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Evaluation of Local Government Disaster Preparedness Capacity - An Empirical Analysis Based on the Zhengzhou "7·20" Heavy Rainfall Disaster

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A B S T R A C T

The purpose of this study is to assess the disaster preparedness capacity in heavy rainstorm disaster. For this purpose, the evaluation model of disaster preparedness capacity was proposed by constructing the target level as an indicator system of disaster preparedness capacity, which was divided into four primary indicators: A1 planning, A2 organization and equipment, A3 training, A4 exercise; Seven secondary evaluation indicators including B1 disaster response plan，B2 disaster risk assessment，B3 disaster response regime，B4 disaster response organization，B5 disaster resources and equipment，B6 disaster training，B7 disaster exercise, and 37 tertiary evaluation indicators. Then, the validity of the evaluation index system was demonstrated, and the results of the weight of each level were calculated by using AHP method and expert survey method and finally take the example of the Zhengzhou "7·20" rainstorm to carry out an empirical analysis of the proposed model. Through the comprehensive assessment of emergency preparedness capacity, the weak points of disaster preparedness capacity were identified.

Key words: disaster preparedness capacity; heavy rainfall; local government; AHP; evaluation index system

1. Introduction

In today's world, various types of emergencies such as natural disasters, accidents and disasters, public health and social security occur frequently, and the importance of emergency response and disaster management has increased significantly in countries around the world. Emergency preparedness is no longer related to other emergency management activities in a simple chronological progression, but has become the core task of emergency management as a fundamental action throughout crisis and emergency management (Liang, 2020).

In particular, China's new urbanization process has been accelerating, with cities becoming larger and gathering more and more people in recent years. While urbanization is progressing, Chinese cities are constantly exposed to a variety of uncertain disasters, including geological disasters (e.g., the Wenchuan earthquake in 2008), meteorological disasters (e.g., Super Typhoon Moranti in 2016, extensive haze and heavy rainfall flooding in many places in recent years), fire disasters (e.g. , the Tianjin Port mega-fire explosion in 2015), traffic disasters (e.g., the rear-end accident of Shanghai Metro Line 10 in 2016), and accident disasters (the collapse of self-built houses in Changsha in 2022), and infectious diseases (such as SARS from winter 2002 to spring 2003, COVID-19 in 2020). Under the impact of these uncertain disasters, many cities suffered catastrophic consequences such as human casualties, property damage, urban function failure, and social order imbalance.

From July 17 to 23, 2021, Henan Province was hit by a historically rare extraordinarily heavy rainstorm, which caused severe flooding. The event was named the "7·20" Zhengzhou rainstorm. According to the "Investigation Report of the '7·20' Extraordinary Rainstorm Disaster in Zhengzhou, Henan Province", it was determined that the "7.20" rainstorm in Zhengzhou, Henan Province, was a natural disaster that caused severe urban flooding, river flooding, landslides and other multiple disasters due to the extreme rainstorm, resulting in significant casualties and property damage, and changed the lives of millions. According to the verification

and assessment, a total of 14,786,000 people were affected, with direct economic losses of 120.6 billion RMB as of September 30, 398 people died and missing in the province due to the disaster. “7.20” Zhengzhou heavy rainstorm disaster was identified by the investigation team as an overall "natural disaster", specifically a "man-made disaster", Zhengzhou municipal government and the relevant districts, counties, departments and units risk awareness was not strong, the understanding of this mega-disaster was not prepared, the organization of prevention was not strong, and there was dereliction of duty and malfeasance in emergency response. The city's ability to cope with uncertain disasters needs to be improved, and its disaster prevention and mitigation is an urgent problem facing government at all levels of and all sectors of society.

Therefore, this paper will take emergency preparedness capability as the research object, study and analyze relevant domestic and foreign literature, refer to previous research results, combine expert survey method and AHP hierarchical analysis method, refine and construct a comprehensive disaster preparedness assessment system, assign weights to indicators, construct an disaster preparedness assessment capability model, and finally take the example of the “7·20” rainstorm in Zhengzhou City to carry out an empirical analysis of the proposed model. Through the comprehensive assessment of disaster preparedness capability, the weak points of disaster preparedness capability will be identified.

2.Theoretical Background

2.1. Disaster preparedness

Social scientists, emergency managers, and public policy makers generally study and guide the process of disaster occurrence around four phases: mitigation, preparedness, response, and recovery (Sutton & Tierney, 2006). Preparedness in the field of emergency management can best be defined as a state of readiness to respond to a disaster, crisis, or any other type of emergency situation and it is not only a state of readiness, but it is also a theme throughout most aspects of emergency management (Bullock et al., 2017). Preparedness is typically understood as consisting of measures that enable different units of analysis—individuals, households, organizations, communities, and societies—to respond effectively and recover more quickly when disasters strike (Sutton & Tierney,2006).

The modern emergency management system, after the challenges of many disaster events, emphasizes that disaster emergency preparedness should be a dynamic and continuous management process, and directly affects the performance of emergency response capabilities, thus determining the development and evolution of the situation (Deng & Liu, 2011). Existing research on preparedness highlights the need for engaging the communities in risk and mitigation activities, rather than just expecting them to respond to passive information sources (Prior & Eriksen, 2011).

Natural hazard preparation is generally considered to be the preferred mechanism to encourage proactive actions (behavioral, cultural, structural or institutional) to mitigate the disastrous potential of these events (CDRSS, 2006). Preparation has dual objectives: to reduce vulnerability to a potential threat (Grothmann & Reusswig, 2006; Siegrist & Gutscher, 2008; Thomalla et al., 2006), and to increase the resilience of the public exposed to a threat (Berkes, 2007; Norris et al., 2008). The activities that are commonly associated with disaster preparedness include developing planning processes to ensure readiness; formulating disaster plans; stockpiling resources necessary for effective response; and developing skills and competencies to ensure effective performance of disaster-related tasks (Sutton & Tierney,2006).

In the above description, disaster preparedness is a series of activities implemented to mitigate the possible damage and reduce the adverse effects of an incident. It is not only a part of the crisis & emergency management activities according to the time division, but also a fundamental action throughout the crisis & emergency management process, which is carried out before, during and after the disaster.

2.2. Components of Disaster Preparedness Capacity

Disaster management requires adequate coordination and cooperation, capabilities can be used as both a preparation tool and a means to achieve goals, there is a high degree of interdependence between capabilities, requiring us to coordinate and unify existing networks and implemented activities, Therefore, disaster preparedness often requires coordination between individuals, governments, agencies and organizations to improve training and exercise plans, improve and innovate the level of technology, and ensure that individuals, social organizations, and businesses in various fields support these ability.

This paper is based on the preparation ability elements classified by FEMA National Preparedness Directorate, and the components of disaster preparedness capacity are shown in Table 1. It shows the planning process that begins with planning for the various hazards that exist and then works in a systematic manner to build and improve preparedness. This cycle recognizes the importance of the four main components of any preparation: planning, organization and equipment, training, and exercise.

<Table 1> Components of disaster preparedness capacity

Planning	Develop a plan that includes description of hazard risks, definition of vulnerability scope, hazard vulnerability assessment, and many other information gathering and analysis.
Organization and Equipment	Equipment, supplies and systems that meet relevant standards or respond in a timely manner as required, as well as individual teams, overall organizational structure, and people and organizational leadership at every level of the organization.
Training	Emergency management training (Governments and Officials, Businesses, NGOs and Individuals)
Exercise	It provides an opportunity to demonstrate, assess and improve core competencies to perform to standards and better understand deficiencies.

Source: Summarized from <Introduction to emergency management> (Bullock et al., 2017)

This cycle represents not only readiness at all levels of government jurisdictions, but also readiness actions taken by individuals, businesses, NGOs and other entities (Bullock et al.2017).

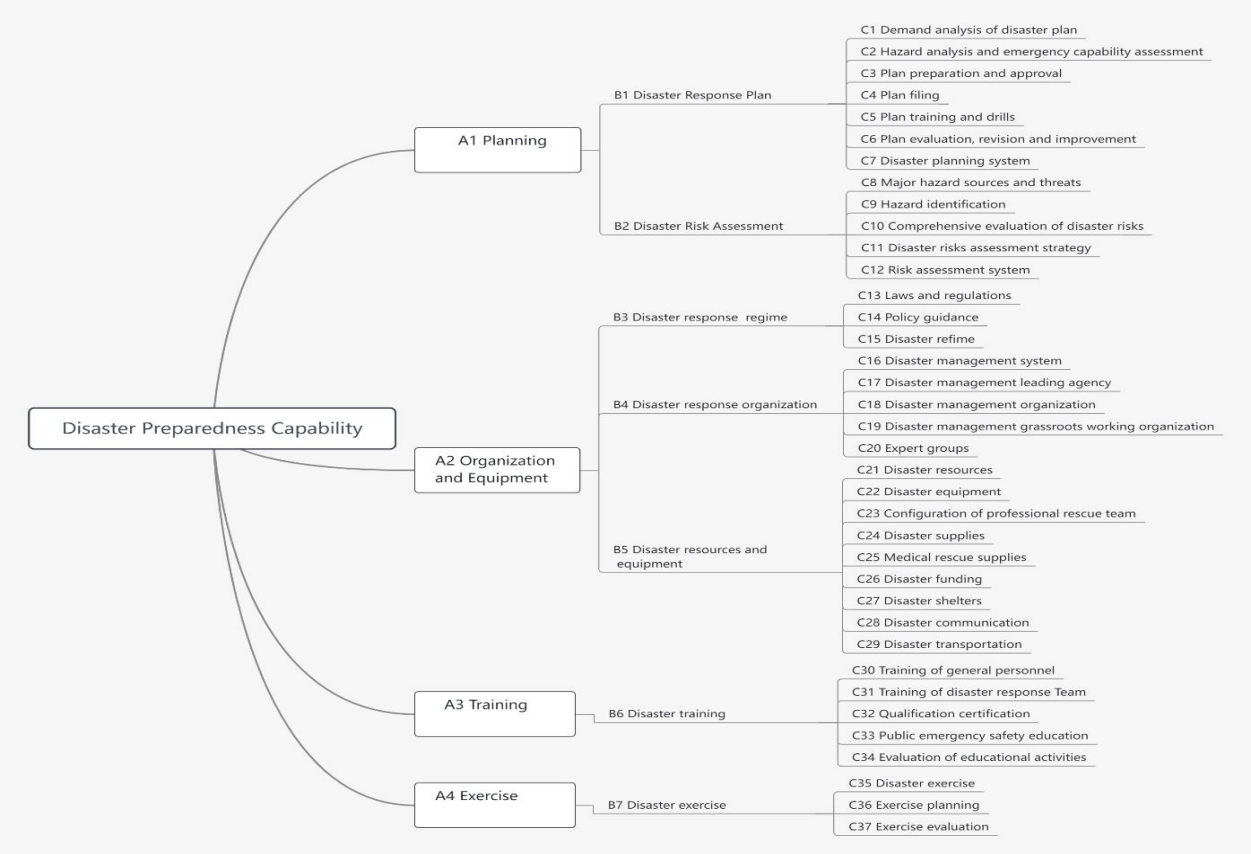


Figure 1. Comprehensive evaluation model of disaster preparedness capability index system

2.3. Construction of Comprehensive Evaluation Model

Based on extensive data research and literature reading, this study constructed a three-level AHP evaluation model with disaster preparedness capability as the target with reference to the U.S. FEMA, as shown in Figure 1. In the AHP model, the target level is the disaster preparedness capability. The evaluation indexes of disaster preparedness are divided into four first-level indicators, the first-level

evaluation indexes include: A1 planning, A2 organization and equipment, A3 training, and A4 exercise, seven second-level indicators, the second-level evaluation indexes include: B1 disaster response plan，B2 disaster risk assessment，B3 disaster response regime，B4 disaster response organization，B5 disaster resources and equipment，B6 disaster training，B7 disaster exercise, and 37 tertiary evaluation indicators. The scores of each primary indicator are the weighted sum of the secondary indicators, and the overall score of disaster preparedness is the weighted sum of all primary indicators, and the strength of its capability is reflected by the total score.

3. Materials and Methods

Analytic Hierarchical Process, proposed by American operations researcher Saaty in the 1970s, is a comprehensive weighted decision-making method that uses mathematics and psychology to organize and analyze complex decisions, assigning weights in the process of comparing the relative importance of indicators to ensure that a logically consistent solution is reached, and is applicable to decision problems involving complex hierarchies and multiple indicators (Saaty, 1987). Hierarchical analysis can deal with both qualitative and quantitative elements of decision making and is practical, systematic and concise (Liang, 2020). The use of hierarchical analysis to determine the evaluation index system and to determine the weights can be divided into these five steps, which are the establishment of the hierarchical structure, build the hierarchical structure according to the hierarchical relationship, construct a judgment matrix, calculate the judgment matrix to obtain the relative weights of the evaluation indexes, and the consistency test of the judgment to obtain the final weights of the evaluation indexes at each level.

In order to scientifically determine and rank the importance of the weights of the indicators to ensure the validity of the indicator system, and also according to the above calculation method, this paper solicits and obtains the data of the weights of each indicator by issuing questionnaires to 15 experts in the field of government disaster management as well as government-related personnel, using the 1~9 symbolic method, the complex problem is broken down level by level, and the indicators in the hierarchy are compared relative importance for determining the overall order of importance of each indicator. On this basis, the index weights were calculated according to AHP, and the weight results of each hierarchical evaluation index system were calculated, and the results are shown in Table 2.

<Table 2>Weight of each index of disaster preparedness capacity evaluation index system

First-level(A)indexes and weights	Second-level(B) indexes and weights	Third-level(C) indexes and weights
A1 Planning(0.4524)	B1 Disaster response plan(0.3347)	C1 Demand analysis of disaster plan(0.025)
		C2 Hazard analysis and emergency capability assessment(0.0524)
		C3 Plan preparation and approval(0.0185)
		C4 Plan filing(0.0316)
		C5 Plan training and drills(0.055)
		C6 Plan evaluation, revision and improvement(0.0467)
		C7 Disaster planning system(0.1053)
	B2 Disaster risk assessment(0.1177)	C8 Major hazard sources and threats(0.0166)
		C9 Hazard identification(0.0086)
		C10 Comprehensive evaluation of disaster risks(0.0344)
		C11 Disaster risks assessment strategy(0.0182)
		C12 Risk assessment system(0.0399)
	B3 Disaster response regime(0.0449)	C13 Laws and regulations(0.0214)

		C14 Policy guidance(0.0083)
		C15 Disaster refime(0.0152)
	B4 Disaster response organization(0.0866)	C16 Disaster management system(0.0366)
		C17 Disaster management leading agency(0.0099)
		C18 Disaster management organization(0.0104)
		C19 Disaster management grassroots working organization(0.0074)
		C20 Expert groups(0.0222)
A2 Organization and Equipment(0.2478)	B5 Disaster resources and equipment(0.1164)	C21 Disaster resources(0.0253)
		C22 Disaster equipment(0.0131)
		C23 Configuration of professional rescue team(0.0153)
		C24 Disaster supplies(0.0112)
		C25 Medical rescue supplies(0.0094)
		C26 Disaster funding(0.0171)
		C27 Disaster shelters(0.008)
		C28 Disaster communication(0.0057)
		C29 Disaster transportation(0.0112)
A3 Training(0.1536)	B6 Disaster training(0.1536)	C30 Training of general personnel(0.0375)
		C31 Training of disaster response Team(0.0324)
		C32 Qualification certification(0.0079)
		C33 Public emergency safety education(0.0175)
		C34 Evaluation of educational activities(0.0582)
A4 Exercise(0.1461)	B7 Disaster exercise(0.1461)	C35 Disaster exercise(0.0847)
		C36 Exercise planning(0.0215)
		C37 Exercise evaluation(0.0399)

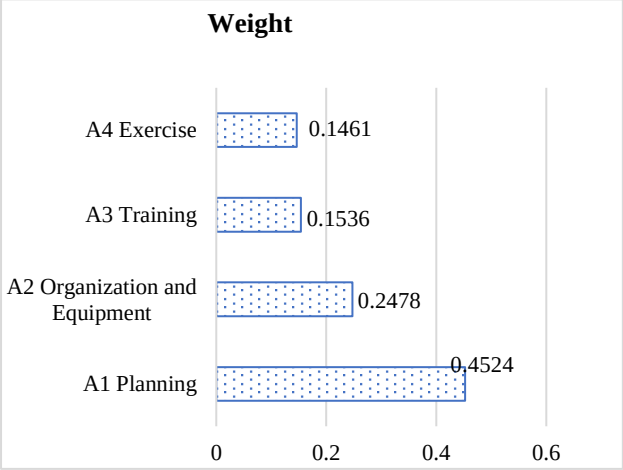
3.1. Determination of weight value between evaluation indexes

In this paper, we used yaahp software to calculate the weights of each level of indicators, i.e., the degree of importance, according to the above calculation steps. Four indicators were evaluated at the first level: A1 planning, A2 organization and equipment, A3 training, and A4 exercise, with weights of (0.4524, 0.2478, 0.1536,0.1461), respectively. Similarly, the weights of each secondary evaluation indicators: B1 disaster response plan，B2 disaster risk assessment，B3 disaster response regime，B4 disaster response organization, B5 disaster resources and equipment，B6 disaster training，B7 disaster exercise were 0.3347, 0.1177, 0.0449, 0.0866, 0.1164, 0.1536, 0.1461. The weights of each indicator C1-C37 were 0.025, 0.0524, 0.0185, 0.0316, 0.055, 0.0467, 0.1053, 0.0166, 0.0086, 0.0344, 0.0182, 0.399, 0.0214, 0.0083, 0.0152, 0.0366 0.0099, 0.0104, 0.0074, 0.0222, 0.0253, 0.0131, 0.0153, 0.0112, 0.0094, 0.0171, 0.008, 0.0057, 0.0112, 0.0375, 0.0324, 0.0079, 0.0175, 0.0582 0.0847, 0.0215, 0.0399, 0.0985.

3.2. The consistency proportion of judgment mat rix

In the consistency test, the consistency ratio CR is generally within 0.1, which indicates that the calculation results are consistent, and the consistency of the judgment matrix is considered to be acceptable (Song et al., 2011). According to the calculation results in the software, the consistency index (CI) and the average random consistency index (RI) can be derived, and the consistency ratio CR is finally calculated according to the $CR = \frac{CI}{RI}$. The analysis results of the AHP model in the disaster preparedness index system showed that the consistency ratio CR of disaster preparedness = 0.0228<0.1, which meets the consistency requirement. Meanwhile, the consistency ratios CR of A1 planning, A2 organization and equipment, A3 training, and A4 exercise were 0.0000, 0.0616, 0.0000, and 0.0000, respectively. All the above consistency indicators showed that the constructed judgment matrix has a high degree of consistency.

Figure 2. The weight ranking of the first layer (A1~A4) to the target layer



Meanwhile, according to the judgment matrix, the weight ranking results of each layer to the corresponding criterion layer can be obtained separately (see Figure 2). Disaster planning (A1) had the largest weight in the overall disaster preparedness capability, followed by organization and equipment (A2), and again by training (A3), and finally training accounts for the smallest weight, and training had the least influence on the overall disaster preparedness capability. In Figure 3, compared with other indicators, disaster response plan (B1) was the most important for assessing overall disaster preparedness capability, indicating that the prevention work plan before an incident was critical to the overall disaster preparedness. Once hazardous accidents and disasters occur, in order to improve emergency rescue and disposal capabilities and minimize losses, we must target our disaster preparedness efforts. Secondly, disaster training (B6), disaster exercises (B7), and disaster risk assessment (B2) had a greater impact on disaster preparedness. In Figure 4, the top three compared to other indicators were disaster planning system (C7), followed by disaster exercise (C35) and evaluation of educational activities (C34).

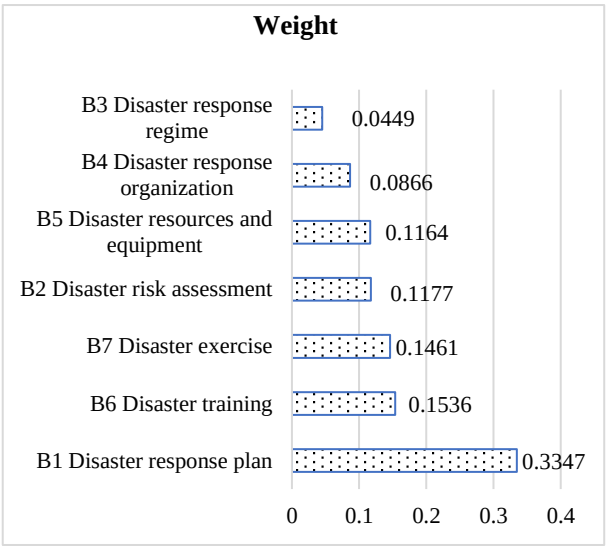


Figure 3. The weight ranking of the second layer (B1~B7) to the target lay

4. Results

4.1. Empirical Analysis

Combined with the disaster preparedness assessment index system established in this paper, 20 experts engaged in government disaster management related to this paper were selected as the subjects of the questionnaire, which was distributed from November 30, 2021 to December 3, 2021, and the questions investigated in the questionnaire were the contents of the three-level indicators, which were divided into quantitative and qualitative indicators according to the form of the basic data obtained from the statistical indicators. Therefore, the questionnaire subjects were divided into two main blocks of quantitative and qualitative content. Quantitative indicators can be judged by specific numerical values, such as the number of personnel, ambulance supplies, shelters, etc. Qualitative indicators were the values of indicators that cannot be expressed by specific numbers, and the participants of the questionnaire often get descriptive data based on intuition or experience.

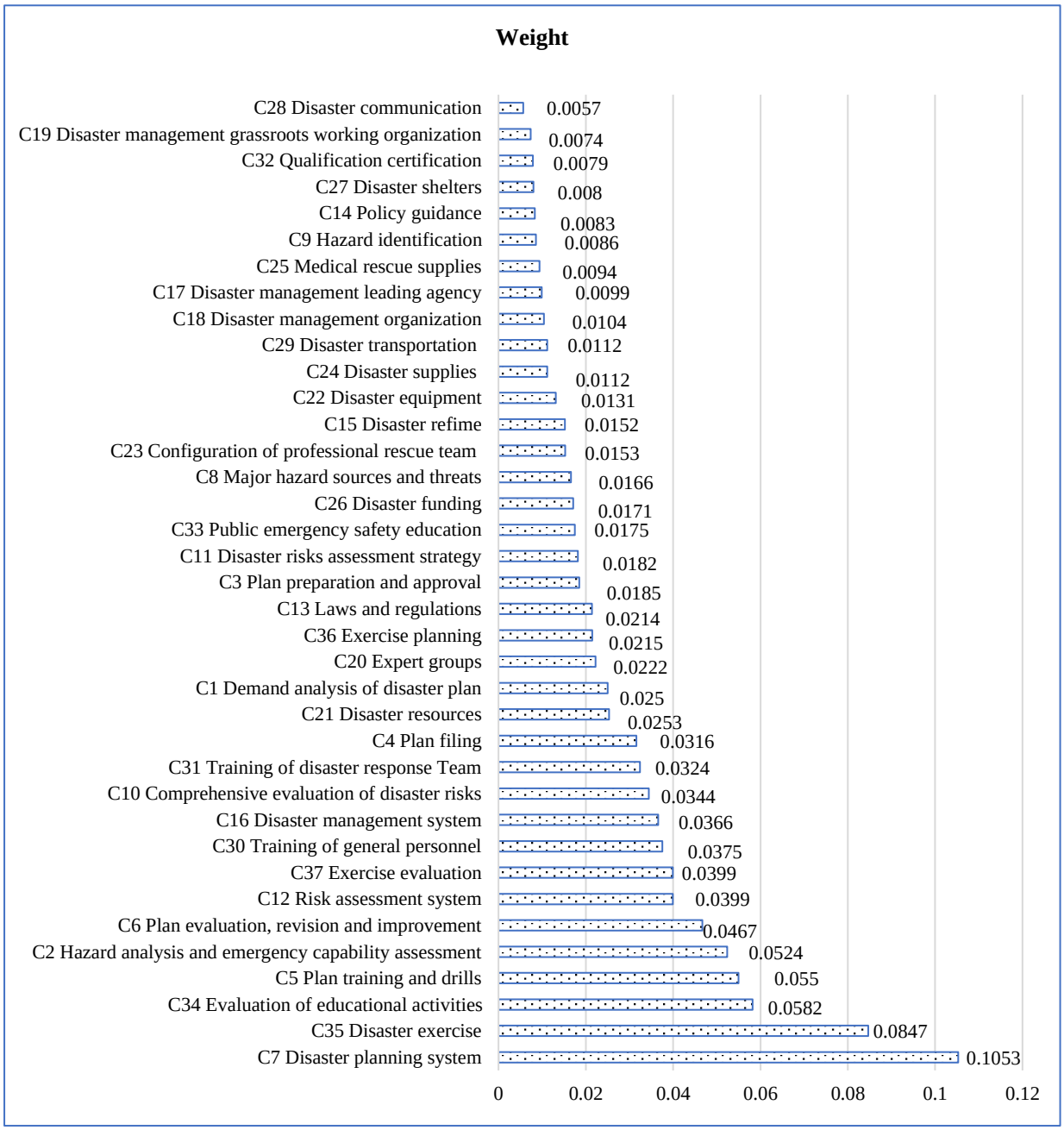


Figure 4. The weight ranking of the third layer (B1~B7) to the target layer

For the convenience of calculation, the 1-5 Likert scale was used in this paper to convert the graded values into statistically significant indicators.

Combining the disaster preparedness evaluation index system and the specific situation of disaster preparedness of Zhengzhou city in response to "7·20" rainstorm, the above evaluation method was used to evaluate the disaster preparedness of Zhengzhou city for this "7·20" rainstorm. As shown in Figure 5, after the collation and calculation of data, the qualitative assessment scores of the second level B1 disaster response plan, B2 disaster risk assessment, B3 disaster response regime, B4 disaster response organization, B5 disaster resources and equipment, B6 disaster training, and B7 disaster exercise were 4.34, 4.43, 4.53, 4.54, 4.38, 4.38, and 4.44, respectively. The score of B4 disaster response organization had the highest score, followed by B3 disaster response regime, and B1 disaster response plan had the lowest score, which can be found that in the qualitative assessment of disaster preparedness, the scores of disaster response organization and disaster response regime were more recognized, and the related ability of disaster plan preparation and disaster training was somewhat inadequate.

First-level(A)	Second-level(B)	Qualitative evaluation scores	Quantitative evaluation scores	Comprehensive scores	
A1 Planning	B1 Disaster response plan	4.34	3.29	3.81	3.87
	B2 Disaster risk assessment	4.43	3.42	3.93	
A2 Organization and Equipment	B3 Disaster response regime	4.53	3.42	3.97	3.94
	B4 Disaster response organization	4.54	3.58	4.06	
	B5 Disaster resources and equipment	4.38	3.19	3.78	
A3 Training	B6 Disaster training	4.38	2.95	3.66	3.66
A4 Exercise	B7 Disaster exercise	4.44	2.58	3.51	3,51

<Table 3>Comprehensive score of first-level and second-level

The quantitative evaluation scores of B1 disaster response plan, B2 disaster risk assessment, B3 disaster response regime, B4 disaster response organization, B5 disaster resources and equipment, B6 disaster training, and B7 disaster exercise were 3.29, 3.42, 3.42, 3.58, 3.19, 2.95, and 2.58, respectively (see fig.6), with B4 disaster response organization having the highest score. This is consistent with the qualitative assessment score, followed by B2 disaster risk assessment and B3 disaster response regime, and B7 disaster exercise had the lowest score, disaster preparedness, the scores of B4 disaster response organization and B3 disaster response regime were the highest. It can be found that in the quantitative assessment of disaster preparedness, the performance of disaster response organization and disaster response regime was more recognized, and the related ability of disaster exercise and disaster training was somewhat lacking.

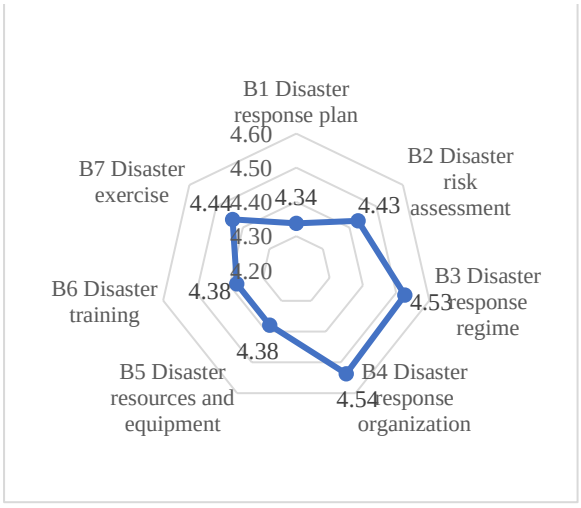


Figure 5. Radar chart of qualitative evaluation scores of B1~B7

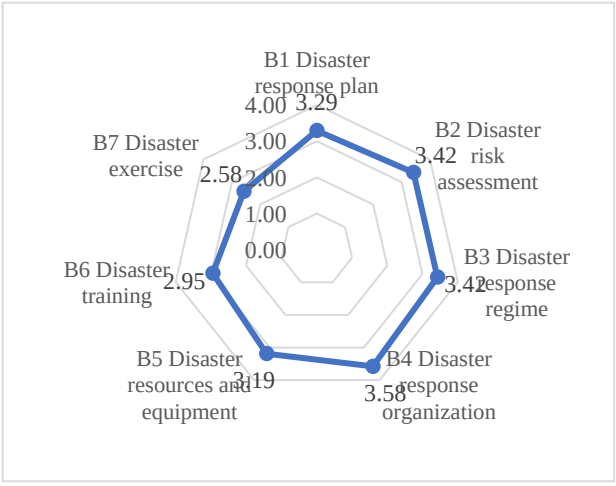


Figure 6. Radar chart of quantitative evaluation scores of B1~B7

4.2. Comprehensive Evaluation Results

Overall, the combined assessment scores for the first level indicators were 3.87, 3.94, 3.66, and 3,51 (out of 5), respectively (see table 3). The highest score for A2 organization and equipment indicated that Zhengzhou had a more complete disaster management organization and system, followed by A1 planning, and finally A3 training and A4 exercise, indicating that Zhengzhou had a large lack of emphasis on daily disaster training and practice areas. Specifically, the qualitative assessment scores of the seven secondary indicators were higher than the quantitative assessment, indicating that the Zhengzhou government had a clear understanding of the content and objectives of the work needed to improve disaster preparedness, but was not sufficiently concerned about the implementation of tasks, furthermore, the relevant authorities should be urged to strengthen the supervision and management of the implementation of the entire disaster preparedness process.

Specifically, from the individual index scores, B4 disaster response organization had the highest score

in both qualitative and quantitative assessments, followed by B3 disaster response regime, and the third highest overall ranked capability was B2 disaster risk assessment, the fourth ranking was B1disaster response plan, and the next three rankings were B5 disaster resources and equipment, B6 disaster training, and B7 disaster exercise, which indicated that Zhengzhou city needs to pay more attention to disaster resources and equipment, disaster training and exercise in the future.

In conclusion, there were still some shortcomings in Zhengzhou City's preparation for this response to the "7·20" extraordinarily heavy rainstorm. Specifically, there was insufficient awareness of major hazard information and threat information, the awareness of disaster risk was not strong, the main person in charge still had a subjective sense of judgment, lacked sensitivity and alertness to major hazard signals, and ignored the forecast information made by the meteorological department; secondly, there was an obvious disconnect between emergency operations and forecast information dissemination, and there was no quick and timely announcement of alert information to the society. The formulation, evaluation and revision were not refined, not to mention the strengthening of the practice of the plan. In the process of response to this extraordinarily heavy rainfall revealed that the dissemination of disaster warning information was not timely and adequate, safety awareness and disaster prevention and avoidance capabilities were not strong, especially the disaster education knowledge of leaders at all levels, disaster management capacity training and safety knowledge education for the public.

5. Conclusions

In this study, the evaluation model of disaster preparedness capability was proposed by constructing the target level as an indicator system of disaster preparedness capability, which was divided into four primary indicators A1 planning, A2 organization and equipment, A3 training, A4 exercise, seven secondary indicators, secondary evaluation indicators including B1 disaster response plan，B2 disaster risk assessment，B3 disaster response regime，B4 disaster response organization，B5 disaster resources and equipment，B6 disaster training，B7 disaster exercise, and 37 tertiary evaluation indicators. Then, the validity of the evaluation index system was demonstrated, and the results of the weight of each level were calculated by using AHP method and expert survey method.

Secondly, an empirical assessment of Zhengzhou City was conducted, which included qualitative and quantitative assessment indicators, and the scores and grades of the indicators obtained from the assessment were summarized and classified to comprehensively analyze and evaluate the disaster preparedness capacity of Zhengzhou city. The results showed that Zhengzhou city had a clear understanding of the content and objectives of the work needed to improve disaster preparedness, and had a relatively complete disaster management organization and system, however there was an overall lack of attention to the planning and implementation of tasks, and the relevant departments need to be further urged to strengthen the supervision and management of the implementation of the whole process of disaster preparedness.

Specifically, in terms of the A1 plan, the information collection of major hazards and threats should be increased, the sensitivity of major hazard signals should be maintained, the upgrading of the monitoring and warning information platform and the warning information release system should be accelerated, and the multi-source information should be fused and processed quickly and efficiently to ensure the timely release of warning information to the community at the first time of an accident. At the same time to further improve the emergency plan system, we should pay attention to the update and improvement of the disaster plan, the plan should be filed with the relevant superior departments or agencies for the record, to enhance the integrity, coordination and effectiveness of the plan system. In terms of the A2 organization and equipment, it is necessary to focus on strengthening the provision and maintenance of disaster relief equipment and materials. Furthermore, we should pay attention to the construction of emergency shelters, open up qualified gymnasiums, parks and other places as emergency shelters, and equip them with corresponding supporting facilities and strengthen emergency material reserves and fund reserves, and regularly update facilities and equipment for living materials and rescue. In A3 training and A4 exercise, regular training activities for emergency management-related practitioners as well as general personnel, educational activities and various forms of emergency plan exercises, improve the proportion of practitioners meeting qualification requirements and the professionalism of rescue teams, and actively carry out multi-form and multi-content public safety culture improvement activities to the public to enhance the public's emergency preparedness capacity.

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