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Research on Evaluation of Emergency Logistics Supply Capacity of Protective Equipment in Emergencies

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Abstract: Large emergencies have had a huge impact on China's economy, and people's health and safety, and in recent years, they have shown a fluctuating rebound trend. The risk situation is severe and complex, and the sudden and abnormal nature of disasters is becoming increasingly evident. As an essential part of emergency rescue, emergency protective equipment plays a pivotal role in ensuring the basic life, health, and safety of the people in the affected areas. To alleviate the problem of insufficient emergency logistics supply capacity of protective articles in China, this paper systematically combed the relevant research of domestic and foreign scholars in this field, established an evaluation index system of emergency logistics supply capacity of protective articles by using fuzzy comprehensive evaluation method, and took the supply of emergency protective articles during the COVID-19 in Wuhan, Hubei Province as an example, empirically tested and analyzed the importance of specific influencing factors on supply capacity, Finally, it proposes countermeasures and suggestions in three aspects: plan and exercise, auxiliary support capabilities, and emergency logistics technology.

1. Introduction

In recent years, the frequency and scale of large-scale emergencies have far exceeded those in the past, and have had a significant impact on the stable development of society and the protection of people's lives, health, property safety, and daily life. The situation is becoming increasingly severe. Due to the uncertainty and suddenness of emergencies, as well as the poor communication conditions and high degree of environmental damage in disaster areas, it is extremely easy to cause mass casualties and various infectious diseases. The demand for emergency supplies is very urgent, especially for protective equipment. In the event of a sudden occurrence of an event, it is difficult for materials such as protective equipment to meet the requirements of responding to the event in both time and space, so improving the supply capacity of emergency supplies in the event of an emergency is particularly critical. The main purpose of this study is to clarify the direction of improvement in the emergency logistics supply capacity of protective equipment in China, effectively improve the supply capacity of emergency logistics of protective equipment, and help achieve maximum social and economic benefits. It is also of great significance in both theoretical and practical aspects.

On the one hand, the current theoretical research and practical experience in the field of emergency logistics in China mainly focus on its significance, characteristics, problems, distribution, and vehicle scheduling. Compared to the former, empirical research on the evaluation of protective equipment supply capacity is significantly insufficient. On the other hand, based on the analysis of the current development situation of the emergency system, it is necessary to quantify and compare the specific factors affecting its supply capacity to provide more targeted improvement methods and strategies for China's emergency protective equipment and materials scheduling efficiency, resource information sharing and emergency requisition compensation mechanisms that need to be improved, and basic emergency response capabilities are weak, with a low level of public relations participation and socialized organization. Therefore, using the method of a fuzzy comprehensive evaluation to conduct empirical testing and research on the emergency logistics supply capacity of protective equipment not only has strong theoretical research value and helps enrich our emergency logistics theory, but also is conducive to obtaining the capacity values of relevant impact indicators of emergencies, and improving the overall operational efficiency of emergency protective equipment materials in China under critical conditions, It has both theoretical and practical significance.

Through reviewing relevant literature, we find that the supply and security of protective equipment and materials often cannot be separated from the coordination of emergency logistics, which are inseparable and come down in one continuous line. Therefore, this article will conduct a comprehensive review from two aspects: research on the optimization of protective equipment and materials and research on emergency logistics mechanism design:

In terms of research on the optimization of protective equipment and materials, Kemball et al. verified that effective and timely logistics management of emergency rescue materials has a significant impact on improving the efficiency of emergency materials by investigating the significant effectiveness of almost all emergency materials delivered to the disaster area in the Somali relief operation [1]. Suleyman's research believes that strengthening the pre-management of emergency protective materials is an important factor in reducing disaster losses caused by emergencies [2]. Gutierrez, Shameur, and others focus on optimizing emergency logistics distribution networks and selecting the best transportation routes and modes, which is a key link in improving the supply efficiency of emergency protective materials [3, 4]. In studies by Yen et al., it was pointed out that the emergency allocation management model of prioritized delivery based on demand can effectively improve the supply capacity of emergency logistics for protective equipment [5].

In terms of research on the mechanism design of emergency logistics, Ou Zhongwen and others discussed the methods and approaches to establishing China's emergency management guarantee mechanism [6]. By studying the current situation and characteristics of emergency logistics for sudden disasters in China, Fan Houming has constructed a relatively complete emergency resource mechanism, which helps to eliminate public panic and ensure the supply of emergency protective equipment [7]. Zhao Shifeng and Li Xuegong analyzed the coordination and command issues of China's emergency logistics system, designed the overall framework of the emergency logistics adjustment and command system for emergency supplies, improved coordination, and the reliability and timeliness of the emergency logistics system for protective supplies [8]. Ji Guojun and Zhu Caihong established an integer programming model based on the relationship between opportunity costs to address the unpredictable dynamics and uncertainties in the implementation of the emergency logistics system transportation strategy, taking into account the demand for disaster relief materials, the development of disaster conditions, and the demand for disaster relief materials for some time thereafter, providing a basis for achieving optimal planning of emergency materials [9]. Zhu Li et al. applied super network theory to study the allocation and operation of emergency protective equipment and materials in emergencies [10]. Ji Xia combed and analyzed the current situation of emergency protective equipment material support in China, and proposed measures and suggestions for constructing the emergency protective equipment material support system in China [11].

In summary, although scholars continue to explore in-depth in the field of emergency management, and the supply capacity of emergency support materials in China has steadily increased, there is less consideration of the literature on the evaluation of the supply capacity of emergency protective equipment, and the depth of specific factor analysis is insufficient, which cannot intuitively reflect the actual level of emergency material supply capacity in specific emergencies. Therefore, based on existing research, this article aims to improve the evaluation method of emergency logistics supply capacity of protective equipment, establish an evaluation system to conduct a fuzzy evaluation of the specific influencing factors of its supply capacity, and more accurately and objectively analyze the importance of the impact factors on supply capacity through the case of the Wuhan epidemic in Hubei Province, hoping to provide reference and guidance in improving the overall operational efficiency of emergency supplies in China.

2. Establish an Indicator Evaluation System

2.1. Source of Indicator System Establishment

According to research and analysis, some scholars believe that relevant factors such as the location of emergency logistics centers, transportation networks and tools, and the quality of emergency logistics personnel are positively correlated with the supply capacity of emergency logistics. Therefore, this article analyzes the specific factors that affect their supply capacity regarding previous research results, mainly starting from four aspects: emergency command and coordination, emergency auxiliary support, emergency protective equipment management, and emergency information processing.

Based on the previous analysis, understanding the specific factors that affect the evaluation system, and based on the specific relationship between the impact indicators, the construction of the evaluation index system will follow the principles of focus, objectivity, operability, and systematization to ensure the scientific and accurate results of the ability evaluation, and thereby build an evaluation index system for the emergency logistics supply capacity of protective equipment.

2.2. Method Model

(1) Based on the four basic design principles of the evaluation index system described above, combined with research findings from relevant fields at home and abroad, this paper constructs an evaluation index system for the emergency logistics supply capacity of protective equipment, starting with factors that affect the emergency logistics supply capacity of protective equipment and emergency management theory, as shown in Table 1.

(2) This article has constructed an evaluation index system for the emergency logistics supply capacity of protective equipment, established the weights of indicators at various levels, and distributed questionnaires to more than 10 experts.

(3) Let them compare and score each indicator based on their importance to each other, to form a comprehensive judgment matrix that gathers expert opinions.

(4) Perform data analysis and processing on the judgment matrix using the analytic hierarchy process to obtain the characteristic vectors corresponding to each hierarchical matrix, thereby determining the weight of each evaluation index in the indicator system. The final weight results are shown in Table 2, where the judgment matrix has satisfactory consistency.

Table 1: Evaluation index system for emergency logistics supply capacity of protective equipment

Target layer	Primary indicator	Secondary indicators
The emergency logistics supply capacity of protective equipment A	Emergency command and coordination B1	Building Capacity of Emergency Command Institution B11
		Government coordination capacity B12
		Social Participation Capacity B13
	Emergency auxiliary support B2	Emergency logistics personnel emergency capacity B21
		Emergency logistics technical support capability B22
		Emergency logistics network support capability B23
		Emergency logistics fund preparation and supervision capacity B24
	Emergency protective equipment management B3	Emergency protective equipment financing capacity B31
		Emergency protective equipment reserve capacity B32
		Transportation capacity of emergency protective equipment B33
		Distribution capacity of emergency protective equipment B34
	Emergency information processing B4	Disaster monitoring and early warning capacity B41
		Information collection, analysis, and feedback capabilities B42
		Real-time information disclosure and sharing B43

Table 2: Determination of Index Weights

Primary indicator	weight	Secondary indicators	weight
Emergency command and coordination B1	0.540	Building Capacity of Emergency Command Institution B11	0.670
		Government coordination capacity B12	0.260
		Social Participation Capacity B13	0.077
Emergency auxiliary support B2	0.105	Emergency logistics personnel emergency capacity B21	0.475
		Emergency logistics technical support capability B22	0.258
		Emergency logistics network support capability B23	0.155
		Emergency logistics fund preparation and supervision capacity B24	0.118
Emergency protective equipment management B3	0.063	Emergency protective equipment financing capacity B31	0.578
		Emergency protective equipment reserve capacity B32	0.053
		Transportation capacity of emergency protective equipment B33	0.255
		Distribution capacity of emergency protective equipment B34	0.118
Emergency information processing B4	0.295	Disaster monitoring and early warning capacity B41	0.683
		Information collection, analysis, and feedback capabilities B42	0.223
		Real-time information disclosure and sharing B43	0.093

3. Example Verification

3.1. Example Overview

At the end of 2019, COVID-19 was the most influential public health emergency since the founding of the People's Republic of China. In the context of the epidemic, people's property losses continued to increase, and the disaster area urgently needed personnel and materials to support them. This article outlines the emergency logistics performance of protective equipment in emergency rescue operations to evaluate the supply capacity of emergency logistics of protective equipment for emergency rescue.

3.2. Evaluation of Emergency Logistics Supply Capacity of Protective Equipment

During a case evaluation, the evaluation index system is divided according to a hierarchical structure, and the weight of each index is determined by using the analytic hierarchy process. Then, the fuzzy comprehensive evaluation method is used to conduct a hierarchical fuzzy comprehensive evaluation, and the evaluation result is obtained. The fuzzy weight vector A of the allocation result is determined by the index weight of 2.2 as follows:

$$A = (0.540\ 0.105\ 0.063\ 0.295) \quad (1)$$

$$A_1 = (0.670\ 0.260\ 0.077) \quad (2)$$

$$A_2 = (0.475\ 0.258\ 0.155\ 0.118) \quad (3)$$

$$A_3 = (0.578\ 0.053\ 0.255\ 0.118) \quad (4)$$

$$A_4 = (0.683\ 0.223\ 0.093) \quad (5)$$

3.2.1. Determine the Comment Set

Table 3: Evaluation and scoring table of emergency logistics supply capacity of protective equipment

Primary indicator	Secondary indicators	Rating			
		excellent	good	Medium	Poor
Emergency command and coordination B1	Building Capacity of Emergency Command Institution B11	0.6	0.3	0.1	0
	Government coordination capacity B12	0.4	0.4	0.2	0
	Social Participation Capacity B13	0.3	0.3	0.4	0
Emergency auxiliary support B2	Emergency logistics personnel emergency capacity B21	0.2	0.7	0.1	0
	Emergency logistics technical support capability B22	0.4	0.1	0.3	0.2
	Emergency logistics network support capability B23	0.4	0.4	0.2	0
	Emergency logistics fund preparation and supervision capacity B24	0.3	0.2	0.2	0.3
Emergency protective equipment management B3	Emergency protective equipment financing capacity B31	0.6	0.4	0	0
	Emergency protective equipment reserve capacity B32	0.3	0.3	0.4	0
	Transportation capacity of emergency protective equipment B33	0.4	0.3	0.2	0.1
	Distribution capacity of emergency protective equipment B34	0.1	0.5	0.2	0.2
Emergency information processing B4	Disaster monitoring and early warning capacity B41	0.3	0.4	0.3	0
	Information collection, analysis, and feedback capabilities B42	0.3	0.6	0.1	0
	Real-time information disclosure and sharing B43	0.5	0.4	0	0.1

Set up $V = (V1, V2, V3, V4)$ =(Excellent, Good, Medium, Poor). In this paper, a 100-point statistical method is used to obtain the evaluation set of indicators based on the scores of 10 experts on the emergency logistics supply capacity of protective equipment. Among them, 10 experts evaluated the B11 level of emergency logistics supply capacity of protective equipment, and 6 experts considered the level to be "excellent", resulting in an "excellent" membership degree of "0.6". In turn, the "good", "medium", and "poor" membership degrees of "0.3", "0.1", and "0" were obtained. The other fuzzy evaluation matrices are summarized as shown in Table 3.

3.2.2. Obtaining the Membership Matrix

Based on experts' evaluation of each basic indicator, a statistical analysis is conducted to obtain an evaluation opinion table for the performance basic indicator. According to the opinion table, the membership degree of each indicator can be calculated, and the membership matrix R can be obtained.

$$R = (r_{ij})_{mn} = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix} \quad (6)$$

r_{ij} represents the frequency distribution of v_i of the i_{th} factor on the j_{th} comment, which is generally normalized to satisfy $\sum r_{ij} = 1$, $r_{ij} = \sum_{K=1}^{H} u_{ij}^{k}, (i = 1,2,\cdots,m, j = 1,2,\cdots,n)$ and u_{ij}^{k} represents the evaluation result of the evaluator k on the evaluation object i; H is the number of evaluators invited; m is the number of evaluation objects; n is the number of evaluation levels.

3.2.3. Comprehensive Evaluation Results

(1) First-level comprehensive evaluation

Because

$$A_1 = (0.670\ 0.260\ 0.077) \quad (7)$$

$$R_1 = \begin{pmatrix} 0.6 & 0.3 & 0.1 & 0 \\ 0.4 & 0.4 & 0.2 & 0 \\ 0.3 & 0.3 & 0.4 & 0 \end{pmatrix} \quad (8)$$

Therefore

$$B_1 = A_1 * R_1 = (0.529\ \ 0.328\ \ 0.149\ \ 0) \quad (9)$$

And

$$A_2 = (0.475\ 0.258\ 0.155\ 0.118) \quad (10)$$

$$R_2 = \begin{pmatrix} 0.2 & 0.7 & 0.1 & 0 \\ 0.4 & 0.1 & 0.3 & 0.2 \\ 0.4 & 0.4 & 0.2 & 0 \\ 0.3 & 0.2 & 0.2 & 0.3 \end{pmatrix} \quad (11)$$

Therefore

$$B_2 = A_2 * R_2 = (0.259\ \ 0.443\ \ 0.170\ \ 0.087) \quad (12)$$

And

$$A_3 = (0.578\ 0.053\ 0.255\ 0.118) \tag{13}$$

$$R_3 = \begin{pmatrix} 0.6 & 0.4 & 0 & 0 \\ 0.3 & 0.3 & 0.4 & 0 \\ 0.4 & 0.3 & 0.2 & 0.1 \\ 0.1 & 0.5 & 0.2 & 0.2 \end{pmatrix} \tag{14}$$

Therefore

$$B_3 = A_3 * R_3 = (0.476\ \ 0.382\ \ 0.095\ \ 0.049) \tag{15}$$

And

$$A_4 = (0.683\ 0.223\ 0.093) \tag{16}$$

$$R_4 = \begin{pmatrix} 0.3 & 0.4 & 0.3 & 0 \\ 0.3 & 0.6 & 0.1 & 0 \\ 0.5 & 0.4 & 0 & 0.1 \end{pmatrix} \tag{17}$$

Therefore

$$B_4 = A_4 * R_4 = (0.318\ \ 0.444\ \ 0.227\ \ 0.009) \tag{18}$$

From the above calculation, Table 4 can be obtained:

Table 4: Comprehensive Results of the First Level Evaluation

Criterion layer	Evaluation results			
	excellent	good	Medium	Poor
Emergency command and coordination B1	0.529	0.328	0.149	0
Emergency auxiliary support B2	0.295	0.443	0.179	0.087
Emergency protective equipment management B3	0.476	0.382	0.095	0.049
Emergency information processing B4	0.318	0.444	0.227	0.009

(2) Second-level comprehensive evaluation

According to the results of the first level comprehensive evaluation, the fuzzy comprehensive evaluation matrix is as follows:

$$R = \begin{pmatrix} 0.529 & 0.328 & 0.149 & 0 \\ 0.295 & 0.443 & 0.179 & 0.087 \\ 0.476 & 0.382 & 0.095 & 0.049 \\ 0.318 & 0.444 & 0.227 & 0.009 \end{pmatrix} \tag{19}$$

Also known

$$A = (0.540\ 0.105\ 0.063\ 0.295) \tag{20}$$

A second-level comprehensive evaluation

$$B = A * R = (0.440\ \ 0.378\ \ 0.172\ \ 0.014) \tag{21}$$

Thus, Table 5 can be obtained:

Table 5: Comprehensive Results of the Second Level Evaluation

The emergency logistics supply capacity of protective equipment	Evaluation results			
	excellent	good	Medium	Poor
	0.440	0.374	0.172	0.014

4. Result Analysis

From Table 5 above, we can draw the following conclusions: 44% of the evaluations are excellent, 37.4% are good, 17.2% are medium, and 1.4% are poor; According to the principle of the maximum degree of membership, the emergency logistics supply capacity of protective equipment in China is excellent, which also happens to confirm that China has responded well to the COVID-19 epidemic. At the same time, however, it should be noted that there is little difference between the proportion of excellent and good evaluation grades, and from the empirical results, in addition to the excellent ability values of emergency command and coordination B1 and emergency protective articles management B3, the emergency auxiliary support B2 and emergency information processing B4 index abilities are still good, which objectively shows that there is still some room for the emergency logistics of protective articles against the COVID-19 epidemic from the ideal state, There is still a need for improvement and improvement in the future.

5. Countermeasures and Suggestions

From the empirical results, China's overall supply capacity of protective equipment for COVID-19 in Wuhan, Hubei Province, was at an excellent level, and the overall performance of emergency logistics was good, which not only guaranteed the basic life and health safety of the people in the disaster area but also played an important role in effectively reducing the losses caused by the disaster, which reflected China's efforts during the emergency rescue of the epidemic in Wuhan, Hubei Province, However, through analysis, it is found that there are three problems in the emergency logistics supply capacity of protective equipment:

(1) Emergency logistics plans and drills for protective equipment still need to be strengthened

After the outbreak of the epidemic, whether the emergency logistics activities of protective equipment can be smoothly carried out and play an effective role mainly depends on the emergency plan of the emergency command center and the specific implementation of the emergency plan. After the outbreak of a sudden public disaster, relevant departments can implement emergency plans within a relatively short period. However, at this stage, most emergency plans have public and common characteristics, focusing on rescue and disaster relief. However, the contents of how to develop emergency logistics for essential food, how to coordinate and cooperate among departments, and how to improve the response speed of emergency logistics for protective equipment are not perfect. From a practical perspective, compared to more common emergency drills, there are significantly fewer emergency simulation drills for protective equipment. The main reason is that the applicable scenarios for emergency logistics for protective equipment are major disaster accidents, and the relevant principals may lack emergency logistics awareness and operational ability. In this situation, it is often unable to meet the requirements for emergency logistics supply of emergency protective equipment.

(2) The auxiliary support ability of emergency protective equipment needs to be improved.

In the empirical test results, 44.3% of the supporting capacity is at a good level, which is in the middle of the overall evaluation index capacity. This is also in line with the actual news reports that the disaster area is extremely short of a large number of emergency supplies, and the phenomenon of "supply exceeding demand, which can only be maintained for a few days" is consistent, revealing the true situation that emergency protective supplies cannot be efficiently distributed to meet the disaster demand points in emergencies. Moreover, the low auxiliary support capacity of emergency protective equipment is mainly due to the insufficient reserve of protective equipment at the disaster site, and the sudden increase in the number of infected persons, resulting in a further increase in the proportion of patients to protective equipment, greatly limiting the development of auxiliary support capacity of emergency protective equipment.

(3) Emergency logistics technology for protective equipment needs to be improved.

During this epidemic, relevant departments have taken a series of measures to solicit dedicated trains from logistics companies to quickly carry out emergency rescue, and in emergency contact with an emergency, processing enterprises to organize the transportation of emergency protective equipment and materials, which is crucial for their efficient and timely supply. Currently, compared to commercial logistics under new technologies and concepts in China, there are significantly fewer applications in the field of emergency logistics for protective equipment in a strong weak economy. Whether it is the means of transportation, facilities, and equipment involved in logistics, or information technology and management strategies, both soft and hard technologies are more mature and widely used in commercial logistics than the former, Moreover, the talent pool for emergency management of protective equipment is not perfect, and many emergency logistics personnel lack logistics awareness and comprehensive ability, which also has a certain impact on the logistics technical support ability of emergency protective equipment.

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