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Practical Strategies for Urban Rail Transit Loop Planning, Construction, and Operation

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Abstract: Urban rail transit loops are essential in urban rail transit systems and transportation networks. However, precise requirements and reference standards for rail transit loop design have yet to be established. There are certain areas for improvement in planning, construction, and operation. In the planning and design of urban rail transit loops, the scale of the city and the relationship between line operations should be considered to ensure that the line conforms to the city's operating traffic conditions and can effectively cater to peak passenger flow requirements. This article presents strategies for planning, constructing, and operating urban rail transit loops, laying the foundation for the healthy operation of urban rail transit.

Keywords: Urban rail; traffic line change; Planning and construction; Operation strategy

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1. Introduction

Urban rail transit lines are important traffic diversion corridors in urban development. Therefore, loops are a standard design model in the design of urban transportation lines. Currently, most cities in China adopt a circular-based transportation network layout for road networks. Compared to other line designs, urban traffic loops have specific differences in functional positioning and loop systems. Therefore, there needs to be a unified positioning in the design of urban rail transit loops. There are many types of urban rail transit loops. In the article, the structural role, planning, construction, and operation of urban rail transit networks are analyzed, and specific operational practice strategies are explored.

2. Functional analysis of urban rail transit loop lines

In the planning and construction of transportation lines, cities generally use the original rail transit to form a ray-like operation mode and use this as a basis to plan loop lines, which can realize the interception, diversion, and series connection of transportation lines. The urban transportation rail pattern design needs to play a leading role in the development of different urban areas from different transportation positioning. However,

the management of rail transit systems in most cities in China is discrete making it challenging to ensure the structural quality of central cities. The design of the loop system is conducive to integrating the city center lines with rail and ray transportation. If a ring system is built in the urban structure, the interception and diversion conditions and traffic functions along the line must be objectively evaluated. It is important to realize effective transfers between the city center and the external environment and prevent problems such as excessive passenger transfers and difficulty controlling the crowd during peak periods [1]. The function of the urban rail transit line-changing system needs to be integrated with urban planning and layout to improve the connection capacity during peak periods to avoid traffic congestion and make traveling easier.

3. Operation characteristics of urban rail transit loop lines

The characteristics of China's current urban rail transit loop operation and management can be analyzed from the following aspects:

First, the urban rail transit loop's passenger flow is relatively large, with a significant transfer volume during peak periods and high passenger flow throughout the day. Besides, the transportation distance of passengers during line operation is relatively short. Secondly, in terms of urban rail transit operation, the inner and outer loops are usually logarithmic, or different types of large and small intersections are used. Thirdly, the operation mode and organizational structure of urban rail transit loops are relatively flexible. The inner and outer lines of the loops generally operate independently allowing passengers to avoid returning to the starting point. This design ensures that the failure of one loop line does not disrupt one-way operations. This allows the line to operate more efficiently, ensures the line network's ability to handle evacuations, and improves the flexibility of transportation coordination. Furthermore, in the design of urban rail transit loop lines, there are typically several loop lines. When the line is long, it is common to include a parking facility along the line, and the track design often incorporates an eight-shaped configuration to facilitate train movements.

4. Key points in the planning and construction of urban rail transit loops

In the planning and construction of urban rail transit loop lines, the loop lines must be consistent with urban planning to ensure that the loop lines meet the long-term development requirements and the transportation needs of the city. Moreover, the station nodes should also be designed based on the people flow of the station's location and the construction requirements of various facilities to avoid crowd congestion and improve line operation efficiency while ensuring a safe and efficient travel experience.

4.1. The relationship between urban rail transit loops and urban planning

In planning urban rail transit loops, it is necessary to consider and analyze from the perspective of passenger flow to determine the relationship between loop design and urban functional layout. If the city's layout is a strong central form, the functional layout of the ring line needs to be evenly laid out to connect various groups. The loop design should encourage passenger flow and make traveling more convenient. Transportation planning of urban rail transit loops is different than ordinary radial planning, the passenger intensity index must be up to the passenger flow index of the largest one-way section [2]. In general, loop transportation covers relatively short distances, and the passenger flow capacity of individual sections is relatively low. Therefore, when establishing key passenger transportation indicators, passenger flow efficiency should be considered as an important criterion. For urban transport networks, it is essential to ensure an initial passenger flow of 10,000 passengers per kilometer per day and a long-term passenger flow intensity exceeding 10,000 passengers per kilometer per

day on the loop lines. This is crucial for achieving improved transportation operational efficiency.

4.2. The relationship between urban rail transit loops and radiation planning

The line should be designed based on ray series connection as much as possible. The number of rays should be more than 8, and over 50% of the stations should be transfer stations to efficiently handle passenger flow collection and evacuation. The radial area experiences the accumulation of passengers from multiple areas. The length ratio of radial lines inside and outside the ring line should be controlled at around 0.5. Therefore, the scale of the city must be large enough to ensure that it can hold a huge number of passengers. Besides, it is important to sort out the relationship between loop lines and transfer lines. First of all, the transfer lines must be adapted to the passenger flow to prevent the problem of having a huge accumulation of passengers at some points and having too few at others. Secondly, in the planning and designing of the ring line, avoid being located at the endpoint of the radial line to prevent passenger flow from being passive when transferring at the ring line location. In the design, a comprehensive transportation construction model with multiple parallel corridors between the loop and the outer ring can be formed, starting with landscape line planning.

4.3. The relationship between urban rail transit loops and combined loops

Various combined rings can be created in urban rail transit network design through the network structure. For instance, two lines can combine to create a loop. The “L”-shaped line can be inverted to generate a closed-loop line or a chessboard-like structure. Different line types can be used to construct various line combination rings [3]. The key is whether the lines can form a ring. In planning passenger flow, it is necessary to determine whether the route needs to be designed into the form of a ring. During the transfer between two lines, especially during peak transportation periods, the node design should guarantee that the passenger flow reaches over 50% of the cross-sectional passenger flow. When evaluating the line, it is crucial to comprehend the line’s ring structure. Moreover, construction inspection and assessment should cover aspects such as site selection and the feasibility of line sections.

5. Strategies for urban rail transit loop planning, construction, and operation

5.1. Setting up transfer stations

Construction and management are important aspects during the early stages of planning and operation of urban rail transit loop systems. In the planning and operation management of transfer stations, it is necessary to identify and predict the transfer channels’ safety factors accurately. Moreover, the passengers’ travel patterns, including travel distance, passenger flow at starting and ending points, and surrounding traffic operation rules, should be analyzed. The construction of transfer stations usually takes a long time. During the initial planning phases, it is essential to develop the preliminary plan considering building and construction conditions and analyze the plan data’s feasibility. Resource analysis should be carried out for multiple aspects, such as the ring system’s spatial configuration, geographical location, and construction conditions. The site setting and operation of transfer stations must meet surrounding traffic operation and travel requirements and comply with corresponding data indicators. Besides, it is important to minimize the impact of the construction of the rail network on surrounding industries and construction projects. Moreover, it is necessary to predict line density and passenger flow based on the long-term planning and structure of the central city to prevent vehicle transfer locations and line operation stability from being adversely affected [4].

5.2. Reasonable planning and operation base

The role of the urban rail transit vehicle base is to ensure that parking, maintenance, and other aspects of all operating vehicles can be carried out smoothly, which means that a large amount of space is required. Generally, the parking area of vehicles needs to include parking lines, car washing lines, maintenance lines, and other aspects. At the same time, there should also be control centers on-site. The planning work must be done based on both entry and exit lines. In the planning and operation of vehicle bases, the balance of the development of the vehicle's internal and external environments must be considered [5]. During the construction of the vehicle base, it is necessary to effectively control the pull-out and operating lines to ensure efficient vehicle dispatching. No other vehicles or people should be allowed to enter the construction areas, such as vehicle bases and parking lots, so a semi-enclosed design model should be adopted. The compatibility between vehicles and management personnel must be reflected in the systematic operation of areas such as vehicle bases and parking lots. During the acceptance and management of line vehicle bases, the line performance should be evaluated to prevent any impact on the central operation and dispatching of vehicles. In constructing the vehicle base, various software and hardware should be utilized to ensure the stable operation of the vehicles in the loop system.

5.3. Do a good job of coupling the ring traffic planning

The urban rail transit planning and design must be carried out in conjunction with the city's scale and development plan. During the construction and operation of the loop system network, a coupled network model must be constructed. This includes forming network integration and spatial support of multiple transportation lines, building a stable transportation hub structure, promoting the radiation of the transportation network grid, and promoting the coordinated development and planning of transportation lines [6]. The inner ring line in the city's central urban area should be designed to relieve the city's traffic pressure and realize the diversion of urban traffic. Therefore, the structure of different urban areas must be optimized from the perspective of overall coordinated development, and diversion and transfer should be reflected at different transfer points. Rail transit lines have become the key to the development of transportation connection capabilities in the current development of cities, which is also a key component of networked line coupling. However, in the rail transit design, it is necessary to predict and evaluate the growth trend of passenger flow from both the peripheral and internal aspects to prevent the flow rate at transfer points from exceeding the safety threshold. In addition, multiple loops can be formed in the urban rail transit planning system with a polycentric structure to lay the foundation for urban development. In the network coupling planning of urban rail transit, the development of different industrial centers in the city should be used to form a coordinated development target model and build a more stable urban traffic diversion and operation model [7].

5.4. The operating speed of urban rail outer ring lines

In the operation of transportation systems in cities of different sizes, the operating speed of circular lines is directly related to the planned scale and radiation of the lines. Therefore, before designing the rail transit loop, it is necessary to conduct a survey and analysis of the primary conditions of the line and site occupancy. At the same time, the outer ring passage lines and rail transportation should be built in accordance with the city's long-term development. The ring line's operating speed and operating conditions during different periods should be analyzed [8]. Currently, in most urban rail transit in China, the distance of a single ride is generally within half of the entire ring line. Therefore, the speed setting of the ring line operation is generally 38 km/h, which can meet the travel requirements of passengers. At the same time, the maximum speed setting for different distances between stations must meet different urban spatial structures and population changes. The goals of land

development and construction project operations along the outer ring urban rail transit lines must be aligned in building a multi-center network structure.

5.5. Guidance model for urban rail transit loop planning

In the design of urban rail transit, it is necessary to form an uplink and downlink operation mode. The route can be planned in the up and down directions, and the passengers do not need to deliberately distinguish between going up or down. They only need to know the train's endpoint [9]. However, ring lines are quite unique, so the traditional up-and-down operation method is not applicable. There are no definitive endpoints. However, it must be determined based on the inner and outer circles of the circular traffic and the clockwise and counterclockwise operation conditions. As a loop does not have clear starting and endpoints, it is important to have clear directories on the stations and incorporate multiple vehicle access stations along the line [10], and the passengers should be guided on the stations along the line. Optimizing the design of stations and carriage guidance systems will help passengers understand the operation of the circle line and choose the optimal travel routes. Circular route signs are also used to facilitate passengers to find routes and determine the direction of travel.

6. Conclusion

In summary, urban rail transit loops' construction, operation, and management are the key to large-scale urban transportation design. It is also a critical transportation line model to solve urban transportation problems and realize the series connection of transportation lines. Circular lines are different than conventional lines in terms of operation, station node design, and passenger flow calculation. Therefore, in the planning and operation practice of lines, it is necessary to combine the characteristics of the city, strengthen the optimization and innovation of line planning, and optimize operation management to avoid passenger congestion during peak periods, and to provide a better traveling experience for passengers.

Disclosure statement

The author declares no conflict of interest.

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