yan, Wang liang, Zhu qin-xuan. Study on dynamic load of air-conditioning systems in subway stations based on hour-by-hour passenger flow. Journal of Southwest University of Science and Technology, 2022, 37(2): 58-63.

[19]Wang Chang, Jiang Xian-tong, Wu Yan-ping. Time division method of bus route resource allocation based on cluster analysis: a case study of Yantai. Transport Research, 2021, 7(5):35-42.