Research on High-speed Railway Hub Passenger Transport System Planning Evaluation System

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Abstract—China’s high-speed rail is already at the forefront of the world. The layout of the high-speed railway bus terminal is not only related to the construction of the high-speed rail network, but also a major strategic decision for urban development, and it is related to another leap forward development opportunity for the city. At present, the evaluation plan of the railway hub passenger transport system is not perfect, because many aspects of the plan are difficult to quantify, and it is prone to inaccurate judgments of factors that lead to more one-sided conclusion. This paper establishes a comparatively comprehensive set of layout evaluation indicators, advocates selecting or creating a corresponding index construction index system according to the characteristics of the evaluation target, and combines the entropy weighting method and the TOPSIS method to form a new rating method and applies it to the layout evaluation.

1. Introduction

According to the latest medium and long-term railway network plan, by 2020, the high-speed railway is expected to reach 30,000 kilometers, basically connecting provincial capital cities and other large and medium-sized cities with a population of more than 500,000, achieving a 1-4 hour traffic circle between adjacent large and medium-sized cities and 0.5-2 hour traffic circle within the city group. Large and medium-sized cities will basically have a high-speed railway passenger station, and some cities will have two or more. The rational layout of the passenger transportation system in the planning of major high-speed railway hubs is not only critical to the engineering investment and operational efficiency of railway projects, but also has a profound impact on promoting urban construction and social development. It is a key factor in judging the railway hub master plan.

For a long time, Chinese scholars have achieved certain results in the evaluation of railway hub planning. Lei Zhonglin[1] further refined the evaluation index system of the railway hub master plan. Jing Fengming[2] discussed the layout planning of my country's railway hub, and emphasized that the layout planning of the passenger transportation system of the railway hub should be focused on. Yang Dong[3] set up an evaluation system for the layout of passenger terminals in railway hubs based on factors such as the technical conditions of high-speed railways, the degree of coordination with urban planning, economic costs, and social impact. Zhang Benyong[4] based on the analysis of the location of Wuhan high-speed rail hub, put forward the development trend of centralization of layout of high-speed rail hub, hub interconnection and intermodal transportation. At present, there are many domestic scholars studying the location of high-speed rail passenger station, but there is relatively little research on the evaluation of the layout of high-speed rail passenger station. Therefore, it is necessary to explore the establishment of a high-speed railway hub passenger transport system planning evaluation system.
2. High-speed Railway Hub Passenger Transport System Planning Evaluation System

This paper divides the evaluation system of the high-speed railway hub passenger transportation system into 5 criteria layers: hub layout, hub transportation capacity, integration of city and station, economy and environment, and integrated transportation. Each level contains the corresponding evaluation indicators to jointly build the evaluation indicator system of the high-speed railway hub passenger transportation system. The evaluation index system is shown in Fig.1.

![Evaluation System Diagram](image)

Figure 1. Evaluation system diagram

2.1. Angular wagon flow rate

This indicator is the ratio of the number of angled cars to the number of all passing trains in the hub. Due to the excessive direction of the connecting lines of the passenger station, part of the passing train will become a corner traffic. Therefore, for a specific passenger station, the direction of the station should be reasonably selected to be horizontal or vertical, so that the proportion of the corner car passing through it is minimized, and the direction with large traffic flow is avoided as far as possible. The calculation formula is as follows:

\[ \alpha = \frac{n_a}{N} \]  

\( n_a \) —— The number of angular wagon.
\( N \) —— The number of all passing trains.

The index size is inversely related to the index score. The smaller the angular wagon flow rate, the better the layout of the passenger terminal in the hub.

2.2. Hub transport capacity adaptability

This indicator refers to the ratio of the passenger sending and arrival volume of passenger stations in the railway hub to the travel needs of passengers in the city, and can reflect whether the railway hub can meet the travel needs of urban residents.

Hub transport capacity adaptability is obtained from the ratio of hub passenger volume to urban passenger travel demand. The calculation formula is as follows:
FXUNN\(=\left(2\right)\)

\(N_F\)——The sum of the annual passenger transport volume of each passenger terminal of the hub during the planning year.

\(N_X\)——The number of urban residents who choose to travel by rail during the planned year.

The greater the hub transport capacity adaptability, the better the number of stations in the railway hub can meet the travel needs of urban residents. When \(1<U<1.2\), it means that although the number of stations in the hub can meet the current travel needs, but the use is relatively tight, you should consider expanding the existing passenger station or building a new passenger station. When \(U<1\), it means that the number of stations in the hub can no longer meet the travel needs of urban residents, and new passenger stations should be considered.

2.3. Station capacity utilization balance

This indicator refers to whether the passenger transportation system in the hub fully exerts the capabilities of each station. With the rapid development of railway construction, a large number of high-speed lines and ordinary speed lines are introduced into railway hubs, and multiple passenger stations coexist in the railway hub. The pros and cons of the division of operations directly affect the passenger transport capacity and service level of the railway hub. The evaluation of the division of labor in the layout of the railway passenger transportation system is helpful for the full play of railway infrastructure capabilities, the coordinated development of ordinary and high-speed lines, and the effective coordination of the railway system and the urban public transportation system. The calculation formula is as follows:

\[
\sigma = \frac{\sum_{i=1}^{n} (r_i - \bar{r})^2}{n}
\]

\(r_i\)——\(i\) station capacity utilization.

\(\bar{r}\)——Average utilization.

\(n\)——The total number of stations.

This indicator reflects the capacity utilization of each passenger terminal in the hub, and indirectly reflects whether the passenger flow distribution plan of the passenger terminal in the hub is reasonable. The size of the index is inversely proportional to the score. The smaller the value of the index, the more balanced the utilization rate of the station's capacity, reflecting the reasonable division of labor in the passenger transportation system.

2.4. Matching rate of maintenance ability of EMU

This indicator refers to the ratio of the overhaul capacity of the train maintenance section in one day and night to the number of trains to be repaired in the connected passenger station in one day and night. It reflects whether the overhaul capability of the EMU overhaul section meets the actual EMU overhaul needs of the connected passenger stations, and indirectly reflects whether the allocation plan of the passenger train station responsible for the EMU overhaul section is reasonable. The calculation formula is as follows:

\[
U = \frac{n_x}{\sum_j \rho_j^*} \cdot a_j
\]

\(n_x\)——Check the ability of the EMU to overhaul all day and night.

\(\rho_j^*\)——Overhaul rate of all vehicles within one day and night at station \(j\).

\(a_j\)——The number of start-up cars completed at station \(j\) throughout the day and night.

\(J\)——The collection of passenger stations responsible for the EMU.

The greater the matching rate of maintenance ability of EMU, the more appropriate the layout planning of the EMUs in the hub. When \(1<U<1.2\), it means that the EMU in the hub can meet the current actual EMU maintenance requirements; when \(U<1\), it means that the EMU in the hub can no longer meet
the actual EMU maintenance needs, should consider enhancing the current EMU maintenance ability or a new EMU.

2.5. External traffic adaptability of the station
The indicator refers to the degree of adaptation of the urban traffic around the railway passenger station to the construction of the railway station. In addition to the impact on the environment, the construction of railway stations will also have a certain impact on the city's traffic conditions. With reference to the relevant theories in traffic impact analysis, construct traffic adaptability indicators outside the station to evaluate the impact of station construction on urban traffic. The calculation formula is as follows:

\[ S = \mu \cdot S_1 + \lambda \cdot S_2 + \omega \cdot S_3, \mu + \lambda + \omega = 1 \]  

(5)

- \( S_1 \) — The degree of road obstruction, which represents the degree of cutting of urban roads by railway passenger stations.
- \( S_2 \) — The transit time is delayed, which means that the time for vehicles to pass through the hub area is increased due to the construction of the hub.
- \( S_3 \) — The detour distance of the vehicle, which represents the detour distance of the vehicle to the original destination due to the construction of the hub.

The higher the traffic adaptability outside the station, the smaller the impact of the construction of the station on the traffic in the surrounding cities and the greater the degree of integration between the city and the station. Therefore, the index size is directly proportional to the score.

3. Application
Zhengzhou is located in the Central Plains, where the Beijing-Guangzhou and Longhai main railway lines intersect. Known as the "railway heart", it is a road network railway hub, and the general layout is double cross type. The Zhengzhou hub plays an important role in the railway network.

Zhengzhou will build a third passenger station in the airport new area, and put forward the plan to construct a third passenger station in the east of the airport, Da guan zhuang and the west of the airport. See Fig.2 for details.

According to the above situation, experts are invited to score the indicators. The weights of each criterion layer and indicators under the criterion layer obtained by the combined weighting method[5] are shown in Tab.1 and Tab.2.

The relative posting progress of each scheme is calculated by the TOPSIS evaluation method[6][7], and the results are shown in Tab.3.

| Table 1. Criterion weight |
|--------------------------|
| Criterion layer          | Weight |
| Hub layout               | 0.24   |
| Hub transportation capacity | 0.30   |
| Integration of city and station | 0.11   |
According to the evaluation results, the airport east plan has the highest relative closeness, indicating that the plan is the best of the three plans. It is recommended that the Zhengzhou hub select this plan for layout. The layout of the new passenger terminal in the east of the airport can effectively promote the development of the airport, which is in line with Zhengzhou's overall plan.

4. Conclusion
This paper puts forward the evaluation index system of high-speed rail passenger transport system planning based on hub layout, hub transport capacity, economic and environment and other sections. Combining the combined weighting method and the improved TOPSIS evaluation method, a complete set of simple and operable quantitative evaluation system for railway passenger transport hub schemes was established. It can be used to quantitatively analyze the planning of the passenger transportation system of the railway hub and provide theoretical decisions and rational suggestions for the planning. In the future, a comprehensive railway hub evaluation index database should be established, and corresponding indexes should be selected from the database for evaluation according to different hub conditions. This approach can reduce the cost of evaluation and enhance the applicability of evaluation.
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