

Study on Evaluation System of Urban Community Emergency Preparedness Ability

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Abstract. Objective: Construct an index system of evaluating emergency preparedness of urban community. Methods: Through two rounds of consultation with experts, the evaluation index system of emergency preparedness capacity of urban community was constructed, and the weight of each index was calculated by Analytic Hierarchy Process and comprehensive evaluation was made by Fuzzy Comprehensive Process. Results: The evaluation index system for emergency preparedness of urban community composed of 7 first-level indexes, 20 second-level indexes and 51 third-level indexes was established. Conclusion: The index system was used to evaluate the emergency preparedness capability of X community in Xi'an. The advantages and disadvantages of emergency preparedness capability construction in this community were found and corresponding countermeasures were put forward.

Introduction

Emergency management is a process where the government and other public agencies take a series of necessary measures to establish a necessary response mechanism in the process of emergency prevention, incident response, incident handling and recovery after the incident, applying science, technology, planning and management and other measures to ensure public life, health and property safety and promote social harmony and healthy development[1]. The whole process of emergency management includes four stages, which are prevention, preparation, response and recovery. Emergency preparedness has always been considered as a link in emergency management. With the continual maturity of emergency management work, the importance of emergency preparedness has become increasingly prominent, and has gradually become the core task of supporting basic work and emergency management of emergency response processes[2].

Community is the main place for residents to work and live. It is also the most concentrated place for vulnerable people [3]. Once an emergency occurs, it will be the area with the highest concentration of casualties. The experience of various types of emergencies at home and abroad shows that the rapid response of communities is a key factor in alleviating the consequences of accidents and reducing casualties [4]. In the domestic research on emergency capability evaluation, some scholars established the evaluation system of urban emergency response capability[5], some scholars studied the government's ability to deal with emergency events[6,7,8], some scholars studied the corresponding capacity building aimed at some kinds of emergency events, such as earthquakes, fires and chemical explosions[9,10], some scholars have also conducted comprehensive research on urban emergency shelters and emergency response capabilities[11]. However, on the whole, there are a lot of studies on macro-level evaluation of emergency response capabilities at the national or city level, and only a few studies on emergency preparedness capabilities at the community level. Urban communities have relatively concentrated population with large density, large number of enterprises and institutions with rapid economic development and relatively large numbers of various types of resources. Therefore, a scientific and reasonable evaluation index system for emergency preparedness of urban communities shall be established. Through the evaluation of the status quo, to strengthen the city community emergency preparedness

capacity and to improve the ability to respond to emergencies are of great significance for the emergency management and community safety construction of our country.

Urban Community Emergency Preparedness Evaluation Index System

Construction of Index System. Drawing on the "Emergency Response Capability Evaluation System" of Federal Emergency Management Agency of the United States and "Disaster Emergency Response Evaluation Index System of Japan, as well as the domestic research results on emergency response capability evaluation, this study builds an evaluation index framework. Through the investigation and interviews with experts in emergency management and emergency workers in the community, combined with the actual situation of street and community emergency work, an index framework was set up. 10 experts and scholars from Shaanxi Provincial Emergency Office, colleges and universities and emergency management, as well as community workers and the armed police officers and soldiers who participated in earthquake relief and emergency rescue formed a group of experts. They reviewed the index system to avoid duplication or the lack of logic. Through two rounds of expert advice and modification, an urban community emergency preparedness index system with 7 first-level indexes, 20 second-level indexes and 51 third-level indexes was established, which is shown in Table 3.

Determine the Weight of the Index. In this study, firstly, AHP was used to construct the comparison matrix of each comparison to calculate the weight of the relevant indexes, and to test the consistency of judgment matrix to calculate the average of the qualified judgment matrix. The weight of each index of evaluation of emergency preparedness for urban community is obtained. Secondly, the entropy method was used to further process the obtained weights, avoiding the cycle caused by expert investigation and not satisfying the transitivity axioms.

Through the consultation of 10 members of the expert group, fill in the questionnaire of comparison matrix. Carry out arithmetic averaging on the results of 10 groups of consistency test to get the index weights. Table 1 is the judgment matrix of the first-level indexes $S = (U_{ij})_{p \times p}$ and the weight of each index.

Table 1 The judgment matrix of the first level index

	A	B	C	D	E	F	G
A	1	1.9101	2.0750	1.0025	1.2093	1.2926	3.1117
B	0.5235	1	2.0333	1.2560	1.2492	2.1533	2.9067
C	0.4819	0.4918	1	1.2435	1.0978	1.3750	2.2283
D	0.9975	0.79621	0.8042	1	1.3167	2.0783	3.0250
E	0.8269	0.8005	0.9109	0.7595	1	2.2700	3.0583
F	0.7736	0.4644	0.7273	0.4812	0.4405	1	2.2667
G	0.3214	0.3440	0.4488	0.3306	0.3270	0.4412	1

The result of the calculation of the largest eigenvalue of the judgment matrix S is $\lambda_{\max} = 7.2092$,

The result of consistency index is $CI = \frac{\lambda_{\max} - n}{n - 1} = \frac{7.2092 - 7}{7 - 1} = 0.0349$,

The table shows that the average random consistency index is $RI = 1.32$. Random consistency rate is: $CR = \frac{CI}{RI} = \frac{0.0349}{1.32} = 0.0264 < 0.10$.

Therefore, the judgment matrix constructed according to the first-level index passes the test of

consistency and the result of the weight value calculated by AHP is reasonable.

Analytic Hierarchy Process (AHP) is used to calculate the weight of the index, and then the entropy method is used to deal with the non-dimensional index at all levels. The entropy, the difference coefficient and the index weight of each index are calculated, and the comprehensive weight is obtained. See Table 2. The value of the comprehensive weight is taken as the final value weight of each index.

Table 2 AHP weight and entropy method to correct the calculation results

	AHP weight	Entropy value	Difference coefficient	Entropy method weight	Comprehensive weight
A	0.2065	0.9945	0.0055	0.1109	0.1606
B	0.1857	0.9929	0.0071	0.1436	0.1869
C	0.1330	0.9933	0.0067	0.1357	0.1266
D	0.1667	0.9928	0.0072	0.1461	0.1708
E	0.1545	0.9912	0.0088	0.1775	0.1921
F	0.0990	0.9915	0.0085	0.1713	0.1189
G	0.0546	0.9943	0.0057	0.1150	0.0441

According to the method of calculating the weight of the first-level index, the weight of the second and the third level index are calculated, and finally the indexes and weights of emergency response capability evaluation of urban community is calculated as follows:

Table 3 Weight of each index of urban community emergency preparedness evaluation index system

Level I	Level II	Level III
A. Organizational system construction (0.1606)	A ₁ . Emergency Management Department (0.6135)	A ₁₁ . Comprehensive level of the setting up of an organization (0.5320)
		A ₁₂ . Staffing situation (0.2768)
		A ₁₃ . Staff coordination and cooperation (0.1912)
	A ₂ . Emergency Management System (0.3865)	A ₂₁ . Emergency rules and regulations construction (0.4227)
		A ₂₂ . The implementation of the system (0.5773)
B. Risk assessment capability (0.1869)	B ₁ . Disaster risk list (0.5846)	B ₁₁ . Investigation of hazard sources and dangerous areas (0.4616)
		B ₁₂ . Public facilities safety hazards list (0.2630)
		B ₁₃ . Preventive management of hidden danger list (0.2754)
	B ₂ . Community vulnerability list (0.2794)	B ₂₁ . Vulnerability list (0.4741)
		B ₂₂ . Rescue situation of vulnerability (0.5259)
	B ₃ . Community map (0.1360)	B ₃₁ . Mapping and promotion of disaster risk maps (0.4186)
		B ₃₂ . Mapping and promotion of emergency evacuation map (0.5814)

C. Monitoring early warning capability (0.1266)	C ₁ . Monitoring ability (0.6460)	C ₁₁ . Completeness and accuracy of the monitoring system (0.5372)
		C ₁₂ . Monitoring staff experience level (0.3301)
		C ₁₃ . Inspection and maintenance frequency of monitoring equipment (0.1327)
	C ₂ . Early warning ability (0.3540)	C ₂₁ . Completeness and accuracy of early warning system (0.4025)
		C ₂₂ . Inspection and maintenance frequency of early warning system (0.1808)
		C ₂₃ . The smoothness of early warning information dissemination channels(0.2997)
		C ₂₄ . Quick report ability of community warning information (0.1170)
D. Emergency plan construction (0.1708)	D ₁ . Integrity of the plan system (0.1398)	D ₁₁ . Community emergency plan construction (0.6700)
		D ₁₂ . Family emergency plan construction (0.3300)
	D ₂ . Completeness of the contents of the plan (0.0709)	D ₂₁ . Clarity of emergency agency authority (0.5392)
		D ₂₂ . Provision of personnel and supplies (0.3048)
		D ₂₃ . Detailed emergency action plan (0.1560)
	D ₃ . Scientific plan (0.5678)	D ₃₁ . Develop expert advice when making changes (0.4045)
		D ₃₂ . Combined with the actual situation of the community (0.5955)
	D ₄ . Start-up and revision of plan (0.2215)	D ₄₁ . A clear starting standard (0.7826)
		D ₄₂ . Regularly revise plans(0.2174)
E. Emergency drills ability (0.1921)	E ₁ . Emergency drill planning (0.1458)	E ₁₁ . Feasibility of the drill plan (0.7826)
		E ₁₂ . Inform residents drill plan in advance (0.2174)
	E ₂ . Drill organization and implementation (0.5005)	E ₂₁ . Annual emergency drill situation (0.4555)
		E ₂₂ . Many parties involve in emergency drills (0.5445)
	E ₃ . Effect feedback (0.3537)	E ₃₁ . Drill effect assessment and improvement (1.0000)
F. Emergency support capabilities (0.1189)	F ₁ . Protective capacity of emergency team (0.4688)	F ₁₁ . Community emergency volunteer team (0.3846)
		F ₁₂ . Ability to contact professional rescue team (0.2548)
		F ₁₃ . Treating ability of community medical team (0.3606)
	F ₂ . Emergency material support ability (0.3897)	F ₂₁ . Community emergency supplies reserve (0.5202)

		F ₂₂ . Resident families emergency supplies reserve (0.1808)
		F ₂₃ . Emergency supplies capacity (0.1854)
		F ₂₄ . Setting and use of special emergency funds (0.1136)
	F ₃ . Infrastructure support capability (0.1415)	F ₃₁ . Emergency communications facilities settings (0.2196)
		F ₃₂ . Water facilities settings (0.4143)
		F ₃₃ . Power generation and substation facilities (0.2651)
		F ₃₄ . Emergency shelter construction (0.1010)
G. Publicity and education ability (0.0441)	G ₁ . Emergency training (0.5327)	G ₁₁ . Situation of carrying out annual emergency training (0.4535)
		G ₁₂ . Training effectiveness evaluation and assessment (0.5465)
	G ₂ . Publicity and education activities (0.1790)	G ₂₁ . Situation of carrying out emergency education activities (0.4975)
		G ₂₂ . Residents' participation in emergency education activities (0.5025)
	G ₃ . Resident emergency awareness and skills (0.2883)	G ₃₁ . Risk potential residents learning degree (0.1997)
		G ₃₂ . Residents evacuation capabilities (0.3313)
		G ₃₃ . Residents self-help and mutual-aid ability (0.4690)

Weight calculation results show that in the process of emergency response capacity in urban communities, emergency drills occupy the most important proportion, followed by risk evaluation ability and emergency preparedness construction in the third place. The result of such a survey is determined by the status and particularity of urban communities in emergency management. On the one hand, urban communities are the ultimate implementers of policies and measures in emergency management. More attention should be paid on the training of emergency response capabilities. Emergency drills are an important measure. On the other hand, each community and its jurisdiction have different economic and social conditions, and emergency management situations are also different, which requires a detailed understanding of the community and a clear risk evaluation in each community. On this basis, we will scientifically formulate a targeted contingency plan in line with the economic and social conditions and risks in this community.

Fuzzy Comprehensive Evaluation

There are many factors that affect the ability of community emergency preparedness. The related indexes that have been identified are mostly qualitative indexes. The evaluation of emergency preparedness capability of urban communities is a multi-factor comprehensive evaluation. The application of fuzzy comprehensive evaluation method can have a clear understanding of community emergency preparedness under the influence of many factors and make the comprehensive evaluation be scientific and reasonable.

Establish Fuzzy Relation Matrix R. Correspond to the urban community emergency preparedness evaluation index structure of the system, establish evaluation model.

The relevant factors in the evaluation index system are expressed as $u = \{u_1, u_2, \dots, u_p\}$, Scoring and factors rating are done by expert team, evaluation rating is set as $v = \{v_1, v_2, \dots, v_p\}$. In this study, a 5-level standard was used to evaluate the resilience of urban communities in

emergency preparedness.

Quantify the emergency preparedness capacity of urban communities from each factor $u_i (i=1,2,\dots,p)$, determine the degree of membership $(R|u_i)$ of each index to the level fuzzy sub-level {factors which are important to the object to be evaluated} under this ability. Fuzzy relation matrix is obtained:

$$R = \begin{bmatrix} R|u_1 \\ R|u_2 \\ \dots \\ R|u_p \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \dots & \dots & \dots & \dots \\ r_{p1} & r_{p2} & \dots & r_{pm} \end{bmatrix}_{p,m}$$

Fuzzy vector $(R|u_i) = (r_{i1}, r_{i2}, \dots, r_{im})$ is used to describe the performance of urban community emergency preparedness ability at certain factor u_i .

Calculate the Result of Fuzzy Comprehensive Evaluation. Determine the weight vector of evaluation factor as $A = (a_1, a_2, \dots, a_p)$, factor a_i in A is the membership degree of factor u_i to fuzzy subset. Combine A with R of each object to be evaluated, the fuzzy comprehensive evaluation result vector B of each object to be evaluated is obtained. which is:

$$A \circ R = (a_1, a_2, \dots, a_p) \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \dots & \dots & \dots & \dots \\ r_{p1} & r_{p2} & \dots & r_{pm} \end{bmatrix} = (b_1, b_2, \dots, b_m) = B$$

Urban community emergency preparedness capacity is divided into five levels, which are excellent, good, general, bad and poor. The scores of each level are shown in Table 4. According to the calculation result of the result vector B of fuzzy comprehensive evaluation and the principle of maximum membership degree, the level of emergency preparedness ability of urban community is determined.

Table 4 Urban Community Emergency Preparedness Evaluation Level

Evaluation level	V1 (Excellent)	V2 (Good)	V3 (General)	V4 (Bad)	V5 (Poor)
Score	5	4	3	2	1

Application Analysis

Evaluation Results. According to the evaluation system of emergency preparedness capacity of urban communities established in this study, the questionnaire and interview outline of emergency response capability of community were prepared in order to grasp all aspects of emergency management in community in an all-round and accurate manner and to conduct emergency preparedness ability evaluation to x community in Xi'an of Shaanxi Province. Eight community staff and two street staff who are more familiar with x community in Xi'an City were invited to evaluate the impact factors corresponding to the index of each level of the community. Based on all the scores, the membership degree of each index on a certain rating level is obtained, so as to establish the single factor fuzzy comprehensive evaluation matrix and calculate the rating vectors at all levels to get the overall rating vector:

$$B = (0.2065, 0.1857, 0.133, 0.1667, 0.1545, 0.099, 0.0546) \circ \begin{bmatrix} 0.742879 & 0.257121 & 0 & 0 & 0 \\ 0.475476 & 0.412909 & 0.111613 & 0 & 0 \\ 0.136915 & 0.384358 & 0.198623 & 0.125624 & 0.15448 \\ 0.296961 & 0.561246 & 0.141793 & 0 & 0 \\ 0.296566 & 0.462189 & 0.241245 & 0 & 0 \\ 0.081964 & 0.347667 & 0.334316 & 0.196346 & 0.039706 \\ 0.216621 & 0.465727 & 0.302991 & 0.014661 & 0 \end{bmatrix}$$

$$= (0.375175, 0.405708, 0.157693, 0.036947, 0.024477)$$

Overall rating:

$$V = 5 \times 0.375175 + 4 \times 0.405708 + 3 \times 0.157693 + 2 \times 0.036947 + 1 \times 0.024477 = 4.0702$$

In which: organization system construction evaluation value is 4.7429, risk assessment capability evaluation value is 4.3639, monitoring and early warning capability evaluation value is 3.2236, emergency plan construction evaluation value is 4.1552, emergency drill capability evaluation value is 4.0553, emergency support ability evaluation value is 3.2358, and publicity and education ability evaluation value is 3.8843. According to the emergency preparedness ability of urban community and the evaluation level, the overall emergency preparedness capability of this community is good, but the monitoring and early warning capability, emergency support capability and publicity and education capability need to be strengthened.

Suggestions for Improvement. First, improve the monitoring and warning capabilities. Emergency management of urban communities shall focus on the prevention and preparation of peacetime. On the one hand, the establishment of various monitoring points of the jurisdiction in the community can observe, capture, predict and carry out dynamic monitoring on various factors and signs that may cause unexpected incidents, and can collect information and provide evidence for emergency decisions. On the other hand, the establishment of early warning communication systems covering every corner in the community can send out warnings to residents and alert them of various preventive preparations through the early warning systems.

Second, strengthen emergency support capacity. From the emergency team, emergency supplies and infrastructure, we should set up our own emergency volunteer teams and improve the ability to contact the rescue teams, and encourage volunteer teams and professional aid organizations to participate in community emergency science education. The community shall reserve a certain amount of emergency supplies, which shall be regularly updated and perfected, enhance the ability to raise emergency supplies, encourage residents and families to reserve basic emergency supplies and establish a family emergency package.

Third, strengthen the emergency knowledge and education. Make full use of existing public places or facilities to carry out emergency publicity and education for daily residents; make full use of various media such as the Internet and mobile phone messages to popularize emergency knowledge to community residents; focus on emergency publicity educational activities by combining disaster prevention, mitigation day and national science popularization day. Regularly carry out training for community staff and residents, encourage residents to actively participate in such activities as screening hidden risks in the community organizations, drawing up risk maps and conducting emergency drills, so as to enhance residents' abilities to seek shelter and escape, as well as to help themselves and others.

Conclusion

The study considers that the factors that affect the emergency preparedness ability of urban community include seven aspects: organizational system construction, risk evaluation ability, monitoring and early warning capability, emergency plan construction, emergency drills ability, emergency support ability and propaganda and education ability. The evaluation index system indexes include 7 Level I, 20 Level II and 51 Level III. The overall structure is reasonable and can comprehensively reflect the main aspects of urban community emergency preparedness capabilities.

The comprehensive evaluation by Analytic Hierarchy Process and Fuzzy Comprehensive Process

can reflect the expert's cognition and judgment in the community emergency preparedness construction more accurately and comprehensively and reflect the level and method of the emergency preparedness ability of urban community more truly.

Based on the evaluation index system established in this study, the emergency preparedness ability of urban communities can be evaluated well. The index system can be applied to the evaluation of emergency preparedness capacity of all urban communities and find out shortages and deficiencies in the construction process, in order to provide reference for emergency response capacity.

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