Optimum Design of Ticketing Service System of Guangzhou-Zhuhai Intercity Railway Zhuhai Station

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Abstract. Aiming at the problems existing in the ticketing service system of Guangzhou-Zhuhai Intercity Railway Zhuahai Station, the paper used the basic principles of IE and queuing theory to model and simulate the system using Flexsim software, and put forward the optimized scheme of the system of Zhuhai Station, which can alleviate the serious situations that the ticketing service time was so long, meanwhile, reduced the number of ticket sellers and made passengers travel more convenient. And this provided new ideas for the optimization of the service platform of Zhuhai Station.

Keywords: Facilities layout · Modeling and simulation · Queuing theory · Service efficiency

1 Introduction

How to scientifically and reasonably set up the number of service windows and layout of facilities in railway service system has always been the research content in the railway passenger station construction.

Queuing theory in operational research is a commonly used method to improve and optimize the efficiency of existing systems in IE research. It takes the number of queues, queue length and arrival rate in service system as the research object, and obtains the optimal service by observing, recording and calculating the field data in detail [1].

Facility planning is a new, improved and expanded manufacture or service system. It comprehensively considers various factors and makes analysis, plans and designs so that the resources can be rationally allocated and the system can be effectively operated after completion to achieve various expected goals [2].

System modeling and simulation technology [3] has been successfully applied in service industries such as banks and highway passenger stations, and achieved good results, such as Flexsim-based highway passenger station simulation system whose

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author is Hu, and Xi [4]. It provides many ideas for the use of simulation technology in relevant passenger service areas.

Industrial Engineering is mostly used in production systems, while service systems are relatively few. This paper takes the ticketing service system of Guangzhou-Zhuhai intercity railway Zhuhai Station as the research object. Based on queuing theory, Flexsim Simulation and Facility Planning, it explores a simple, effective and practical improvement plan in the paper.

2 Basic Information

Zhuhai Station is the terminal of Guangzhou-Zhuhai Intercity Railway, at the same time, it is also the starting station of Zhuhai-Jinwan Airport intercity railway under construction, which is close to Gongbei Port, the largest land crossing in China. There are more than 140 trains are sent to Guangzhou South, Guilin, Chengdu, Nanning, Zhengzhou, Kunming, Beijing and Shanghai every day. Since February 2013, the average daily passenger flow of Zhuhai Station has reached more than 15,000 people, and which on the peak day during National Day in 2017 has reached more than 60,000 people.

The main building of the station has four floors. The first and second floors of the underground are taxi station and social parking space, the first floor is ticket selling and waiting hall, and the second floor is train arrival and departure platform. On the first floor, there are 10 manual windows, 29 self-service ticket machines and 10 self-service ticketing machines. Figure 1 shows the layout of the ticket office and the entrance.

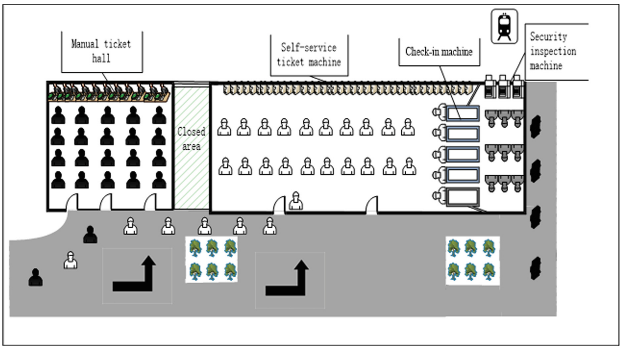

Fig. 1. Plane layout of ticket office and entrance of Zhuhai Station

3 Situation Analysis and Improvement

The status of Zhuhai Station is analyzed by using the system thinking method of Industrial Engineering, System modeling and simulation, questionnaire survey, 5W1H questioning method and ECRS improvement principle [5].

Flexsim software is used to model and simulate [6] the process from ticket selling to ticket checking in Zhuhai Station. According to the data collected from field investigation and questionnaire, the Flexsim is imported to set and run the relevant parameters. The results are shown in Fig. 2.

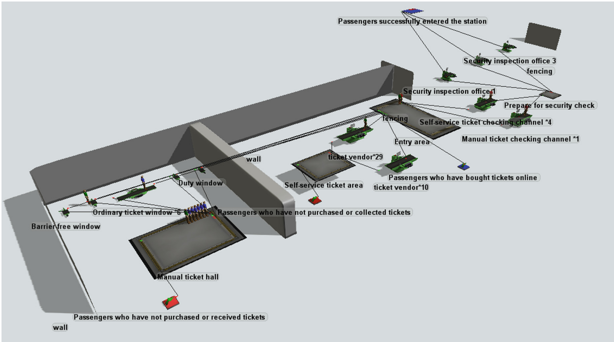

Fig. 2. Flexsim simulation diagram of ticketing service system (before)

The simulation results show that the flow of passenger is not balanced in the manual and the self-service ticketing areas, the manual ticketing window is congested, that the waiting time is long, and some self-service ticket machines are idle.

Using 5W1H method, combined with the results of simulation, field investigation and questionnaire, the main reasons are found as follows:

a. The manual ticketing window business distribution is inappropriate and the processing efficiency is low.
b. The improper placement of self-service ticketing equipment leads most people to go to the manual ticketing hall, and some machines are idle. It takes a long time for passengers to enter the ticketing hall until the tickets are purchased.
c. The unreasonable location planning of manual ticketing hall and self-service ticketing area leads to crowding in manual ticketing hall.

After analysis, the above three aspects are the key to determine the inefficiency of ticketing service at Zhuhai Station, so we should optimize these three aspects.

3.1 Artificial Ticketing Hall

Statistical analysis [7] of field observation data of effective days shows that the ticketing service system of Zhuhai Station is busy at 11:00–12:00 and 16:00–17:00. The total number of arrivals is 2424, of which 90% are for ordinary business. Therefore, the arrival rate of passengers handling business at ordinary windows:

$$\lambda = 2424 \times 90\%/120 = 18.18 \ \ (\text{person/min})$$

At the same time, the time of 100 passengers in the manual service windows were observed in these two periods. According to the statistics of relevant data, after calculation and test, it was determined that the service processing time obeyed Poisson

Distribution at a certain significant level, and the average time of each passenger's service processing in a window was obtained (v value was taken as the median value of the interval). Assuming that each window has the same business capability, meanwhile, six windows have the same service rate:

$$v = \frac{\sum v f_v}{100} = 118.42 \quad \text{(sec/person)}$$

Average number of business processes completed (service rate):

$$\mu = 60/118.42 \times 6 = 3.05 \quad (\text{person/min})$$

According to: c = 6, λ = 18.18 (person/min),

$$\mu = 3.05 \quad (\text{person/min}),$$

We derive the following calculations:
Busy rate of six ordinary windows

$$(\rho) = \frac{\lambda}{c\mu} = \frac{18.18}{6 \times 3.05} = 99\%$$

$$P_0 = 1/[\sum_{n=0}^{c-1} \frac{(\lambda/\mu)^n}{n!} + \frac{(\lambda/\mu)^c}{c!} \cdot \frac{1}{1-(\lambda/Cu)}] = 2.28 \times 10^{-5}$$

According to the system idle probability P_o, the following data are calculated respectively:

Length of queue: $L_q = \frac{P_0(\lambda/\mu)^c \rho}{c!(1-\rho)^2} = 14.1$ (person/min)

Number of people in queuing: $L_s = L_q + \frac{\lambda}{\mu} = 20.06$ (person/min)

Average waiting time: $W_q = \frac{L_q}{\lambda} = 0.78$ (min/person)

Average length of stay: $W_s = \frac{L_s}{\lambda} = 1.10$ (min/person)

Passenger handling per unit time: $Z = 60/W_s = 60/1.10 = 55$ (person)

As can be seen above, when the number of the manual ticketing window is 6, the manual busy rate is as high as 99%. In this queuing system, the best waiting time calculated is 1.1 min per person. However, from the field observation time, it can be seen that in reality, the queuing waiting time is far more than 1.1 min per person, so the number of service windows in this queuing system is seriously insufficient.

After further analysis, it is due to the improper distribution of window services, resulting in low service efficiency of each service window. In this regard, based on the actual situation of the manual ticketing hall, without changing the total number of business processing windows, after ESCRI analysis, the refund window, duty room and Hong Kong, Macao and Taiwan business were merged. The two additional windows were changed to ordinary windows, alleviating the queuing situation of ordinary windows and retaining barrier-free windows. The improved manual ticketing system is calculated.

Arrival rate: $\lambda = 18.18$ (person/min)
By adding two windows, $\mu = \frac{60}{118.42} \times 8 = 4.05$ (person/min)
Reception c = 8, $\lambda = 18.18$ person/min, $\mu = 4.05$ person/min
From that, we get this calculation:
Business Rate: $\rho = \frac{\lambda}{c\mu} = \frac{18.18}{8 \times 4.05} = 56\%$

$$P_0 = 1/[\sum_{n=0}^{c-1} \frac{(\lambda/\mu)^n}{n!} + \frac{(\lambda/\mu)^c}{c!} \cdot \frac{1}{1-(\lambda/Cu)}] = 0.13$$

Length of queue: $L_q = \frac{P_0(\lambda/\mu)^c \rho}{c!(1-\rho)^2} = 1.54$ (person/min)
Number of people in queuing system: $L_s = L_q + \frac{\lambda}{\mu} = 6.03$ (person/min)
Average waiting time: $W_q = \frac{L_q}{\lambda} = 0.08$ (min/person)
Average length of stay: $W_s = \frac{L_s}{\lambda} = 0.33$ (min/person)
Passenger handling per unit time: $Z = 60/W_S = 60/0.33 = 181$ (person)

After adding two windows, the artificial busy rate is reduced to 56%, and the queuing time is reduced to 0.33 min per person.

3.2 Self-service Ticket Area

According to the same observation and analysis method, it was found that the improper placement of equipment in the self-service ticketing area cause most people to go to the manual ticket hall, some machines were idle, and the time for passengers to enter the area to purchase tickets was longer. In this regard, under the condition that the overall layout of the self-service ticketing area remains unchanged, the number of self-service equipment is reasonably arranged according to the results calculated by queuing theory,

Table 1. Data computation of self-service ticket area

Calculated Amount	Formula	Before Improvement	After Improvement
Station Numbers of ordinary business C (a)	——	39	17
Arrival rate λ (person/min)	The number of arrivals per unit of time / time	16.0	16.0
Average transaction time (sec/person)	$\frac{\sum v f_v}{100}$	57.57	57.57
Service rate μ (person/min)	$\frac{60}{t} \times C$	1.04	——
Business rate ρ	$\frac{\lambda}{c\mu}$	39%	95%
System idle probability P_0	$1/[\sum_{n=0}^{c-1} \frac{(\lambda/\mu)^n}{n!} + \frac{(\lambda/\mu)^c}{c!} \cdot \frac{1}{1-(\lambda/Cu)}]$	2.31×10^{-7}	1.8×10^{-8}
The length of the queue L_q (person/min)	$\frac{P_0(\lambda/\mu)^c \rho}{C!(1-\rho)^2}$	2.38×10^{-7}	2.90
Number of people in the queue system L_S (person/min)	$L_q + \frac{\lambda}{\mu}$	15.38	18.28
Average waiting time W_q (min/person)	$\frac{L_q}{\lambda}$	1.4875×10^{-8}	0.18
Average staying time W_s (min/person)	$\frac{L_s}{\lambda}$	0.96	1.14

and the number of self-service ticketing machines is reduced from 39 to 17. The calculation method is the same as the above which based on queuing theory, and the process is slight [8]. Data comparison before and after improvement is shown in Table 1.

3.3 Self-service Ticketing and Ticket-Checking Area

After on-the-spot investigation, passengers need to walk out of the gate of the manual ticketing hall and than enter the ticket-checking area from another gate. The distance they need to walk is 68 m. Between the self-service ticketing and ticket-checking area, 29 ticket-selling and ticket-collecting machines and 10 student ticket-collecting machines account for 60% of the total area, and there are intersections between the ticket-selling queue and the ticket-checking queue. The layout before improvement is shown in Fig. 3.

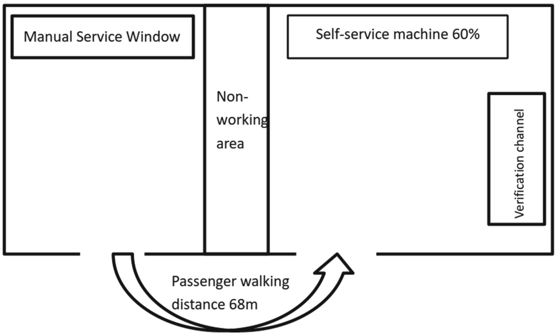

Fig. 3. Self-service ticketing and ticket-checking area (before)

In these two closed areas, there is a delay in the transmission of information, in other words, when passengers queue in the manual ticketing area, they can not receive broadcasting reminders in the check-in area, and the queuers in the manual ticketing area can not see the use of the self-service ticket machine.

According to the principle of space minimization in facility planning [9], we get these improvements:

a. To transform two separate closed ticket-selling areas, manual and self-service, into an open area;
b. The proportion of self-service ticket machines and ticket-checking machines in the self-service ticketing and ticket-checking areas will be adjusted from 6:4 to 4:6.

The improved layout is shown in Fig. 4.

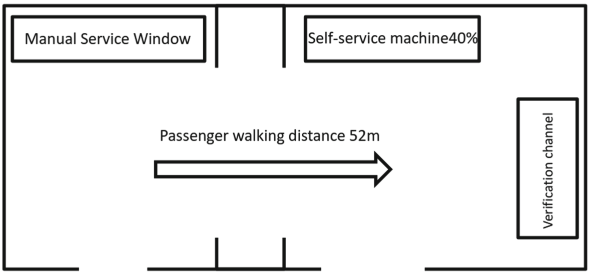

Fig. 4. Self-service ticketing and ticket-checking area (after)

4 Analysis of Improvement Effect

In the manual ticketing hall, three windows (the refund window, Hong Kong, Macao and Taiwan resident window and duty room) are merged, and the busy rate of the whole ticketing hall system is taken as a comparative reference. Under the condition that the passenger arrival rate remains unchanged, the number of people served per minute is increased by increasing the window, the busy rate is reduced from 99% to 73%, and the busy rate of staff is reduced by 26 percentage points, which is handled in unit time. The number of passengers increased from 55 to 181, which effectively alleviated the original queuing phenomenon.

In the aspect of self-service ticketing machines, 39 self-service ticketing machines were reduced to 17 because of the low utilization rate of the machines. Under the condition that the arrival rate of passengers and the service rate of the machines remain unchanged, the busy rate increased to 95%, effectively improving the utilization rate of the machines.

In terms of facility layout, separate closed manual and self-service ticket selling areas were transformed into an open area, and the distance of customers' walking was reduced from 68 m to 52 m, which improved the service level of the system. The proportion of the self-service ticket machines and ticket checking machines in the self-service ticket selling and checking area was adjusted from 6:4 to 4:6, which improved the utilization rate of the station.

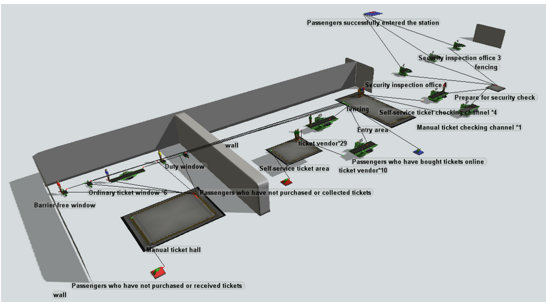

Fig. 5. Flexsim simulation diagram of ticketing service system (after)

Flexsim simulation of Zhuhai Railway Station after improvement is shown in Fig. 5 [10]. The simulation shows that the above improvement measures effectively alleviate the phenomenon of passenger queuing for ticket purchasing.

It is known that the average time spent by passengers in the manual ticketing hall decreases from 1.10 min/person to 0.33 min/person, the straight line distance from the gate of the self-service ticket office to the ticket checking office is 71 m. Before improvement, the distance from the manual ticketing hall to the self-service ticketing area is 68 m while the distance is 52 m after. We assume that the walking speed is 0.75 m/s, and the time spent by passengers in the whole ticketing service is calculated:

Before improvement: $T_I = 1.1 \times 60 + 68/0.75 + 71/0.75 = 251.0$ (s)

After improvement: $T_2 = 0.33 \times 60 + 52/0.75 + 71/0.75 = 183.8$ (s)

Average saving time: $T = T_1 - T_2 = 67.2$ (s)

After the adjustment of ticket windows and areas, the average time spent by passengers decreased from 251.0 s to 183.8 s, and the average time saved by each passenger was 67.2 s.

5 Conclusion

a. Flexsim modeling and simulation software is used to simulate the current situation, find the key problems, and then improve and optimize the system.
b. The application of queuing theory to the calculation and analysis of manual and self-service ticketing areas can alleviate the situation of queuing and idle machines, which also improve the service efficiency and the utilization rate of the self-service ticketing machines per unit time, and reduce the busy rate of artificial windows.
c. Through the spatial layout analysis of Facility Planning, the pedestrian distance is shortened, concurrently the information is more convenient and the situation of cross-flow chaos is eliminated.

Aiming at the problem of system modeling and simulation in the ticketing service system of Zhuhai Station, this optimization design uses queuing theory and Facility Planning to optimize the system, and explores the simple mode of service system optimization design. This method has a good reference value for other service systems.

Clarification. The data is anonymized. The reason why anonymous is chosen in this questionnaire survey is that the questions involved do not need the respondents to provide their invalid information, and the respondents can directly express their true inner thoughts and situations. I promise that the questionnaire survey of this paper is true, the data source and data processing are true, and I am responsible for the authenticity of the questionnaire survey. If there is any falsehood, I am willing to bear all the consequences.

Declarant: Da-wei Zhou

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