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Research on Transfer Organization of Integrated Passenger Transportation Hub

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Abstract. The paper introduces the definition, main functions, and classification of the integrated passenger transportation hub from a holistic perspective; Elaborated on the definition of the basic forms of transfer and conducted corresponding comparative evaluations; Using the fuzzy analytic hierarchy process, select reasonable evaluation indicators, establish corresponding evaluation indicator system, and systematically evaluate the transfer organization of the integrated passenger transportation hub, in order to identify areas of unreasonable and non-standard layout within the hub and propose corresponding improvement measures, thereby further optimizing the spatial structure of the hub.

Keywords: Integrated passenger transportation hub; transfer organization; fuzzy analytic hierarchy process.

1. Introduction

The integrated passenger transportation hub is a connecting facility for various passenger transportation modes and an important connecting place for passengers to successfully complete a trip.With the rapid development of China's economy and the accelerating urbanization process, people's living standards are gradually improving,which has led to an increasing number of trips for residents.Especially during holidays,the passenger flow within the integrated passenger transportation hub is even greater.Therefore,the rational layout of various transportation infrastructure,coordination and optimization of various flow line organizational structures,minimizing passenger transfer times,shortening transfer distances,and saving transfer time have become the areas that require human and material research in the field of the integrated passenger transportation hub.

2. Basic Theory of Integrated Passenger Transportation Hub

2.1 Definition of Integrated Passenger Transportation Hub

The integrated passenger transportation hub covers two or more transportation modes, Including public transportation, subway, railway, aviation, etc.Various transportation facilities are organically combined in terms of function and space to achieve passenger distribution, transfer, and provide other service oriented places that are convenient for passengers to transfer.

2.2 The Main Functions of Integrated Passenger Transportation Hub

The integrated passenger transportation hub is a comprehensive system that integrates various transportation operation functions and additional service functions. The healthy development of the integrated passenger transportation hub can not only meet the daily needs of passengers, but also further promote the gradual development of surrounding areas. To meet the travel needs of passengers, the functions of the integrated passenger transportation hub mainly include transfer function, integrated evacuation function, parking function, and additional service function.

2.3 Classification of Integrated Passenger Transportation Hub

The integrated passenger transportation hub can be divided into urban external integrated passenger transportation hub and urban internal integrated passenger transportation hub[1].Among them, urban external integrated passenger transportation hub can achieve transportation connections between cities, facilitate passengers' travel and transfer between cities,effectively connect various transportation modes between cities that can be connected by hub,and meet passengers' travel needs to the greatest extent;urban internal integrated passenger transportation hub can be divided into group level hub and urban level hub[2],as well as urban public transportation hub and urban rail transportation hub.

3. Definition and Comparative Evaluation of the Basic Forms of Transfer

3.1 Definition of the Basic Forms of Transfer

Cross-platform transfer refers to the transfer connection between two subway lines that can be achieved on the same platform. Generally, the layout of the cross-platform transfer station will be designed as a double island platform.Connecting staircase transfer refers to passengers making corresponding transfer by connecting staircases, which is generally used for side platform. Whether passengers who transfer within the integrated passenger transportation hub or passengers who need to leave the hub after completing transfer, they need to gather in the corresponding public hall before making the corresponding transfer. This transfer method can be called station hall transfer. Passageway transfer refers to passengers getting off a railway line, passing through the corresponding transfer passageway, and then continuing to board the railway line required for travel. Generally, when passengers transfer between two or more non adjacent stations, passageway transfer is often required. Transfer outside the station refers to the design of two subway stations that are relatively close to each other and cannot be built together due to geographical location or other reasons, which means it is not possible to achieve transfer within the station.

3.2 Comparative Evaluation of the Basic Forms of Transfer

From the above explanations of various transfer methods such as cross-platform transfer , connecting staircase transfer, station hall transfer, passageway transfer, and transfer outside the station, it can be concluded that cross-platform transfer is the best choice for transfer from the perspective of passengers, with clear transfer objectives and less transfer time.The structural layout of station hall transfer is relatively simple, and the transfer method is convenient. This transfer method is relatively scientific and practical. Therefore, in the layout design of transfer organization of integrated passenger transportation hub， many subways prioritize using cross-platform transfer and station hall transfer. Passageway transfer increases the travel distance for passengers to transfer, reduces congestion, and alleviates the pressure on the station.

The layout of transfer organization of integrated passenger transportation hub often combines the two or more transfer methods mentioned above. For example, when applying cross-platform transfer, the actual layout of integrated passenger transportation hub can be combined with station hall transfer to improve the operational efficiency of the hub; Connecting staircase transfer is often paired with cross-platform transfer or passageway transfer to meet passenger transfer needs[3]; Station hall transfer is combined with passageway transfer to reduce the amount of hub transfer work[4]. From the combination of the above transfer methods, it can be seen that the combined transfer mode has more flexibility in layout design, meets the needs of passenger transfer and improves transfer conditions.

4. Evaluation of Transfer Organization in Integrated Passenger Transportation Hub

Conduct a comprehensive evaluation of the transfer organization of integrated passenger transportation hub, identify areas of unreasonable and non-standard layout within the hub, and propose corresponding improvement measures to further optimize the spatial structure of the hub,reduce passenger transfer time, and achieve the goal of improving passenger travel comfort.Therefore, it is particularly important to evaluate the transfer organization of integrated passenger transportation hub reasonably and accurately.

4.1 Establishment of evaluation indicator system

4.1.1 Analysis of Factors Influencing Transfer

When passengers transfer in integrated passenger transportation hub, there are many factors that affect their transfer time and distance. Moreover, due to individual differences, the transfer process for each passenger is also different. Some passengers have relatively simple transfer processes,while others have complex transfer processes. Therefore, the factors affecting their transfer should be analyzed based on the specific situation of integrated passenger transportation hub.This article measures the transfer effect of integrated passenger transportation hub from six aspects:compatibility,adaptability,transmissibility, rapidity,dispersivity,and safety.

4.1.2 Transfer evaluation indicator system

This article considers establishing a structural analysis model of "target layer, criterion layer,and indicator layer",and establishing a three-layer hierarchical evaluation indicator system.That is, first establish research objective,then select corresponding criterion, and finally select appropriate indicators for each criterion.

4.2 Quantification of Evaluation Indicators

4.2.1 Compatibility

(1) Average transfer area for passengers c_{11}

Average transfer area for passengers c_{11} is the simplest and most intuitive indicator to measure compatibility between transfer facilities and passengers in integrated passenger transportation hub. It specifically reflects the capacity of transfer facilities to accommodate passengers in the hub, the quality of the transfer environment in the hub, and also reflects the experience of passengers in the transfer process of the hub. Its quantification formula is expressed as

$$c_{11} = \frac{S}{Q} \tag{1}$$

In the formula, S is the total area of the transfer area within the hub (specifically expressed as the total area available for passengers to rest, travel, and board), and Q is the maximum passenger flow aggregation value (daily peak passenger volume) within integrated passenger transportation hub. The measurement standards of average transfer area for passengers are shown in Table 1.

Table 1 The measurement standards of average transfer area for passengers

Measurement level	Excellent	Good	Average	Fair	Poor
Average transfer area for passengers(m^2)	≥1.0	0.75-1.0	0.51-0.75	0.31-0.50	≤0.30

(2) Supply level of auxiliary transfer facilities c_{12}

The supply level of auxiliary transfer facilities is an indicator that measures the passenger hub's ability to provide passenger transfer facilities, such as the installation of escalators, elevators, and other automatic transmission facilities.Its quantification indicators can be expressed as the ratio of the horizontal length of the automatic transmission facility to the horizontal distance of passengers transfer,plus the ratio of the vertical length of the automatic transmission facility to the vertical distance of passengers transfer[5]. Its quantification formula is expressed as

$$c_{12} = \frac{1}{2}(\frac{L_s}{L_h} + \frac{H_c}{H_h}) \tag{2}$$

In the formula, L_s is the horizontal length of the automatic transmission facility, L_h is the horizontal distance of passengers transfer, H_c is the vertical length of the automatic transmission facility, H_h is the vertical distance of passengers transfer.

4.2.2 Adaptability

(1) Capacity adaptability c_{21}

The adaptability of various transportation modes within the hub can be measured by indicators such as capacity adaptability[6]. Capacity adaptability is an indicator that reflects the coordination and adaptability of different transportation modes in the integrated passenger transportation hub. It can specifically measure whether the configuration of various transportation modes in the integrated passenger transportation hub is reasonable. Its quantification formula is expressed as

$$c_{21} = \frac{Q}{\sum_{i=1}^{n} p_i k_i} \tag{3}$$

In the formula, Q is the passenger flow volume that needs to be evacuated per unit time during peak passenger flow hours, p_i is the ability of the i-th mode of transportation to evacuate passenger flow per unit time, k_i is the proportion of the i-th mode of transportation in the passenger flow evacuation process.

The grading range of various indicators for capacity adaptability is shown in Table 2.

Table 2 The grading range of capacity adaptability

Measurement level	Excellent	Good	Average	Fair	Poor
Capacity adaptability	0.78-0.83	0.65-0.77 or 0.84-0.95	0.55-0.64 or 0.96-1.15	0.45-0.54 or 1.16-1.25	≤0.45 or ≥1.25

(2) Occupancy rate of passenger station parking lot c_{22}

The occupancy rate of passenger station parking lot is an indicator that measures the parking space provided by the integrated passenger transportation hub, which can be specifically expressed as the ratio of the parking lot area of motor and non motor vehicles within the hub to the total area of the hub. Its quantification formula is expressed as

$$c_{22} = \frac{s_1}{s_2} \tag{4}$$

In the formula, s_1 is the parking lot area of motor and non motor vehicles within the hub, s_2 is the total area of the hub.

4.2.3 Transmissibility

(1) Information Integrity c_{31}

Information integrity is an important indicator that reflects the degree to which the information system in the hub can provide passengers with the required information integrity, which can be represented by corresponding measurement levels.

$$c_{31} = \{\text{Excellent, Good, Average, Fair, Poor}\} \tag{5}$$

(2) Information sharing c_{32}

Information sharing refers to the need for complete transfer and connection information between various modes of transportation in the hub, achieving full information sharing.

$$c_{32} = \{\text{Excellent, Good, Average, Fair, Poor}\} \tag{6}$$

4.2.4 Rapidity

(1) Average transfer travel distance c_{41}

The average transfer travel distance is a key indicator to measure the convenience of the hub, which simply and intuitively reflects whether the layout planning of various transportation modes within the hub is reasonable. Its quantification formula is expressed as

$$c_{41} = \frac{\sum Q_i L_i}{\sum Q_i} \tag{7}$$

In the formula, Q_i represents the transfer volume completed by the i-th transportation facility, L_i represents the distance traveled by passengers on the i-th transportation facility.

(2) Maximum transfer travel distance c_{42}

The maximum transfer travel distance measures whether the streamline organization structure of various transportation transfer modes within the hub is reasonable. Its quantification formula is expressed as

$$c_{42} = \sum d_{ij} \tag{8}$$

$$d_{ij} = l_{ij} + h_{ij} \tag{9}$$

In the formula, d_{ij} represents the distance traveled by passengers transferring from the i-th mode of transportation to the j-th mode of transportation, l_{ij} represents the corresponding horizontal distance of transfer, h_{ij} represents the corresponding vertical distance of transfer.

The grading range of various indicators for rapidity is shown in Table 3.

Table 3 The grading range of various indicators for rapidity

Measurement level	Excellent	Good	Average	Fair	Poor
Average transfer travel distance	≤150	150-250	250-350	350-450	≥450
Maximum transfer travel distance	≤200	200-350	350-450	450-600	≥600

4.2.5 Dispersivity

(1) Maximum transfer time for passengers c_{51}

The maximum transfer time for passengers includes three parts: the travel time during the transfer process, the waiting time in the queue, and other transfer time (such as the additional time required to purchase tickets). Its quantification formula is expressed as

$$c_{51} = \max\{t_i\} \tag{10}$$

In the formula, t_i represents the transfer time between the transportation facility used by the passenger and the i-th mode of transportation that needs to be transferred.

(2) Average transfer time for passengers c_{52}

The average transfer time for passengers refers to the average service level of transportation transfer facilities within the hub. Its quantification formula is expressed as

$$c_{52} = \frac{\sum_{i}^{4} \sum_{j}^{4} q_{ij} t_{ij}}{\sum_{i}^{4} \sum_{j}^{4} q_{ij}} \tag{11}$$

In the formula, q_{ij} represents the passenger flow between various transportation transfer modes, t_{ij} represents the time required for passengers to transfer between various transportation facilities.

The grading range of various indicators for dispersivity is shown in Table 4.

Table 4 The grading range of various indicators for dispersivity

Measurement level	Excellent	Good	Average	Fair	Poor
Maximum transfer time for passengers	≤6.0	6.0-8.0	8.0-11.0	11.0-15.0	≥15.0
Average transfer time for passengers	≤4.0	4.0-5.0	5.0-8.0	8.0-11.0	≥11.0

4.2.6 Safety

(1) Number of interference between passengers and vehicles c_{61}

The number of interference between passengers and vehicles reflects the safety of passenger travel, especially during the process of passenger transfer. The safety threat coefficient of various types of intersections to passengers is relatively large. Its quantification formula is expressed as

$$c_{61} = \frac{\sum_{i} \sum_{j} n_{ij} q_{ij}}{\sum_{i} \sum_{j} q_{ij}} \tag{12}$$

In the formula, n_{ij} represents the number of vehicle roads that passengers need to pass through for transfer between the two transportation modes i and j within the hub, and q_{ij} represents the transfer volume between the two transportation modes i and j within the hub.

The grading range of various indicators for dispersivity is shown in Table 5.

Table 5 The grading range of dispersivity

Measurement level	Excellent	Good	Average	Fair	Poor
Number of interference between passengers and vehicles	0.01-1.5	1.51-3.0	3.00-4.5	4.51-5.0	≥5.01

(2) Stability of transfer facilities c_{62}

Stability of transfer facilities mainly measures the stability of the operation of various transfer facilities within the hub, that is, the level at which transfer facilities can provide safety guarantees for passengers.

$$c_{62} = \{\text{Excellent}, \text{Good}, \text{Average}, \text{Fair}, \text{Poor}\} \tag{13}$$

4.3 Overall Evaluation

The fuzzy analytic hierarchy process integrates the dual advantages of fuzzy evaluation and analytic hierarchy. Based on fuzzy theory, it quantifies some unclear and difficult to quantify factors in the evaluation of transfer organization. In specific evaluation, the quantification of various qualitative evaluation indicators is carried out using expert consultation method. When establishing the weight set of evaluation indicators, the analytic hierarchy process is used, which can more scientifically and reasonably reflect the importance of indicators and the degree of differences between indicators.

4.3.1 Evaluation of Each Indicator Subsystem

The evaluation of the transfer organization of the integrated passenger transportation hub requires the use of importance ranking method to obtain the single factor evaluation matrix of the sub indicator system.

$$\tilde{R}_k = \begin{bmatrix} \tilde{R}_{c1} \\ \tilde{R}_{c2} \\ \vdots \\ \tilde{R}_{cm} \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ \cdots & & & & \vdots \\ r_{m1} & r_{m2} & r_{m3} & r_{m4} & r_{m5} \end{bmatrix} \tag{14}$$

In order to obtain the weight of the upper level indicators, the single factor membership vector of lower level indicators or elements belonging to upper level indicators is $\tilde{R}_k = (r_{ij})_{m\times 5}$,According to the expert consultation method, the weight vector of the upper level elements or indicators is obtained as $W(C_k) = (w_{k1}, w_{k2}, \ldots, w_{kn})$, the single factor evaluation results of upper level elements or indicators can be expressed as[5]

$$\tilde{B}_k = W(C_k) \circ \tilde{R}_k = (w_{i1}, w_{i2}, \ldots, w_{im}) \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ \cdots & & & & \vdots \\ r_{m1} & r_{m2} & r_{m3} & r_{m4} & r_{m5} \end{bmatrix} = (b_{k1}, b_{k2}, b_{k3}, b_{k4}, b_{k5}) \tag{15}$$

4.3.2 Overall System Evaluation

$$\tilde{D} = W(C) \circ \tilde{B} = (w_1, w_2, \ldots, w_k) \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} \\ \cdots & & & & \vdots \\ b_{k1} & b_{k2} & b_{k3} & b_{k4} & b_{k5} \end{bmatrix} = (d_1, d_2, d_3, d_4, d_5) \tag{16}$$

In the formula, $\tilde{B}=\begin{bmatrix}\tilde{B}_1\\ \tilde{B}_2\\ \cdots\\ \tilde{B}_k\end{bmatrix}=\begin{bmatrix}b_{11} & b_{12} & b_{13} & b_{14} & b_{15}\\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25}\\ \cdots & & & & \vdots\\ b_{k1} & b_{k2} & b_{k3} & b_{k4} & b_{k5}\end{bmatrix}$ (17)

According to maximum membership principle, it can be concluded that the transfer organization of the integrated passenger transportation hub can effectively meet the needs of passengers only when the evaluation results obtained are good or above.

5. Summary

The main research object of this article is the integrated passenger transportation hub, and its transfer organization has been studied and explored. Introduced the definition, main functions, and classification of the integrated passenger transportation hub; Elaborated on the definition of the basic forms of transfer and conducted corresponding comparative evaluations; Using the fuzzy analytic hierarchy process,select reasonable evaluation indicators, establish corresponding evaluation indicator system, and systematically evaluate the transfer organization of the integrated passenger transportation hub.However, there are still shortcomings in this article's research. For example, when studying how to improve passenger transfer efficiency, this article mainly explores and studies from the perspective of transfer organization within the hub, without considering the traffic conditions and corresponding operational condition of the surrounding areas of the hub. Further exploration is needed in the following research.

References

[1] Zhijing Yan. Research on Urban Integrated Passenger Transportation Hub Planning [C]. Lanzhou Jiaotong University, 2015.

[2] Shuxia Feng. Research on the Coordination Analysis Model Method of Large Passenger Station Traffic Release System [C]. Beijing Jiaotong University, 2010.

[3] Wang Fei. Research on Capacity Matching of Urban Rail Transit Transfer Channel Facilities [C]. Beijing Jiaotong University, 2012.

[4] Zhang Hong. Research on the Configuration of Pedestrian Facilities in Urban Rail Transit Transfer Hub [C]. Southwest Jiaotong University, 2011.

[5] Guocheng Lin. Research on Transfer Connection of Urban Integrated Passenger Transportation Hub [C]. Chang'an University, 2010.

[6] Li Xiao. Performance Analysis of Regional Integrated Transportation Hub [C]. South China University of Technology, 2012.