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Integrated Layout and Transfer of Urban Rail Transit Hubs

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Abstract: This paper is engaged in the research of urban rail transit hub integration and transfer. Firstly, this paper focuses on the space division, the aggregation form of hub subsystems, the spatial layout of hub subsystems, and the design of integrated functions to achieve an integrated layout. In addition, this study also conducted a selection of transfer classification and transfer station layout of urban rail transit hubs, with the aims to promote the improvement of the functions of urban rail transit hubs, the rationality of transfers, and to improve the service quality of the hub system which meet the demand of the public travel.

Keywords: Urban rail transit hub; Integrated layout; Transfer design

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1. Introduction

The urban rail transit hub is an overall transportation system composed of a series of subsystems, such as transportation, commerce, entertainment and leisure, business, and services. Meanwhile, the transportation subsystem includes rail transit, private cars, non-motor vehicles, and ground public transportation. At the same time, the urban rail transit hub includes many development modes, such as the transportation center station mode, the commercial center station mode, and the business center station mode. Therefore, the integrated layout and transfer design of the urban rail transit hub directly affects the functional rationality, and the service efficiency of the transportation hub [1]. This study is a high-value research measure, which engage in the research on the integrated layout and transfer of urban rail transit hubs to promote the healthy development of the country's urban rail transit industry.

2. Research on the integrated layout of urban rail transit hubs

2.1. Space division

Due to the different perspectives of passengers, urban rail transit hubs can be divided into four spaces, which are the transportation function, direct passenger access service, passenger indirect access service, and public open space [2].

Firstly, under the traffic function space, which covers the traffic transfer space and static traffic land. Among them, the transportation transfer space is mainly a series of connection spaces, such as halls, stairs, and way for passages who require to take different modes of transportation. Meanwhile, static traffic land is a station that is required by various transportation modes, such as subway, public transportation, taxis, and bicycles [3].

Secondly, passengers can directly reach the service space, which is mainly referring to the large and medium-sized commercial spaces directly connected to the urban rail transit hub, such as shopping malls, supermarkets, and others. These spaces will use by the overpasses, underground passages, and other connecting facilities, which can directly lead to the urban rail transit hub. In this area, passengers can use a series of connecting facilities to travel between the traffic function space and the passenger directly accessible service space [4].

Thirdly, most of the public open spaces are open 24 hours, which belong to the same transportation function, and the passenger can directly use this space to reach the service space [5].

Finally, passengers can indirectly reach the service space, which generally includes cinemas, office buildings, exhibition venues, entertainment and leisure venues, and others. Usually, such spaces are arranged above the rail transit hub complex, where the indirectly accessible service space will not be directly connected with the transportation subsystem. In addition, passengers usually need to follow a certain streamline structure to enter the indirectly accessible service space from the public open space [6].

2.2. Aggregation form of hub subsystems

The aggregation form of urban rail transit hub subsystem, includes centripetal combination, linear combination, and radial combination [7]. The centripetal combination form uses the public open space as the center of the hub, and connects several surrounding sub-functional systems together. The public open space under the centripetal combination condition is usually in forms of building atrium area, outdoor square, and indoor square, which is more suitable for large-scale rail transit hubs [8].

In addition, the linear combination form is to arrange the different spaces in the hub with a certain linear trajectory, with various sub-functions which is connected with a series of the linear path. During the designing stage, the linear combination can be designed in a form of curve, straight line, discount, or in the form of branch and vine, which has the characteristics of a polygon, and interestingly there is no fixed center position in the hub under this design combination [9].

The radial combination form is a combination of centripetal and linear forms. During the designing stage, different linear combinations can be adopted, gradually extended from the public open space of the hub center to the outside, and finally connect each other by several radial routes, subsequently developed into a streamlined network. This method is very suitable for the construction of urban rail transit hubs with huge scale [10].

2.3. Spatial layout of hub subsystem

The sub-space layout of urban rail transit hubs can be divided into four categories, namely; Vertical stacking mode: Is a mode in which the commerce, transportation, business, residence, and services are superimposed and distributed in a vertical direction; Parallel stacking mode: The side-by-side and superimposed, which is the sub-functions are arranged in a horizontal manner, and a superimposed form is used in the vertical direction; Penetration mode: The subsystems of the transportation hub, which are located in different buildings, and connected by the public space in the hub, which can realize the superposition or juxtaposition of the vertical and horizontal directions; [11] and Separation mode: The functional subsystems under the transportation hub take the form of a single unit, and are connected with the outdoor space, which is mainly flat and relatively loose [12].

2.4. Integrated functional design

Integrated function designing stage is a stage of the integration of the hub external interface design and internal subsystems. When dealing with the external connection structure of the rail transit hub, it is essential to pay attention to the different needs of the service objects, distinguish the different nature of the flow lines, and reasonably introduce the traffic lanes and sidewalks. In addition, the integration of the subsystems of commerce, transportation, leisure and entertainment, and commerce within the rail transit hub should be determined initially, relative to the position and building scale of the systems based on the object and frequency of use.

On the stage of using public space as a hub, subsystems with higher usage rates should be closely connected to the lobby, in contrast the business and leisure facilities, which are less frequently used should be kept away from the public space lobby.

During the designing stage of space division, the exhibition hall usually includes the ticket hall, the comprehensive hall, and the ticket gate, thereby the designing of ticketing facilities should be calculated in combination with Equation 1:

$$N_1 = M_1 k m_1 \qquad (1)$$

In Equation 1, the flow of ticket-buying passengers during peak hours is M_1, and the coefficient of ultra-peak hours is k, which usually ranges from 1.2 to 1.4, and the ticketing capacity is 1200 and 600 persons/h for manual ticketing and automatic ticketing equipment, respectively.

In addition, the ticket gates should be placed in an open and good area to ensure that people can come and go freely. Meanwhile, the comprehensive hall plays the role as a buffer and diversion, and the design of the hall area should be determined by the passenger flow during the peak period.

The design of the platform floor includes island type and side type, mainly for passengers to get on and off, and to wait for the bus. Thereby, the calculation method of the platform area should be based on Equation 2 and Equation 3:

$$\begin{aligned} B_d &= 2b + n \cdot z + t \\ B_e &= b + n \cdot z + t \end{aligned} \qquad (2)$$

$$b = \frac{Q_{up、off} \cdot \rho}{L} + M \qquad (3)$$

In Equation 2 and Equation 3, B_d is the width of the island platform, and B_e is the width of the side platform. Equation 3 takes the maximum value. B represents the width of the side platform, m, n, and z are the number of horizontal columns and the width of the horizontal columns, respectively, and t is the sum of the widths of each group of pedestrians and escalators. $Q_{up,off}$, is the calculation of the passenger flow of each train on one side during peak hours in the future, ρ is the density of people on the platform, generally 0.5 m^2/person, L is the calculated length of the platform, the unit is m, and the distance from the edge of the platform to the inner side of the column of the screen door is expressed in M.

For the distribution channel, the width of the one-way staircase should be ≥1.8m, the two-way staircase should be ≥2.4m, and the inclination angle should be 26*34’, while the inclination angle of the escalator should be 30°, and the moving sidewalk should be 0°~12°.

Streamline planning is a planning work to ensure that passengers can freely travel between different areas, and that there is no conflict among the passengers due to the difference in behaviors. In terms of per capita space requirements, the linear movement area of one-way passage in the same direction should meet 0.46 square meters, the linear forward and reverse movement area of two-way passage should satisfy 0.55 square meters, simple intersection/diversion should satisfy 0.66 square meters, and vertical intersection/diversion should satisfy 0.88 square meters.

In addition, the rail transit hub station should be strictly arranged with a guide sign system, where the ticket hall, ticket gate, comprehensive hall, platform level, and distribution area should be ready with the guide signs, in an orderly arrangement of information [13].

3. Research on the transfer of urban rail transit hubs

3.1. Transferring classification of urban rail transit hubs

The transfer classification under the urban rail transit hub includes the transferring organization between subways and pedestrian transportation, private transportation, ground transportation, and pedestrian transportation, referring to the railway system transfer organization [14].

3.1.1. Transferring organization

The transferring organization between the subways should be comprehensively considered certain conditions, including the transfer directions, transfer points, transfer passenger flow, and transfer station construction conditions before carrying out the transfer organization design [15].

3.1.2. The design stage of the transferring organization

During the design stage of the transferring organization between subway and pedestrian transportation, the urban land use planning, urban transportation planning, and urban ground and underground space development requirements should be fully integrated, to ensure the transportation function is regulated wisely, and to improve the accessibility of the hub. If the conditions permit, we should consider setting-up subway entrances and exits in the pedestrian streets, underground shopping malls, near supermarkets, dedicated passages, or inside large buildings to effectively reduce the conflict of flow lines, subsequently improve the pedestrian traffic safety [16].

3.1.3. The design stage of the subway private transportation transfer organization

During the design stage of the subway private transportation transfer organization, it is important to fully consider the setting of the parking lot for non-motor vehicles, and the parking lot can be placed at ground or underground parking lots by including a special passage for non-motor vehicles in the design. Private cars have certain requirements for parking spaces; however, the rail transit hubs usually lack in the parking conditions, therefore the urban car parking lots can be built in the transportation hub area in the suburban area [17].

3.1.4. The design stage of subway and ground transportation transfer organization

During the designing stage of subway and ground transportation transfer organization, subway entrances and exits should be as close as possible to the ground transportation stations, while bus stops can be introduced into the urban rail transit hub to form a comprehensive hub transfer hall [18].

3.2. Selection of the layout of the transfer station

The transfer station contains a variety of design layouts, and during the layout selection period, the passenger flow used by the layout method of the transfer station should be fully considered [19]. During this process, the subway architectural design unit should by fully consider the service level of the transfer station facing pedestrian traffic, the relationship between pedestrian density and speed (such as the speed of climbing stairs, speed of descending stairs, speed of passing doors, and others). At the same time combine effectively the width theory, cluster flow theory, the level of service, level of rail transit stations, the average density of the platform and hall areas, the maximum flow of stairs and aisle areas, calculate the service capacity classification of rail transit transfer stations. In addition, assign node transfer, such as island transfer, island-side transfer, and side-island transfer to calculate the relationship between the scale of passenger flow, transfer form, and the relationship table between transfer form and transfer passenger flow range, and use the two data as a reference to choose a transportation reasonably, and to draw the layout of hub transfer stations [20]. **Table 1** and **Table 2** are the calculated results of the parameters of a city transportation rail hub in China as an example.

Table 1. Relationship between the scale of the transfer passenger flow and the transfer form at the transfer station of an urban transit rail hub

Transfer form classification	**Station form**	**Number of facilities**	**Transfer time parameter (min)**	**One-way maximum exchange passenger flow (Person/.h)**
Channel type	Island-island Interchange	2	5	1805
Station hall type	Island-island Interchange	2	5	7660
Nodal type	Island-island Interchange	1	2	680
	Side-to-side transfer	4	2	4234
	Island-side transfer	2	2	1360
	Side-island transfer	2	2	2117

Table 2. The relationship between transfer driving and transfer passenger flow range in an urban transit rail hub

Transfer form classification	**Station form**	**Number of facilities**	**Transfer time parameter (min)**	**One-way maximum exchange passenger flow (Person/.h)**
Channel type	Island-island Interchange	2	5-7	1800-2000
Station hall type	Island-island Interchange	2	5-7	7500-8000
Nodal type	Island-island Interchange	1	2-3	650-750
	Side-to-side transfer	4	2-3	4200-4600
	Island-side transfer	2	2-3	1300-1500
	Side-island transfer	2	2-3	2100-2300

4. Conclusion

This paper realizes the integration layout design and transfer design of urban rail transit hubs, which can be used as a reference in China. In addition to the mastering the integrated layout and transfer design, the design unit should also consider the use of different land patterns, passenger preferences, and the actual national conditions of the country. Therefore, there is still a room for improvement in the design of urban rail transit hubs.

Disclosure statement

The author declares no conflict of interest.

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