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Fire Risk Assessment of Subway Stations Based on Combination Weighting of Game Theory and TOPSIS Method

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Abstract: With the rapid development of urban modernization, traffic congestion, travel delays, and other related inconveniences have become central features in people's daily lives. The development of subway transit systems has alleviated some of these problems. However, numerous underground subway stations lack adequate fire safety protections, and this can cause rescue difficulties in the event of fire. Once the fire occurs, there will be huge property losses and casualties. In addition, this can have a vicious impact on sustainable development. Therefore, in order to make prevention in advance and implement targeted measures, we should quantify the risk and calculate the fire risk value. In this study, through consulting experts and analysis of data obtained from Changzhou Railway Company and the Emergency Management Bureau, the fire risk index system of subway stations was determined. We calculated the index weight by selecting the combination weighting method of game theory to eliminate the limitations and dependence of subjective and objective evaluation methods. The idea of relative closeness degree in TOPSIS method iwas introduced to calculate the risk value of each subway station. Finally, the subway station risk value model was established, and the risk values for each subway station were calculated and sorted. According to expert advice and the literature review, we divided the risk level into five levels, very high; high; moderate; low and very low. The results shown that 2 subway stations on Line 1 have very high fire risk, 2 subway stations on Line 1 have high fire risk, 2 subway stations on Line 1 have moderate fire risk, 8 subway stations on Line 1 have low fire risk, and 13 subway stations on Line 1 have very low fire risk. We hope that through this evaluation model method and the results to bring some references for local rail companies. Meanwhile, this evaluation model method also promotes resilience and sustainability in social development.

Keywords: subway station fire; risk assessment; game theory combination weighting; problems caused by construction quality; relative closeness

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1. Introduction

With the rapid development of China's economy in recent years, China has become one of the fastest growing countries in the world. By 2030, the number of vehicles in China will reach 363.8 million according to the Hao [1] prediction model, which is a huge number. This trend not only appears in China, but also the world's total number of vehicles will exceed 2 billion [2]. These vast amounts of data mean rapid growth in petroleum demand, which poses great challenges to sustainable development.

Nowadays, an increasing number of cities have begun to build subway systems. According to recent statistics, China will add 62 new subway lines in 2021, with a total mileage of 1281.59 km. Urban rail transit has enhanced travel convenience for the public, effectively mitigated urban road congestion, optimized how residents travel, and played a role in energy conservation. However, the marked increase in the construction of new subway systems have also resulted in some drawbacks. For example, the underground space typical of subway systems presents difficulties to fire rescue personnel that do not exist for aboveground fire rescue; such difficulties have placed fire rescue personnel under substantial additional strain. Subway fire accidents can cause tremendous loss of life and destruction of property. Special attention should be paid to the serious consequences of subway station accidents, such as the king's cross railway station accident (in 1987, more than 31 causalities) and Daegu, Korea (in 2003, more than 198 causalities) [3]. These tragic casualties are caused by fires in subway stations [4–6]. There are many such accidents around the world. The main problem is that no correct and reasonable fire risk assessment has been conducted. There are no specific risk levels and corresponding fire protection measures. Therefore, to reduce the risk of accidents, it is a very important issue to carry out fire risk assessment.

Fire risk value is the specific value that should be calculated after the risk assessment. These specific values are used to reflect the current risk level of the evaluation target. Firstly, a large amount of primary data is needed to calculation the fire risk value. Secondly, experts are invited to score and consult. Finally, a huge number of mathematical calculations are carried out on the data and scoring results. Due to the frequent fire accidents in subway stations in recent years, in order to prevent more scientifically in advance, specific fire risk values are needed as a reference. When evaluation objectives emerge, we need to consider their risks.

Accordingly, many scholars have analyzed subway fires. Luo [7] evaluated the construction cross risk of subway transfer stations from two aspects: existing subway stations and new subway stations. Gao [8] applied the fuzzy consistent matrix and AHP to analyze risk factors for tunnel fire management, subway tunnel fire extinguishing systems, and crowd evacuation system indicators. Liu [9] used probability analysis method to analyze the structural vulnerability of subway station. Liu [10] applied AHP method and experts grading method to evaluate the risk of subway stations. Wu [11] used Bayesian network analysis to evaluate the risk of subway station fires. Zhang [12] proposed a simulation method for the most serious subway fire scenarios. Different fire scenarios were examined by using Fire Dynamics Simulator software, and the simulation results were used as a reference for evacuation scenarios. Peng [13] conducted an experimental study on the fire plume characteristics of subway car doors. A set of small-scale experiments was performed in a subway car with both ends open to examine the characteristics of fire smoke columns at different fire location. Lan [14] established a subway fire risk assessment model from four aspects: human factors, equipment-related factors, environmental factors, management factors. Wang [15] used the fuzzy AHP and set pair analysis to assess the risks for the construction environments of subway stations. The research showed that evaluating the fire risk of subway stations through the construction of fire risk evaluation index systems for subway stations is crucial. In the analysis of traditional fire characteristics, many scholars have also conducted simulation analysis [16–23]. Roh [24] used FDS software to study the impact of installation platform screen doors on passengers' emergency evacuation time. The experimental results showed that the subway stations with platform screen doors have more possible evacuation time than that without installation, which is about 350 s. In addition, Corri [25] assessed the terrorist incidents in crowded places. Mehmet [26] proposed a stop safety index to evaluate pedestrian safety around bus stations. Margarita [27] studied safety management of the light rail transit in Spain and other countries.

However, these scholars have overlooked the effectiveness of objective data and scientific comprehensive evaluation through their complete reliance on computer simulations to assess the risk of subway fires. Traditional subjective and objective weighting evaluation methods, such as analytic hierarchy process, the entropy weight method and the fuzzy comprehensive evaluation method have subjective and objective limitations. The subjective evaluation method needs to rely too much on the experience and professional knowledge of experts, while the objective evaluation method has a strong requirement for the primary data. Once the change of the index value is small or the fluctuation is large, this kind of data is not suitable for the objective evaluation weighting method. Moreover, the objective weighting method conforms to the mathematical rule and has strict mathematical significance. But it often ignores the subjective intention of decision makers and cannot truly achieve comprehensive evaluation. In order to solve the limitations of previous scholars' work, we propose an evaluation theory based on a game theory combined weighting-TOPSIS model. The game theory combination weighting method is a process of linear combination of weights obtained by different methods to seek the most reasonable index weight. This method obtains the final weight by solving mathematical equations with the idea of game, which not only takes into account the experience and professional knowledge of subjective experts, but also takes into account the standardization of objective data. This model effectively solves the limitations of previous work. The TOPSIS method is a commonly used and effective method in multi-objective decision analysis, also known as the distance method of superior and inferior solutions. It sorts according to the closeness between the limited evaluation objects and the idealized targets. It has applied the combination weighting method of game theory and the TPSIS method to the fire risk assessment of subway stations, which is a new attempt. We hope to effectively evaluate the fire risk of subway stations by using reasonable and scientific mathematical models. On this basis, it is expected to achieve the goal of reducing risks, enhancing fire safety awareness and improving the emergency rescue system.

This study proceeds as follows. Section 2 analyzes the risk assessment indicators and methods and introduces the technical route of the research. Section 3 introduces an engineering example and calculates its risk value. Section 4 analyzes the results of risk value and puts forward some suggestions.

2. Methodology

In this study, with the aim of establishing a fire risk assessment index system, we analyzed previous domestic and foreign subway fire accident causes, investigation reports, relevant laws and regulations. In addition, we invited experts to consult and obtained internal daily inspection report data from Changzhou Rail Company. After an extensive literature review, the AHP and entropy weight method were selected as the subjective and objective evaluation methods, respectively. The concept of game theory was introduced to reduce the error between the two methods. We combined the results of two evaluation methods to obtain the final comprehensive weight, which ensures that the results are accurate and reliable. The risk value model was established by calculating the numerical product of the comprehensive weighting of each index and its corresponding data. Finally, leveraging the opinions of experts and relevant literature, we established the risk level model. Subsequently, we determined the risk level for each subway station in the rail network. An overview of the research concept is shown in Figure 1. The assessment methods used in this article are compared with previous work, as shown in Table 1.

The research was conducted in three stages, with specific procedures as follows:

Stage 1: We collected the fire accident data of subway stations and consulted experts to analyze risks. The causes of disasters were analyzed, and relevant laws and regulations were scrutinized for the establishment of a subway station fire risk assessment index system.

Stage 2: Combined with the selected risk assessment indicators and the support of Changzhou Railway Company, the objective primary data required for the assessment indicators were obtained. The fire risk value model for subway stations was constructed by selecting an evaluation method suitable for the research object.

Stage 3: Based on expert opinions and relevant literature, the risk value classification model was constructed. The aforementioned model and methods were applied to the research on the Changzhou Rail Company, and the reliability of the model was corroborated through comparisons with engineering studies.

Table 1. Comparison with previous methods.

Methods	Characteristic	Advantages	Limitations
Analytic hierarchy process	Method of subjectively determining weight	system analysis	affected by subjective factors of analysts
Entropy weight method	Method of objectively determining weight	Strong objectivity	requirement for data format
Safety checklist analysis	The safety level was assessed by item-by-item inspection according to the standard required checklist prepared in advance	easy	heavy workload
Preliminary hazard analysis	Analysis of risk and harmful factors in the system	easy for operation	affected by subjective factors of analysts
Fault tree analysis	Deductive method to calculate accident probability from basic event probability	software can be used	heavy workload and distortion
Hazard and operability analysis	The results can be used to evaluate both design and operation	detailed results	affected by subjective factors of analysts
Game theory combination weighting	Linear weighting based on game theory	It is necessary to solve linear equations. The results are more convincing by combining subjective and objective methods	
Technique for order preference by similarity to an ideal solution (TOPSIS)	It is a comprehensive evaluation method that can make full use of the information of the primary data	The results can accurately reflect the gap between the evaluation schemes	
Game theory combination weighting-TOPSIS	We hope that through this combination method to solve the limitations of previous work, and make the results more scientific and reasonable		

Establishment of an evaluation index system

To select the risk assessment indicators more accurately and scientifically, we conducted field research on the construction and the operation of branches of Changzhou Rail Company. We carefully considered their opinions and ideas, and comprehensively evaluated the fire risk during the all period. We ensured the inclusion of experts with diverse professional backgrounds, which included safety engineering, fire engineering, civil engineering, structural engineering, and municipal engineering. Thus, a favorable basis for selecting risk assessment indicators was established.

Analysis of the influencing factors for fires

In the analysis, multiple factors were considered, including the characteristics of the Changzhou Rail Company, field investigations, fire accident cause analyses, studies from the literature, and existing subway station fire risk assessment index systems. Some additional criteria were also considered, such as laws and regulations on fire protection in Changzhou: the building code for fire protection design (GB 50016-2014), the subway design code (GB50157-2013), the subway fire protection design code (GB51298-2018), the construction and acceptance of cable line electric equipment installation engineering standards (GB50168-2006), and the sprinkler system design code (GB50084-2017). The influencing factors for subway station fires were divided into human factors, building characteristics, fire prevention facilities, management factors, and factors related to construction and materials. On this basis, 21 secondary indicators were expanded. The specific risk assessment indicators are presented in Table 2.

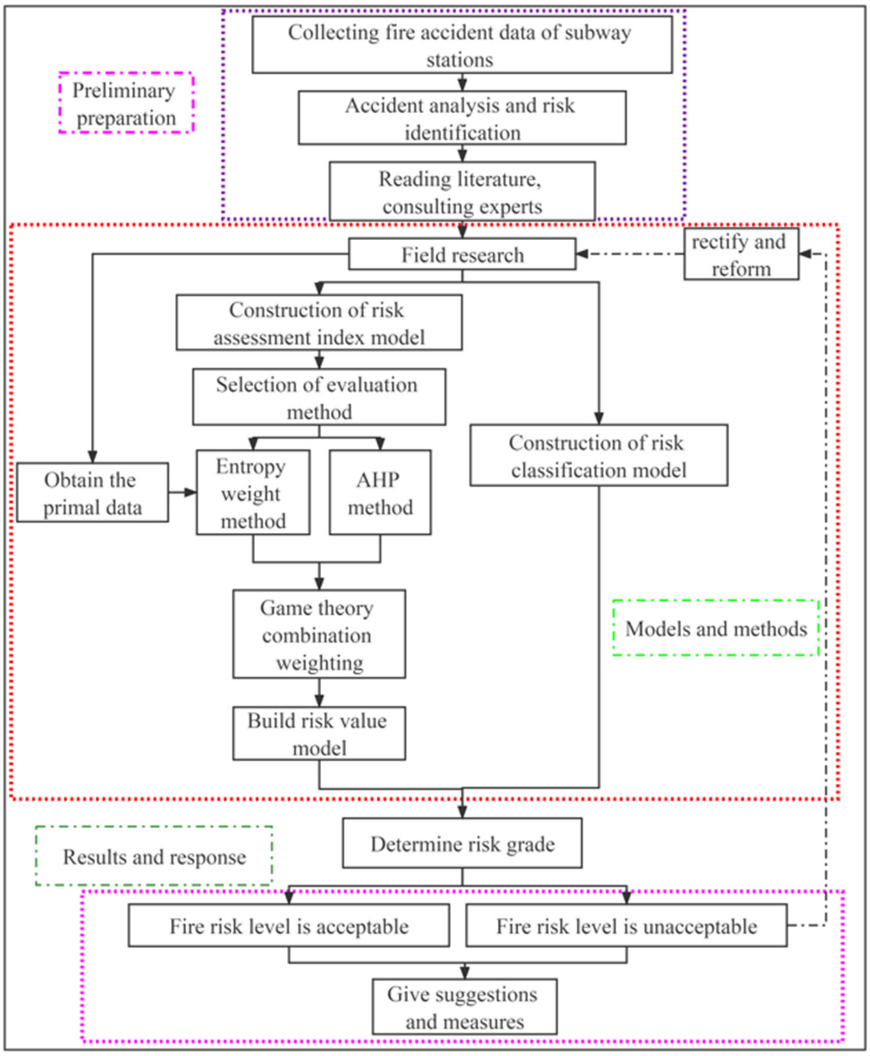

Figure 1. Overview of the research concept.

Human factors mainly included the fire safety awareness of passengers and subway workers, factors related to passenger flow, and the number of subway workers present in a given area. Zhu [28] analyzed global subway fires from 2000 to 2019. Among the causes of subway fires in China, the number of fire accidents caused through electrical equipment failure was the largest, followed by inadequate fire safety management and passenger arson. In China's subway stations, each station is equipped with a certain number of security personnel. Passengers must pass subway security inspections of their belongings similar to analogous inspections conducted in airport facilities. No dangerous goods such as lighters, explosives, or combustibles can be brought into the subway station. For first-level indicators of human factors, we obtained information regarding passenger flow and the number of subway workers in each station of Metro Line 1 from the Changzhou Rail Company. The rail company provided data support for the objective weighting of the entropy weight method as subsequently outlined.

Building characteristics are major indicating factors in subway station fire risk assessment. A subway station is essentially an underground building. Therefore, we accounted for four secondary indicators: subway station area B21, the station length B22, the station width B23, the distance between the building and the nearest fire station B24. Subways are typically constructed at a depth of more than 10 m underground [29]. Large rescue equipment and fire engines encounter difficulty entering the area because of a lack of adequate entry channels. In addition, compared with aboveground buildings [30], the environment in underground stations is closed and the space is narrow. When an accident occurs, rescue personnel must venture deep underground for rescue operations, which are limited by the narrow spaces. This results in the cross phenomenon of human flow, thereby affecting rescue efficiency. In this study, we considered the nearest fire station distance to each subway station for emergency rescue capabilities. According to the obtained data, the distance between each station of Changzhou Metro Line 1 and the nearest fire station does not exceed 3.5 km, which ensures that fires are extinguished promptly.

Table 2. Evaluation of the index system for fire risk.

Evaluation index system for fire risk	Human factor B1	Fire safety awareness of passengers and subway workers B11 passenger flow B12 Number of employees in subway station B13
	Building characteristics B2	subway station area B21 the station length B22 the station width B23 the distance between the building and the nearest fire station B24
	Fire prevention facilities factors B3	automatic fire alarm system B31 fire extinguishing systems B32 fire separation facilities B33 smoke control facilities B34 fire accident broadcast communication facilities B35 fire emergency lighting and evacuation instructions B36
	Management factor B4	daily fire inspection B41 professional team building B42 emergency fire drills B43 safety training B44
	Construction and material factors B5	fire resistance limit of material B51 fire resistance limit of cables B52 the train-fire calorific value B53 the problem of construction quality B54

When a fire occurs, the firefighting facilities at the scene should be employed to [31] effectively slow down the development of the fire until the arrival of fire rescue personnel. Therefore, we accounted for fire facility-related factors in each station: automatic fire alarm system B31, fire extinguishing systems B32, fire separation facilities B33, smoke control facilities B34, fire accident broadcast communication facilities B35, fire emergency lighting and evacuation instructions B36. These fire prevention facilities ensure the safety of subway stations and play a key role in early fire monitoring and prevention. Therefore, factors related to fire prevention facilities must be carefully examined. The inspection of subway stations can be mainly divided into three categories. The first category is the self-examination of the staff in the subway station, which is also their daily work. Through daily inspection of the equipment and facilities inside the station, they record the inspection and write inspection reports. The second is the inspection of the subway company. The frequency of this examination is about 2–3 weeks. In addition to the way of inspection, some parameters that include the train-fire calorific value and the fire resistance limit of the fireproof coating are also measured by working instruments. On this basis, the subway company will also regularly test the fire protection system to detect the stability and integrity of the fire system. The third category is government inspection. Such examinations are generally based on the above two examinations. Government departments will invite experts in the field of industry to form inspection teams. They checked the situation of fire equipment and facilities and evaluated the conditions of fire prevention and control at the scene. Finally, they put forward opinions. Within the specified time, the subway company is required to carry out rectification. For those that seriously do not meet the engineering standards, it is required to stop operation and organize re-inspection.

We conducted on-site inspections of fire prevention facilities and equipment. We also examined the subway station fire equipment self-test reports and the relevant government inspection reports. Pictures of on-site investigation are shown in Figure 2. The following systems were examined: automatic fire alarm systems, gas fire extinguishing systems, fireproof doors, fireproof observation windows, ceiling screens, rail top air ducts, rail bottom air ducts, tunnel ventilation fans, jet fans, air valves, mufflers, wind pipes, evacuation lighting, and other fire prevention equipment. These objective assessment reports and field research surveys provided a realistic basis for us to assess the on-site factors in fire prevention facilities.

Figure 2. On-site investigation: (**a**) tunnel ventilation fan, (**b**) smoke exhaust pipe and muffler, and (**c**) rail bottom air duct.

If the fire facility factor is a hard indicator of subway fire risk, then the management factor is a soft indicator of subway fire risk. Management activities require long-term input to have a favorable influence. According to data obtained from the Changzhou Metro Operations Branch, we considered four indicators: daily fire inspection B41, professional team building B42, emergency fire drills B43, and safety training B44. The subway operations branch conducts daily fire inspections and records the relevant inspection results. This requires the specific responsible person to address many types of dangerous incidents, record the closures and dates of rectification. This inspection report offers opportunities for guidance in our evaluation of management factors. According to the daily fire inspection reports of subway operations branches in 2020, the main problems were related to fire safety, education, training, risk management, external environment issues, equipment and facility problems. We found some examples in the inspection report, including the charging of security car batteries indoors, host failures of fire alarm system, leakage in the equipment monitoring room, failure to perform safety training, platform door control problems, and inadequate water supply in indoor control cable cabinet. Emergency drills and safety training are effective means to prevent fires [32]. In the construction phase of the weekly inspection report, we also found that there are many problems in the construction process, such as fire sealing being not standardized, exposed wiring on the fire damper, construction refuse not being removed, and fire hydrant pipeline leakage. These problems constitute unsafe factors for future fire risk. Pictures of on-site investigation are shown in

Figure 3. In addition to ordinary fire emergency drills, Changzhou Metro also conducts other individual emergency drills, such as operation catenary disconnection emergency drills, earthquake emergency drills, operation train fault rescue emergency drills, and comprehensive antiterrorism attack emergency drills. More than 3000 subway workers receive fire safety training annually. These daily inspections and regular drills contribute to the overall readiness for the prevention of fires at key moments.

Figure 3. On-site investigation: (**a**) fire blocking, (**b**) exposed wiring on the fire damper, (**c**) construction refuse not removed, and (**d**) fire hydrant leakage.

Few researchers have studied the influence of construction problems and the flammability of construction materials. We examined the fire resistance limit B51, the cable fire resistance limit B52, the train-fire calorific value B53, and the problem of construction quality B54. The fire resistance limit for fireproof sealing materials, wiring, and cables represents the maximum duration of normal operation for each component once a fire ignites [33]. In the construction materials used in the plugging of pipeline holes present in the subway system, a selection of fireproof glue, fireproof mud, fireproof coatings, and mineral wool board was examined [34]. The fire resistance of these materials largely determines the heat resistance of the wiring and exhaust pipes. Moreover, the fire resistance limit of wiring and cable directly determines the normal operation of both the fire extinguishing and automatic alarm systems. The reason is that these components require a circuit to operate. Train-fire heat is also a key parameter for investigating fire risk, and excessive heat causes serious thermal radiation in the direction of surrounding combustibles [35]. It has aggravated the severity of the fire. Finally, the problem of construction quality is a novel concept first proposed in this study. For the first time, the risk of potential fire safety hazards caused by unapproved processes in the construction stages is considered in relation to the subway operation stage. Few studies have considered the problems remaining after construction when examining subway fires. These problems are often investigated by the operating branch and require the original construction personnel to rectify them. The following scenarios serve as illustrations of this phenomenon. When proper construction technology standards are not adopted, sealing material may fall off and cannot effectively block leaks. Poor waterproofing treatment in the energy feed room may lead to the accumulation of water in the cable layer on rainy days. The manual fire valve may fail, causing the wiring to be exposed. The water gun head may be missing from the fire hydrant box in the station hall. The escalator evacuation indicator light may be dim. The maintenance mouth of the wall ditch in the comprehensive monitoring equipment room may not be blocked as required. Construction waste is not cleaned or removed, leaving the area prone to fire. Since the construction in these scenarios has already been completed, reworking a large area is difficult. With a lack of access to concealed works, only remedial measures can be implemented in some areas, which introduces uncertainty into the fire prevention capabilities of subway stations.

2.1. Risk Assessment Method

2.1.1. Analytical Hierarchy Process

AHP is a subjective weighting analysis method [36–40]. First, a hierarchical structure model is established, followed by experts scoring the relevant factors; subsequently, a judgment matrix is constructed. Finally, the weight of each index that meets the consistency standard is calculated by mathematical logic operation, and the consistency index (CI) and the consistency ratio (CR) were calculated based on Equations (1) and (2).

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} < 0.10 \quad (1)$$

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \quad (2)$$

Equation (1) is used to determine whether the matrix meets the consistency requirements; if not, the calculation is repeated. The RI values are listed in Table 3.

Table 3. AHP weighting table.

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

2.1.2. Entropy Weight Method

The entropy weight method is an objective weighting evaluation method. The larger the information entropy value is, the lower the weighting is [41–44]. The specific calculation process is as follows:

(1) The quantitative index values are forward or reverse processed.

$$\text{positive indexes: } (\mathrm{X} - \mathrm{Min})/(\mathrm{Max} - \mathrm{Min}) \quad (3)$$

$$\text{negative indexes: } (\mathrm{Max} - \mathrm{X})/(\mathrm{Max} - \mathrm{Min}) \quad (4)$$

Here, X is the primary data of each index, Max is the maximum value of the primary data of each index, and Min is the minimum value of the primary data of each index.

(2) The standardized data are combined to calculate the information entropy of each index (E_j); the formula is as follows:

$$E_j = -\frac{1}{\ln(n)} \sum_{i=1}^{n} p_{ij} \ln p_{ij}, i = 1, 2 \cdots n \quad (5)$$

(3) The difference coefficient of each index(g_j) is calculated according to the calculated information entropy, and the formula is as follows:

$$g_j = 1 - E_j \quad (6)$$

(4) The weighting W_j is calculated as follows:

$$W_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \tag{7}$$

2.1.3. Game Theory Combination Weighting

The limitations of analytic hierarchy process and entropy weight method are obvious. The former relies heavily on the experience, age and professional knowledge of experts. The latter has strict requirements for data format, and often affects the evaluation results because of the data format problem. Therefore, in order to solve the limitations of the application of these two methods, we propose a game theory combination weighting method to solve this problem. Game theory combinatorial weighting involves the linear combination of weightings obtained by different methods to seek the most accurate index weighting [45–48]. This study adopted a combination of the AHP and entropy weight method to avoid the deficiencies in either method alone, thus maximizing the accuracy of the estimation process. The specific steps of the game theory combinatorial weighting method are as follows:

(1) The system of linear equations is equivalently transformed into optimal first derivative conditions by the matrix differential property as follows:

$$\begin{pmatrix} \omega_1{\omega_1}^T & \omega_1{\omega_2}^T \\ \omega_2{\omega_1}^T & \omega_2{\omega_2}^T \end{pmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} = \begin{bmatrix} \omega_1{\omega_1}^T \\ \omega_2{\omega_2}^T \end{bmatrix} \tag{8}$$

(2) After the optimal linear combination coefficient is obtained and normalized from Equation (8), the comprehensive weighting of game theory combinatorial weighting is finally obtained as follows:

$$W = {\alpha_1}^* {\omega_1}^T + {\alpha_2}^* {\omega_2}^T, {\alpha_1}^* = \frac{\alpha_1}{\alpha_1 + \alpha_2}; {\alpha_2}^* = \frac{\alpha_2}{\alpha_1 + \alpha_2} \tag{9}$$

2.2. Ranking Method

Based on the relevant literature, we construct the fire risk value model of Changzhou subway stations. The corresponding risk value is obtained by introducing the concept of relative closeness in TOPSIS method [49–51]. The specific steps of the relative closeness method are as follows:

(1) denote the combination weighting matrix as follows:

$$\beta = \begin{pmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \cdots \\ \beta_n \end{pmatrix} \tag{10}$$

The matrix after data standardization as follows:

$$X^m = \begin{pmatrix} X_1 \\ X_2 \\ X_3 \\ \cdots \\ X_n \end{pmatrix} \tag{11}$$

where m is the number of evaluation objects, n is the number of evaluation indicators.

(2) Construct a weighted standardized decision matrix as follows:

$$Z^m = \begin{pmatrix} Z_1{}^m \\ Z_2{}^m \\ Z_3{}^m \\ \cdots \\ Z_k{}^m \end{pmatrix} = \begin{pmatrix} \beta_1 X_1 \\ \beta_2 X_2 \\ \beta_3 X_3 \\ \cdots \\ \beta_k X_k \end{pmatrix} \tag{12}$$

(3) Determine the ideal solution and negative ideal solution with the following formula:

$$Z^{m+} = \max\{Z_1{}^m, Z_2{}^m, \ldots, Z_k{}^m\}, Z^{\mathrm{m}-} = \min\{Z_1{}^m, Z_2{}^m, \ldots, Z_k{}^m\} \tag{13}$$

where Z^{m+} and Z^{m-} are positive and negative ideal solutions for each index of subway stations respectively.

(4) The distance D^{m+} and D^{m-} from the feasible solution of any index to the positive and negative ideal solution are calculated respectively as follows:

$$D^{m+} = \sqrt{\sum_{k=1}^{n} (Z_k{}^m - Z^{m+})^2}, D^{m-} = \sqrt{\sum_{k=1}^{n} (Z_k{}^m - Z^{m-})^2} \tag{14}$$

(5) The relative closeness C^m is calculated, and the relative closeness is used to represent the fire risk value of each subway stations. The calculation formula as follows:

$$C^m = \frac{D^{m-}}{D^{m+} + D^{m-}} \tag{15}$$

3. Case Study

3.1. Region of the Evaluation

Changzhou is located in the south of Jiangsu Province, between 31°09′–32°04′ N and 119°08′–120°12′ E, with an area of 4372 km^2. The location map of Changzhou city is shown in Figure 4. We can clearly see the lakes around Changzhou. Changzhou is located in the Yangtze River Delta Economic Zone near Shanghai. The research target of this paper was the Changzhou Metro. The Changzhou Metro has two lines with a total length of 34.24 km. Lines 1 and 2 were opened on 21 September 2019, and 28 June 2021, respectively. Because Line 2 has been in operation for a relatively short period, the relevant data cannot constitute a scientific reference. Therefore, this study examined a total of 29 subway stations in Changzhou Metro Line 1 as the research area. The total length of the line is 34.24 km, including 31.635 km of underground track, 2.189 km of elevated track, 0.413 km of transition section, 27 underground stations, and 2 elevated stations. This study only analyzed underground stations; the two elevated stations in Line 1 were not considered within the scope of assessment.

3.2. Analysis Results for the AHP Method

We invited experts from different industry backgrounds to evaluate the indicators. The weight of each index in the AHP method was calculated using MATLAB. The weight table of AHP for primary indicators are listed in Table 4.

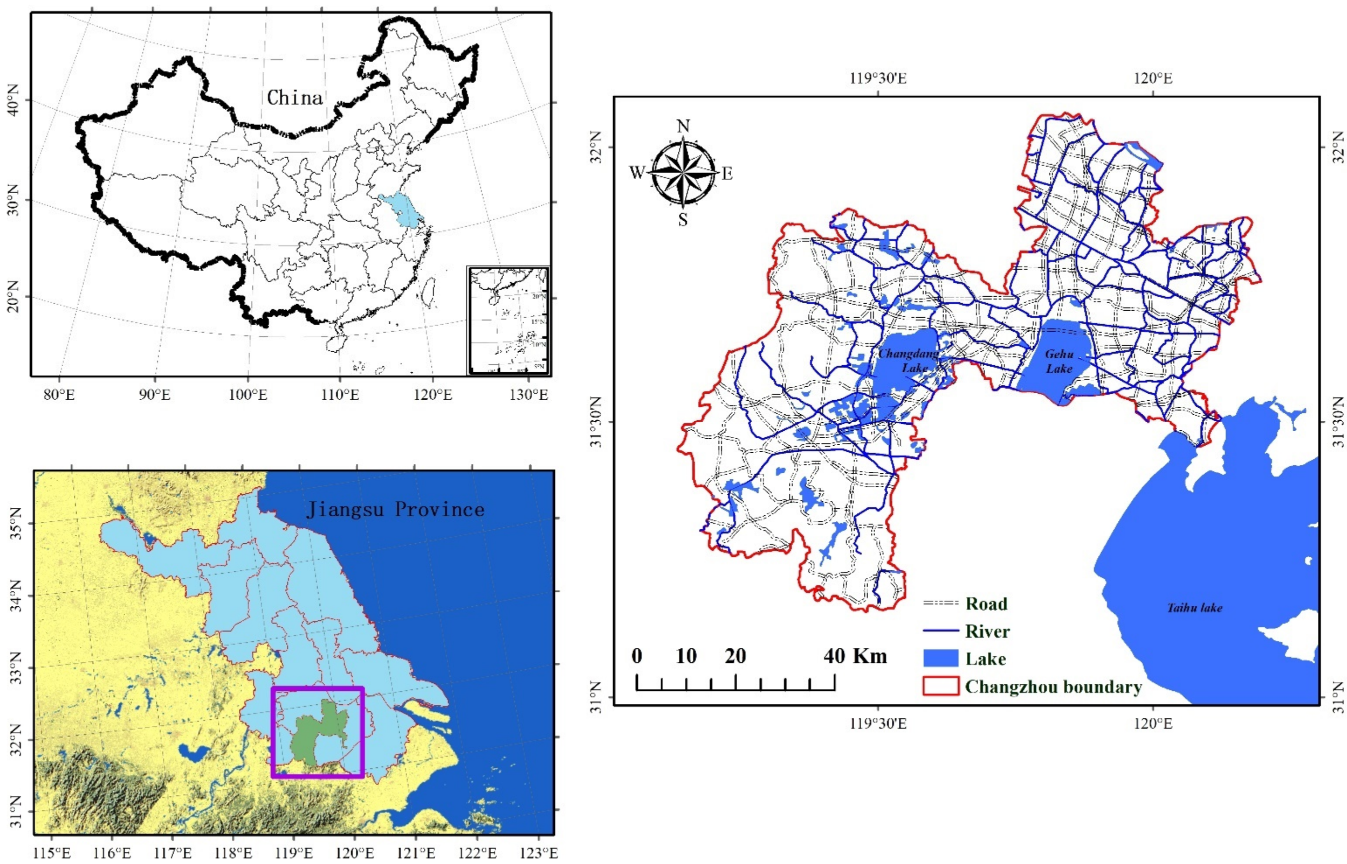

Figure 4. Location map of Changzhou city.

Table 4. Weight table of primary indicators.

	B1	**B2**	**B3**	**B4**	**B5**	**CR**
B1	1	1/3	1/7	1/4	1/6	CR = 0.078 <0.1
B2	3	1	1/6	1/3	1/5	
B3	7	6	1	5	3	
B4	4	3	1/5	1	1/4	
B5	6	5	1/3	4	1	
ω	0.039	0.068	0.490	0.122	0.281	

The judgment matrix and weight of human factor B1 are listed in Table 5.

Table 5. Weight of human factor B1.

B1	**B11**	**B12**	**B13**	**CR**
B11	1	3	5	CR = 0.046 <0.1
B12	1/3	1	4	
B13	1/5	1/4	1	
ω	0.109	0.345	0.547	

The judgment matrix and weight of building factors B2 are listed in Table 6.

Table 6. Weight of building characteristic B2.

B2	**B21**	**B22**	**B23**	**B24**	**CR**
B21	1	3	1/4	1/6	CR = 0.078 <0.1
B22	1/3	1	1/5	1/6	
B23	4	5	1	1/3	
B24	6	6	3	1	
ω	0.104	0.057	0.277	0.561	

The judgment matrix and weighting of fire prevention facilities factor B3 are listed in Table 7.

Table 7. Weight of fire prevention facilities factor B3.

B3	**B31**	**B32**	**B33**	**B34**	**B35**	**B36**	**CR**
B31	1	7	4	5	3	6	CR = 0.073 <0.1
B32	1/7	1	1/5	1/4	1/6	1/3	
B33	1/4	5	1	2	1/3	4	
B34	1/5	4	1/2	1	1/5	3	
B35	1/3	6	3	5	1	6	
B36	1/6	3	1/4	1/3	1/6	1	
ω	0.425	0.032	0.134	0.089	0.271	0.050	

The judgment matrix and weight of management factor B4 are listed in Table 8.

Table 8. Weight of management factor B4.

B4	**B41**	**B42**	**B43**	**B44**	**CR**
B41	1	7	4	5	CR = 0.066 <0.1
B42	1/7	1	1/5	1/3	
B43	1/4	5	1	3	
B44	1/5	3	1/3	1	
ω	0.595	0.054	0.238	0.113	

The judgment matrix and weight of construction and material factor B5 are listed in Table 9.

Table 9. Weight of construction and material factor B5.

B4	**B51**	**B52**	**B53**	**B54**	**CR**
B51	1	1/4	3	1/5	CR = 0.063 <0.1
B52	4	1	5	1/3	
B53	1/3	1/5	1	1/7	
B54	5	3	7	1	
ω	0.109	0.281	0.054	0.557	

After calculating the weights of criterion layer and indicator layer, we obtained the comprehensive weight of AHP. The comprehensive weights calculated by the AHP are listed in Table 10.

Table 10. Weight table of the AHP.

Criterion Layer	Weight	Indicator Layer	Weight	Comprehensive Total Weight
human factor B1	0.039	fire safety awareness of passengers and subway workers B11	0.109	0.004
		passenger flow B12	0.345	0.013
		number of employees in subway station B13	0.547	0.021
building characteristic B2	0.068	subway station area B21	0.104	0.007
		the station length B22	0.057	0.004
		the station width B23	0.277	0.019
		the distance between the building and the nearest fire station B24	0.561	0.038
fire prevention facilities factor B3	0.490	automatic fire alarm system B31	0.425	0.208
		fire extinguishing systems B32	0.032	0.016
		fire separation facilities B33	0.134	0.066
		smoke control facilities B34	0.089	0.044
		fire accident broadcast communication facilities B35	0.271	0.133
		fire emergency lighting and evacuation instructions B36	0.050	0.025
management factor B4	0.122	daily fire inspection B41	0.595	0.073
		professional team building B42	0.054	0.007
		emergency fire drills B43	0.238	0.029
		safety training B44	0.113	0.014
construction and material factor B5	0.281	fire resistance limit B51	0.109	0.031
		the cable fire resistance limit B52	0.281	0.079
		the train-fire calorific value B53	0.054	0.015
		the problem of construction quality B54	0.557	0.157

3.3. Analysis Results for the Entropy Weight Method

The primary data and data standardization results are presented in Appendix A, Tables A1 and A2. We collated the data in the daily inspection report record of the operation branch of Changzhou Rail Company and regarded the unsafe behavior of passengers and subway workers in the record as the criterion of the B11 index.

The weight of each part of the entropy weight method is listed in Table 11.

3.4. Analysis Results for Game Theory Combined with the Weighting Method

According to the subjective and objective weighting data in this study, the linear equations are as follows:

$$\begin{pmatrix} 0.109 & 0.061 \\ 0.061 & 0.145 \end{pmatrix} \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} = \begin{pmatrix} 0.109 \\ 0.145 \end{pmatrix}, \alpha_1 = 0.577, \alpha_2 = 0.759,$$

Introduce into the formula 9 to solve. $\alpha_1^* = 0.432$, $\alpha_2^* = 0.568$. According to linear combination weighting, the final comprehensive weight is shown in Table 12. After reading a large number of previous references [52–72], we compare the results calculated by the analytic hierarchy process method (AHP); entropy weight method (EW); and game and theory combined weight (GTCW). A comparison of results calculated by three different methods is shown in Figure 5.

Table 11. Entropy method weighting method.

Criterion Layer	Weight	Indicator Layer	Weight
human factorB1	0.040	fire safety awareness of passengers and subway workers B11	0.009
		passenger flow B12	0.018
		number of employees in subway station B13	0.013
building characteristicB2	0.250	subway station area B21	0.065
		the station length B22	0.066
		the station width B23	0.101
		the distance between the building and the nearest fire station B24	0.018
fire facilities factorB3	0.330	automatic fire alarm system B31	0.009
		fire extinguishing systems B32	0.008
		fire separation facilities B33	0.018
		smoke control facilities B34	0.014
		fire accident broadcast communication facilities B35	0.273
		fire emergency lighting and evacuation instructions B36	0.008
management factorB4	0.108	daily fire inspection B41	0.032
		professional team building B42	0.051
		emergency fire drills B43	0.020
		safety training B44	0.005
construction and material factorB5	0.272	fire resistance limit B51	0.212
		the cable fire resistance limit B52	0.021
		the train-fire calorific value B53	0.007
		the problem of construction quality B54	0.032

Table 12. Game theory combinatorial weighting.

Criterion Layer	Indicator Layer	Weight
human factor B1	fire safety awareness of passengers and subway workers B11	0.007
	passenger flow B12	0.016
	number of employees in subway station B13	0.016
building characteristic B2	subway station area B21	0.040
	the station length B22	0.039
	the station width B23	0.066
	the distance between the building and the nearest fire station B24	0.027
fire facilities factor B3	automatic fire alarm system B31	0.095
	fire extinguishing systems B32	0.011
	fire separation facilities B33	0.039
	smoke control facilities B34	0.027
	fire accident broadcast communication facilities B35	0.213
	fire emergency lighting and evacuation instructions B36	0.015
management factor B4	daily fire inspection B41	0.050
	professional team building B42	0.032
	emergency fire drills B43	0.024
	safety training B44	0.009
construction and material factor B5	fire resistance limit B51	0.134
	the cable fire resistance limit B52	0.046
	the train-fire calorific value B53	0.010
	the problem of construction quality B54	0.086

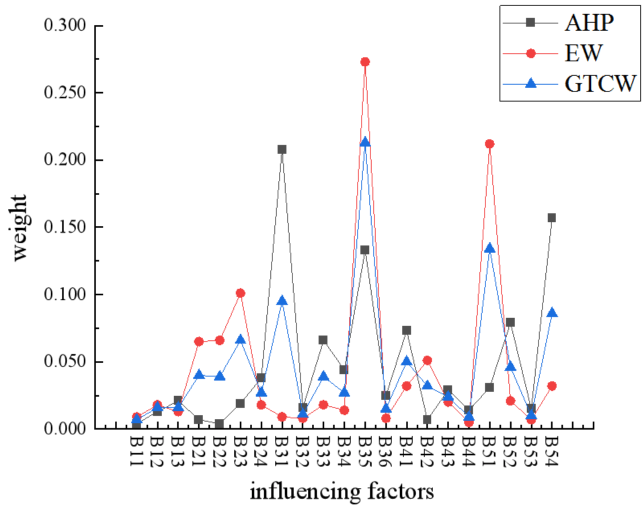

Figure 5. Comparison of results calculated by three different methods.

3.5. Analysis Results for Ranking Method

According to the risk distribution and the degree of possible harm, the risk level of each subway station is determined by referring to the weighted score ratio of each factor. As listed in Table 13, the security risk level was divided into five levels from 1 (*very high*) to 5 (*very low*).

Table 13. Risk levels for fires.

Serial Number	Risk Level	Range of Scores	Color
1	Very high	0.81–1	
2	high	0.61–0.80	
3	moderate	0.41–0.60	
4	low	0.21–0.40	
5	Very low	0–0.20	

The fire risk values and ranking of each subway stations are listed in Table 14.

Table 14. Fire risk value of subway station.

STATION	Risk Value	Risk Level	Rank	Color
CULTURAL PALACE	0.828	Very high	1	
CHA SHAN	0.826	Very high	2	
YANZHENG DADAO	0.799	high	3	
HE HAI	0.657	high	4	
FOREST PARK	0.439	moderate	5	
TOURISM AND COMMERCE INSTITUTE	0.429	moderate	6	
XINQU PARK	0.369	low	7	
CITIZENS' SQUARE	0.341	low	8	
CHANGZHOU RAILWAY STATION	0.331	low	9	
JUHU ROAD	0.299	low	10	
WUJIN YANJIANG RAILWAY STATION	0.288	low	11	
CUI ZHU	0.239	low	12	
NORTH RAILWAY STATION	0.219	low	13	
FOREIGN LANGUAGE SCHOOL	0.216	low	14	
XINTIANDI PARK	0.189	Very low	15	
XIN LONG	0.179	Very low	16	
KEJIAOCHENG NAN	0.174	Very low	17	
GLOBAL HARBOR	0.172	Very low	18	
QINGLIANG TEMPLE	0.142	Very low	19	
OLYMPIC SPORTS CENTER	0.127	Very low	20	

Table 14. *Cont.*

STATION	Risk Value	Risk Level	Rank	Color
BOAI ROAD	0.117	Very low	21	
KEJIAOCHENG BEI	0.116	Very low	22	
HU TANG	0.098	Very low	23	
CHANGHONG ROAD	0.094	Very low	24	
TONGJIQIAO	0.074	Very low	25	
BEIJIAO HIGH SCHOOL	0.070	Very low	26	
XIN QIAO	0.047	Very low	27	

We use ARCGIS software to display the calculated risk value on the map. According to the risk level of each subway station, the corresponding colors in the table are marked. The fire risk level of Changzhou Metro Line 1 is shown in Figure 6.

Figure 6. Fire risk grade diagram of Changzhou Metro Line 1.

4. Conclusions

To assess the risk of subway station fires, we proposed and analyzed the subway station fire risk assessment index system. Based on the combination weighting evaluation, the subway station fire risk value model was introduced. The final risk value was obtained and sorted using mathematical operations. The following conclusions were obtained regarding the combination weighting evaluation method:

(1) First, game theory combined weighting overcomes the limitations of subjective and objective evaluation methods. In the Figure 5, we can see clearly that the curve of game

theory combination weighting method is in the middle of the other two curves. Whenever analytic hierarchy process or entropy weight method has a minimum or maximum weight, game theory combination weighting will correct it. The curve after linear weighting is closer to the real result, which effectively solves the limitations of analytic hierarchy process and entropy weight method. Meanwhile, the concept of relative closeness degree in TOPSIS method is introduced to represent the risk value, so that the risk value can be quantified and expressed more clearly.

(2) Second, according to the fire risk values for subway stations in Table 14, the two highest risk subway stations were CULTURAL PALACE and CHASHAN, and its risk level was very high. Four other subway stations also exhibited high and moderate risk, whereas eight subway stations had low risk levels, and 13 subway stations had very low risk levels. Regarding the weighting proportion of the evaluation index system, the top five factors were fire accident broadcasting and communication facilities B35, fire resistance limit B51, automatic fire alarm system B31, construction quality problems B54 and the width of stations B23. Among them, the remaining problems of construction quality remain a concern throughout the entire project life cycle. Therefore, more attention should be paid to the firefighting equipment, facilities of subway stations and the problems that occur in the facility construction stage. If the fire risk level of stations is very high, they should indeed close until the corresponding inspection meets the standard requirements. Moreover, if the fire risk level of stations is high, we believe that such subway stations should receive warnings. When the number of warnings reaches 3 or more, the site should be closed. Once the rectification is completed, the data in the Table A1 and the final risk value will change. To reduce the risk of fire, we offer some suggestions to the subway operation branch, which include strengthening the fire safety training awareness of personnel, increasing the number of emergency drills, handling security issues, and improving the emergency rescue system. The results of this assessment may serve as a reference for the local rail department and fire management department.

(3) Finally, although the risk value model was established through optimized combination weighting, the model still has several limitations. First, the legacy problem of construction quality is a novel concept, and accurately quantifying this factor through data indicators is challenging. Second, this study only examined and analyzed the subway station buildings, disregarding fires in the subway tunnels. Third, most of the subway stations are underground island buildings, and only a few are elevated platforms. Therefore, elevated platforms were not considered in this study. For a more comprehensive understanding of subway station fire risk, additional in-depth research is necessary.

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Appendix A

Table A1. Primary data.

STATION	B11/EA	B12/IE	B13/IE	B21/m^2	B22/m	B23/m	B24/m	B31/SET	B32/SET	B33/EA	B34/SET	B35/SET	B36/SET	B41/EA	B42/IE	B43/EA	B44/EA	B51/h	B52/h	B53/MW	B54/EA
WUJIN YANJIANG RAILWAY STATION	1	2548	41	15,991	273.71	13	1.9	346	182	209	459	52	500	6	6	12	111	2	1.5	10.5	0
KEJIAOCHENG NAN	0	4377	42	13,142	136.13	13	2.3	346	623	253	243	52	740	2	7	12	112	2	1.5	10.5	0
KEJIAOCHENG BEI	3	3365	43	12,258	207.224	11	3.5	346	485	259	212	52	669	10	5	12	112	2	1.5	10.5	5
YANZHENG DADAO	4	4792	68	25,662	396.599	16.5	3.4	346	1040	209	104	52	1027	16	6	12	112	2	1.5	10.5	3
CHANGHONG ROAD	1	3391	43	11,259	190.4	11	3.3	346	547	209	32	52	759	7	7	12	111	1.5	1.5	10.5	3
XINTIANDI PARK	6	3917	40	13,741.45	140.25	13	3.4	346	408	209	41	52	708	16	5	12	111	3	1.5	10.5	3
HUTANG	4	3390	44	11,575.7	183	11	3.2	346	283	209	20	52	748	16	6	12	111	3	1.5	10.5	1
JUHU ROAD	2	6025	49	15,251.7	284.8	11	3	346	406	209	23	52	1047	19	5	12	112	3	1.5	10.5	3
CHA SHAN	8	4227	53	27,605	494.975	14	1.2	346	270	209	228	52	1120	32	6	12	112	3	3	10.6	4
QINGLIANG TEMPLE	2	4316	43	12,269.4	193.5	11	0.857	346	240	209	210	52	1005	21	7	12	112	3	2	10.5	10
TONGJIQIAO	1	2743	49	11,392	186	11	0.8	346	297	209	186	52	604	9	6	12	111	3	1.5	10.5	4
CULTURAL PALACE	2	6959	68	25,227	317.133	14	0.182	360	486	209	280	52	769	12	5	15	112	3	3	10.6	3
BOAI ROAD	1	4094	43	11,478	194	11	0.917	346	295	209	198	52	700	9	6	12	111	3	1.5	10.5	4
CHANGZHOU RAILWAY STATION	0	9598	55	14,424	178.001	14	1.5	355	398	209	257	52	700	7	5	15	112	3	3	10.5	2
CUIZHU	2	4741	42	14,421	850	12	1.7	346	298	209	201	52	700	6	7	12	112	3	1.5	10.5	2
CITIZENS' SQUARE	1	5461	52	16,284	730.5	13	1.6	346	446	304	201	52	459	8	6	12	112	3	1.5	10.5	2
OLYMPIC SPORTS CENTER	4	4537	47	11,203.8	183.95	13	2.5	346	331	259	144	52	344	9	5	12	112	3	1.5	10.5	2
HE HAI	1	3928	47	22,688	463	11	2.4	346	558	353	282	52	584	18	6	12	112	3	2	10.5	5

Table A1. *Cont.*

STATION	B11/EA	B12/IE	B13/IE	B21/m²	B22/m	B23/m	B24/m	B31/SET	B32/SET	B33/EA	B34/SET	B35/SET	B36/SET	B41/EA	B42/IE	B43/EA	B44/EA	B51/h	B52/h	B53/MW	B54/EA
XINQU PARK	1	2746	47	17,435.96	176.5	13	2.4	346	190	217	240	52	797	13	6	12	112	3	2	10.5	4
GLOBAL HARBOR	1	5517	52	12,198.93	188.229	11	2.4	358	96	220	170	52	802	6	6	12	112	3	1.5	10.6	2
FOREIGN LANGUAGE SCHOOL	0	1998	47	14,763.4	286.4	11	3.3	346	124	217	216	52	794	15	7	12	121	3	1.5	10.5	7
BEIJIAO HIGH SCHOOL	3	2293	44	11,093	186.005	11	3.2	346	374	457	896	52	712	8	6	12	112	3	1.5	10.5	2
NORTH RAILWAY STATION	1	2732	53	14,619	193.003	13	3.3	350	404	468	921	52	744	6	7	15	112	3	1.5	10.6	2
XINQIAO	1	699	41	11,361	186	11	4.2	346	397	446	898	52	703	6	7	12	112	3	1.5	10.5	1
TOURISM AND COMMERCE INSTITUTE	0	2161	46	18,629.64	527.15	11	5.4	346	817	406	307	31	997	3	7	12	112	3	1.5	10.5	3
XIN LONG	1	3133	27	13,796.97	199.5	13	3.6	346	316	355	274	31	874	3	5	12	112	3	1.5	10.4	1
FOREST PARK	1	2694	49	18,716.58	655.66	11	2.1	346	361	382	257	31	1516	18	5	15	112	3	3	10.3	9

Table A2. Standardization of primary data.

STATION	B11	B12	B13	B21	B22	B23	B24	B31	B32	B33	B34	B35	B36	B41	B42	B43	B44	B51	B52	B53	B54
WUJIN YANJIANG RAILWAY STATION	0.875	0.208	0.659	0.297	0.193	0.364	0.329	1.000	0.909	1.000	0.513	0.000	0.867	0.133	0.500	1.000	1.000	0.667	1.000	0.667	0.000
KEJIAOCHENG NAN	1.000	0.413	0.634	0.124	0.000	0.364	0.406	1.000	0.442	0.830	0.752	0.000	0.662	0.000	0.000	1.000	0.900	0.667	1.000	0.667	0.000
KEJIAOCHENG BEI	0.625	0.300	0.610	0.071	0.100	0.000	0.636	1.000	0.588	0.807	0.787	0.000	0.723	0.267	1.000	1.000	0.900	0.667	1.000	0.667	0.500
YANZHENG DADAO	0.500	0.460	0.000	0.882	0.365	1.000	0.617	1.000	0.000	1.000	0.907	0.000	0.417	0.467	0.500	1.000	0.900	0.667	1.000	0.667	0.300
CHANGHONG ROAD	0.875	0.303	0.610	0.010	0.076	0.000	0.598	1.000	0.522	1.000	0.987	0.000	0.646	0.167	0.000	1.000	1.000	1.000	1.000	0.667	0.300
XINTIANDI PARK	0.250	0.362	0.683	0.160	0.006	0.364	0.617	1.000	0.669	1.000	0.977	0.000	0.689	0.467	1.000	1.000	1.000	0.000	1.000	0.667	0.300
HUTANG	0.500	0.302	0.585	0.029	0.066	0.000	0.578	1.000	0.802	1.000	1.000	0.000	0.655	0.467	0.500	1.000	1.000	0.000	1.000	0.667	0.100

Table A2. *Cont.*

STATION	B11	B12	B13	B21	B22	B23	B24	B31	B32	B33	B34	B35	B36	B41	B42	B43	B44	B51	B52	B53	B54
JUHU ROAD	0.750	0.598	0.463	0.252	0.208	0.000	0.540	1.000	0.672	1.000	0.997	0.000	0.400	0.567	1.000	1.000	0.900	0.000	1.000	0.667	0.300
CHA SHAN	0.000	0.396	0.366	1.000	0.503	0.545	0.195	1.000	0.816	1.000	0.769	0.000	0.338	1.000	0.500	1.000	0.900	0.000	0.000	1.000	0.400
QINGLIANG TEMPLE	0.750	0.406	0.610	0.071	0.080	0.000	0.129	1.000	0.847	1.000	0.789	0.000	0.436	0.633	0.000	1.000	0.900	0.000	0.667	0.667	1.000
TONGJIQIAO	0.875	0.230	0.463	0.018	0.070	0.000	0.118	1.000	0.787	1.000	0.816	0.000	0.778	0.233	0.500	1.000	1.000	0.000	1.000	0.667	0.400
CULTURAL PALACE	0.750	0.703	0.000	0.856	0.254	0.545	0.000	0.000	0.587	1.000	0.711	0.000	0.637	0.333	1.000	0.000	0.900	0.000	0.000	1.000	0.300
BOAI ROAD	0.875	0.382	0.610	0.023	0.081	0.000	0.141	1.000	0.789	1.000	0.802	0.000	0.696	0.233	0.500	1.000	1.000	0.000	1.000	0.667	0.400
CHANGZHOU RAILWAY STATION	1.000	1.000	0.317	0.202	0.059	0.545	0.253	0.357	0.680	1.000	0.737	0.000	0.696	0.167	1.000	0.000	0.900	0.000	0.000	0.667	0.200
CUIZHU	0.750	0.454	0.634	0.202	1.000	0.182	0.291	1.000	0.786	1.000	0.799	0.000	0.696	0.133	0.000	1.000	0.900	0.000	1.000	0.667	0.200
CITIZENS' SQUARE	0.875	0.535	0.390	0.314	0.833	0.364	0.272	1.000	0.629	0.633	0.799	0.000	0.902	0.200	0.500	1.000	0.900	0.000	1.000	0.667	0.200
OLYMPIC SPORTS CENTER	0.500	0.431	0.512	0.007	0.067	0.364	0.444	1.000	0.751	0.807	0.862	0.000	1.000	0.233	1.000	1.000	0.900	0.000	1.000	0.667	0.200
HE HAI	0.875	0.363	0.512	0.702	0.458	0.000	0.425	1.000	0.511	0.444	0.709	0.000	0.795	0.533	0.500	1.000	0.900	0.000	0.667	0.667	0.500
XINQU PARK	0.875	0.230	0.512	0.384	0.057	0.364	0.425	1.000	0.900	0.969	0.756	0.000	0.613	0.367	0.500	1.000	0.900	0.000	0.667	0.667	0.400
GLOBAL HARBOR	0.875	0.541	0.390	0.067	0.073	0.000	0.425	0.143	1.000	0.958	0.834	0.000	0.609	0.133	0.500	1.000	0.900	0.000	1.000	1.000	0.200
FOREIGN LANGUAGE SCHOOL	1.000	0.146	0.512	0.222	0.211	0.000	0.598	1.000	0.970	0.969	0.782	0.000	0.616	0.433	0.000	1.000	0.000	0.000	1.000	0.667	0.700
BEIJIAO HIGH SCHOOL	0.625	0.179	0.585	0.000	0.070	0.000	0.578	1.000	0.706	0.042	0.028	0.000	0.686	0.200	0.500	1.000	0.900	0.000	1.000	0.667	0.200
NORTH RAILWAY STATION	0.875	0.228	0.366	0.214	0.080	0.364	0.598	0.714	0.674	0.000	0.000	0.000	0.659	0.133	0.000	0.000	0.900	0.000	1.000	1.000	0.200
XINQIAO	0.875	0.000	0.659	0.016	0.070	0.000	0.770	1.000	0.681	0.085	0.026	0.000	0.694	0.133	0.000	1.000	0.900	0.000	1.000	0.667	0.100
TOURISM AND COMMERCE INSTITUTE	1.000	0.164	0.537	0.456	0.548	0.000	1.000	1.000	0.236	0.239	0.681	1.000	0.443	0.033	0.000	1.000	0.900	0.000	1.000	0.667	0.300
XIN LONG	0.875	0.274	1.000	0.164	0.089	0.364	0.655	1.000	0.767	0.436	0.718	1.000	0.548	0.033	1.000	1.000	0.900	0.000	1.000	0.333	0.100
FOREST PARK	0.875	0.224	0.463	0.462	0.728	0.000	0.368	1.000	0.719	0.332	0.737	1.000	0.000	0.533	1.000	0.000	0.900	0.000	0.000	0.000	0.900

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