The multi-level urban rail traffic safety based on fuzzy TOPSIS evaluation research

Jiaxu Chen

1 School of Traffic and Transportation, Beijing Jiaotong University, Beijing 100044, China

Abstract. With the expansion of the scale of the urban rail transit network and the increase of the factors affecting the safety of the operation of the network, the operation risk of urban rail transit is also increasing. For urban rail transit network security problems, according to the statistical analysis of urban rail traffic accident, first constructed oriented network station, line, different levels of urban rail traffic safety evaluation index system, from the three levels of urban rail transit network security influence factors were analysed, and further improving the system of safety evaluation index; Secondly, TOPSIS evaluation method based on triangular fuzzy number is used in this paper to evaluate the safety risk of urban rail transit, which overcomes the disadvantage of subjective factors in AHP and FAHP evaluation methods. Finally, the model is calculated and analysed. This paper provides decision-making basis for the safety management department of urban rail transit, and has certain reference significance for improving the safety management level of urban rail transit.

1. Introduction

With the continuous construction and development of the urban rail transit system, its structure is more and more closely related. Different stations and lines are interrelated and interact with each other. When there is a local problem in the urban rail system, it is easy to trigger a chain reaction of the entire operation network, causing serious consequences [1]. For example, on March 29, 2010, in Moscow "rupees sample card" and "cultural park" subway station successively two explosions occurred, a total of 40 people were killed and injured nearly, lead to train emergency shutdown, makes the station along the passengers stranded in large area, evacuation is difficult, caused serious influence [2]. This is typical because the influence of the line makes the relationship between stations become more complex. The change of passenger flow between different lines and different stations in the whole urban rail network may be caused by the change of passenger flow at one station. Therefore, under the condition of the operation of the urban rail transit network, the consequences caused by the accident will continue to expand along with the network effect, thus affecting the whole urban rail transit network system. By affecting the safety of urban rail transit network comprehensive evaluation index system building, the security risk assessment, risk management to strengthen the urban rail transit network security has important research significance.

In the process of safety assessment of urban rail transit operation, the establishment of safety assessment model and the selection of appropriate safety assessment methods are the two most important aspects. Su Xuming[3] et al. started from the safety management link of "human, machine, environment and management" to model, improved the fault mode analysis method, and applied it to the evaluation of urban rail transit safety. Xiao Xuemei[4] et al. discussed the application of evaluation methods for operation safety of urban rail transit network by studying complex network and entropy.
Cai Guoqiang[5] et al. put forward a safety assessment method for rail transit based on fuzzy hole model, analyzed and studied safety-related factors and their relationship and dynamic evolution mechanism, and achieved good results in improving active safety warning. Yan Fei[6] et al. analyzed and summarized the signal system safety related technologies in rail transit. On the safety assessment methods, Pan Ke[7] the variable weight theory, and the relative difference function is introduced to the evaluation of subway operation safety. Zhao Huixiang[8] measured the severity of the accident's impact on operation based on the frequency and severity of the accident, proposed some operational safety indexes, and evaluated the safety status of urban rail transit by using the fault mode analysis method. Wang Hongde[9] et al. studied the application of set pair analysis principle in urban rail transit safety evaluation by combining AHP.

However, most of the researches on the safety state evaluation of the urban rail transit network system focus on qualitative analysis of a station or key equipment, lacking a comprehensive safety state evaluation index system under the background of the network operation of urban rail transit. For the research of multi-objective decision-making problems, AHP or fuzzy AHP are mostly adopted to solve them. Due to the imperfection of the expression of expert opinions, the final results may be inconsistent with the actual situation when the expert opinions are transformed from qualitative to quantitative[10]. Therefore, according to the characteristics of the network operation of urban rail transit, this paper constructs an evaluation index system for the operation safety of urban rail transit facing stations, lines and networks, and studies the operation safety situation of urban rail transit under the influence of multiple factors. And related mathematical properties based on triangular fuzzy number, using the method of TOPSIS, the safety evaluation index system in some difficult to direct quantitative index quantitative said, to the safety of the urban rail transit line station network state evaluation, for the work of urban rail traffic safety management department to provide the corresponding direction.

2. Urban rail transit network multi-level safety evaluation index system

2.1. Station safety evaluation index system

The important infrastructure in the urban rail transit system is the station, which is the basic point of the entire urban rail network. Therefore, the safety evaluation of the station belongs to the micro level. The risk of the station is mastered from four aspects, namely, personnel, equipment, environment and management factors, so as to find out its relatively weak links and provide an effective basis for the safety management of each station. Based on this, the evaluation system is established as shown in figure 2-1.

Fig.2-1 Urban rail transit station safety evaluation index
(1) Personnel factor

Average passenger flow intensity refers to the internal passenger flow relative to the scale of the station, and it is an important index reflecting the passenger flow of urban rail transit station. The greater the intensity, the more the passenger flow, the more likely it is to cause congestion, and then safety accidents such as stampede may occur. The average passenger flow strength calculation formula 2.1 shown in the following type:

\[ SI_i = \frac{P_i}{M_i} (2.1) \]

The professional skill quality of the staff refers to the comprehensive value of working years, working characteristics, working intensity and safety awareness of the staff in the station. This index can be quantified by questionnaire survey or expert rating.

(2) Equipment factors

Urban rail transit station equipment factors are mainly evaluated from the FAS system, water supply and drainage system, power supply system, lighting system and electromechanical system in the station. Failure of various equipment and facilities, even if it does not directly cause the accident, also increases the risk factors of the station to a certain extent. Equipment factors in safety index calculation formula 2.2 shown in the following type:

\[ F = 1 - f (2.2) \]

Where: \( F \) represents the safety index of equipment and facilities within \((t, t + \Delta t)\) time; \( f \) represents the failure rate of various equipment and facilities within \((t, t + \Delta t)\) time.

(3) Environmental factors

The station comprehensive environment index refers to the comprehensive value of temperature and humidity at a certain time in various places (platforms, passages, etc.) in the station. Temperature and humidity will affect the state of equipment and facilities in the station, as well as the comfort level of passengers. The calculation formula is shown in equation (2.3):

\[ IE = 0.72(T_1 + T_2) + 40.6 (2.3) \]

Where, \( IE \) represents the comprehensive environment index value of the station at time \( t \); \( T_1 \) represents the temperature in the station at time \( t \) in degrees Celsius; \( T_2 \) represents the temperature value of humidity in the station at time \( t \), in degrees Celsius, which can be obtained from the conversion table of humidity temperature and humidity.

(4) Management factors

The factors of station management are mainly reflected from the two aspects of station safety management and emergency comprehensive management. It is difficult to make quantitative evaluation on the management indexes, which are usually expressed by semi-quantitative method. On the basis of qualitative evaluation, the safety management system, the completeness of emergency plan, the completeness of emergency resources and other related factors of the station can be evaluated by expert scoring.

2.2. Line safety evaluation index system

On a line with a number of the station, the higher the safety of the station, the station of line relatively security will be high. Evaluation belongs to medium level evaluation of lines in a certain period of time, comprehensive statistics on the safety of each station on line, and considering some safety factors influencing factors on line interval, build lines safety evaluation index system is shown in figure 2-2.
Urban rail line safety evaluation index system

(1) Station factors
A single station in series circuit, so for the evaluation of each station on line should be on line level evaluation play a supporting role. The station safety composite index on the line refers to the comprehensive value of the safety of each station on the line, as shown in equation (2.4):

\[ X((t, t+\Delta t), (s_j)) = \sum_{j=1}^{m} k((t, t+\Delta t), (s_{ij})) x(s_{ij}) \] (2.4)

Where:
- \( X((t, t+\Delta t), (s_j)) \) represents the security of each station of line \( s_j \) in time \( (t, t+\Delta t) \);
- \( k((t, t+\Delta t), (s_{ij})) \) represents the weight of station \( s_{ij} \);
- \( x(s_{ij}) \) represents the security of station \( s_{ij} \) during \( (t, t+\Delta t) \) time.

(2) Personnel factors
Line traffic capacity matching degree is to point to in a certain period of time, line interval between traffic over the train of the number of traffic and route the ratio of total interval number. When the capacity of a section exceeds the maximum capacity of the line, the security of the line will be affected and some measures need to be taken to channel or limit the flow. The calculation formula is shown in equation 2.5.

\[ L(s_j) = \lambda_{upper} \frac{m_{upper}}{m} + \lambda_{lower} \frac{m_{lower}}{m} \]

\[ \lambda_{upper} = \frac{\gamma_{upper}}{\gamma_{upper} + \gamma_{lower}} \]

\[ \lambda_{lower} = \frac{\gamma_{lower}}{\gamma_{upper} + \gamma_{lower}} \] (2.5)

Where:
- \( L(s_j) \) represents the capacity and volume matching degree of line \( s_j \) within \( (t, t+\Delta t) \) time;
- \( m_{upper} \) and \( m_{lower} \) represent the number of intervals with the loading rate of upper and lower sections exceeding 80% respectively;
- \( m \) represents the number of line intervals;
- \( \lambda_{upper} \) and \( \lambda_{lower} \) represent the weight of the upper and lower rows respectively.

Line staff skills quality refers to the drivers and dispatchers skill quality, urban rail transit vehicle drivers driving, the driving experience, driving skills and ability to respond to an emergency he is his skill. As the most direct commander and safety manager on the line, the technical quality of dispatcher needs to be reflected through its strain capacity, emergency command ability and overall coordination ability.

(3) Equipment factors
As the carrier of passengers, the vehicle plays an important role in the urban rail transit system. Vehicle safety index refers to the comprehensive evaluation function established by the fault probability and fault influence degree of the vehicle during operation, as shown in equation (2.6).
\[ R(s_i) = f(F_{\text{train}}, \Theta_{\text{train}}) \quad (2.6) \]

Where: \( R(s_i) \) represents the comprehensive value of line \( s_i \) vehicle system safety index within the statistical cycle; \( F_{\text{train}} \) represents the failure rate of line \( s_i \) vehicle system in the statistical cycle; \( \Theta_{\text{train}} \) said vehicle failure affect the operating range.

Signal, power supplies, telecommunications and power supply system is to ensure that the urban rail transit line interval operation safety of the train on key equipment, equipment running state will directly affect the operation of urban rail transit lines security, the security index can be represented by the type (2.7).

\[ P(s_i) = 1 - \frac{t_{\text{fail}}}{t_{\text{total}}} \times 100\% \quad (2.7) \]

Where, \( P(s_i) \) represents the safety index of line \( s_i \) equipment and facilities within the statistical cycle; \( t_{\text{fail}} \) the failure time of line \( s_i \) equipment and facilities within the statistical cycle; \( t_{\text{total}} \) the total running time of equipment and facilities.

The track safety index of the line is based on the inspection and feedback of the staff on the corresponding indicators of the track, the damage situation of the rail and the distribution of the damaged rail. The road section with poor track condition needs to be repaired in time to ensure the road safety of the line to the maximum extent.

(4) Environmental factors

The comprehensive environmental index of the line is the comprehensive value of the environmental index of each station on the line and the environmental condition of the railway station section. The environmental condition of each station and section on the line will affect the environmental condition of the whole line. The calculation formula is shown in formula (2.8).

\[ M_{(t,t+\Delta t)}(s_i) = \sum k_{(t,t+\Delta t)}(s_i) E_{(t,t+\Delta t)}(s_{ij}) + \sum b_{(t,t+\Delta t)}(s_{ik}) O_{(t,t+\Delta t)}(s_{ik}) \quad (2.8) \]

Where: \( M_{(t,t+\Delta t)}(s_i) \) represents the comprehensive environment index of line \( s_i \) within the time of \((t, t + \Delta t)\); \( E_{(t,t+\Delta t)}(s_{ij}) \) represents the comprehensive environment index of the \( j \) station of line \( s_i \) within the time period of \((t, t + \Delta t)\); \( O_{(t,t+\Delta t)}(s_{ik}) \) represents the comprehensive environment index of the \( k \) interval of line \( s_i \); \( k_{(t,t+\Delta t)}(s_i) \), \( b_{(t,t+\Delta t)}(s_{i}) \) respectively represent the weight of line \( s_i \), station \( j \) and line network and the weight of line \( s_i \), interval \( k \) and line network;

(5) Management factors

In terms of management, the working state of the line safety management organization can reflect the level of the line safety management. The equivalent accident rate of a line refers to the number of accidents, casualties and economic losses of a line within a specific time, which is an important basis to measure the safety status of the urban rail transit network. The calculation formula is shown in equation (2.9).

\[ \Gamma S(s_i) = \frac{\sum_{j=1}^{\eta} y_j \times a_j}{l} \quad (2.9) \]

Where: \( \Gamma S(s_i) \) said in time \((t, t + \Delta t)\), line \( s_i \) equivalent accident rate; \( y_j \) represents the number of \( j \) accidents within \((t, t + \Delta t)\) time; \( a_j \) represents the accident impact factor of accident \( j \) within the time \((t, t + \Delta t)\); \( l \) is millions of kilometers.

### 2.3. Network safety evaluation index system

The line network belongs to the highest level of the urban rail transit system, and it is the macro level for the decision-making of government departments and the leadership of the metro company. Through the safety evaluation of urban rail transit network, related factors can be identified in a timely manner, to understand the occurrence of the location and degree of risk, provides the effective decision-making basis for the relevant management department, also help after the accident emergency rescue work. Based on this, the safety evaluation index system of urban rail transit network is shown in figure 2-3.
(1) Line factors

The larger the safety value of each line in the line network is, the larger the comprehensive safety value of the line network will be. Therefore, the comprehensive safety index of the line network is the comprehensive value of the safety degree of each line in the entire line network. The weight of a certain line in the online network is large, when the safety condition of the line changes, the impact on the stability of the entire line network is also greater. The calculation formula is shown in formula (2.10).

\[ X_{(t, t+\Delta t)}(s) = \sum_{i=1}^{N} l_{(t, t+\Delta t)}(s_i) X_{(t, t+\Delta t)}(s_i) \] (2.10)

Where: \( X_{(t, t+\Delta t)}(s) \) represents the comprehensive safety index of line network line within the time \((t, t+\Delta t)\); \( l_{(t, t+\Delta t)}(s_i) \) represents the weight of line \( s_i \); \( X_{(t, t+\Delta t)}(s_i) \) represents the comprehensive safety index of each station of line \( s_i \) within the time of \((t, t+\Delta t)\).

(2) Network factors

The state index of line network connection is the ratio between the degree value of the line network at the current moment and the degree under normal connection condition of the line network. It can represent the operation matching situation between passenger flows of each line in the line network. The specific calculation formula is shown in (2.11).

\[ D(s) = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} d(s_{ij}) - \sum_{i=1}^{n} \sum_{j=1}^{m} (\Delta d(s_{ij}))}{\sum_{i=1}^{n} \sum_{j=1}^{m} d(s_{ij})} \] (2.11)

Where: \( D(s) \) represents the connectivity rate of the wire network within the time \((t, t+\Delta t)\); \( d(s_{ij}) \) represents the degree of each station in the line network; \( \Delta d(s_{ij}) \) represents the change value of each station degree in the line network.

As a transfer node and attracting passenger flow node in line network, transfer station plays an important role in online network. The matching degree of transfer capacity of line network is the weighted average of transfer capacity of each transfer station, as shown in formula (2.12).

\[ TC(s) = \sum k(s_{ij}) \frac{t_{c}(s_{ij})}{t_{c_{max}}(s_{ij})} \] (2.12)

Where: \( TC(s) \) wire transfer ability; \( k(s_{ij}) \) transfer station \( s_{ij} \) weight; \( t_{c}(s_{ij}) \) represents the transfer quantity \( s_{ij} \) of the transfer station; \( t_{c_{max}}(s_{ij}) \) represents the maximum transfer amount of \( s_{ij} \) at the transfer station.

(3) Environmental factors

For the environment of line network, in addition to the environment of stations and lines, natural disasters such as rainstorm, strong wind, snow and ice and earthquake should also be considered. The comprehensive environment index of line network refers to the comprehensive value of the sum of the comprehensive environment index of each line and the natural environment of the line network at a certain moment. The calculation formula is shown in formula (2.13).

\[ \Omega_t(s) = \alpha \sum_{i=1}^{m} \chi(s_i) M_t(s_i) + \beta N_t(s) \] (2.13)
Where: $\Omega_t(s)$ represents the comprehensive index of urban rail transit network at moment $t$; $M_t^s$ represents the comprehensive environment index of line $s_t$ at time $t$; $\chi(s_t)$ denotes the weights in the line $t$ online network. $m$ represents the total number of urban rail transit lines in the network; $N_t(s)$ represents the natural environment safety index of the wire network at time $t$; $\alpha, \beta$ represents the weight of integrated environment and natural environment of the line.

(4) Management factors

The safety management ability of wire network can be measured by the standard degree, perfection and implementation degree of relevant safety management rules and regulations. The organization state of the wire network can be reflected by the emergency management index of the wire network. Semi-quantitative method can be adopted to evaluate the perfection of the emergency plan, safety organization coordination and the completeness of materials of the wire network.

3. Decision-making principle and method of TOPSIS method based on triangular fuzzy number

The TOPSIS method is a multi-attribute comprehensive evaluation method, which was proposed by Hwang and Yoon[11] and used to analyze the distance to judge the scheme. TOPSIS[12]method is first to determine an ideal solution is $a^+$, the best solution, is the ideal is a solution selected from the set X index characteristic values of the optimal value of the new are ideal solution; Define a negative ideal solution $a^-$ plan for the worst, is a set of solution X to select one of the worst value of index characteristic values of new negative ideal solution; By mathematical method, comparing each scheme and ideal scheme close to the extent that comprehensive evaluation index to prioritize, alternatives to determine the priority of each sequence, finally the comparison.

TOPSIS evaluation method based on triangular fuzzy number is the most important improvement of TOPSIS method in all attribute values with triangular fuzzy number to represent, the core idea is an expert in by triangular fuzzy Numbers to each individual opinion weighted calculation, get a comprehensive standardization of triangular fuzzy number decision matrix, integrating the concept of the ideal approximation to determine is the ideal state of a negative ideal $a^+$ and $a^-$ to find out the corresponding distance, the evaluation objects. The TOPSIS method based on triangular fuzzy number can be a good treatment effect of urban rail/system security quantitative, qualitative and uncertain factors, to eliminate the influence of caused by expert scoring each index weight subjectivity, more objective evaluation on the safety of urban rail transit system. The specific evaluation process is as follows:

Step1: Determine the evaluation index value

An expert group was established by multiple experts in the first place $E=\{e_1, e_2 ... e_n\}$, $m$ urban rail transit subsystems and $n$ safety evaluation indexes were evaluated. The safety index value USES triangular fuzzy number to determine the index and fuzzy semantic words to describe the qualitative index. Fuzzy semantic words and their corresponding trig functions are shown in table 3.1:

| Fuzzy linguistic variable | Triangular fuzzy number | Evaluation criteria |
|--------------------------|------------------------|--------------------|
| Very bad (very low)      | (0, 0, 0.25)           | 0                  |
| Bad (low)                | (0, 0.25, 0.5)         | 0.25               |
| General                  | (0.25, 0.5, 0.75)      | 0.5                |
| Good (high)              | (0.5, 0.75, 1)         | 0.75               |
| Fine (very high)         | (0.75, 1, 1)           | 1                  |

Of this decision in the safety evaluation index values are available $a^P_{ij}$, said the first $p$ expert for the $i$ the first $j$ a fuzzy evaluation indicators and evaluation objects are available (3.1) to calculate the $a_{ij}$.

$$a_{ij} = \frac{1}{p} \times \sum_{p=1}^{p} a^P_{ij} = (a_{ij1}, a_{ij2}, a_{ij3})(3.1)$$

Step 2: Determine index weight

Fuzzy semantics to determine the index weight, and also set up is not important, is not important, moderately important, and a very important category five semantic word, use table 3.1 conversion
rules into triangular fuzzy Numbers. Set \( w_p^f \) said the first \( p \) a expert of the \( i \) a fuzzy evaluation index weight value, the type (3.2) and the weight value of integrated expert \( w_j \).

\[
w_i = \frac{1}{m} \times \sum_{p=1}^{m} w_p^f = (w_{i1}, w_{i2}, w_{i3})(3.2)
\]

Step 3: Establish standardized decision matrix

Comprehensive evaluation, should be the original data with the trend and standardized processing, processing method, minimum endpoint for fuzzy number indicators:

\[
b_{ij} = \frac{\max(a_{ij}) - a_{ij}}{\max(a_{ij}) - \min(a_{ij})}(3.3)
\]

For the endpoint index with the maximum fuzzy number:

\[
b_{ij} = \frac{a_{ij} - \min(a_{ij})}{\max(a_{ij}) - \min(a_{ij})}(3.4)
\]

Where, \( b_{ij} \) said after handling the case of a sample \( i \) first \( j \) parameter values, thus can get a standard decision matrix \( B = (b_{ij})_{n \times m} \).

Step 4: Calculate the normalized weighted matrix

Standardized weighted matrix \( C = (c_{ij})_{n \times m} \) in the \( c_{ij} \) can be represented as:

\[
c_{ij} = w_j b_{ij} (3.5)
\]

Step 5: Determine the positive and negative ideal solution \( C^+ \) and \( C^- \), distance calculation

In safety evaluation of urban rail transit system, \( C^+ \) positive ideal solution and negative ideal solution \( C^- \) can be set according to the relevant national standard thought, can also be selected from each evaluation index of object data [12], represented as:

\[
C^+ = \{(\max_i c_{ij}) = \{c_1^+, c_2^+ \ldots c_n^+\}(3.6)
\]

\[
C^- = \{(\min_i c_{ij}) = \{c_1^-, c_2^- \ldots c_n^-\}(3.7)
\]

The \( i \) a \( C^+ \) distance evaluation objects to the positive ideal solution for:

\[
D_i^+ = \frac{1}{3} \sum_{j=1}^{m} (c_{ij} - c_{j}^+)^2 (3.8)
\]

The \( i \) a \( C^- \) distance evaluation objects to the negative ideal solution for:

\[
D_i^- = \frac{1}{3} \sum_{j=1}^{m} (c_{ij} - c_{j}^-)^2 (3.9)
\]

Step 5: Calculation and fuzzy positive ideal closest to the degree of the order.

\[
H_i = \frac{D_i^-}{D_i^+ + D_i^-} (3.10)
\]

Where, \( H_i \) represents the relative close degree between the \( i \) evaluation object and the fuzzy positive ideal solution. If the value of \( H_i \) is higher, it means that the security of the evaluation object is higher.

4. Case analysis

The following is an example of the station safety evaluation index in the multi-layer evaluation index of the urban rail transit network established in this paper. Figure 2-1 shows the station safety evaluation index system of the urban rail transit network. Through a survey of a subway company, five stations were selected as the basic data for analysis, and a three-person evaluation team was established by corresponding experts. The specific evaluation process is as follows.

4.1. Evaluation index integration process

According to the specific calculation values of some specific national standards and some quantitative indicators, experts give the fuzzy semantics of each evaluation index, and use table 3.1 and formula (3.1) to process the fuzzy number.
4.2. Determine the weight of safety evaluation index

Equation (3.2) is used to process the fuzzy number in table 4.1 to obtain the weight of safety evaluation index.

| Expert decision group | X1   | X2   | X3   | X4   | X5   | X6   | X7   | X8   | X9   | X10  |
|-----------------------|------|------|------|------|------|------|------|------|------|------|
| Expert 1              | Very important | General important | Important | Very important | Important | General important | Important | Very important | General important | Important |
| Expert 2              | Very important | General important | Important | Very important | General important | Important | Very important | General important | Important |
| Expert 3              | Very important | General important | Important | Very important | General important | Important | Very important | General important | Important |
| Integrated weight     | (0.88, 0.91, 0.95) | (0.34, 0.48, 0.8) | (0.92, 0.9, 0.87) | (0.88, 0.91, 0.95) | (0.54, 0.48, 0.42) | (0.88, 0.91, 0.95) | (0.78, 0.91, 0.95) | (0.92, 0.9, 0.87) | (0.88, 0.91, 0.95) |

4.3. Weighted decision matrix

According to equations (3.3), (3.4) and (3.5), the weighted decision matrix in table 4.2 is calculated.

| Station number | X1   | X2   | X3   | X4   |
|----------------|------|------|------|------|
| 1              | (0.88, 0.74, 0.85) | (0.58, 0.73, 0.95) | (0.87, 0.88, 0.95) | (0.88, 0.76, 0.84) |
| 2              | (0.41, 0.49, 0.73) | (0.36, 0.48, 0.9)  | (0.57, 0.48, 1)    | (0.38, 0.48, 0.88) |
| 3              | (0.82, 0.9, 0.8)  | (0.67, 0.85, 0.87) | (0.91, 0.84, 0.87) | (0.75, 0.7, 0.87)  |
| 4              | (0.26, 0.45, 0.73) | (0.23, 0.49, 0.73) | (0.31, 0.78, 0.79) | (0.33, 0.7, 0.73)  |
| 5              | (0.72, 0.84, 0.95) | (0.85, 0.58, 0.95) | (0.88, 0.78, 0.89) | (0.7, 0.91, 0.57)  |
| 6              | (0.4, 0.42, 0.42)  | (0.49, 0.46, 0.42) | (0.54, 0.41, 0.34) | (0.51, 0.48, 0.38) |
| 7              | (0.85, 0.72, 0.95) | (0.56, 0.52, 0.95) | (0.85, 0.91, 0.92) | (0.76, 0.91, 0.87) |
| 8              | (0.34, 0.32, 0.21) | (0.34, 0.45, 0.37) | (0.23, 0.46, 0.42) | (0.32, 0.45, 0.42) |
| 9              | (0.67, 0.73, 0.87) | (0.89, 0.72, 0.87) | (0.79, 0.74, 0.87) | (0.87, 0.9, 0.79)  |
| 10             | (0.8, 0.85, 0.95)  | (0.75, 0.91, 0.74) | (0.75, 0.91, 0.67) | (0.81, 0.8, 0.95)  |

4.4. Fuzzy positive and negative ideal solutions

According to formula (3.6) and formula (3.7), the following ideal fuzzy solutions are obtained:

\[ C^+ = \{(0.87, 0.88, 0.95), (0.57, 0.48, 1), (0.91, 0.84, 0.87), (0.31, 0.78, 0.79), (0.81, 0.91, 0.95), (0.49, 0.46, 0.42), (0.85, 0.91, 0.92), (0.33, 0.48, 0.31), (0.92, 0.85, 0.8), (0.8, 0.85, 0.95)\} \]

\[ C^- = \{(0.58, 0.73, 0.95), (0.41, 0.49, 0.73), (0.67, 0.85, 0.87), (0.23, 0.49, 0.73), (0.85, 0.58, 0.95), (0.38, 0.46, 0.42), (0.56, 0.52, 0.95), (0.34, 0.32, 0.21), (0.67, 0.73, 0.87), (0.69, 0.91, 0.86)\} \]

4.5. Calculation of distance

According to equations (3.8), (3.9) and (3.10), the distance between each station and the ideal solution in table 4.3 is calculated.

| Station number | \( D_i^+ \) | \( D_i^- \) | \( D_i^+ + D_i^- \) | \( H_i \) |
|----------------|-------------|-------------|---------------------|--------|
| 1              | 0.784       | 0.118       | 0.902               | 0.130  |
| 2              | 0.856       | 0.120       | 0.976               | 0.122  |
| 3              | 0.586       | 0.235       | 0.821               | 0.286  |
As can be seen from the calculation results in table 4.4, the security level of five stations selected is ranked as station 5> station 3> station 4> station 1> station 2.

5. Conclusion
Around the evaluation of urban rail traffic safety problem, this paper studied the establishment of evaluation index system of urban rail traffic safety and the safety assessment of TOPSIS method based on triangular fuzzy number. Based on the analysis results of urban rail transit safety factors affecting stations, lines and networks, this paper constructs a multi-level comprehensive evaluation index system and puts forward the calculation methods of each index. The TOPSIS safety evaluation method based on triangular fuzzy number strengthens the objectivity of TOPSIS method, reduces the influence of subjective factors on decision-making results, improves the scientific reliability and credibility of urban rail transit safety evaluation, provides effective decision-making support for relevant departments and urban rail transit safety managers, and has certain reference significance for improving the safety management level of urban rail transit.

References
[1] Tan Kai. Rail traffic network operating security risk management and impact factor analysis[J]. East China science(technology), 2014(6): 464.(in Chinese)
[2] Zhu Wenmin, Fire Risk Assessment of Subway Operation Based on Fuzzy Fault Tree Analysis[D].Beijing Jiaotong University,2018. (in Chinese)
[3] Su Xuming, Wang Yanhui, Zhu Lingxi, Safety Evaluation of Urban Rail Transit Operation Based on Improved Fault Model and Effect Analysis. Urban Mass Transit 2011,14(5):65-69. (in Chinese)
[4] Xiao Xuemei, Wang Yanhui Jia Limin .Safety Assessment Model for Urban Rail Transit Network Operations Based on Complex Network and Entropy Theory[J]. China Safety Science Journal .2011,21(11):41-47. (in Chinese)
[5] Cai Guoqiang, Jia Limin, Jia Yuquan, Research and Application of Fuzzy-cell Based Rail Traffic Safety Analysis Method[J].Fuzzy Systems and Mathematics.2008,22(2):162-168. (in Chinese)
[6] Yan Fei, Tang tao, Gao Chunhai. Research on Safety Assessment Framework for Urban Rail Transi [J].Urban Rapid Rail Transit, 2010, 23(3): 32-36. (in Chinese)
[7] Pan Ke ,Shi Jianyun. Application of Variable weight Theory and Relative Difference Function in Safety Assessment of Urban Subway Operation. Journal of The China Railway Society.2009,31(3):20-25. (in Chinese)
[8] Zhao Huixiang. Study on operational safety and reliability of urban rail transit system[D], Shanghai: Tongji University, 2006. (in Chinese)
[9] Wang Hongde, Lv Dong. Study of Safety Assessment for Subway Operation Based on Set-Pair Analysis[J]. Journal of Dalian Jiaotong University2011, 32(3): 35-39. (in Chinese)
[10] Xiang Yu. Application of TOPSIS Evaluation Method Based on Triangle Fuzzy Number in New Railway Line Selection. Journal of Shijiazhuang Railway University (Natural Science Edition) ,2011,24(02):56-60. (in Chinese)
[11] Chen C T. Extensions of the TOPSIS for group decision-making under fuzzy environment[J] . Fuzzy Sets and Systems; 2000, (2)114-129.
[12] Wang Y J, LEE H S. Generalizing TOPSIS for fuzzy multiple-criteria group decision-making[J]. Computers and Mathematics with Applications. 2007, (1): 84-93.