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Research on the capacity of the escalator in subway station

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Abstract: This paper analyzed passenger transport features and passenger behavior at different locations of the escalators and studied the factors affecting the actual through capabilities of the escalators in subway station by doing field surveys about technical characteristics and passenger transport characteristics of typical escalators in subway station. On the basis of existing research results, this paper presented a way based on applying queuing theory to calculate the actual capabilities of the escalators in subway station, and verified its legitimacy.

Keywords: Engineering of communications and transportation; Urban Rail Transit; Escalators; Capacity; Queueing Theory

1.Instruction

As we all know, escalators has never been fully utilized. Even if there is a very large demand, 100% utilization rate has never appeared. "Metro Design Code" [1,2] has been concerned about the capacity of the escalator problem, "Metro Design Code" is proposed by the actual situation, based on the theoretical value of the different degrees of reduction. 2003 version provides: when the escalators' speed is 0.5m/s, the maximum capacity is 8100 people/h, when the speed is 0.65m/s, the maximum capacity is no more than 9600 people / h. Compared to the 2003 version, 2013 version made 14.7% down—when the speed is 0.5m/s, the maximum capacity is 6720 people/h, when the speed is 0.65m/s escalators, the maximum capacity is no more than 8190 people / h. Two versions of "Metro Design Code" through the capacity is 82%, 70% of the theoretical value.

In actually, it is found that the capacity of the subway station escalators are often less than the specified value. So we need to explore the actual capacity of the subway station escalator. First, the study must first make clearly the difference between theory and practice, and the influencing factors of the reasonable calculation method to calculate the actual capacity of the escalators.

2.Investigation and analysis

2.1 Factors affecting actual capacity of escalator

The definition of escalator [3] is a fixed electrical drive unit with a run-run step for tilting passengers up or down.

During the investigation, it is found that the actual capacity of the escalator is mainly affected by the passenger flow, the passenger arriving rule and the passenger distribution.

1. The size of traffic. Passenger is directly affected the size of the escalator. It can be regarded that at this time of queuing congestion, escalator has given the greatest service.
2. Passenger flow. It is no queuing congestion until passenger traffic capacity is greater than the escalator itself.
3. Passenger distribution. Even in the most crowded traffic, passengers will not stand close to each other, it always has empty steps (or empty location) appears.

2.2 Vacant ladder section

"Metro Design Code" provides the reason of why the maximum capacity is less than the theoretical value, the theory is based on the ability to assume that all the steps is full of 2 people. In fact, the use of escalators in the process, certainly not stand or not stand full of 2 individuals. We definite those ladder as the "vacant ladder."

The study found that the production of vacant steps have the following reasons:

1. Passenger intermittent arrival at the escalator. The passenger flow is not continuous, the escalator will has vacant steps;
2. The reaction time is too long. The greater the speed of the escalator, the longer the passenger can confirm that the step is safe. An escalator with a speed of 0.65 m/s has a running time of 0.62 s for one rung, and a vacant rung is generated when the passenger's run time is greater than one rung. So the greater the speed the greater the vacancy rate of escalators;
3. Individual psychological factors. Passengers want to ensure a certain private space, the subjective and passengers do not want to leave too close.
4. Passengers carry luggage will take up space.

2.3 Actual capacity through the investigation

The passenger flow characteristics of the escalators at different locations of the subway station are different. Select the Xizhimen Station's escalator on behalf of the capacity and queue through the investigation shown in Table 1.

Table 1. Survey results of various escalators

location	length	speed	Speed Peak Actual Pass Through Capacity Peak Peak	Average Number of Queues
Underground escalator down the direction of	33.5m	0.65m/s	4641people/h	17people
Line 2 up the direction of the escalator	26.3m	0.65m/s	5711people/h	22people
Line 13 to the station floor	16.1 m	0.5m/s	4890people/h	25people

3.Capacity calculation based on the queuing theory model

3.1 Study on passing capacity of escalator

There are many scholars at home and abroad to do on the escalator through the capacity of the study. Paul [4] such as considered the escalator running speed, vertical height and step width and other factors to get the actual passenger capacity of the escalator multiple regression equation. Portland State University scholars [5] that the arrival of discrete pedestrians, pedestrians on the escalator when the delay will reduce the actual capacity of the escalator.

Meng Xiangqiang [6]· such as the establishment of the capacity of the escalator capacity model including the semi-semi-stand case of the escalator capacity model, the situation of passengers sitting all the escalator capacity model and passenger evacuation escalator capacity. Yao Xiaolin [7] and others for the subway station evacuation problems, the use of FDS + Evac simulation, derived in China's current "Metro Design Code" escalator and pedestrian staircase capacity reduction coefficient of the larger value of the conclusions. Tan Songtao [8] from the impact of the mechanism, the escalator through the baggage capacity changes in the impact of law, and through the survey data fitting quantitative relationship for the escalator scale design to provide reasonable parameters for the "Metro Design Code" supplement.

Above research methods, although feasible, the actual operation requires a lot of manpower and material resources. In view of the difficulty of field survey operation, this paper proposes the use of queuing theory to find the capacity of escalator. The queuing theory is used to construct the appropriate queuing theory model. By using the known queuing length, waiting time and anti-rollout service rate, the passing capacity of the escalator is established.

Taking the service time as the fixed value M/D/1 [9] model as an example. It is known that the arrival law of passenger flow obeys Poisson distribution, the arrival rate of passenger flow is λ, and the number of queues is Lq. Using the number of queues Lq find the service rate μ formula derivation process is as follows:

$$Lq = \frac{\rho^2}{2(1-\rho)} \quad (1)$$

$$\rho^2 + 2\,Lq \bullet \rho - 2\,Lq = 0 \quad (2)$$

$$\rho = \frac{\sqrt{4Lq^2 + 8Lq} - 2Lq}{2} \quad (3)$$

$$\rho = \frac{\lambda}{\mu} \quad (4)$$

it can be deduced that,

$$\mu = \frac{\lambda}{\rho} = \frac{2\lambda}{\sqrt{4Lq^2 + 8Lq} - 2Lq} \quad (5)$$

$T=1/\mu$ $Var[T]=0$

If the service time is known to be a certain constant. λ is the passenger arrival rate, μ is the service rate, that is, the actual capacity of the escalator. It is necessary to study the value of the passenger arrival rate λ to study the queuing problem at the entrance of the escalator.

3.2 Arrival rate λ of passenger flow

The unit time (1min) to reach the escalator at the entrance to the number of passengers to investigate the collection of data collected to obtain data 60 groups. The single sample K-S test is used to test the Poisson distribution, and the test results are shown in Table 2.

Table 2. One-sample Kolmogorov-Smirnov test

N		60
Poisson parametera,b	Mean	93.6833
The most extreme difference	Absolute value	.165
	positive	.165
	negative	-.128
Kolmogorov-Smirnov Z		1.277
Asymptotic significance (bilateral)		.077

a.Test distribution is Poisson distribution.
b.Calculated from the data.

From the above table we can see that the probability value p is 0.077, and if the significance level α is 0.05, the probability distribution p can not be rejected because the probability value p is greater than the significance level, so the overall distribution of passenger arrivals at the escalator is not significantly different from the Poisson distribution , Where the rate of passenger traffic follows the Poisson distribution.

The number of passengers arriving at the escalator entrance per unit time (1 min) was investigated, and the collected data was recorded and 61 sets of data were obtained. By using the one-sample K-S test for the Poisson distribution test, the test results are shown in Table 3.

Table 3. Single sample Kolmogorov-Smirnov test

N		61
Poisson parametera,b	Mean	77.4754
The most extreme difference	Absolute value	.086
	positive	.086
	negative	-.085
Kolmogorov-Smirnov Z		1.277
Asymptotic significance (bilateral)		.077

a.Test distribution is Poisson distribution.
b. Calculated from the data.

From the Table 3 we can see that the probability value p is 0.759. If the significance level α is 0.05, since the probability value p is greater than the significance level, the null hypothesis can not be rejected, and the overall distribution of passenger arrivals at the escalator is not significantly different from the Poisson distribution , Where the rate of passenger traffic follows the Poisson distribution.

Escalator on line 2, line 13 from the station floor to the landing layer of the escalator to reach the station to reach the law subject to Poisson distribution. The two locations can be solved using the M / D / 1 formula.

3.2 M/D/1 model checking and calculation

The M / D / 1 model is used to calculate the relevant queuing indexes, and the results are compared with the actual situation to verify its rationality.

Line 2 escalator service rate μ = 8190 * 0.7 = 5733 people / h = 1.59 people / s, then P = λ / μ = 1.56 / 1.59 = 0.98

The number of queues Lq= 0.982 / 2 * (1-0.98) = 24 people

The results and the actual (the average number of queues for 22) is basically consistent. It can be concluded that the M / D / 1 queuing theory can be established when the passenger arriving rule obeys the Poisson distribution and the service time is a constant.

The queuing theory model M / D / 1 is established and verified to show that it is reasonable to build a queuing theory model. By the arrival rate λ, we can infer the actual capacity of the escalator through queuing length and waiting time.

It is known that the passenger flow arrives at the escalator of the station on the 13th line. The arrival rate of the passenger reaches λ = 77.4754 person / min = 1.29 person / s (see Table 3-3). The average number of queues at the entrance of the escalator is 25 (see Table 2-1). Use the formula 3-5

$$\mu = \frac{\lambda}{\rho} = \frac{2\lambda}{\sqrt{4Lq^2 + 8Lq} - 2Lq} = \frac{2\times 1.29}{\sqrt{4\times 25^2 + 8\times 25} - 2\times 25} = 1.316 \text{people}/s = 4739 \text{people}/h$$

Actual capacity is 4890 people / h (see Table 2-1), the theoretical and actual difference of 157 people, the error about 3%.

4. Conclusion

The core of the queuing theory model is to establish the queuing theory model by using the queuing condition and the passenger arriving rate λ, and the service rate μ, which is the actual throughput capacity of the escalator. The queuing theory focuses on queuing rather than the distribution of passengers and the movement on the escalator. The survey is simple and feasible, clear thinking of data processing, record personnel requirements are not high and so on. The queuing theory model is established under the condition that the arrival rate λ and the service rate μ are known. At the same time, queuing theory model is an idealized mathematical model. The queue length and waiting time used here are average queue length and average waiting time. If the survey sample is unreasonable, average queue number or average waiting time is too large or too small, it will affect the calculation of throughput capacity.

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