Passenger Flow Enhancement Strategies for Metro Operations

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Abstract. This paper introduces a comprehensive framework for passenger flow enhancement for metro operations. The proposed framework takes into account the state of urban transportation and the forecasting of passenger flow, based on which the internal and external influencing factors on passenger flow are analyzed. By utilizing the Suzhou Metro as a case study, specific strategies for enhancing passenger flow are suggested. This research contributes valuable insights and actionable strategies for metro systems, offering a holistic approach to address the challenges associated with passenger flow enhancement in metro system.

Keywords: Passenger flow enhancement; urban rail transit; metro operations

1. Introduction

Urbanization has led to an unprecedented growth in population density, making efficient public transportation systems crucial for sustaining metropolitan lifestyles[1-3]. The contemporary landscape of metro operations is marked by an intricate web of challenges, ranging from congestion and delays to the need for environmental sustainability[4-5]. In light of these complexities, the imperative to enhance passenger flow within metro operations becomes evident.

The burgeoning demand for metro services necessitates a comprehensive understanding of the intricate dynamics governing passenger movements. This understanding is derived from the wealth of data generated by metro systems, including but not limited to smart card transactions, video surveillance, and other sources[6]. These data sets serve as invaluable resources, offering insights into passenger behavior, traffic patterns, and potential areas for passenger flow enhancement.

This paper contributes to the discourse by introducing a metro passenger flow enhancement strategy analysis framework. The framework serves as a comprehensive tool for evaluating and devising strategies to enhance passenger flow within metro systems. To demonstrate its applicability, the framework is applied to a case study involving the metro system in Suzhou, China.

2. Metro Passenger Flow Enhancement Strategy Analysis Framework

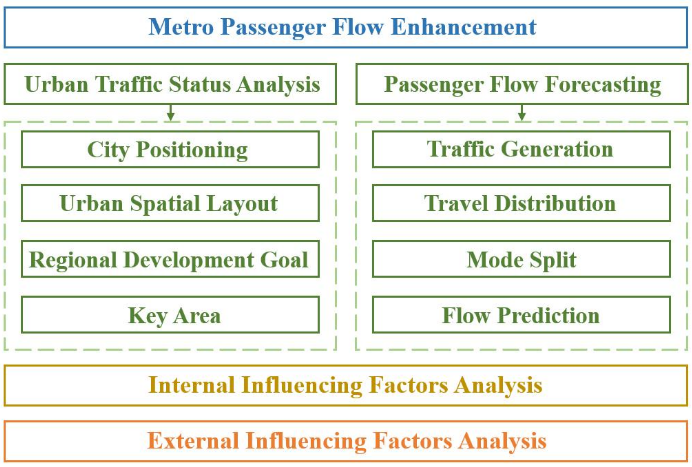

Figure 1. Technical Framework

The technical framework for strategic analysis is illustrated in Figure 1.

2.1 Urban Traffic Status Analysis

In the analysis framework for metro passenger flow enhancement, the initial step involves conducting an in-depth analysis of the current urban traffic status. This process encompasses an examination of the city positioning, spatial layout, regional development goals, and the construction plans for key areas.

City positioning refers to the city's role and position in overall economic and social development. This involves studying aspects such as the city's economic status, industrial structure, and cultural characteristics. Urban spatial layout involves the planning and organization of various regions within the city. Regional development goals outline the city's overall objectives and directions for future development over a specific period. The construction plans for key areas focus on the detailed planning of significant regions within the city. This may include central business districts, transportation hubs, densely populated areas, etc.

In conclusion, a comprehensive analysis of the city's current state provides a thorough and foundational basis for the metro passenger flow enhancement analysis framework. This groundwork establishes a solid theoretical foundation for subsequent research and proposals.

2.2 Metro Passenger Flow Forecasting

Traffic Generation: This initial stage involves understanding and estimating the generation of transportation demand in the city.

Travel Distribution: Travel distribution takes into account the spatial patterns of land use, the accessibility of various locations, and the attractiveness of different areas for commuters.

Mode Split: In the mode split stage, the focus is on understanding the preferences of commuters in choosing different modes of transportation. Factors like the availability, convenience, cost, and travel time of metro lines play a crucial role in determining the proportion of commuters opting for metro.

Flow Prediction: Historical data analysis, statistical models, and machine learning algorithms may be employed to forecast the expected number of passengers, considering the dynamic interplay of land use, social dynamics, population density, and transportation infrastructure.

By systematically progressing through these four stages, we can develop a comprehensive understanding of metro passenger flow patterns, allowing for the formulation of effective strategies to enhance the overall efficiency and capacity of the metro system. This process contributes crucial insights for the development of a robust metro passenger flow enhancement analysis framework.

2.3 Internal Influencing Factors Analysis

The core of internal influencing factors is the fare, which is crucial for boosting the overall passenger flow of the metro. With the acceleration of urbanization, the passenger volume of urban rail transit continues to rise, and the congestion during peak hours becomes increasingly severe. This leads to increased travel delays for passengers, reducing their willingness to use public transportation and rail transit. Urban rail transit operators commonly adopt measures such as increasing capacity and station flow control to restrict peak-hour flow, but they do not fundamentally reduce the travel demand during peak hours.

Therefore, based on the study of the characteristics of peak-hour and off-peak-hour flow within metro systems, designing a fare incentive strategy that considers users' metro travel behavior can guide passengers to adjust their departure times and travel by metro with different shifts,which helps to achieve the balance of peak-hour flow, alleviate congestion during peak hours, and increase the overall flow of the metro.

2.4 External Influencing Factors Analysis

The core of external influencing factors is the accessibility of metro lines.The accessibility of metro travel is mainly influenced by factors such as the origin and destination, travelers, and the transportation mode:

Origin and Destination Factors: The back-and-forth travel between the origin and destination needs to overcome spatial barriers. Citizens typically choose the shortest or quickest route for their commute. The more developed and dense a city's rail transit network is, the less transportation cost citizens will incur in reaching their destinations, resulting in higher accessibility levels.

Traveler's Personal Factors: Personal factors of travelers include age, occupation, personal preferences, and needs. Due to differences in economic levels and personal preferences, there may be variations in the choice of transportation. Additionally, policies promoting green and sustainable commuting in different cities can also impact the level of accessibility.

Inherent Attractiveness of Rail Transit: The attractiveness of rail transit depends on its capacity to provide travel services. This is influenced by factors such as fare prices, network density, types of rail transit vehicles, operating hours, frequency of trains, and station facilities. The stronger the attractiveness of rail transit, the more intense the desire of passengers to choose rail transit for their commute.

Surrounding Facilities of Rail Transit: Public service facilities, land use layout, and bus network density around rail transit stations also affect the accessibility of rail transit. If metro stations are located near well-developed areas with essential facilities such as residential neighborhoods, hospitals, schools, office buildings, malls, supermarkets, parks, and green spaces, there will be a higher demand for commuting due to the dense population and significant citizen travel needs. Conversely, if metro stations are in less populated areas, the travel demand will decrease, leading to a decrease in the accessibility level of rail transit.

Understanding these external factors is essential for evaluating and enhancing the overall accessibility of metro lines in urban areas.

3. Case study

3.1 Case Description

Suzhou Metro is an urban rail transit system serving Suzhou, China, and its first line, Suzhou Metro Line 1, was officially opened for operation on April 28, 2012. As of August 2018, Suzhou Metro operates three metro lines: Line 1, Line 2, and Line 4 (including a branch), comprising a total of 93 metro stations.

3.2 Passenger Flow Enhancement Strategies for Suzhou Metro

According to the framework proposed in this paper, the following passenger flow enhancement strategies are proposed based on the current situation of Suzhou Metro operation, as shown in Figure 2.

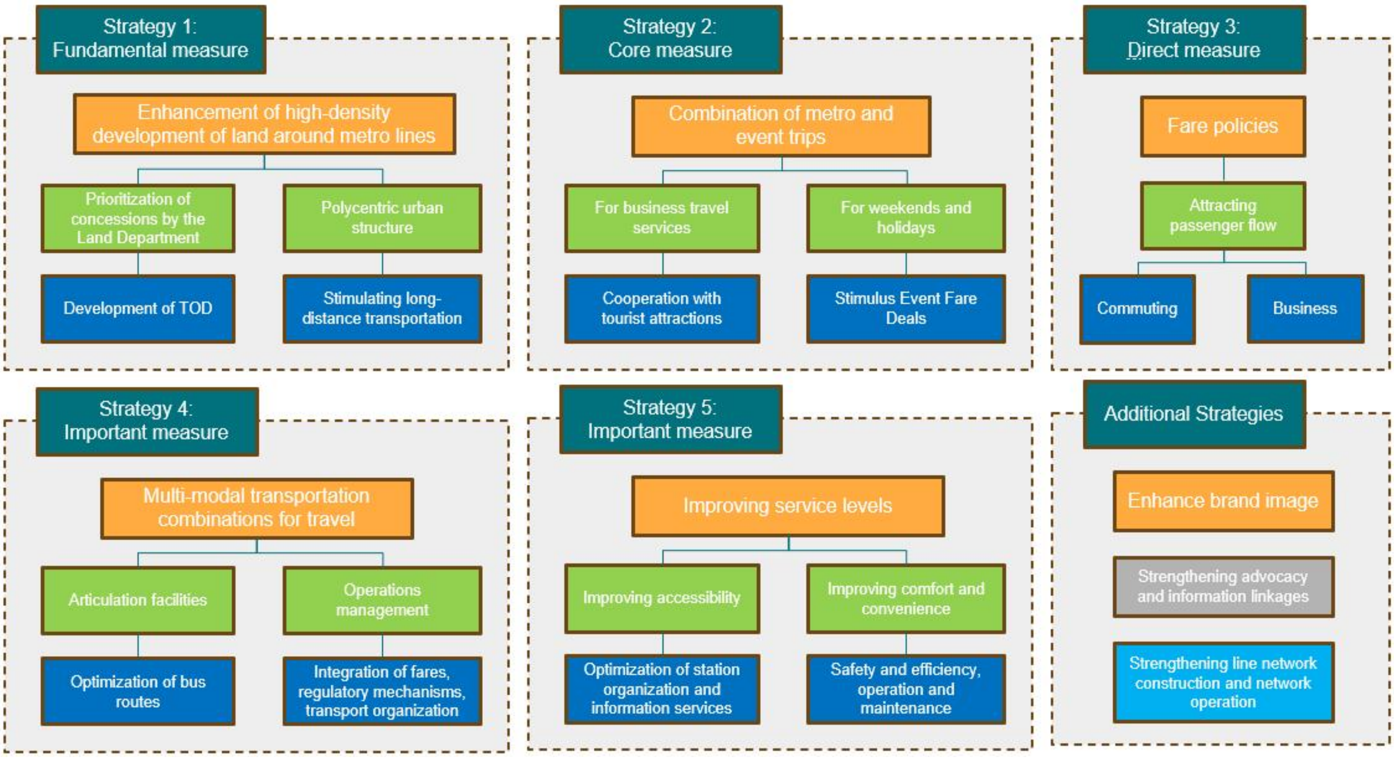

Figure 2. Strategies for Suzhou Metro

3.2.1 Enhancement of high-density development of land around metro lines

For the Suzhou Metro Line 4 along the unsold land, the need for high floor area ratio projects to be placed more in the enhancement of rail transit side, should give priority to the land along the metro station. As Suzhou Metro Line 4 passes through a large number of suburban areas, it is easier to fall into the initial low passenger flow bottleneck, so the integration of rail transit and comprehensive utilization of urban land is more critical. Taking the metro station as the center and 400-800 meters as the radius, the functions of travel, residence, work, shopping, leisure, entertainment, etc. are concentrated in one, and through the mutual combination of transportation hub and commercial functions and overall planning, the passenger flow of the metro can be realized to enhance the passenger flow.

3.2.2 Combination of metro and event trips

Based on the passenger flow cultivation curve of Line 1 and Line 2, it is predicted that the passenger flow of Line 4 will still increase steadily year by year in the case that the metro is not yet on the network. However, the level of growth may be constrained by bottlenecks in single-line growth. In the scenario of networked operation, the optimal design of interchange stations should be strengthened to enhance travel convenience. For example, in the operation stage, avoiding the trains of two lines arriving at the interchange station at the same time is a good choice, which will result in a long transfer time, and ensure that the passenger flow in the direction of the largest interchange can be docked quickly.

3.2.3 Strengthening the construction and network operation of the rail line network

Suzhou Metro Line 4 is directly connected to the famous 5A scenic spots in Suzhou City, which has good potential for attracting passenger flow. It is recommended to bind the deep integration of metro travel with tourism and commercial services to fully explore tourism and consumption resources. For example, in the peak tourist season and scenic spots to carry out coordinated transportation organization, commercial companies to cooperate with the title of the metro station, metro station and commercial real estate development, in the major platforms to carry out the metro and travel advertising and promotion, and so on.

3.2.4 Dynamic and flexible fare policies

From the fare-distance changes in Suzhou in the past year, the average distance of Suzhou metro passenger flow increases substantially as the average fare decreases. The impact of fares on passenger flow can be directly fed back. In the early stage of operation, the basic starting point for pricing is to attract and induce passenger flow. Price promotions should be designed separately for commuters and business travelers. In addition, the means of one card and electronic payment are conducive to enhancing user stickiness and should be promoted and applied. Price promotion should be carried out in synchronization with new media placement publicity and marketing activities. The application of big data analysis can be explored to meet passengers' personalized travel needs and achieve accurate marketing push. Eventually, the price mechanism will be adjusted and differentiated pricing will be carried out after the operation stabilization period.

3.2.5 Multi-modal transportation combinations for travel

For stations in commercial areas, they should be equipped with perfect walking systems and high-quality feeder transfer systems. In the residential area stations, the walking time is the more concerned factor for the layout of the interchange facilities, so the design of the station should be simple, the interchange should be fast, and the main consideration for the interchange should be the bicycle interchange, but the importance of the bus interchange should not be ignored. The car transfer facilities should be located around the center of the city and close to the main roads, and at the same time, should be reasonably located in conjunction with the corresponding land supply situation. Strengthen the linkage mechanism with important destinations in the neighborhood, such as green corridors for hospitals, school care corridors, and passenger and logistics corridors for shopping malls.

4. Conclusion

This study delves into vital strategies for augmenting passenger flow in metro operations. The proposed framework, encompassing urban traffic status analysis, metro passenger flow forecasting, and internal/external influencing factors analysis, provides a comprehensive approach. Through the case study of Suzhou Metro, specific enhancement strategies are identified. The findings underscore the significance of tailored solutions for individual metro systems and contribute valuable insights to the broader discourse on optimizing urban transportation efficiency.

Acknowledgements

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