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Functional Evaluation of Chinese High-speed Railway Station

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Abstract: Function orientation plays a very important role in the design of a high-speed railway station. The functions include the passing function, transfer function and commercial function. The qualitative and quantitative analysis methods were used in analyzing the function. According to the high-speed train's features of high density, less regulation capacity and high punctuality, the numbers of the time for waiting for train's departure and for gathering passengers were calculated after some parameters were given, the two numbers are decreased, respectively, to 49.1 and 53.2% of the conventional railway passenger station, the passing function should be included in the design of the high-speed railway passenger station. Considering that it is unable to provide a door to door service, a high-speed railway station is often connected by two or more lines and a railway hub with several stations. Thus it is necessary for high-speed railway stations to have convenient and rapid transfer function with other traffic modes, as well as interior transfer in station and railway hubs. The business function improves the revenue and the service standard. Enough spaces for commercial development should be designed to make full use of the superiority of attracting people, commodities and information. Some practical problems should be solved to achieve the three functions.

Key words: High-speed railway, railway passenger station, function, passing, transfer

INTRODUCTION

A railway station is the intersection point of a certain amount of railway lines, with the purposes of fulfilling the task of passenger and freight transportation, ensuring train safety and improving the carrying capacity. Railway passenger stations have other purposes, such as providing various services, ticketing, locations for waiting for the train, locations to get on and off the train safely, transferring and so on. Having the characteristics of high-speed, convenience, safety and comfort and being in successful operation in Japan and Europe for many years, the high-speed railway is becoming increasingly popular. The design and construction of railway passenger stations are synchronous with high-speed railway construction.

An effective design and orientation will lead to better operation and meet better the demands of railway passengers and workers. High-speed railway passenger stations are mainly distributed in the railway lines of Beijing-Tianjin, Wuhan-Guangzhou, Zhengzhou-Xi'an, Shanghai-Nanjing, Shanghai-Hangzhou and Beijing- Shanghai. These stations have different functions.

Zheng *et al*. (2009) used a qualitative analysis method to summarize the function changes of railway passenger stations in China from a relatively macroscopic level. Basing on this work, this study uses the quantitative and qualitative analysis methods to study the functions of a high-speed railway passenger station. The key functions are passing, transfer and business, each dealt with in turn below.

PASSING FUNCTION

In contrast to the waiting function of a conventional railway passenger station, the passing function of a high-speed railway passenger station is more obvious.

REDUCING WAIT TIMES

Wait time of conventional railway passenger stations: Third-order headings, as in this paragraph, are discouraged. However, if you must use them, use 10-point Times New Roman, boldface, initially capitalized, flush left, preceded by one blank line, followed by a colon and your text on the same line.

There are so few trains to choose in a conventional railway line that most passengers have to buy tickets in advance or go to a station well before the departure time of the train. Fig. 1 illustrates the wait time.

In Fig. 1., t_1 is the begin time of passenger travel, t_2 is the time that passenger go into waiting room, t_3 is the

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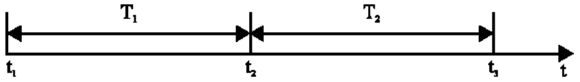

Fig. 1: Time point before the beginning of railway journey

punctual departure time of passenger train, $T_1 = t_2 - t_1$, $T_2 = t_3 - t_2$, T_2 is the wait time. There is a random feature only to T_1 or T_2 but passenger are often sensitive to the sum of T_1 and T_2. The value of $T_1 + T_2$ is determined by the distance between the railway station and the place that the passenger begins travel, the reliability of urban traffic (Yao *et al*., 2009) and the difficulty in buying a ticket. The influence factors are stochastic. Thus, the wait time is stochastic. Ma *et al*. (2009) studied the wait time of a conventional railway passenger station and the average wait time was 63.98 min. Zhang (2009) studied the assembling rule of a railway passenger, without providing a definite wait time. Using a uniform distribution to calculate the survey data, the average wait time is 46.01 min. There is a different average wait time at different passenger stations. Here 55.00 min is used as the average wait time of a conventional railway passenger station. Train delay is not considered (Zhang *et al*., 2011).

Wait time of a high-speed railway passenger station: With the operation of high-speed railway, passengers have more choice and buying a ticket may be easier, most being purchased at the station. In this circumstances, T_2 will be less random.

$L = \{l_j\}$ is the train set that the passenger wants to get on, j is the numerical order, j = 1, 2, Y, n and n is the train number of passengers. t_{jd} is the punctual departure time of train . To simplify calculations, $t_{jd} < t_{(j+1)d}$ is assumed in this paper. To ensure safety, $t_{jd} - t_2 = T_b$, T_b is a smallinterval time the value is about 5 min in China (Zhang and Zhao, 2012). p_j is the probability of successfully buying the ticket for a given train j and the wait time is:

$$T_2 = \sum_{j=1}^{n} p_j (t_{jd} - t_2) \tag{1}$$

It is very difficult to calculate the exact value of T_2 because the value of p_j is not known. Equestion 1 can be translated into Eq. 2 when having some survey data:

$$T_2 = \sum_{t_w} \lambda_w t_w \tag{2}$$

where, t_w is the wait time of railway passenger, is the ratio that the number of railway passengers whose wait time is t_w and the total number.

Two investigations were conducted in Beijing south railway station in August 2010 and April 2011 and the proportion of passengers whose wait time is between 10 and 45 min is more than 75%, the longest wait time being not more than 50 min. After examining with the survey data from Beijing south railway station, we reached the conclusion that the average wait time is about 28 min (8H0.08+26H0.75+48H0.17 = 28.3≈28), 49.1% of that of to a conventional railway. 8 is the weighted mean wait time to not more than 10 min, 26 is the weighted mean wait time between 10 and 45 min and 48 is the weighted mean waiting time to more than 45 min.

REDUCING GATHERING PASSENGERS

Calculation model of gathering passengers: $G = \{g_i\}$ is the train set that departs from the railway passenger station, i is the numerical order, i = 1, 2, Y, m, m is the train number departing from the railway passenger station. t_{zi} is the punctual departure time of train i. To simplify calculations, $t_{zi} < t_{z(i+1)}$ is assumed in this study. N_i is the regulation capacity of train i. β_i is the ratio of passengers on board and the capacity of train i, the value being between 0.7 and 1.3. β_i is the ratio of the number of people who see off the passengers and the number of passengers and the value is between 0.0 and 0.3 .

Departing passengers of train i should arrive at the station in the time during $[t_{zi} - T_{fi}, t_{zi} - T_{li}]$. T_{fi} and T_{li} are the times, respectively, from the moment the first and last passenger arrives at the station to the departure time of train i. A_{ki} is the number of passengers who get on train i at the moment k and the calculation Equestion is:

$$A_{ki} = \begin{cases} N_i \times \alpha_i \times (1+\beta_i) \times \int_{t_{zi}-T_{fi}-k}^{T_{fi}-T_{li}} g(T)dT & k \in [t_{zi} - T_{fi}, t_{zi} - T_{li}] \\ 0 & k \notin [t_{zi} - T_{fi}, t_{zi} - T_{li}] \end{cases} \tag{3}$$

where, g (T) is the density function of passenger arrival which differs between a conventional railway and a high-speed railway.

When there are too many passengers at the beginning of checking in, the passing velocity is constant. After a while, passengers can finish checking in without queuing. Thus, this study assumes a constant velocity for checking in.

The probability of train delay is very low. t_{si} is the factual departure time of train i. In China $t_{si} \geq t_{zi}$ is correct but this paper assumes $t_{si} = t_{zi}$. is the time between the moment of checking in and departure time of train and the value is between 20-30 min. t_{si}-t_{zi} is the start time of checking in. The number of passengers who have arrived at the passenger station is Api, p = min $\{T_{si} - T_{zi}, t_{zi} - t_{li}\}$, is the velocity of constant checking in, p min^{-1}. The interval time for constant checking in of train i is:

$$\left[t_{si} - T_{ti}, t_{si} - T_{ti} + \frac{A_{pi}}{v_t}\right]$$

and some passengers will arrive at the station in this interval time, so the interval is revised:

$$\left[t_{si} - T_{ti}, t_{si} - T_{ti} + \frac{A_{qi}}{v_t}\right], q = \min\{t_{si} - T_{ti} + \frac{A_{pi}}{v_t}, t_{zi} - T_{li}\} \quad x_{ki} = 0$$

or 1, when:

$$k \in \left[t_{si} - T_{ti}, t_{si} - T_{ti} + \frac{A_{qi}}{v_t}\right], x_{ki} = 1, \text{or } x_{ki} = 0$$

Thus, the number of passengers who leave the station to get on the train is:

$$D_k = \sum_{i=1}^{m} x_{ki} \times (k - t_{si} + T_{ti}) \times v_t \tag{4}$$

The number of gathering passengers in the moment k is:

$$H_k = \sum_{i=1}^{m} A_{ki} - D_k \tag{5}$$

Result analysis: For a conventional railway passenger station, the hypothesis is that all trains have the same parameters, that is, for all i, $N_i = 1200$, $\alpha_i = 1$, $\beta_i = 0$, $T_{fi} = 175$, $T_{li} = 5$, $t_{si} = t_{zi}$, the punctual departure time is 10:05, 10:10, 10:15, 10:20, 10:25, 10:30, 10:35, 10:40, 10:45, 10:50, 10:55, 11:00, 11:05, 11:10, 11:15, $m = 15$, $T_{ti} = 30$, $v_t = 90$. There is:

$$\begin{aligned} g(T) = {} & 0.001363e^{-[(T-34.45)/2.03]^2} + 0.010350e^{-[(T-39.94)/14.12]^2} \\ & -0.000649e^{-[(T-27.2)/5.50]^2} - 0.004484e^{-[(T-45.89)/10.29]^2} \\ & +0.003125e^{-[(T-30.46)/25.00]^2} - 0.001760e^{-[(T-40.89)/6.65]^2} \\ & +0.002001e^{-[(T-54.09)/101.90]^2} + 0.005905e^{-[(T-43.26)/40.76]^2} \end{aligned}$$

For a high-speed railway passenger station, the hypothesis is that all trains have the same parameters, that is, for all i, $N_i = 600$, $\alpha_i = 1$, $\beta_i = 0$, $T_{fi} = 60$, $T_{li} = 5$, $t_{si} = t_{zi}$, the punctual departure time is the same as the conventional railway $m = 15$, $T_{ti} = 20$, $v_t = 60$. There is:

$$g(T) = \begin{cases} \dfrac{1}{2^{28/2}\Gamma(28/2)} T^{28/2-1} e^{-T/2} & T > 0 \\ 0 & T \leq 0 \end{cases}$$

The calculation results are shown in Fig. 2.

Fig. 2 shows that the maximum number of gathering passengers in a conventional station is 6148 which appears at 9:40 and the maximum number of gathering passengers in high-speed station is 1440 which appears from 9:40 to 10:18. Even with the same parameters, except g (T), the maximum number of gathering passengers in a high-speed station is 46.8% that of the conventional station. The calculation result is comfort to the investigation but the hypothesis is a little easy to the actuality of railway passenger organization.

TRANSFER FUNCTION

The whole travel chain of a railway passenger is shown in Fig. 3. There are three types of transfers, including other transport modes, interior transfer in the passenger station, and transfer in a railway hub (Lin and Liu, 2012).

Compared to road transportation, the greatest weakness of a railway is in not being able to provide a door to door service. Thus, the railway passenger has to transfer with other traffic modes at the two ends of the train journey. The travel time, beyond the railway journey, has an important impact on travel satisfaction (Givoni and Rietveld, 2007; Brons *et al*., 2009). In order to ensure the high-speed advantage of a high-speed railway, a rapid and convenient transfer with other traffic modes should be sought with in a high-speed railway passenger station.

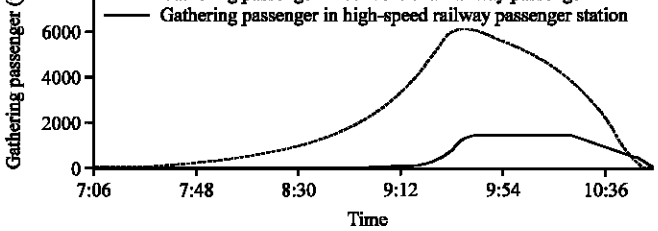

Fig. 2: Gathering passenger in conventional and highspeed railway passenger station

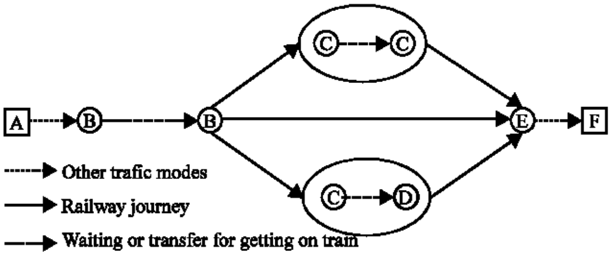

Fig. 3: Travel chain of railway passenger

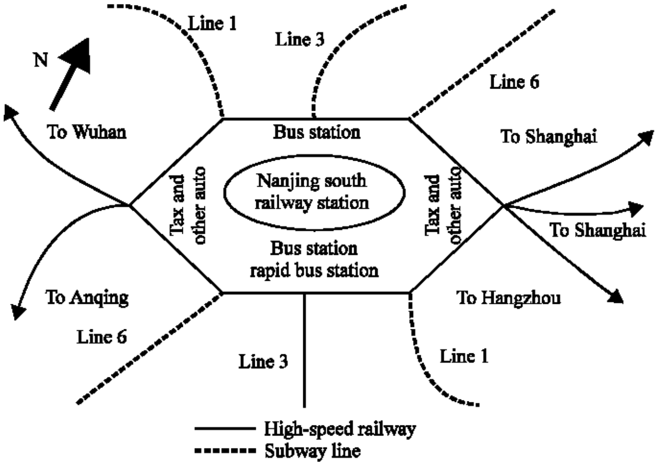

Fig. 4: Schematic diagram of transfer function and connecting railway lines in Nanjing south railway station

Due to the technological and economic features of a high-speed railway, the short and medium distances of a high-speed railway are very popular while long and super long distances are less than in the conventional railway. More passengers, especially the long-distance passenger will transfer at some stations. Passengers prefer to exchange inside a railway station (Liebchen, 2008; Shi *et al.*, 2012).

A new railway passenger station will be built when the high-speed railway connects to the railway hub. There will be more than two conventional and high-speed railway passenger stations. Each station has its special service in connecting different railway lines. Some passengers have to transfer between two stations in a railway hub (Couto and Graham, 2008).

Nanjing south railway passenger station is a good case for the three types of transfer. Five high-speed railway lines connect to this station, as shown in Fig. 4. Except Nanjing south railway station, there are two passenger stations in the Nanjing railway hub, the Nanjing west railway passenger station and the Nanjing railway passenger station. Subway lines 1, 3 and 6 are connected to the transfer square of the Nanjing south railway station which is on the first floor. Bus stations are on the North side and South side. Taxi and other auto parking areas are on the East side and West side in the transfer square. There is a rapid bus parking area for rapid buses to Lukou airport on the South side in the transfer square. Design can solve the transfer problems with other transport modes and in the railway hub. In order to provide the maximum places in the platform for interior transfer of passengers, the designs of "join of railway station and platform awning" and "platform without pillars" are used.

COMMERCIAL FUNCTION

The large investment in high-speed railway construction and operation make the associated commercial function of importance.

Commercial function of conventional railway passenger station: The railway passenger stations in China can form the economic and social center but, most of commercial function are in a scattered state. The provided commercial services are mainly those of food and beverage, hotel, travel, advertising, bookstore, drugstore, internet bar, fruit shop, exclusive agency and so on. Some large scale railway stations produce a good profit, such as the Beijing west railway station, Nanjing railway station, Shanghai railway station and Shanghai south railway station.

Often business functions are not taken into consideration in design and the good and convenient environment are not provided by the railway station so the shopping enthusiasm of passengers is reduced. Second, the poor quality and high price of goods caused by monopoly reduces the initiative of railway passengers. Lastly, the goods lack unique features and are lacking in quantity. The situation has been improved in China but the commercial modes in conventional railway passenger station have numerous limitations.

Commercial function of a high-speed railway passenger station: The Japanese railway company makes very good profit through commercial services. The turnover contributed by station commerce is about 28% of all turnover. The commercial services provided by the railway company are mainly hotel, food and beverage, commercial logistics, advertising publishing, leisure sports and real estate management (Hsu, 2010; Rong and Bouf, 2005).

Enough space for commercial development should be included in design, such as in the ticketing office and waiting room. A convenient shopping environment with good ventilation and light can attract business. Some spaces can be used for parking, shopping renting and so on in the underground connecting urban rail transit. Some spaces in the office area can be reserved for commercial development, such as hotel and logistics. The commercial function of a high-speed railway passenger station should be emphasized in the design period to make use of its advantages of convenient traffic and heavy consumption.

CONCLUSION

This study deals with the passing function, transfer function and commercial function to be considered in the design of high-speed railway station. To specialize these functions, for example, how to design the passenger station, how to plan division of the station building and how to organize the passengers flow still need further study.

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REFERENCES

Brons, M., M. Givoni and P. Rietveld, 2009. Access journey to railway stations and its potential in increasing rail use. Transportation Res. Part A: Policy Practice, 43: 136-149.

Couto, A. and D.J. Graham, 2008. The impact of high-speed technology on railway demand. Transportation, 35: 111-128.

Givoni, M. and P. Rietveld, 2007. The access journey to the railway station and its role in passengers satisfaction with r ail travel. Transportation Policy, 14: 357-365.

Hsu, S.C., 2010. Determinants of passenger transfer waiting time at multi-modal connecting stations. Transportation Res. Part E: Logistics Transportation Rev., 46: 404-413.

Liebchen, C., 2008. The first optimized railway timetable in practice. Transportation Sci., 42: 420-435.

Lin, D.M. and J. Liu, 2012. Research on train timetable-based railway route planning problem. Adv. Inform. Sci. Ser. Sci., 4: 71-79.

Ma, W.W., X.Y. Liu and L.Q. Li, 2009. Research of waiting time of passengers at railway stations. J. China Railway Soc., 31: 104-107.

Rong, Z. and D. Bouf, 2005. How can competition be introduced into Chinese railways? Transportation Policy, 12: 345-352.

Shi, F., Z. Zhou, J. Yao and H. Huang, 2012. Incorporating transfer reliability into equilibrium analysis of railway passenger flow. Eur. J. Operational Res., 220: 378-385.

Yao, J.L., Z.W. Wu and Z.X. Yang, 2009. The influence of urban traffic reliability to railway passenger station maximum assembling passengers. J. Railway Sci. Eng., 6: 84-88.

Zhang, J.N. and P. Zhao, 2012. Research on spatial affected areas of central cities based on generalized-distance. Adv. Inform. Sci. Ser. Sci., 4: 168-176.

Zhang, T.W., 2009. Research on the assembling rule of passengers at railway passenger stations. J. China Railway Soc., 31: 31-34.

Zhang, T.W., G.F. Gao, Y.P. Luo and L. Nie, 2011. Calculation model of maximum number for gathering passenger at railway passenger station. J. Traffic Transportation Eng., 11: 79-83.

Zheng, J., Z.W. Shen and S.F. Cai, 2009. Theoretical Exploration of Chinese Contemporary Railway Passenger Station Design. China Communication Press, Beijing, Chnia, pp: 26-37.