Quantitative Risk Assessment Method Based on Risk Theory of Subway Station

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Abstract. With the development of economy and the improvement of society in China, the problem of traffic jam in cities is increasingly serious. The subway is an effect way to reduce the traffic jam in big cities, such as Beijing. This article takes subway station of Beijing as the main study subject. Through the analysis on factors and features of subway station accidents, the subway station data categories were determined with core of accident prevention. The subway station data categories include passengers injure, unexpected death, interrupted operation and equipment failure. Based on the analysis of accident, failure rules and mutual relationship, according to risk theory, the paper gives the quantitative risk assessment methods of subway station. Subway station comprehensive risk classification method is established by risk matrix method. Different managers can take different management strategies through different classification station.

Guidelines

At present, some countries and regions have carried out related research on the quantitative assessment method of the subway. Such as, safety self- assessment of the Hong Kong Mass Transit Railway found risk sources and hidden dangers for the subway, but t But the main assessment method is the safety check list, the lack of quantitative assessment and safety level classification.[1-2] Lots of researches have been carried out about risk quantitative assessment of the subway in the UK London Underground Ltd. Based on their historical data over the years, London subway used the probability statistical analysis method, classified various influence factors of subway safety, and determined the weight of various factors and accident control index of subway stations. We had just begun in subway system safety quantitative analysis and research work in China[3]. Because of lack suitable methods about safety comprehensive quantitative assessment of subway operation system, so it is difficult to evaluate the safety level of a station, a subway line and the whole systems.

Analyzing the Accident Impact Factor of Subway Station

In order to promote the improvement of overall management, we preliminary determine the following index to evaluate operational management in metro station by means of analysis and processing the of accident and failure data involved in actuality of metro station .Specific indicators data as shown in figure 1:

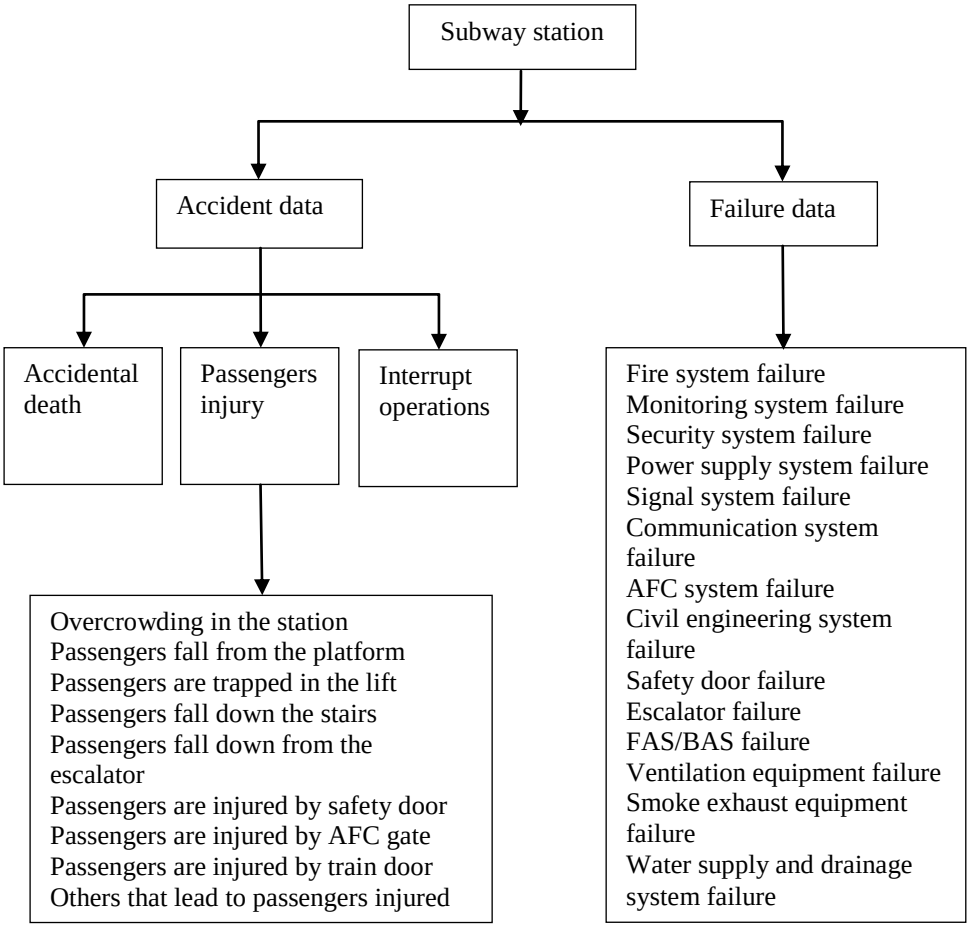

Figure 1. Risk assessment data frame system of subway station

Establishing the Quantitative Risk Assessment Method of the Subway Station

The Accident Index Calculation Method Involving Casualties

For the accidents or incidents involving employees and passenger injury, we adopt accident impact factor coefficient as one of the factors to measure the station or line[4-6].According to the situation of worker and passenger injury degree we confirm the different conversion factors, we adopt the method of "equivalent" conversion to calculated casualty accidents index. As shown in table 1.

Table 1. Injury fatalities equivalent conversion factor

The injury degree	Conversion factor	The worker injury type
Minor injury	0.05	The fingers, toes fracture (fingers and toes) Strains and sprains Scratches, cuts and bruises Minor burns Any leave less than 3 days' injury
Medium injury	0.1	Fractures (hand, wrist, ankle, etc.) Moderate burns Broken fingers, toes(fingers and toes) Loss of sight or hearing (temporary) Any leave in three days to one month's injury
Serious injury	0.5	Main bone or skull fractures Amputation or remove eye Loss of sight or hearing (permanent) Loss of consciousness need to be rescued Any leave more than a month's injury
Fatal injury	1	Death

The risk degree of casualty involved in subway station or single line is showed by equivalent accident impact factor of accidents every year. For the accidents that have happened don't always lead to the worst consequences, instead there may be some different consequences, some of which don't cause death, therefore, the computation formula of the severity degree of consequences is as follows :

$$S = [Fa+0.1M_1+0.01M_2+0.005M_3]$$

The symbolic meaning is:

S—Severity degree of consequences

Fa—Death number M_1—Fatal injury number

M_2—Medium injury number M_3—Minor injury number

The Accident Index Calculation Method Involving Interrupt Operations

For accidents or incidents involving interrupt operations, using the size of interrupt operation time as one of the factors to measure the station or line. The conversion factors of different influence are confirmed according to the time of interrupt operation. Using the conversion methods of "conversion death factor of interrupt operation time to calculate interrupt operation accidents index, as shown in table 2.

Table2 Interrupt operation equivalent conversion factor

The injury degree	Conversion factor
interrupt operation time t: 5min≤t≤20min	0.05
interrupt operation time t: 20min<t≤60min	0.1
interrupt operation time t: 60min<t≤180min	0.5
interrupt operation time t: t>180min	t/180

The risk degree of interrupt operation involved in subway station or single line is showed by equivalent accident impact factor of interrupt operation every year. Therefore, the computation formula of degree of risk involving discontinued operations, namely risk value, is as follows:

S = [Y1+0.5 Y2+0.1 Y3+0.05 Y4]

The symbolic meaning is:

S—Risk

Y1—The times of interrupt operation time t:t>180min

Y2—The times of interrupt operation time t:60min<t≤180min

Y3—The times of interrupt operation time t:20min<t≤60min

Y4—The times of interrupt operation time t:5min≤t≤20min.

If discontinued operations affect the subsequent trains, the effect to system shall be modified according to the actual situation.

The Index Calculation Method Involving The Failure

Using hour failure frequency to count the equipment failures of the station. Table 3 shows the calculation method .

Table3 Station index failure rate calculation method

Fault project	Calculation method	The daily running time/hour
Failure rate of FAS	The times of equipment failure/equipment run time	24
Failure rate of air conditioning		24
Failure rate of water supply and drainage system		24
Failure rate of fire system		24
Failure rate of elevator system		18.5
Failure rate of safety door		18.5
Failure rate of signal system		24

The Comprehensive Risk Calculation Model Of Subway Station

For the comprehensive risk calculation model of subway station, the concept of risk is mainly referenced. Risk=severity×possibility, But it is just a conceptual formula in terms of risk calculation formula, which does not have practical significance of calculation[7-10],Therefore, considering the calculation results of severity of onsequences and the failure rate of equipment, the risk matrix method is adopted in the calculation of subway station comprehensive risk. The selection method of the boundary conditions of severity degree of consequences and failure rate of equipment is shown in figure 2:

Severity degree of consequences		S≤0.1	0.1<S≤0.5	0.5<S≤1	1<S≤2	S>2
Failure rate	F≤0.02	Low	Low	Low	Middle	Middle
	0.02<F≤0.1	Low	Low	Middle	Middle	High
	0.1<F≤0.3	Low	Middle	Middle	High	Very high
	0.3<F≤0.6	Middle	Middle	High	High	Very high
	F>0.6	Middle	High	High	Very high	Very high

Fig.2 Subway station comprehensive risk classification

Conclusions

(1)Aiming at the accidents of the subway station and based data information of failure which have been acquired, quantitative risk assessment method including accident index calculation method involving casualties, the accident index calculation method involving interrupt operations and the index calculation method involving failure is established.

(2)Referencing the concept of risk, considering calculation results of the consequences severity and failure rate of equipment and adopting risk matrix method, the comprehensive risk classification model in subway station is established.

(3)A subway station in Beijing as an application case, adopting quantitative risk assessment method and comprehensive classification model to calculate the risk, the result can reflect the actual situation of risk of the subway.

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