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Article

# Resilience assessment of metro stations based on AHP-PSO fuzzy combined empowerment method with baggage impact perspective

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**Abstract:** Fire accidents are one of the serious security threats facing the metro, and the accurate determination of the index system and weights for fire assessment in underground stations is the key to conducting fire hazard assessment. Among them, the type and quantity of baggage, which varies with the number of passengers, is an important factor affecting the fire hazard assessment. This study is based on the combination of subjective and objective AHP (Analytic Hierarchy Process) with the available Particle Swarm Optimisation algorithm PSO (Particle Swarm Optimization) and the perfect CRITIC (Criteria Importance Through Intercriteria Correlation) empowered fuzzy evaluation method on the metro station fire hazard toughness indicator system and its weights were determined, and a fuzzy comprehensive evaluation model of metro station safety toughness under the influence of baggage was constructed. The practical application proves that the method provides a new perspective for the fire risk assessment of underground stations, and also provides a theoretical basis for the prevention and control of mobile fire load hazards in underground stations.

**Keywords:** metro evacuation; fire hazard; resilience assessment; AHP-PSO; fuzzy combinatorial power modelling; baggage impacts

## 1. Introduction

Stations are an important part of the metro system, not only do they contain a large amount of technical equipment and operational management systems, but they are also places where metro passengers and carry-on luggage must pass through. In particular, underground transfer stations have a high density of people inside, with many types of carry-on luggage and high mobility. Most metro stations are underground buildings with closed spaces and narrow passages, making station fire hazards and safety evacuation problems particularly prominent.

According to research statistics, speed of travel is an important factor in reducing evacuation time. In addition to the age and gender of the personnel, it is also affected by large luggage and carry-on items, as well as by the structure of the building and the density of the crowd. 53.07 per cent of the passengers chose to give up their heavy and general luggage and evacuate with only their small and valuable luggage; 11.06 per cent of the passengers thought that they would carry their large and valuable luggage, although it was inconvenient, and gave up their general luggage only; 5.03 per cent of the passengers chose to evacuate with all their baggage; 30.84% chose to evacuate without their baggage; and 30.84% chose to evacuate without their baggage (Ying et al., 2023). Ensuring the life safety of people in case of fire and emergency evacuation is the fundamental goal of safety assessment and management in metro stations. However, in current metro station safety assessments, the participants are usually young and middle-aged people who are physically fit and mobile, and the impact of carrying luggage on passenger evacuation is generally not addressed. Clearly, this is inconsistent with most actual evacuation scenarios.

Metro fire accidents in various countries around the world have contributed to the study of fire safety and related measures in metro systems, and have drawn the attention of many fire safety personnel to this field and the establishment of measures to reduce the fire risk in metro systems (Huang et al., 2024). In addition to metro fire design codes and regulations, fire risk assessment of metro systems is another effective way to ensure the safety of people and property in metro systems. Ma et al. (2023) studied and analysed the cases of fire accidents in metro stations in the past 15 years, combined with the fault tree theory, constructed a model to analyse the risk of fire in metro stations, and put forward countermeasures for on-site operation and management (Purser et al., 2023). Based on the fuzzy fault tree method to analyse the main factors of the potential fire hazards in metro stations, through the combination of the probability of occurrence of each factor and the magnitude of the impact of the accident, the results can be quantitatively assessed the risk of fire in the metro (L. Wang et al., 2019). Fire risk assessment of metro stations was carried out using the hierarchical analysis method (AHP), summarising the statistics of station staff and outlining the four main factors affecting the fire risk of metro stations: passengers, fire safety management system, fire fighting facilities and metro structure. In order to assess the fire risk of metro stations more accurately and realistically, Omidkhah et al. (2023) based on the hierarchical analysis method and the survey of metro station related experts, summarised and established a multilevel topological assessment method based on the topological method as the core, and the results of the study can identify the weak links of metro station fire risk and the key points of the management of the passenger site (Wei et al., 2023). Based on the assessment method according to different time sequences and stages of fire occurrence, a fire risk assessment system architecture can be used for urban underground transport, and combined with relevant experimental data to construct a multilevel assessment index weighting model, forming an effective evaluation standard for judging fire hazards. Bernardini et al. (2023) established an underground fire risk assessment model based on genetic neural network, completed the model through the data provided by security inspectors in underground stations, and showed that the model can be used for assessing the fire risk of underground through actual engineering cases.

K. Wang et al. (2023) constructed a Bayesian network model to calculate the fire risk of underground system. The innovation of this study is to consider the factors and their interrelationships, such as cigarette butt disposal, high temperature, spontaneous combustion of materials, underground system fire, and injuries that often occur in underground stations. The results of the study show that the probability of fire fluctuates greatly with the probability of cigarette butt disposal, and give the station Security agencies and on-site passenger transport managers should focus on cigarette butt disposal and anti-smoking campaigns. Fuerte et al.

(2023) established a fire risk assessment model for metro operation based on group topological fuzzy theory, which used fuzzy mathematics and topological theory to comprehensively assess six aspects of fire sources, fire prevention performance, fire extinguishing ability, evacuation ability, safety management and environment in metro stations, and constructed a fully completed fire hazard evaluation system. Lu et al. (2023) constructed a fuzzy hierarchical integrated assessment model to assess the fire risk of underground stations, the study adopted the influence of multiple factors on station fires and portrayed the relationship between each factor and its belonging object by means of the affiliation function, the study overcame the drawbacks of the previous assessment methods that were complicated and error prone to be calculated, and the calculation method had a fixed calculation step, which was easy to be implemented by the programmers.

Currently, there are few studies considering passenger baggage (mobile fire loads) in metro stations for risk assessment, and some researchers define them as parcels, baggage, temporary combustibles and carry-on fire loads. Chen et al. (2023) defined passenger-carried baggage as temporary combustibles and conducted a field investigation in Chengdu metro station to obtain the changing number of temporary combustibles in the metro station and their distribution pattern on the platform. At the same time, a simulation study on the fire process of metro caused by baggage was carried out, and the relationship between baggage and the fire risk at metro platforms was obtained (H. Wang et al., 2023). The types of backpacks and baggage of the passengers in the metro stations were obtained through actual counting in the metro stations, and a series of combustion tests were carried out on the fire loads of different types of carry-on baggage, etc., and the different hazards of the fire loads were evaluated by combining with the combustion behavioural patterns obtained from the experiments (Zhang et al., 2022). In Qingdao metro station, a field survey was carried out to statistically determine the types and quantities of luggage carried by passengers and their contents, and to analyse and calculate the fire loads on them, this study derived the intensive time period and distribution area of the fire loads of passengers' carry-on baggage, and put forward the strategy of peak diversion of passengers for the on-site management of this metro station.

Therefore, in order to evaluate the fire hazard danger of underground underground stations more reasonably, in addition to improving the accuracy of the simulation model, it is necessary to carry out a systematic research on the fire hazard under the influence of people carrying baggage using the AHP-PSO fuzzy combination weighting method. Based on the above background, the author organised a number of passenger flow observation experiments in an underground interchange station in Jinan City, combined with the video data provided by the security department of the relevant this metro station, studied the number of passengers, the number of baggage parcels, the types of parcels, etc., and carried out a resilience assessment combined with the AHP-PSO fuzzy combinatorial weighting method, which provided the basis for the subsequent establishment of a reliable data security assessment model of the underground station.

## 2. Metro station fire resilience framework construction

The fire safety assessment system for metro stations is a complex system with multiple factors. Accident causation theory suggests that the main causes of accidents lie in four aspects: people, materials, management and environment. According to the accident causation theory, the traditional metro fire hazard assessment will focus on: personnel situation, mechanical equipment, organisational management and operational environment are divided into personnel system, equipment system, management system and environmental system. Often overlooked are the large number of mobile fire loads that enter metro stations with passenger traffic. An accurate and reasonable assessment of the mobile fire loads affecting fire safety in metro stations is a crucial step in translating the theory of fire assessment in metro stations into the practice of building fire safety and resilience in metro stations.

According to the theory of resilience, fire safety resilience of metro station is defined as the ability of metro system to reduce the rate of fire accidents or casualties and economic losses due to sufficient emergency response capacity or preventive mechanism under the interference of various disaster factors (Afrane et al., 2021). According to the principles of operability, hierarchy and systematicity of fuzzy comprehensive evaluation indexes, hierarchical analysis is used to construct a hierarchical index system to assess the possibility and sensitivity of the impact of luggage on fire hazards in metro stations.

At present, there are two main methods for toughness measurement and evaluation based on system performance curve and based on toughness tolerance characterisation, and the evaluation method based on toughness tolerance characterisation better reflects the system's own continuity, adaptability, transformability, and constantly shapes the nature of the system's cyclic dynamic equilibrium, which has a high degree of flexibility (Mao et al., 2023). Based on this, this paper takes the toughness absorptive capacity and resistance capacity characterisation of the type and number of bags appearing in dynamic changes as the core to evaluate the fire safety toughness level of underground stations.

Absorption capacity refers to the ability of the system to eliminate the fire hazard disturbance when the station baggage fire risk and evacuation risk have not yet had a significant impact on the underground station, which is embodied in the pre-disaster prevention stage; resistance capacity refers to the ability of the system to quickly respond to the station baggage fire disturbance and the impact of baggage evacuation to withstand the fire impact and reduce the fire loss, which is embodied in the post-disaster response stage (Xu et al., 2019). Underground system safety toughness evaluation methods mainly include fuzzy comprehensive evaluation method, Bayesian network method, approximate ideal solution method and Euclidean distance method. Although these methods have achieved better results, the fire safety toughness evaluation indexes of underground stations involve many and complex factors, and there is often a part of the overlap of information between the indexes, and the factors interact with each other, so that the above research methods fail to fully consider the evaluation of the evaluation against the above problems.

The combination of Analytic Hierarchy Process (AHP) and fuzzy theory will not be objective because of strong subjectivity in the assessment, while the Particle Swarm Optimization (PSO) can be used to maximise the consistency of the judgement matrix and improve the weight values when using AHP for the fire safety resilience assessment of metro stations. Particle Swarm Optimisation (PSO) can be used to improve the consistency of the judgement matrix and improve the weights while maintaining the original information of the decision maker and the judgement matrix is determined. For example, Zheng et al. (2022) optimised the input weights of ELM with the help of the PSO algorithm to prevent and control the bottom-plate water disaster and the safe and rational mining of coal mines. Mei et al. (2019) established the EEMD-PSO-ELM model to predict slope displacement quickly and accurately. Existing research applies objective assignment methods such as entropy weighting method and principal component analysis method to consider only the amount of indicator information and lacks the judgement of indicator correlation, so the CRITIC method, which combines both comparative strength and conflict between indicators, can be applied to objectively correct the weights of indicators. According to Lyu et al. (2023) using the combination of subjectivity and objectivity assessment method, the construction of metro station fire safety based on the toughness of the model to draw a fuzzy combination of empowerment method analysis flow chart as shown in **Figure 1**:

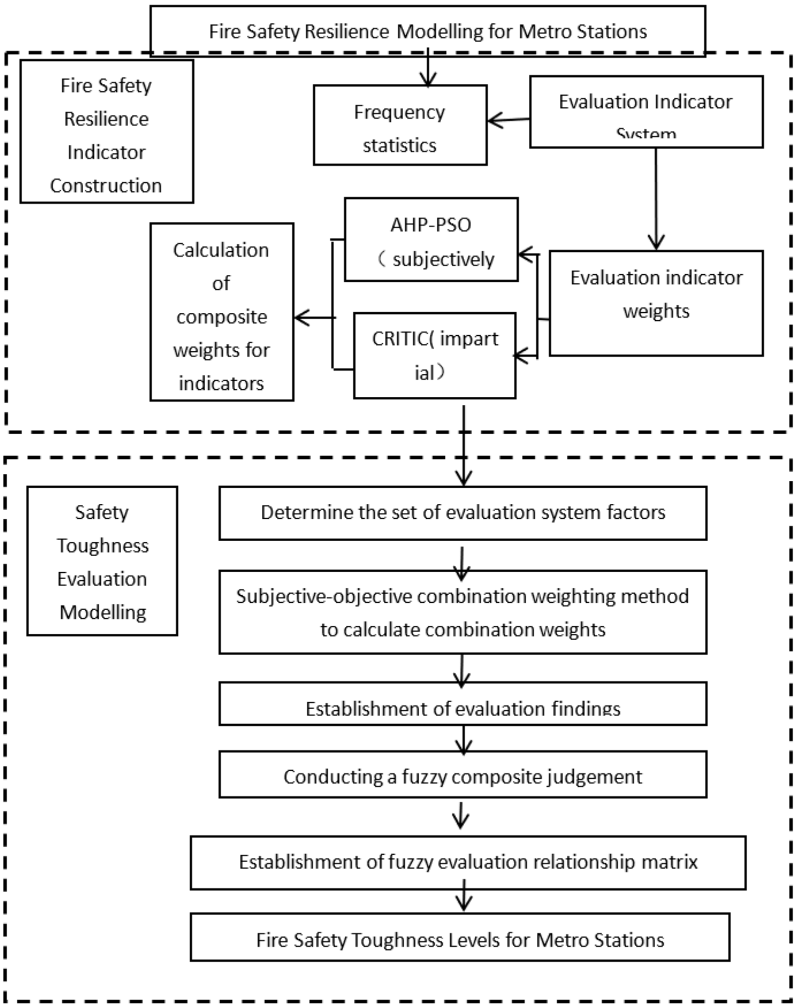


**Figure 1.** Fire Safety Resilience Modelling for Metro Station.

## 3. Fire safety resilience assessment model for metro station based on fuzzy combinatorial assignment method

### 3.1. AHP-PSO method for determining subjective weights

The AHP method quantifies the subjective judgement of the experts by constructing the structure of the relevant constituent factors at different levels, so as to obtain the multilevel factor weights. PSO is a global stochastic search algorithm based on group intelligence and employs the biological population model of biologist FRANK Heppner, the basic idea of which is to initialise a group of random particles, and then to find the optimal solution through the process of multiple iterations, with the advantage that the velocity and position of the particles are modelled at the same time to improve the solution efficiency. The speed and position of the particles are modelled at the same time to improve the efficiency of the solution.

The steps to determine the weights of AHP-PSO are: ① Construct a hierarchical model; ② Create a judgement matrix; ③ Build a weight optimisation model; ④ Solve the weights of the AHP-PSO model and carry out a consistency test; ⑤ Normalisation process.

Passenger baggage information from the underground station security part of the category is divided into: portable electric transport, backpacks, handbags, trolley cases 4 categories, and accordingly established a level 1 indicator factor. According to the weight, use, volume, material and other connotations of the four first-level indicator factors to select the secondary indicators that appear many times, the preliminary establishment of the underground station luggage in the AHP-PSO fuzzy combination of assignment method under the influence of the security toughness assessment index system is as follows: A1 Portable electric transport: A11 electric wheelchair, A12 folding electric car, A13 electric balance car. a2 backpacks: A21 shoulder bag, A22 single shoulder bag, A23 trolley case, A22 backpack, A23 backpack, A23 trolley case, A23 trolley case. A22 Shoulder bag, A23 Mountaineering bag: A31 Briefcase, A32 Handbag, A33 Woven bag: A41 Folding shopping trolley, A42 Baby pram, A43 Trolley case.

### 3.2. Improved CRITIC method for determining objective weights

The CRITIC method is an objective weighting method that can objectively reflect the weights of the indicators, and the basic idea is to determine the objective weights of the indicators on the basis of two basic concepts, namely, comparative strength and conflict between evaluation indicators. Some of the factors affecting safety cannot be easily described by specific numerical values, but only by qualitative descriptions such as “toughness”. The study is expressed in terms of five levels, i.e., the set of rubrics $V$ = {high toughness, high toughness, medium toughness, low toughness, low toughness}. With $n$ evaluation factors and s evaluators, the original data matrix $L = (l_{ij}\ n \times s$ is constructed, where $l_{ij}$ ($i$ = 1, 2, 3, …, $n$; $j$ = 1, 2, 3, …, $s$) is the toughness rating of the $j$th evaluator evaluating the $i$th evaluation factor. The toughness level of the toughness grade is scored as a percentage of the indicator as shown below: high toughness ≥ 90, 90 > higher toughness ≥ 80, 80 > higher toughness ≥ 70, 70 > higher toughness ≥ 60, 60 > low toughness.

The main steps of the CRITIC method are as follows.

(1) Raw data processing. The raw data were first processed as follows.

$$S_{ij} = \frac{x_{ij} - x_{i-min}}{x_{i-max} - x_{i-min}} \quad (1)$$

In the formula $S_{ij}$ is a standardised value, $x_{ij}$ is the original value of variable $j$, $x_i$—max is the maximum value of indicator $i$, $x_i$—min is the minimum value of indicator $i$.

(2) Calculation of standard deviation for each indicator $\sigma i$.

(3) Calculate the linear correlation coefficient between indicator $i$ and indicator $j$ using EXCEL $r_{ij}$, the correlation matrix $R$ is obtained.

(4) Calculate the amount of information. Calculate the amount of information contained in indicator $i$ $C'i$:

$$C_i^{'} = \sigma i \sum_{j=1}^{n} (1 - |r_{ij}|) \quad (2)$$

Two improvements to the formula of the conventional CRITIC weighting method are: ① the conflict between the metrics is calculated by the $\sum_{j=1}^{n}(1 - |r_{ij}|)$ indicators; ② The standard deviation coefficient is applied to measure the discriminatory power of the indicator.

(5) Normalisation. The information vector $C'i$ of the indicator is normalised, and the objective weight of the $i$th indicator $\omega_i$ improves the calculation.

The formula is:

$$w_i = \frac{C_i^{'}}{\sum_{i=1}^{n} C_i^{'}} \quad (3)$$

where: $\omega_i$ is the weight of indicator $i$, $C'i$ is the amount of information contained in indicator $i$, and n is the number of indicators.

### 3.3. Engineering verificatio

The key problem of multi-attribute decision-making is how to determine the reasonable weights of attributes. According to the importance ranking of attributes in subjective and objective combination weights, the attribute importance ranking of subjective weights has the smallest deviation from the ranking of subjective weights; meanwhile, the "intensity information" of objective weights is prioritised over the smallest deviation between subjective and objective combination weights and objective weights. Minimum deviation between subjective and objective combination weights and objective weights.

The intersection of the δ-neighbourhood of the subjective weights and the δ-neighbourhood of the objective weights of the attributes is used to standardise the reasonable interval of the combination weights and to ensure that the combination weights take into account both the "intensity information" of the subjective weights and the "order information" of the objective weights. The values of δ1 and δ2 of the study are taken equal to the absolute value of the difference between the subjective and objective weights of the attribute. The upper and lower bounds of the rational interval for the ith attribute are $a_i^+$ and $a_i^-$.

$$a_i^+ = \max\{a1i, a2i\} \quad (4)$$

$$a_i^- = \min\{a1i, a2i\} \quad (5)$$

Finally, the subjective and objective combination weights of the attributes are solved based on the following optimisation model and relevant data.

$$\min\sum_{i=1}^{n} (w_i - \beta_i)^2 (9a) \quad (6)$$

$$\text{S. t.} \begin{cases} w_i \geq w_j \quad i < j (9b) \\ a_i^- \leq w_i \leq a_i^+ (9c) \\ \sum_{i=1}^{n} w_t = 1 (9d) \end{cases}$$

### 3.4. Fuzzy integrated evaluation based on composite weights

The following six steps are required to evaluate the safety resilience under the influence of passenger luggage in metro stations using fuzzy comprehensive evaluation.

Step 1: For the security toughness of luggage in underground stations, determine the evaluation system factor set *U* = {folding electric car, electric wheelchair and electric balance car, shopping cart, pram and pull bar box, shoulder bag, shoulder bag, hiking bag, handbag, knitting bag, handbag travelling bag}, the set of rubrics *V* = {high toughness (100~90), high toughness (89~80), medium toughness (79~70), low toughness (69~60), low toughness (59~0)}, and the evaluation system factor set *V* = {high toughness (100~90), high toughness 89~80), medium toughness (79~70), low toughness (69 to 60), low toughness (59 to 0) }.

Step 2: Calculate the combination weights by the above subjective-objective combination weighting method. ω = { ω1, ω2, …, ωm}, included among these

$$0 \leq \omega i \leq 1, \sum_{i=1}^{m} w_i = 1.$$

Step 3: Perform a fuzzy integrated assessment, where the target is assessed according to the *i*th factor in the factor set *ui* in conducting the assessment. The degree of affiliation to the *j*th element *vj* in the factor set is the degree of affiliation to the *j*th element *vj* of the factor set is *r*ij, the result assessed by the *i*th factor *uj* can be expressed by the fuzzy set as

$$R_i = \frac{r_{i1}}{v_1} + \frac{r_{i2}}{v_2} + \cdots \frac{r_{im}}{v_m}$$

Step 4: Establishment of fuzzy evaluation relationship moments *B*.

$$B = w \times R = (w_1, w_2, \cdots w_i) \times \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} = b_1, b_2, \cdots b_m$$

where: B is the fuzzy comprehensive assessment set $b_j$($j$ = 1, 2, …, m) is a fuzzy composite assessment indicator, where $b_j = \sum_{i=1}^{m}(\omega i \times rij)$.

Step 5: According to the principle of maximum affiliation, the final result can be obtained, and the level of comprehensive evaluation is the evaluation level corresponding to the maximum affiliation.

## 4. Application of engineering examples

### 4.1. Summary of works

Conducting verification experiments metro station main body 276.2 m long, 43.4 m wide, the platform width of 14 m, the effective platform length of 120 m. Underground main building area of 24872.96 square metres, station hall level equipment management room area of 7140.48 square metres, the public area of 5296 square metres, the area of 2197.3 square metres of payment area, non-payment area of 3098. 7 square metres; platform level public area of 3040.8 square metres; entrance and exit building area of 2962.12 square metres; duct building area of 1724.62 square metres; station total building area of 29,559.7 square metres. 1724.62 square metres; total station building area 29,559.7 square metres.

The first basement level is the station hall level, with the main equipment management room area at the west end, the necessary equipment rooms and commercial rooms at the east end, the public area in the middle of the station hall, the paid area in the middle of the public area, the non-paid area at the two ends, the two areas are separated by an entry/exit gate and a fixed fence, and there is a ticketing office on the separation strip close to the entry/exit gate, and there is enough space for passengers to gather and disperse in the non-paid area.

As at July 2023, the station has four entrances and exits, and the design passenger flow of the interchange hall is 19,100 passengers per hour. According to statistics, the current average daily passenger flow at the station is about 30,000, and the average daily scanning and collection of passenger parcel X-rays is 10,000 per day. Average daily scanning and collection of passenger parcel X-ray film 10,000 sheets. Peak period can reach 20,000, these mobile fire load X-ray film can clearly distinguish the contents of the parcel inside, the experts more accurate assignment assessment to provide a reliable basis for the typical luggage X-ray photo shown in **Figure 2**.

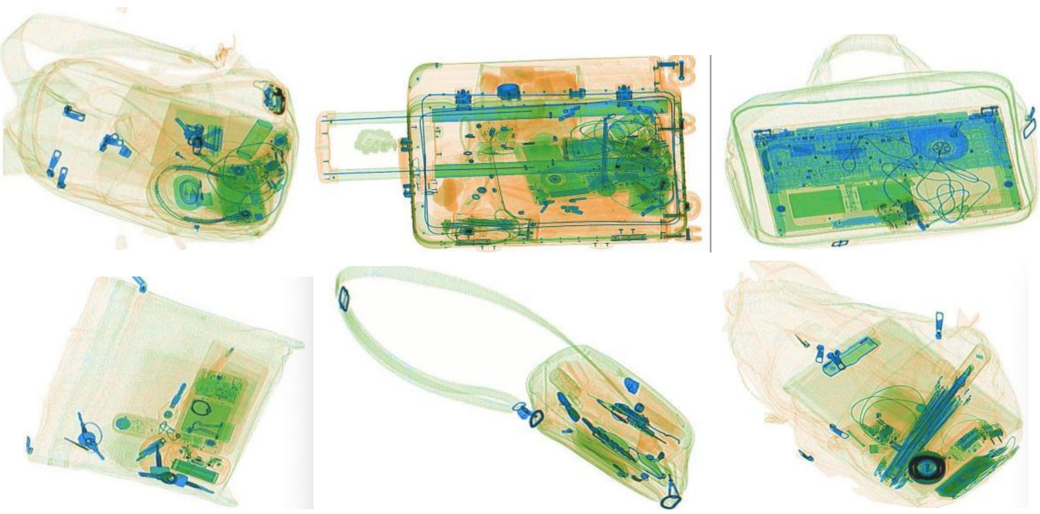

**Figure 2.** Typical luggage x photo.

In summary, the amount and type of luggage in metro stations has the potential and sensitivity to influence fire hazards, hence the safety resilience assessment of passenger luggage management.

## 4.2. Data acquisition

According to the emergency evacuation plan of this metro station: during an emergency evacuation, the evacuation route for passengers on the platform level goes from the platform level to the stairs on the platform level, from the concourse level to the ticket gates, and from the stairs on the concourse level to the ground level exits.

The high density of people during evacuation will converge on the stairs, passages and exits in a very short period of time, which is very likely to cause blockage and reduce the speed of evacuation. In particular, a large number of electronic products, handbags and other large pieces of luggage are commonly found in underground stations, and these mobile fire loads not only have the natural possibility that some of the luggage can easily burn under high temperature environments, but also the large pieces of luggage will seriously hinder the evacuation of passengers, which will greatly prolong the evacuation time.

Data acquisition is a key step in conducting the study, and the Delphi method was used to initially develop a resilience indicator questionnaire, and 30 experts and scholars (including 10 urban rail transport managers, 10 technical engineers in the field of rail transport, and 10 academics from universities and colleges in the field of rail transport) were invited to rate and rank the importance of the impact of baggage fire hazards and evacuation resilience in metro stations.

With the help of camera equipment, the observed parameters of this test include: handbags, backpacks, portable power tools, and trolley cases in four major categories of baggage in three different time scenarios: weekdays, weekends, and holidays, and sampling was conducted twice a month in April, June, and July 2023, and the statistical results are shown in **Figure 3** below.

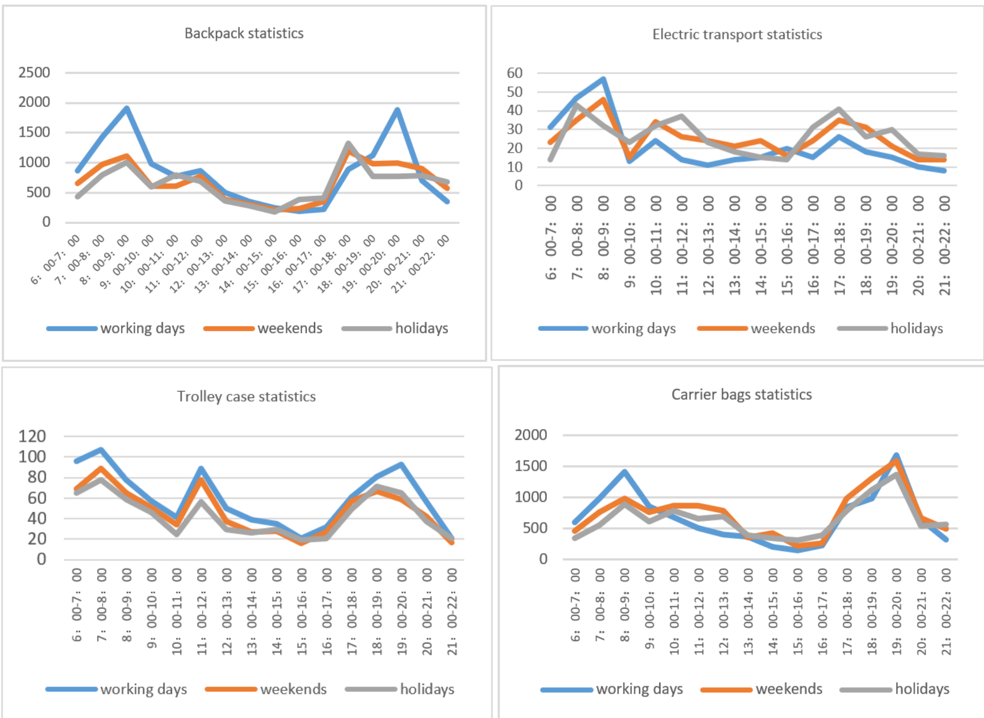


**Figure 3.** Statistics on the number of baggage in the four categories.

### 4.3. Fire resilience assessment of metro stations

Firstly, the subjective weights of the evaluation indexes are determined according to the AHP-PSO method, the judgement matrix is constructed according to the expert questionnaire data and corrected by the Consistency test, and the weights of the total indexes are calculated and normalised. Next, the improved CRITIC method was used to determine the objective weights of the evaluation indicators and normalised to obtain the ultimate weights. Thereafter, the comprehensive weights of the evaluation indexes were calculated, and according to the optimisation

According to the optimisation model, Matlab 7.0 is used to calculate the comprehensive weights of the evaluation indicators and the results are analysed as shown in the **Table 1** below.

**Table 1.** List of composite weighting indicators.

| | AHP-PSO | | Improved CRITIC method | | Combined weights | | |
|---|---|---|---|---|---|---|---|
| **norm** | **weights** | **arrange in order** | **weights** | **arrange in order** | **reasonable interval** | **weights** | **arrange in order** |
| Electric wheelchair | 0.49 | 1 | 0.07 | 11 | [0.07, 0.49] | 0.49 | 1 |
| Folding electric car | 0.43 | 4 | 0.09 | 4 | [0.09, 0.43] | 0.26 | 2 |
| electric balance scooter | 0.14 | 9 | 0.66 | 12 | [0.14, 0.66] | 0.14 | 3 |
| Folding Shopping Cart | 0.11 | 11 | 0.09 | 6 | [0.09, 0.11] | 0.11 | 4 |
| pushchair | 0.43 | 4 | 0.1 | 1 | [0.10, 0.43] | 0.10 | 5 |
| duffel bag | 0.43 | 4 | 0.09 | 2 | [0.09, 0.43] | 0.10 | 5 |
| shoulder bag | 0.14 | 9 | 0.09 | 5 | [0.09, 0.14] | 0.09 | 7 |
| single-shoulder backpack | 0.41 | 8 | 0.09 | 3 | [0.09, 0.41] | 0.09 | 7 |
| mountaineering bag | 0.07 | 12 | 0.08 | 7 | [0.07, 0.08] | 0.08 | 9 |
| hold-all | 0.43 | 4 | 0.07 | 10 | [0.07, 0.43] | 0.08 | 10 |
| woven bag | 0.48 | 2 | 0.08 | 8 | [0.08, 0.48] | 0.08 | 10 |
| Travel bag | 0.44 | 3 | 0.08 | 9 | [0.08, 0.44] | 0.08 | 10 |

By calculating the combined weights of the evaluation indexes, it can be concluded that Electric wheelchair (0.49), Folding electric car (0.26) and electric balance scooter (0.14) have a greater influence on the comprehensive evaluation grade of fire safety toughness of the metro station.

Folding Shopping Cart (0.11), pushchair (0.10), duffel bag (0.10), shoulder bag (0.09), single-shoulder backpack (0.09), mountaineering bag (0.08), hold-all (0.08), and wigwam (0.14) had a greater impact on the fire safety toughness of metro stations. All (0.08), woven bag (0.08), Travel bag (0.08) also have different weights on the fire safety resilience composite rating of metro stations.

Finally, based on the fuzzy comprehensive evaluation of comprehensive weights, the following data were obtained by questionnaire survey of 12 experts and the results were analysed as shown in **Table 2**.

The results are analysed as shown in **Table 2**. According to the data in **Table 2**, it is found that the comprehensive evaluation grade of this metro station is higher toughness, and the evaluation results are basically consistent with the actual situation of this metro station. All aspects of the underground station evaluation is better, only the electric wheelchair exists lower toughness, indicating that the overall safety level of the underground station is higher, in the underground station fire hazards, emergency evacuation management has a certain safety capacity, but focus on the improvement of the automatic fire alarm system to improve.

**Table 2.** List of comprehensive evaluations.

| | **High toughness (100~90)** | **Higher toughness (89~80)** | **Medium toughness (79~70)** | **Lower toughness (69~60)** | **low toughness (59~0)** |
|---|---|---|---|---|---|
| Travel bag | 1 | 11 | - | - | - |
| Hold-all | - | 7 | 5 | - | - |
| Mountaineering bag | - | 12 | - | - | - |
| Folding Shopping Cart | 1 | 9 | 2 | - | - |
| Pushchair | - | 10 | 2 | - | - |
| Duffel bag | - | 12 | - | - | - |
| Shoulder bag | 2 | 4 | 5 | 1 | - |
| Single-shoulder backpack | 1 | 6 | 5 | - | - |
| Electric balance scooter | 2 | 5 | 5 | - | - |
| Folding electric car | 3 | 6 | 3 | - | - |
| Woven bag | - | 10 | 2 | - | - |
| Electric wheelchair | - | 11 | 1 | - | - |
| Composite affiliation | 0.02 | 0.36 | 0.07 | 0.01 | - |
| Combined rating scale | Higher toughness | | | | |

## 5. Summary

According to the connotation and characteristics of toughness theory, the fire safety toughness evaluation index system of underground passenger luggage (mobile fire load) is constructed, including 12 indexes such as folding electric car, electric wheelchair and electric balance car, shopping cart, pram and trolley case, shoulder bag, shoulder bag, hiking bag, handbag, knitting bag, hand-held travelling bag and so on.

The underground fire safety toughness evaluation model based on AHP-PSO fuzzy combination assignment method considering mobile fire load is proposed, and the framework is used to evaluate the fire safety toughness of underground station, the calculation process is more clear and simple, and the final result is more consistent with the actual situation; the underground fire safety toughness evaluation based on AHP-PSO fuzzy combination assignment method provides a new perspective and new ideas for the evaluation of the fire protection system of underground station. The evaluation of underground fire safety toughness based on AHP-PSO fuzzy combination assignment method provides a new perspective and new ideas for the evaluation of fire protection system in underground stations, combining the weights of passenger flow and mobile fire load, and the results of the evaluation are more in line with the actual situation of metro stations.

According to the comprehensive evaluation level and the comprehensive weighting of the evaluation indicators, proposals are made to establish on-site management of passenger transport that meets local realities:

1) Station management:

Improve the level of station control room staff's ability to manage heavy passenger traffic as well as mobile fire loads, improve the rate of contraband detection and removal and publicise fire knowledge; by focusing on the inspection of electric vehicles and prohibiting high-power electric vehicles from entering metro stations; and establish and improve the management of passenger flow wind direction during peak passenger flow periods, and other measures. In the future, practical fire emergency plans for metro stations can be customised according to the actual situation in metro stations, and station staff will conduct consumption training and fire-fighting drills on a regular basis according to the stipulated time.

2) Fire prevention and control aspects:

①Establish early alarms. Real-time monitoring of the number of people entering and leaving the station as well as the number of moving fire loads, and effective evacuation of concentrated areas. Emergency management of heavy passenger flow not only determines the length of evacuation pre-action time, but also determines whether the operation mode of the station can be converted from normal mode to fire mode at the first time.

②Control the use of combustible and toxic materials. In the station platforms, station halls, escalators, evacuation routes, equipment management rooms, advertising light boxes and other places to use highly fire-resistant construction and decoration materials and combustion of less toxic building materials, in order to improve the fire evacuation of the critical conditions, reduce the degree of harm.

③ Ensure that other fire prevention and extinguishing facilities are complete, reasonably distributed and in good working condition. If the fire-related equipment is not switched to the fire mode in time, then the escalator to keep one up and one down, the gate exit is still in accordance with the mode of operation of the ticket, the personnel through the gate and the normal exit close to the station, into the station hall, due to the gate is not completely open, the gate exit in the second blockage, the entire journey two bottlenecks to the speed of evacuation occurs in the obstruction, resulting in the evacuation of the passengers hidden danger.

3) Guidance facilities:

① from the guidance facilities to improve the evacuation ability is first of all a reasonable deployment of guidance facilities, in the fire evacuation to play a good role in guiding. Specifically can be strengthened from the following aspects: focusing on the orderly deployment of signs, to ensure the seamless flow of information, the sudden loss of information in the middle of the evacuation may intensify the psychological panic of the flow of passengers, resulting in confusion. Improve the user-friendliness of the guidance facilities, can be the most simple, direct to provide passengers with the maximum information, can make passengers understand the combination of guidance facilities and evacuation facilities. In other words, it should be 'simple and concise' and 'easy to understand'. Evacuation broadcasts should be clear instructions, no redundant information, easy to understand, and to ensure appropriate broadcast frequency.

② Strengthen the inspection and maintenance of guidance facilities to ensure that they are in good working order during evacuation.

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