Correlation analysis of platform intelligent electric screen doors and accidents in urban rail transit

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Abstract. In order to determine the main factors affecting the accident of passenger falling off the track, 223 cases of subway station passengers falling off the track in mainland China from 2000 to 2020 (up to September) were collected as the research object. Among them, 13% of the samples had platform screen doors, and 87% had no platform screen doors. Considering the limitations of the statistical sample data, in order to accurately and scientifically study and judge the effectiveness of PSD in reducing the accident of passengers falling off the track, this paper uses the knowledge of advanced mathematics and statistics, combined with the passenger volume information of the station, to analyse and verify the relationship between the existence of PSD and the occurrence of the accident. The statistical results of the case show that the installation of platform screen doors in the station can reduce the occurrence of passenger falling off the rail to a certain extent. The mathematical analysis shows that the correlation between the installation of platform screen doors in the station and the passenger falling off the rail in the operation process of Urban Rail Transit reaches 0.99, which is consistent with the statistical results of this case.

Keywords: urban rail transit; platform screen door; passenger falling accident; passenger volume; mathematical analysis.

1. Introduction

Huang Zhao [1] made a statistical analysis on the causes of 17 accidents in Guangzhou. Due to the lack of analysis on the causes of the accidents, and the strong limitations of Huang Zhao's sample data, this paper makes a new statistical analysis on the accidents. This paper collected 223 typical accidents of urban rail transit passengers falling off the track in the mainland of China from 2000 to 2020 (up to September), and classified the causes of these cases. It was found that the main factors were passengers' suicide, accidental falling off the track, unexplained falling off the track, their own physical reasons, careless falling off the track and drunk falling off the track, accounting for 86% of the total number of falling off the track, to a certain extent, it increases the diversity and representativeness of statistics related to urban rail transit passenger falling accidents.

As for the role of platform screen door, Ouyang [2] said that platform screen door is an important factor in the normal operation of subway and plays an important role in the safety of subway operation. Hou Xinran [3] and Chen [4] proposed relevant risk control measures through the analysis of typical accident cases and fault tree of platform screen door. As for the proof of the safety of platform screen
door system, Chung [5] and Portillo [6] et al. considered that the installation of platform screen door in the station is one of the most effective strategies to prevent suicide, proving that the installation of full height platform screen door can completely prevent suicide. Xing et al. [7] analyzed the suicide data of rail jumping in Shanghai, verified the effect of different types of platform screen doors, and concluded that 1.5m platform screen door is better than 1.2m platform screen door in preventing suicide. All the above studies focus on the prevention effect of platform screen door on the suicide of passengers jumping off the rail, without considering the situation of passengers falling off the rail due to their own physical reasons, drunk falling off the rail, accidental falling off the rail and so on.

In order to prove the safety of the platform screen door, the relationship between the platform screen door and the number of passengers falling off the track is studied. The differences between this paper and other research methods are as follows: (1) the statistical cases of rail fall accidents are more abundant, including not only suicide rail jump accidents, but also other causes of rail fall accidents. (2) This paper links the number of rail accidents with or without platform screen doors with the total passenger volume of urban rail transit, and deduces the number of no rail accidents by using the thinking of Higher Mathematics limit, so as to establish a model of 2 × 2 contingency table model. (3) Based on probability theory and statistical knowledge, to test the hypothesis of the relationship between the number of accidents of platform screen door and the number of accidents of falling rail. Using this method, we can use mathematical method to verify the relationship between the statistical data and the trend that the PSD can reduce the occurrence of passenger falling off the track, so as to increase the accuracy and persuasion of the article.

2. Data sources
The accident information of this study is collected from professional literature, the official website of the subway company and the formal media. The statistical information is refined, screened and verified to ensure the accuracy.

3. Statistical results
According to the statistics of the track falling accidents with or without PSD in the station, the results show that there are 30 accidents with PSD in the station and 193 accidents without PSD in the station. It can be inferred that there may be a certain relationship between the use of platform doors and the occurrence of accidents.

In the process of case statistics, it is found that the accidents of accidental falling rail, careless falling rail and being pushed off the platform account for 24% of the total number of falling rail accidents, and these three types of accidents are largely restricted by the platform screen door. To a certain extent, the addition of platform screen doors will reduce the occurrence of drunken falling off the track, physical falling off the track, picking up things and jumping off the track, and falling off the track due to fighting. These four types of accidents account for 22.6% of the statistical samples. Therefore, the installation and use of platform screen door has a factual basis for the prevention of rail fall accident.

4. Mathematical analysis and verification
Due to the incomplete statistics of sample size and sample information, there are some limitations. In order to make the proof of PSD safety more scientific, this study uses mathematical knowledge to verify. According to the passenger volume information of China's urban rail transit, combined with the knowledge of limit in higher mathematics, establishing a contingency table model. Secondly, the relationship between the existence of platform screen doors and the number of accidents is tested to verify the relationship between the existence of platform screen doors and the occurrence of accidents. In order to make the data processing simple and extensive, first use letters to replace the relevant data, data letter 2 × 2 contingency table is shown in Table 1.

| Table 1. Substituting letter 2 × 2 contingency table. |
Whether the accident happened or not

| With or without PSD | Number of accidents (B) | Number of no accidents (\(\bar{B}\)) | Total |
|---------------------|-------------------------|--------------------------------------|-------|
| Have platform screen door (A) | \(n_{11}\) | \(n_{12}\) | \(n_{1+}\) |
| No platform screen door (\(\bar{A}\)) | \(n_{21}\) | \(n_{22}\) | \(n_{2+}\) |
| Total | \(n_{1+}\) | \(n_{2+}\) | \(n\) |

4.1. Inferences by using the independence of events.

To prove whether the two are related, it is assumed that the station has a platform screen door (A) and the number of falling rail accidents (B), that is, event A and event B are independent. Then \(P(AB) = P(A)P(B)\) should be established, expressed by the letter \(H_0\).

When \(H_0\) is assumed to be true, then \(P(\bar{A}B) = P(\bar{A})P(B), P(AB) = P(A)P(\bar{B}), P(\bar{A}\bar{B}) = P(\bar{A})P(\bar{B})\) is true, we can see that \(P(AB) = \frac{n_{11}}{n}, P(\bar{A}) = \frac{n_{1+}}{n}, P(B) = \frac{n_{1+}}{n}\). So \(n_{1+} \approx \frac{n_{11}}{n}, \frac{n_{1+}}{n}, \frac{n_{11}}{n} \approx \frac{n_{22}}{n}\) should be true.

It can be inferred that when the original hypothesis \(H_0\) is true, \(\left(\frac{n_{11}}{n}, \frac{n_{12}}{n}, \frac{n_{1+}}{n}\right)^2 + \left(\frac{n_{12}}{n}, \frac{n_{22}}{n}, \frac{n_{1+}}{n}\right)^2 + \left(\frac{n_{22}}{n}, \frac{n_{22}}{n}, \frac{n_{2+}}{n}\right)^2\) is small.

The sum of the above four terms is represented by \(\chi^2\), that is:

\[
\chi^2 = \left(\frac{n_{11}}{n}, \frac{n_{12}}{n}, \frac{n_{1+}}{n}\right)^2 + \left(\frac{n_{12}}{n}, \frac{n_{22}}{n}, \frac{n_{1+}}{n}\right)^2 + \left(\frac{n_{22}}{n}, \frac{n_{22}}{n}, \frac{n_{2+}}{n}\right)^2 + \left(\frac{n_{11}}{n}, \frac{n_{12}}{n}, \frac{n_{1+}}{n}\right)^2
\]

Simplify:

\[
\chi^2 = \frac{n(n_{11}n_{22} - n_{12}n_{21})^2}{n_{1+}n_{2+}n_{1+}n_{2+}}
\]

4.2. Form data filling.

According to the statistical data, we can know that \(n_{11} = 30, n_{12} = 193\). Based on the contingency table model, we can deduce the accident non-occurrence number through the limit thinking. During the process of passenger flow transportation, the passenger drop off accident is a small probability event. According to the observation of the accumulated passenger volume information of urban rail transit in 2012-2019, the annual passenger volume is billions of people. It can be inferred that the total passenger transport volume in the past 21 years is a great number. All passengers who take the urban rail, except for the ones who have fallen, all the rest are not. Therefore, the data of no falling track accidents are quite large. Compared with the number of accidents, the number of accidents does not occur tends to be infinite.

Suppose that whether the station has PSD or not, the number of accidents is \(m\), then \(m \to +\infty\), and the analysis conclusion is that: \(n_{12} = m, n_{22} = m, m \to +\infty\). Results are shown in table 2.

Table 2. Data calculation table.

| With or without PSD | Whether the accident happened or not | Total |
|---------------------|--------------------------------------|-------|
|                     | Number of accidents (B) | Number of no accidents (\(\bar{B}\)) |       |
| Have platform screen door (A) | 30 | \(m\) | \(m + 30\) |
| No platform screen door (\(\bar{A}\)) | 193 | \(m\) | \(m + 193\) |
| Total | 223 | \(2m\) | \(2m + 223\) |
4.3. The calculation is based on the above inference.

Hypothesis: hypothesis $H_0$: whether the station has platform screen door or not has nothing to do with the accident; $H_1$: whether the station has platform screen doors or not is related to the occurrence of the accident.

From the above formula (2), we can see that:

$$
\chi^2 = \frac{n(n_1n_{22} - n_{12}n_{21})^2}{n_1n_{22}n_{12}n_{21}}
$$

Take the data in Table 2 with formula (2) to get:

$$
\chi^2 = \frac{(30m - 193m)^2(2m + 223)}{223 \cdot 2m \cdot (m + 30)(m + 193)}
$$

(3)

By simplifying equation (4.3), it can be concluded that:

$$
\chi^2 = \frac{163^2 \cdot (2 + 223/m)}{446 \cdot (1 + 30/m)(1 + 193/m)}
$$

And $g_{(m)} = \frac{(2 + 223/m)}{(1 + 30/m)(1 + 193/m)}

(4)

(5)

The simplified formula (5) can be obtained:

$$
g_{(m)} = \frac{2 + 223/m}{1 + 223/m + 193 \cdot 2 \cdot 30/m^2}
$$

(6)

When $m \to +\infty$, $\lim_{m \to +\infty} g_{(m)} = 2$, Take $\lim_{m \to +\infty} g_{(m)} = 2$ into equation (4)

Calculated: $\chi^2 = 163^2 \cdot 2 \approx 119.14$, So reject $H_0$, accept $H_1$, that is, whether there is a correlation between the existence of PSD and the occurrence of the accident.

According to the statistical distribution of $\chi^2$, when $\chi^2 > 6.635$, there is 99% assurance that event A is related to event B, where $\chi^2 \approx 119.14 > 6.635$, so we can get 99% assurance that there is a correlation between whether there is a platform screen door in the station and whether there is a rail fall accident.

5. Conclusions

Based on the statistical analysis of the cases of urban rail transit passenger derailment accidents in the past 21 years, it is found that the number of passenger derailment accidents without platform screen doors is 64% higher than that with platform screen doors. The fact shows that the installation and use of platform screen doors can reduce the occurrence of passenger derailment accidents. Through the relevant mathematical analysis and calculation, the correlation between the installation of platform screen door in the station and the occurrence of the passenger falling off the rail in the operation of urban rail transit is 0.99, which increases the accuracy of the article.

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