

## Research on Assessment Model of Disaster Prevention Capability of Urban Residential Area

**Buri Qi**, College of Architecture, Inner Mongolia University of Technology; Key Laboratory of Green Building at Universities of Inner Mongolia Autonomous Region; Engineering Technology and Research Center on Green Building of Inner Mongolia.

[qiburi0113@126.com](mailto:qiburi0113@126.com)

**Jiaqi Lin**, College of Architecture, Inner Mongolia University of Technology; Key Laboratory of Green Building at Universities of Inner Mongolia Autonomous Region; Engineering Technology and Research Center on Green Building of Inner Mongolia.

[2644726843@qq.com](mailto:2644726843@qq.com)

**Lei He**, College of Architecture and Urban Planning, Tongji University.

[leih@tongji.edu.cn](mailto:leih@tongji.edu.cn)

**Abstract:** Urban residential areas are an important unit of urban disaster prevention and reduction, which affects the goals, strategies and countermeasures of urban disaster prevention and reduction. The characteristics of current research on evaluating residents' disaster prevention capabilities are not applicable to urban planning research and practice. Based on the concept of comprehensive disaster prevention, this paper establishes a theoretical formula for assessing vulnerability and constructs six evaluation indicators that affect the disaster prevention capacity of residential areas. The weight of factors is determined by Delphi method and establish an evaluation model. Evaluate the disaster prevention capacity of residential areas using the standard evaluation guideline method. It provide guidance for evaluating the disaster prevention capacity of urban residential areas in China and formulating disaster prevention countermeasures.

**Key words:** the residential area, disaster prevention capability assessment, vulnerability, assessment model, Standard Assessment Guide Method

As a composite unit of humanities and space, urban residential area is composed of social groups living in a specific area. These groups have common interests, social interaction and corresponding service system (Jacobs, 1961). In the process of urban development, residential function has always been one of the important functions it undertakes. With the development of society, large-scale, high-density and high volume rate have become the mainstream architectural trends in modern urban residential areas. The agglomeration of buildings and population leads to more security risks in residential land (Zhao Yiting et al. 2013, Meng Fanliang et al. 2011). However, the planning and construction of residential areas in China generally lack disaster prevention and safety considerations. At the same time, the occurrence of disasters is often sudden, and it is easy to cause secondary disasters, resulting in

serious loss of life and property. Therefore, it is of great practical significance to study the problem of disaster prevention and mitigation in urban residential areas, and to put forward the improvement scheme of physical space and the guiding measures of public policy, so as to reduce the loss of urban disasters and improve the safety and resilience of cities. Through these measures, we can effectively deal with various disaster risks, ensure the safety of life and property of urban residents, and also help promote sustainable urban development (Sun Shiwen, 2021).

Currently, there are more studies on disaster risk assessment in China, while relatively less attention is paid to the assessment of disaster prevention capacity. In terms of residential disaster prevention research, more attention is paid to single-system disaster prevention and safety, while relatively little research is done on comprehensive disaster prevention in residential areas. In addition, many scholars have conducted a large number of studies on disaster prevention planning in residential areas, but there is a relative lack of studies on the evaluation of disaster prevention capacity. In summary, a relatively complete research technical route on the evaluation of disaster prevention capacity of residential areas has been initially formed: the route is based on disaster prevention theory and aims to construct a comprehensive set of evaluation criteria and subdivide the evaluation elements. Next, the disaster prevention capacity of the study area is systematically assessed through quantitative evaluation methods. Finally, based on the assessment results, effective disaster prevention countermeasures are formulated to enhance the disaster prevention capacity of the residential area. For example, from 2009 to 2016, Liu Peng (2017) studied the risk assessment model of residential communities, and proposed 16 kinds of community hazard factor assessment indicators. The risks of Shanghai communities through demographic and economic data were assessed, and the risk maps of Shanghai communities were drawn. The identifying risk types, vulnerable areas, important infrastructure, safe places, countermeasures, and suggestions were proposed. A security risk assessment method for old urban communities based on Bow-tie model ( BT ) and Bayesian network ( BN ) was proposed by Gu Tiantian (2023). It was inferred that the personal unsafe behavior, the vulnerability of community infrastructure and the risk of surrounding facilities in Y community of Shenzhen City were high-risk factors. This study evaluated the security risk level of Y community in Shenzhen City. Lian Dajun et al (2017) built a community disaster reduction capability index assessment system with 30 secondary indicators from six aspects: disaster risk assessment capabilities, rescue and support capabilities, engineering defense capabilities, economic base support capabilities, disaster management capabilities, and residents' cognitive capabilities. The entropy grey target model and the approaching degree classification were used to classify and assess the disaster reduction capability of the community, and the disaster prevention capability of the residential area in Suzhou was calculated with the help of GIS spatial overlay analysis technology. In his study, Kong Feng (2019) pointed out that the problems of disaster prevention, mitigation and relief in urban and rural communities are reflected in the obvious regional differences in infrastructure, the prominent problem of coordination of disaster

mitigation resources, the weak applicability and practicability of disaster prevention and mitigation plans in urban and rural communities, as well as the weak awareness and ability of residents to mitigate disasters. Wu Dafang et al (2015) evaluated the fire protection capability of buildings in city villages in Guangzhou. A fire risk evaluation indicator system was constructed based on the fire resistance rating and purpose of the house, the layout of fire hydrants and the setting of fire passages. The analytic hierarchy process, Kriging spatial interpolation, and buffer analysis were applied to obtain the building fire prevention capability evaluation model. The weak links were found to improve the fire prevention capability of the city village. By analyzing and summarizing the potential of enhancing community resilience in disaster prevention and mitigation planning and the impact of improving community resilience on the implementation efficiency of disaster prevention and mitigation planning, Ma Chao et al (2020) proposed to enhance community resilience through four methods. Obviously, in the process of assessing the disaster prevention capacity of residential areas, there are differences in the understanding and knowledge of experts and scholars in various academic fields about disaster prevention in residential areas, which mainly stems from their different research focuses, thus leading to inconsistencies in disaster prevention strategies and goal setting. Therefore, in order to assess the disaster prevention capacity of residential areas as comprehensively and accurately as possible, researchers have adopted diversified evaluation indicators and complex quantitative evaluation techniques, and ultimately come up with a variety of different disaster prevention countermeasures and measure recommendations, with a view to better improving the level of disaster prevention and the ability to cope with disasters in residential areas.

From the perspective of urban planning, this paper focuses on the theory and evaluation index of disaster prevention in urban planning system. Therefore, in terms of evaluation objectives, evaluation indicators and evaluation methods, this paper is significantly different from the existing research. This study focuses on the evaluation of disaster prevention capacity of residential areas by scholars and planners in the field of planning. This study takes the disaster prevention and mitigation of residential areas as the research object, and constructs the theory of urban disaster prevention planning from the concept of urban comprehensive disaster prevention. By establishing the theoretical formula of the vulnerability of the bearing body and coordinating with the planning elements of the residential area, six evaluation indexes affecting the disaster prevention ability of the residential area are constructed. Delphi method is used to determine the weight of factors, and the evaluation model is established. The standard assessment guide method is used to assess the disaster prevention capacity of residential areas. The conclusions of the study have important support for the assessment of disaster prevention capacity and the formulation of disaster prevention countermeasures in urban residential areas in China.

## **1. Basic thoughts and planning elements of disaster prevention in residential areas**

### **1.1 Basic thoughts of disaster prevention in residential areas**

Based on the basic concept of urban disaster prevention, ‘a variety of preventive measures for the loss of life and property of urban residents and various types of engineering facilities in order to resist and mitigate all kinds of natural and man-made disasters and the secondary disasters caused by them’ (He Lei, 2016), as well as the basic components and formation mechanisms of disasters, this idea is based on the fundamental composition and formation mechanisms of disasters understanding of disasters and aims to protect the safety and property of urban residents and ensure the sustainable development of the city. The idea of disaster prevention can be summarized as follows:

(1) Reducing the exposure of the disaster-bearing body: in order to reduce the probability of a disaster occurring, it is necessary to fundamentally change the environment or conditions of the disaster-forming mechanism in order to reduce the scope of action of the disaster force and separate it from the coverage of the disaster-bearing body so that the disaster is not likely to occur.

(2) Reducing the vulnerability of the disaster-bearing body: in order to reduce the impact of the disaster, it is necessary to change the state of the physical spatial components in order to reduce the vulnerability of the disaster-bearing body, and consequently to reduce the probability of the occurrence of an extreme disaster state.

(3) Improvement of emergency evacuation capacity: In order to reduce the casualties caused by disasters, the emergency evacuation system should be improved according to the occurrence of disasters in order to reduce the casualties. Residential areas are considered to be densely populated ‘target areas’<sup>1</sup> where the exposure of disaster carriers is generally stable. Disaster preparedness strategies focus on emergency actions aimed at reducing vulnerability and casualties in the aftermath of a disaster. Self-help and mutual aid by community residents before, during and after a disaster, as well as the timely evacuation and relocation of people to safe areas, can significantly reduce casualties. Therefore, the construction of a sound evacuation and rescue system is an important material foundation. Based on this concept, this paper starts from building an evacuation and rescue system to establish a model of the disaster prevention capacity of residential areas.

---

<sup>1</sup> refers to the weak areas in the built-up areas of cities that are affected by disasters, have disaster losses, and require emergency rescue.

## 1.2 Planning element screening

According to the current national standard 'Code for Urban Residential Area Planning and Design', the planning elements of residential areas can be divided into four aspects, namely land use and construction, housing, public service facilities and roads. By carefully combing the planning elements in the national standard 'Urban Residential Area Planning and Design Code', combined with the micro-mechanism of disasters and urban space, the elements closely related to community safety in residential area planning can be determined.(1) In terms of land use and construction, it includes factors such as floor area ratio, building density and population density related to the prediction of the size of the affected population and the spatial layout of the affected buildings after the disaster. These factors are of great significance for post-disaster reconstruction and population evacuation.(2) public service facilities, including facilities such as education, health care, culture, sports, business services, community services, administrative management and public parking lots (garages). These facilities play an important role in emergency services during disasters<sup>2</sup>. (3) Road system, including factors such as road density and road width. Good road planning is essential for emergency evacuation and rescue operations. The goal of disaster prevention in residential areas is to reduce material and property losses and casualties. Therefore, in the combing of the elements of residential area safety planning, it is necessary to comprehensively consider the details and interrelationships of the above factors:

1. Reduce material and property losses and reduce the vulnerability of residential areas.

The factors affecting the vulnerability of disaster carriers can be considered at three levels: (1) the disaster resistance and building quality standards of physical space, which are closely related to the degree of disaster damage; (2) demographic characteristics, including factors such as population distribution and population density, which affect the degree to which people are affected by disasters; and (3) the ability of physical space to recover from damage, which is linked to the local level of economic development and the ability to prevent and mitigate disasters. capacity is associated. However, the characteristics of different population groups affected by disasters are often neglected. Population distribution and population density are closely related to the spatial distribution of buildings, building density, and floor area ratio. In general, the level of economic development and disaster prevention and mitigation capacity are consistent with the development trend of emergency shelter buildings: the higher the level of economic development, the higher the emphasis on safety; the higher the disaster prevention and mitigation capacity, the more balanced the layout of evacuation and emergency shelter sites and the higher the level of service. Therefore,

---

<sup>2</sup> refers to places and facilities such as medical and sanitation, water storage, material storage and distribution, and fixed refuge necessary for emergency rescue, emergency evacuation, and post-disaster life.

vulnerability has an inverse relationship with building quality and shelter layout, and a positive relationship with building density, building volume ratio, and proximity of spatial distribution. The logical relationship of vulnerability is as follows:

$$V = \frac{De \cdot Fr}{Qa \cdot Sl} \cdot Lo \quad (1)$$

Among them:

V: vulnerability

De: building density

Fr: floor area ratio

Qa: building quality

Sl: shelter layout

Lo: proximity of building space distribution. According to the distance to the disaster-prone area, the Lo value is between 0 and 1. The Lo value is 1 of the disaster-prone area, and the Lo value is 0 of the area far away from the disaster-prone area, and the value of the rest takes the difference based on the distance to disaster-prone area.

The vulnerability theory of disaster bearing body reveals the following viewpoints: when determining the location of residential area ( keeping Lo value unchanged ), the area with low plot ratio, low building density, high building quality and reasonable layout of shelter has low vulnerability, that is, less material and property loss. Therefore, the planning elements of residential areas need to meet the following requirements: the overall spatial structure adopts the layout mode of low building density and low floor area ratio. At the same time, the construction quality must be strictly controlled to meet the standards of disaster prevention and resistance.

2. Reduce casualties, including emergency evacuation, emergency rescue and emergency resettlement.

(1) Refuge population evacuation: During a disaster, the number of evacuated people is directly related to the quality of the buildings, the density of the buildings and the plot ratio of the residential area. The quality of a building determines whether or not it is damaged during a disaster: if a certain type of building is completely destroyed, then everyone living in that type of building should be evacuated. According to the 'Code for design of disasters mitigation emergency congregate shelter' (GB51143-2015), the size of the emergency evacuation population should take into account the urban resident population and the mobile population. In the area around crowded public places, the size of the emergency evacuation population should be no less than 80% of the annual maximum daily flow. For permanent refugees, the size should not be less than 20% of the permanent population, and the following requirements need to be met: a) the area where the area of buildings (structures) with low

disaster resistance exceeding 60% shall not be less than 45% of the permanent population; b) areas where the area of buildings (structures) with low disaster resistance exceeding 40% should not be less than 35% of the permanent population; c) areas where the area of buildings (structures) with low disaster resistance exceeding 20% should not be less than 25% of the permanent population.

(2) Refuge channel evacuation: Evacuation of evacuation routes is an important measure to ensure effective evacuation of refugees before they enter an evacuation area. The accessibility and capacity of evacuation roads are therefore critical to the efficiency and capacity of evacuation. In community planning, the design of refuge roads is directly related to the layout of the road network, the organization of roads and land, and the width of roads. According to the 'Code for design of disasters mitigation emergency congregate shelter' (GB51143-2015), under the conditions of calculation of the building collapse model on both sides, the width of the main evacuation road should be no less than 7 meters, the width of the secondary evacuation road should be no less than 4 meters, and the width of the general evacuation road should be no less than 3 meters. In addition, there should be convenient transportation access between buildings and evacuation shelters. In order to increase the density of the road network, a square grid-like road network layout is usually adopted, which can improve the connectivity of roads in the community and enhance the efficiency and capacity of evacuation.

(3) Shelter evacuations: During a disaster, buildings and open spaces used to accommodate refugees may include educational facilities such as schools, sports facilities such as stadiums, other large public buildings, squares, and green spaces (especially public green spaces), and these places should have a certain effective refuge area. These functional facilities should not only meet the normal needs of normal use, but also assume the function of sheltering and evacuating refugees in the event of a disaster. Therefore, when planning and laying out these places, it is necessary to take into account their ease of use during a disaster, and their capacity should not only meet the needs of daily use, but also be able to cope with the evacuation needs fixed in the service area. Therefore, the total capacity of such public facilities and green spaces should be designed and checked against evacuation needs.

(4) Emergency rescue channel: The emergency relief channel is the main channel connecting the residential area with the outside world and is used to connect various services in the residential area such as medical and health services, community services, administration and commercial services. It provides a transmission channel for basic living materials such as medical aid, community organization, special people aid, disabled people aid, food and drinking water. According to the 'Code for design of disasters mitigation emergency congregate shelter' (GB51143-2015), the width of the emergency relief channel should be 15 meters, taking into account the model of building collapse on both sides.

(5) Emergency service facilities: they mainly include the functions of medical and health services, commercial services, community services and administration in public service facilities. Medical and health facilities assume the important responsibilities of emergency rescue and rescue of the injured during disasters; service facilities in residential areas are important institutions for vulnerable groups to take refuge during disasters; administrative facilities are the organizational centers for refuge, rescue and emergency services in residential areas; and commercial service facilities are the places for storing and distributing emergency food and drinking water. Therefore, in addition to meeting the day-to-day needs of a residential area, there is a need to assess its configurability for emergency use during a disaster.

(6) Emergency support infrastructure: Emergency protection infrastructure is the municipal public facilities that directly provide emergency water, electricity, road and communication services during disasters. To ensure their reliability in times of disaster, they should be designed and constructed in a disaster-proof manner to enhance their ability to withstand disaster damage. In addition, redundancy and multi-source planning need to be considered to ensure continuity of supply during disasters. Therefore, municipal planning should be reviewed with special attention to the security of water, electricity and information supply during disasters.

(7) Disaster prevention engineering facilities: Disaster prevention engineering facilities are important municipal infrastructures, such as flood walls, levees, and rainwater regulating basins, which are part of municipal infrastructures in a broad sense as disaster prevention engineering facilities to ensure community safety. However, such facilities are usually seldom seen in residential areas because these disaster prevention engineering facilities are usually municipal public investment projects with limited relevance to residential areas. In contrast, people's air defense engineering facilities are more widely distributed in residential areas. When planning and laying out these facilities, they not only need to comply with the requirements of the Civil Air Defense Law and relevant national standards, but also assume responsibility for disaster prevention in residential areas. Therefore, when planning and constructing disaster prevention engineering facilities, comprehensive consideration needs to be given to the rational distribution of different types of facilities to ensure the overall disaster prevention capability of the community.

The above elements are summarized in Figure 1.

Figure 1 Influencing factors of the disaster prevention capability model of residential areas

'Disaster prevention' objects	System of planning elements	Segmentation of planning elements	Layout element
Material	Land use and	Residential	Building density

property	construction	building	Building floor area ratio
		Building quality	--
People	Road	Road	Road network density
			Road width
		Road square	Accessibility Effective area meeting evacuation needs.
	Sports facilities		
	educational facility		
	Parking lot		
	Public service facilities	Grassland	Accessibility Effective area meeting emergency needs
		Medical and health	
		Commercial service	
		Community service	
	Municipal public service facilities	Administrative management	Meeting emergency supply needs.
		Water supply	
		Electricity supply	
	Communication		

Source: it is made by the author

## 2 Weights of element in the assessment of disaster prevention capability in residential areas

### 2.1 Major issues identification

The basic idea of model construction is shown in Figure 2. The expert scoring method is used. Each expert's opinion passes the consistency test of the pairwise comparison matrix, and qualitative issues are transferred into quantitative calculations.

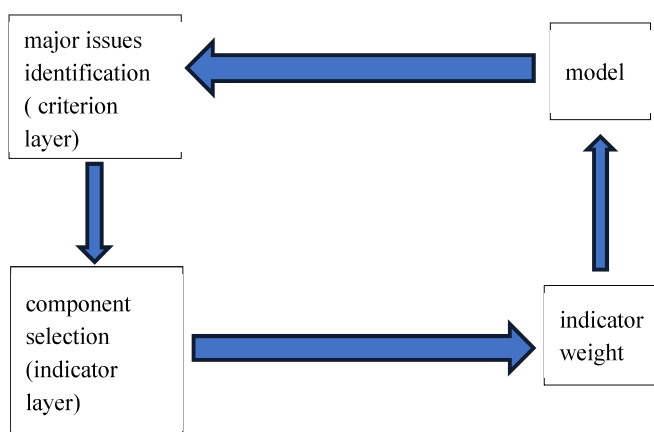


Figure 2 Model building work flow

Source: it is made by the author

The basic goal of disaster prevention in residential areas is to reduce material losses and casualties. Reducing the material loss, that is, reducing the loss rate of buildings and structures when damaged by disasters, is the foundation of disaster prevention in residential areas; reducing casualties, that is, improving the capability of personnel emergency evacuation and rescue, is the focus of disaster prevention in residential areas. Therefore, take the personnel emergency evacuation and rescue in residential areas as the major research issues, and the research is conducted around the relevant elements of the evacuation and rescue system in residential areas. The elements that are not closely related to it, such as the scale of residential buildings (building density, building floor area ratio) are eliminated.

## 2.2 Component selection

With reference to the research conclusions of the influencing elements of the disaster prevention capability model of the residential area, the main components that affect the disaster prevention capability are as follows:

(1) Building quality: whether the building quality meets the standard determines whether the building is damaged during the disaster, which affects the loss of material property, the number of casualties, further impacting the number of emergency personnel resettlement. Especially public buildings that undertake important functions, such as hospitals, fire stations, stadiums, police offices, schools, etc., have higher building quality requirements to ensure normal functions during disasters.

(2) The road traffic: once the damage to the building is inevitable, the road traffic is responsible for emergency evacuation and rescue of affected people. The density of the road network of road traffic, the width of the main evacuation road and the main rescue road should meet the requirements of safety and capacity.

(4) Evacuation shelters: affected people enter the evacuation shelters through the road traffic. The accessibility, safety and effective area of evacuation shelters should meet specific requirements. The location, their spatial layout with residential buildings, and building capacity (floor area ratio, density) and other indicators of public service facilities, green space, open space, etc. that can be used as evacuation shelters should meet certain requirements.

(5) Emergency service facilities: the affected people are separated from the disaster site. After being placed in a relatively safe area, they need the most basic living materials such as medical treatment, food, and drinking water. Therefore, medical and health, commercial facilities, community services, and administrative management in public service facilities should bear the emergency needs at this time.

(6) Emergency support infrastructure: the water supply, electricity supply, and communication in the municipal infrastructure directly serve for emergency support during disasters, and play an important role in post-disaster restoration, resettlement and reconstruction. If the infrastructure can be restored as soon as possible after the disaster, not only can the confidence in reconstruction be established, but also the lives of the people in the disaster area can be restored to normal order in the shortest time.

### 2.3 Determination of element weight

The Delphi method is used to determine the weight. Based on a total of 111 people including design professionals, experts, government management practitioners tested scoring (original data is omitted), their mean value, variance, and mode are analyzed, as shown in Figure 3 below.

Figure 3 Summary of opinions from the expert questionnaire

(1) Design professionals (31 people)					
	Building quality	Road traffic	Emergency shelter	Emergency service facility	Emergency support infrastructure
Mean value	27.1	21.6	16.7	15.4	19.2
Variance	119.1	31.2	22.9	14.3	23.6
Mode	20	20	15	15	20
(2) Experts (10 people)					

Mean value	27.3	21.6	19.3	14.7	17.1
Variance	72.6	29.9	13.9	14.9	22.2
Mode	20	15	20	15	20
(3) Government management practitioners (70 people)					
Mean value	25.2	19.5	17.5	16.4	21.4
Variance	107.9	23.2	20.2	17.2	26.7
Mode	20	20	15	15	20

T test is used to test whether the mean values of the three types of people's opinions are significantly different. Assume that there is no difference between the scores of the three types of personnel, that is, the mean values are the same. The EXCEL is adopted to perform calculations to obtain the conclusions shown in Figure 4 below. After checking the value figure of the T distribution, it can be seen that the t values among the three groups in Figure 4 are all less than the threshold value, indicating that the hypothesis test can be accepted at the 95% level, that is, the mean values of the three groups are the same. Therefore, the three groups of people have basically the same judgment on the problem, and the components and weight are relatively stable. The average of the three groups can be used as the final weight of the Delphi method, see Figure 5.

Figure 4 T-value analysis results of the significance test of the difference in the mean values of the three groups

T value	Building quality	Road traffic	Emergency shelter	Emergency service facility	Emergency support infrastructure	T test value (n) (95% level)
t <sub>12</sub>	-0.0048	0	-0.3284	0.1267	0.2361	1.69(39)
t <sub>13</sub>	0.0941	0.2956	-0.2067	-0.2894	-0.4148	1.66 (99)
t <sub>23</sub>	0.0585	0.2519	0.26742	-0.2899	-0.4744	1.67 (68)

Note: t<sub>12</sub> in the figure represents the T-test value between the first group of design professionals and the second group of experts. t<sub>13</sub> in the figure represents the T-test value between the first group of design professionals and the third group of government management practitioners. t<sub>23</sub> in the figure represents the T-test value between the second group of experts and the third group of government management practitioners.

Figure 5 Final weights of expert scoring method

Mean value	Building quality	Traffic	Emergency shelter	Emergency service facility	Emergency infrastructure
Mean	27.1	21.6	16.7	15.4	19.2

value 1					
Mean	27.3	21.6	19.3	14.7	17.1
value 2					
Mean	25.2	19.5	17.5	16.4	21.4
value 3					
Grand mean	26.5	20.9	17.8	15.5	19.3

#### 2.4 Element weight subdivision

The weight of subdivision elements can be obtained in the same way, see Figure 6 below.

Figure 6 Element subdivision and weight analysis

Basic elements	Element characteristics	Element subdivision	Control variable	Value standard
Building quality (0.265)	--	--	Building quality (Qa)	The value is set as 3 for higher than the standard; the value is set as 1 for reaching the standard; the value is set as 0 for being substandard
Road traffic (0.209)	Road network density (0.4)	Relation ship between traffic and land use	Overall spatial structure (SS)	The value is set as 3 with higher road network density; the value is set as 1 with middle road network density; the value is set as 0 with large road network
			Road width (RW) (0.4)	The value is set as 3 for higher than the standard; the value is set as 1 for reaching the standard; the value is set as 0 for being substandard
	Road width (0.6)	Route selection and surrounding building restrictions	Land function along the road (RL) (0.15)	The value is set as 3 for small flow traffic, 1 for general flow traffic, and 0 for high flow traffic
			Building setbacks along the road	The setbacks is set as 3 for more than 15 meters,

			(RB) (0.3)	as 1 for more than 5 meters, and as 0 for less than 5 meters.
			Building quality along the road (RQ) (0.15)	The value is set as 3 when it is beyond the standard; the value is set as 1 when it is satisfy the standard; the value is set as 0 when it is substandard
Evacuation shelter (0.178)	Accessibility (0.3)	Public facilities layout	Time for taking refuge (ST)	The value is set as 3 for satisfying requirements. The value is set as 1 for not satisfying requirements.
	Effective area (0.3)	Building capacity	Capacity for taking refuge (SC)	The value is set as 3 for satisfying requirements. The value is set as 0 for not satisfying requirements
	Safety (0.4)	Location	Safety of location (SL)	The value is set as 3 for satisfying requirements. The value is set as 0 for not satisfying requirements
Emergency service facilities (0.155)	Medical and health (0.4)	Location and capacity of medical institutions	Medical institution capacity (EH) (0.6)	The value is set as 3 for satisfying requirements. If there is an emergency plan but it does not meet the capacity requirements, set it as 1; if there is no emergency preparation, set it as 0
	Food (0.3)	Location and capacity of commercial facility	Commercial facility capacity (EC) (0.4)	The value is set as 3 for satisfying requirements. If there is a reserve of emergency supplies but the quantity does not meet the requirements, set it as 1; if there is no

	Drinking water (0.3)	Location and capacity commercial facility		reserve, set it as 0
Emergency support infrastructure (0.193)	Electricity supply (0.3)	Electricity supply system	Safety measures for electricity supply system planning (IP) (0.3)	The value is set as 3 for those with disaster relief safety considerations, 0 for those without such considerations
	Water supply (0.4)	Water supply system	Safety measures for water supply system planning (IW) (0.4)	The value is set as 3 for those with disaster relief safety considerations, 0 for those without such considerations
	Communication (0.3)	Communication system	Safety measures for communication system planning (IC) (0.3)	The value is set as 3 for those with disaster relief safety considerations, 0 for those without such considerations

Source: it is made by the author

Based on the above analysis, a disaster prevention capability model can be obtained, as shown in formula 2.

$$\begin{aligned} \text{Disaster prevention capability} = & 0.26Qa + 0.12SS + 0.05RW + 0.02RL + 0.04RB + \\ & 0.02RQ + 0.05ST + 0.05SC + 0.07SL + 0.08EH + 0.06EC \\ & + 0.05IP + 0.08IW + 0.05IC \quad (2) \end{aligned}$$

### 3. Assessment method and practice of disaster prevention capability in residential area

#### 3.1 Assessment method of disaster prevention capability

Standard Assessment Guideline Method is used for disaster prevention capability assessment. Figure 6 shows the value standard. The items in Figure 6 are scored one by one by trained professionals who are proficient in the principle of scoring. For example, the scores can be divided into three levels of 0, 1, and 3, and scores are based on the degree of compliance described in the item: 3 means higher than the standard or disaster relief considerations, 1 means that the standard is met, 0 means that the standard is not met or there is no disaster relief consideration. Generally, the more levels are designed, the higher the

requirements for scoring personnel, the greater the risk of error. The score is divided into three levels for easy operation. According to the disaster prevention capability model constructed above, see Formula 2, and the scoring rules, the residential areas are scored. Based on the pre-set assessment criteria, the highest score of the ideal plan can be calculated. In Figure 6, take the highest score for the 14 selected elements as 3, so the full score for disaster prevention capability is 3. The scores are compared with the highest score after disaster prevention capability assessment in the study area, and the level of disaster prevention capability in residential area can be roughly assessed. For example, it can be set: (1) 80% or more, that is, disaster relief capability with a score of 2.4 points or more is at the excellent level and have good disaster prevention capabilities; (2) between 50% and 80%, that is, the disaster prevention capability with a score of 1.5 to 2.4 belongs is at the middle level and has a specific disaster prevention capability; (3) between 30% and 50%, that is, the disaster prevention capability with a score of 0.9 to 1.5 is at the poor level and has a certain disaster prevention capability; (4) less than 30%, that is, the disaster prevention capability with a score less than 0.9 is at the worst level, that is, it does not have the disaster prevention capability.

Usually, in order to improve the credibility of the assessment method, two rounds of assessment are performed. In the first round, two people are selected to assess the disaster prevention capabilities of the same residential area, the assessment is conducted independently. Afterwards, the assessment results are compared and analyzed to find out the difference in scoring, and discuss and correct them. After the first round, the assessment staff reaches an agreement on the assessment standards. The second round is a formal capability assessment, which also adopts the method of double assessment and mutual check. According to experience (He Lei, Dai Shenzhi and Song Yan, 2011), without correction, when the same part of the two scores exceeds 70%, the assessment is considered to be very effective and the assessment results are highly reliable.

This method is suitable for the assessment of disaster prevention capability of mature residential areas and the residential areas that have not yet been implemented and in the planning stage. The variables in the formula are estimated and scored according to the evaluation criteria, and the disaster prevention capabilities, strengths and weaknesses of the assessment objects can be basically known.

### **3.2 Assessment practice of disaster prevention capabilities in residential areas**

The model formula of disaster prevention capability, formula (2), shows that the 14 elements that affect disaster prevention capability are ranked as follows according to the impact weight: building quality (0.26), spatial structure (0.12), medical institution capacity (0.08), emergency water supply (0.08), location safety of evacuation shelter (0.07), emergency commercial facility capacity (0.06), road width (0.05), accessibility of evacuation shelter (0.05), evacuation shelter capacity (0.05), communication system (0.05), electricity

supply system (0.05), buildings setbacks along the road (0.04), land function along the road (0.02), and building quality along the road (0.02). The disaster prevention capabilities can be changed through changing the status of influential factors with larger weights. The following are the main methods to improve disaster prevention capabilities:

(1) Improving the building quality can greatly improve disaster prevention capabilities. The disaster resistance level standard of the building is proposed based on the prediction of the disaster level and disaster scale of the residential area, and the design, construction and maintenance of the building are carried out based on this standard. The overall safety of the residential area is closely related to the safety of each building. Improving the building quality can also effectively reduce the need for emergency refuge and ease the contradiction between supply and demand for refuge systems in residential areas.

(2) The spatial structure of residential areas can improve the efficiency of disaster prevention and evacuation of residents in residential areas. Increase the density of the road network, promote small-scale spaces and a pedestrian environment, improve the closed access control system with only one entrance and exit, connect groups and residential communities with each other, and improve the connection and space sharing between different areas in the community.

(3) The location and capacity of medical institutions is an important force to ensure emergency medical assistance during disasters. The allocation capacity of residential hospitals, health centers, and medical points should be checked according to the emergency medical assistance needs during disasters.

(4) Emergency water supply is the most important infrastructure to sustain life. From the two aspects of drinking water storage and emergency water supply, the safety of emergency water supply is comprehensively improved in terms of location safety, facility reliability, and emergency response capabilities.

(5) The safety of evacuation and refuge location is the basic prerequisite for ensuring evacuation safety. Choose buildings with strong earthquake resistance for evacuation shelters; choose areas with high terrain that are not flooded or buildings with reliable structures; choose places with convenient transportation that are free from bad geological disasters and far away from dangerous sources.

(6) The capacity of emergency commercial facilities includes the storage of important materials such as food and drinking water, which are the most important materials for sustaining life and living after disasters. For residential areas with a certain scale, there should be a stock of materials that can meet the basic needs of residents within 1-3 days after the disaster.

The methods corresponding to the above 6 variables are the main methods, accounting for 61% of the total impact. The remaining 8 variables, due to their smaller weights, are of limited importance compared with the 6 variables, so the variables with smaller weights are ignored.

#### **4. Conclusion**

As the most basic component unit of a city, residential area is the 'target area' affected by disasters, the basic unit of disaster prevention and mitigation, and the cell and cornerstone of urban safety and disaster prevention. In the urban disaster prevention planning system ('disaster avoidance -- disaster reduction -- disaster relief'), the residential area, as a micro unit, takes the reduction of material property losses and casualties as the disaster prevention goal, and the reduction of vulnerability and the improvement of disaster relief and emergency response capability as the overall disaster prevention requirements. On this basis, the safety plan elements in residential area are sorted and analyzed, and this paper puts forward that six elements such as the building quality, spatial structure, location and capacity of medical institutions, emergency water supply, safety of evacuation shelter, and emergency commercial facilities greatly affect the disaster prevention capability in residential area, and are the main influencing factors to improve the disaster prevention capability in residential areas. In the planning and design of disaster prevention and mitigation in residential areas, the above six elements are prioritized as strategic measures for planning and improvement, which can effectively improve the disaster prevention capabilities in residential areas.

Meanwhile, a complete research idea for the assessment of disaster prevention capabilities in residential areas is constructed, namely 'basic disaster prevention ideas--disaster prevention goals--element indicators--element weights--assessment methods'. The element indicators are systematic, and the assessment method is simple and easy to operate. It not only contributes to the research on the disaster prevention capability assessment of residential areas in China, but also facilitates the guidance of planning practice. The deficiencies are that the expert scoring method is used to determine the element weight, which is subjective; meanwhile, the disaster prevention capability assessment model has not yet been applied in practice. These aspects will be further study in this paper.

#### **Acknowledgement**

This paper is supported by the Inner Mongolia Natural Science Foundation (2023M05019) and the scientific research project of Inner Mongolia University of Technology (BS201953).

#### **Reference**

- Gu, T and Ma, L and Liu, X and Hao, E. (2023) Research on safety risk evaluation of urban old neighborhoods based on BT-BN. *China Production Safety Science and Technology* (11), pp. 166-172.
- He, L and Dai, S and Song, Y. (2011) The U.S. experience in the preparation and evaluation of comprehensive urban disaster preparedness planning and its implications for China. *Journal of Urban Planning* (05), pp. 87-94.
- He, L. (2016) Research on Underground Space Planning Strategy Based on Urban Disaster Prevention[D]. *Tongji University PhD thesis*.
- Jacobs, J. (1961) The death and life of great American cities. *New York: Random House*.
- Kong, F. (2019) Perspectives on Capacity Building and Regional Collaboration for Disaster Prevention, Mitigation and Relief in Urban and Rural Grassroots Communities in China. *Journal of Capital Normal University (Natural Science Edition)* (05), pp. 89-96. doi:10.19789/j.1004-9398.2019.05.015.
- Lian, D and Zhu, J and Li, G. (2017) Research on Entropy Weight-Gray Target Evaluation Method of Community Disaster Reduction Capability-Taking Suzhou New District as an Example. *Surveying and Mapping Bulletin* (12), pp. 98-102. doi:10.13474/j.cnki.11-2246.2017.0388.
- Liu, P. (2017) Shanghai:Cooperation between expert teams and social forces to promote community disaster risk management. *China Disaster Reduction* (09), pp. 18-19.
- Ma, C and Yun, Y and Ma, X. (2020) Research on methods to enhance community resilience in urban disaster prevention and mitigation planning. *Urban Planning* (06), pp. 65-72.
- Meng, F and Feng, L. (2011) A Summary of Research on Earthquake Resistance in China[J]. *Henan Building Materials* (3): pp. 163-164.
- Sun, S. (2021). Research on the future development direction of urban and rural planning discipline in China. *Urban Planning* (02), pp. 23-35.
- Wu, D and Liu, Y and Chen, J. (2015) Evaluation and Classification of Fire Disaster Resilience in Urban Villages——Taking Nanting Village of Guangzhou University as an Example[J]. *Journal of Geography and Geo-Information Science*, 31(4): pp. 107-110.
- Zhao, Y and Mao, Q. (2013) Exploring the Concept and Practice of ‘Disaster-Proof Community’. *Cities and Disaster Reduction* (03), pp. 43-47.