Demand Grading of Emergency Medical Materials Based on Factor Analysis

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Abstract. Reasonable and scientific classification and urgency classification of emergency materials is the premise and basis of emergency management, which affects the effect and efficiency of emergency rescue. Emergency medical materials are related to people's life, health, and safety. In this paper, based on the early stage of COVID-19, the demand for emergency medical materials is combined to determine the demand grading evaluation indicator system, and factor analysis is used to reduce the dimensionality of data and to determine the weights of each indicator. Therefore, a comprehensive evaluation model is established and the demand for emergency medical materials is graded by clustering.

Keywords: Emergency medical materials, Demand for grading, Factor analysis.

1. Introduction

In the case of public health emergencies, emergency logistics will play a huge role. It realizes its logistics benefits through efficiency and pursues maximum effectiveness and minimum loss rate. Taking the COVID-19 outbreak in 2020 as an example, in the process of organizing the distribution of emergency medical materials, asymmetric supply and demand information of some supplies led to repeated delivery or sustained shortage. At the same time, the public donated various supplies, including some ordinary medical materials that were not in the urgent need or had been reserved. To ensure the timeliness and accuracy of emergency medical materials, it is necessary to classify the demands of medical materials according to the urgency of different materials, clarify the guarantee order of emergency medical materials distribution, so as to formulate the corresponding optimal distribution scheme and ensure the efficient and accurate completion of rescue tasks.

In terms of the demand classification of emergency materials distribution, Wang Zhile [1] et al. reclassified emergency materials from the perspective of the whole process and classified them according to urgency by the analytic hierarchy process. According to the information on each disaster point, Yao Enting [2] et al. established a hierarchical model of demand urgency for disaster points based on the BP neural network. Bai Guanchao et al. [3] used the fuzzy comprehensive evaluation method to construct the classification indicator system of demand for emergency materials to grade the degree of urgency of demand, and used information entropy to determine the weight. Xu Chengrui [4] et al., aiming to improve rescue efficiency, proposed to use the method of an over-limit learning machine to study the classification of emergency materials. In general, the research methods [1-5] used in existing literature mainly include fuzzy judgment, machine learning, case-based reasoning, etc. In practical application, case-based reasoning, machine learning, and other methods need to rely on similar cases as data support, while public health emergencies are often random. Fuzzy evaluation relies on subjective judgment and has a high probability of obtaining a pseudo-optimal solution. Based on this, this paper adopts a demand classification method based on factor analysis. Factor analysis uses the idea of dimensionality reduction to recombine the information of original variables and simplify the data while retaining most of the information in the original data. In addition, factor analysis makes factor variables more explanatory and naming clearer through rotation.

2. Construction of Grading Indicators

2.1. Analysis of factors influencing demand for emergency medical materials

2.1.1 Sudden demand for emergency medical materials

The suddenness of public health emergencies themselves leads to the demand for and distribution of emergency medical materials of this nature. In the early stages of an epidemic, the demand for supplies expands dramatically, leading to relative shortages. To reduce the sudden impact of emergency medical materials demand, this is directly related to the inventory balance, procurement difficulty, emergency transportation difficulty, and emergency supply capacity.

2.1.2 Uncertainty over the demand for emergency medical materials

The time and intensity of public health emergencies are unpredictable, which also determines the quantity of emergency medical materials difficult to determine. Taking the early stage of the COVID-19 outbreak as an example, its therapeutic drugs are characterized by stage and dynamic adjustment. There is also a degree of uncertainty due to the additional demand for improved care.

2.1.3 Timeliness of emergency medical materials

Emergency medical materials need to have high timeliness, which is affected by the urgency of the material demand and the effect of the material used. The urgency of the material demand refers to the urgency of such materials in this stage, and the effect of the material used is affected by the task stage.

2.1.4 Irreplaceability of emergency medical materials

Some emergency medical materials are used at particular times and cannot be replaced, such as reagents and blood. They determine the extent to which the benefit of the material can be exerted. The other two influencing factors are the cost of materials and the cost of material shortages. At the same time, backorder cost, in turn, affects the irreplaceability of materials. If they are easy to be replaced, the backorder loss will be relatively small.

2.1.5 Diversity of emergency medical materials

Emergency medical materials have particular uses, and most are single-purpose, so the types of materials needed in a public health emergency are diverse, leading to different emergency relief benefits and quality assurance.

2.2. Criteria for grading indicators

The composition of the demand grading evaluation indicator system (0).

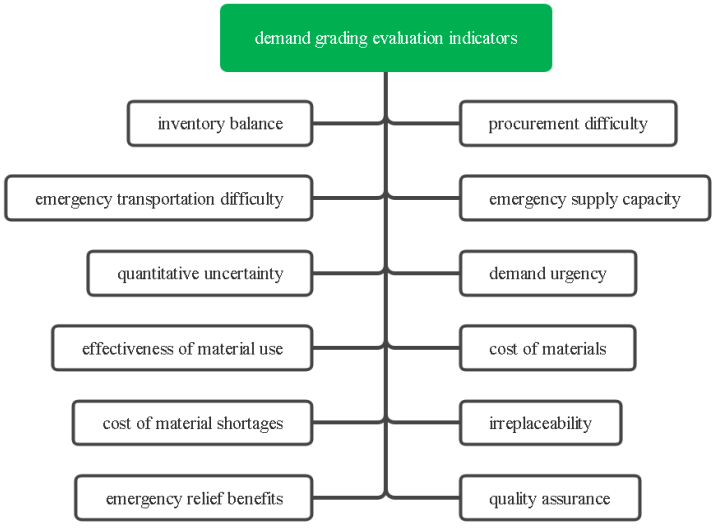


Fig. 1 Example of a figure caption

The grading of demand for emergency medical materials under sudden public health events is a comprehensive and ambiguous issue involving many influencing factors, so the relevant information needs to be reasonably quantified and comprehensively judged. In this study, an expert scoring system was used in which several experts were invited to anonymously score the various types of medical materials according to demand grading indicators. The scoring range is from 1-5. 1: only a slight economic loss; 2: indirect but compensable impact; 3: the direct slowdown of the rescue process; 4: affect the rescue result; 5: cause rescue failure with far-reaching consequences. The final scoring result is the average of all scores.

2.3. Grade classification

Drawing on the classification of public health emergencies in the National Public Health Emergency Response Plan, the emergency distribution needs for medical materials have also been classified into four levels: Level I is a special demand, which has priority in the distribution of emergency medical materials and has a high value, and its delivery has a crucial impact on the rescue mission. Level Ⅱ is an emergency demand, which is relatively mild but has a more significant benefit in the rescue mission; Level Ⅲ is a more urgent demand, which is moderately difficult to raise and has a greater value in the rescue process; Level Ⅳ is a general demand, which is relatively mild and has a relatively small impact on the success of the rescue mission.

3. Construction of a Demand Grading Evaluation Model

This paper constructs a demand grading evaluation indicator system to score emergency medical materials accordingly, uses factor analysis to establish a comprehensive evaluation model, and then uses cluster analysis to classify emergency medical materials according to demand levels.

3.1. Processing data

Factor analysis of evaluation indicators must be preceded by data standardization to make the subsequent analysis more accurate.

This paper uses z-score standardization, and its conversion formula is as follows:

$$z = \frac{x - \mu}{\sigma} \tag{1}$$

3.2. Factor analysis to build a comprehensive evaluation model

Factor analysis is a statistical technique for extracting common factors from a population of variables in the following steps.

3.2.1 Determine whether the data are suitable for factor analysis

KMO and Bartlett's tests were performed on the original variables. Usually, a KMO value greater than 0.6 indicates that factor analysis is appropriate, while Bartlett's test corresponding to a p-value less than 0.05 indicates that the factor analysis is valid.

3.2.2 Determining the number of extraction factors

The total variance interpretation rate reflects each factor’s variance interpretation rate and the cumulative variance interpretation rate, with a higher variance interpretation rate indicating that the factor contains more information about the original data. This is used to determine the weighting ratio of the demand rating indicators.

3.2.3 Interpretation and naming of factors

The factors are named in conjunction with the factor loading coefficients. In factor analysis, the main focus is on the rotating part of the data, which is more explanatory, and the "maximum variance" method is used here to achieve factor rotation.

3.2.4 Building a comprehensive evaluation model

The factor scores from the factor analysis were used to evaluate the raw data and to calculate a composite score for each emergency medical supply after the weighting of the factors.

3.3. Clustering by class

Based on factor analysis, a cluster analysis is conducted to classify the demand for emergency distribution of medical supplies into four levels: especially significant (level I), significant (level II), large (level III), and general (level IV).

4. Model Empirical Analysis

4.1. Introduction data

As the demand for emergency distribution of medical materials is also influenced by the types and task phases of public health emergencies, this paper takes the early stage of the COVID-19 outbreak in Hubei Province in 2020 as an example. It selects fourteen types of medical materials that are representative of the epidemic to analyze emergency distribution demand grading. They are ambulances for various kinds, novel coronavirus test kits, drugs for the treatment of general and heavy cases, medications for the treatment of Chinese medicine, extermination supplies, primary raw materials for extermination supplies, extermination equipment, protective supplies, primary raw materials for protective supplies, electronic instruments and meters, key components, diagnostic medical devices, therapeutic medical devices, and first-aid medical devices.

4.2. Factor analysis of demand grading indicators

An evaluation panel of experts scored the selected fourteen categories of medical materials according to the demand grading indicators and standardized these raw data, after which the corresponding calculations were made using SPSS 25.

The results show that the value of the KMO statistic for the data is 0.710, and the significance of Bartlett's sphericity test is 0.000, which is significantly less than 0.05 and allows for factor analysis. The common factor variances were all greater than 0.7, indicating that the variables were reasonably well expressed by the common factor, with strong correlations between entries and no need to remove access.

Using principal component analysis, three main components were extracted, with a cumulative variance contribution of 90.088%, which could well achieve the state of expression (0). This resulted in determining the weighting ratios of 40%, 33%, and 27%, respectively, for these three demand grading rubrics.

According to the factor loading coefficients in the rotated component matrix, the three common factors extracted were named "application benefit factor of emergency medical materials," "difficulty in obtaining emergency medical materials," and "dynamic change factor of emergency medical materials."

Tab. 1 Total Variance Explanation

Ingredients	Initial eigenvalues			Extract the sum of squares of loads			Sum of squared rotating loads		
	Total	Percentage variance	Cumulative %	Total	Percentage variance	Cumulative %	Total	Percentage variance	Cumulative %
1	8.852	73.765	73.765	8.852	73.765	73.765	4.350	36.247	36.247
2	1.087	9.055	82.820	1.087	9.055	82.820	3.654	30.450	66.697
3	872.	7.268	90.088	872.	7.268	90.088	2.807	23.391	90.088
Extraction method: Principal component analysis.									

A comprehensive evaluation model was established to evaluate the raw data according to the factor analysis results. The score values of the raw data under the three factors and the composite score of each material after assigning weights to the factors were calculated (0).

Tab. 2 Raw Data Composite Score

Supplies	Application benefit factor	Obtain difficulty factor	Dynamic change factor	composite score
Ambulances of various types	-1.840	1.374	-0.098	-0.309
Novel coronavirus test kits	0.510	-1.681	-0.732	-0.548
Drugs for the treatment of general and heavy cases	-0.498	0.167	2.458	0.519
Medications for the treatment of Chinese medicine	-0.376	-1.221	0.024	-0.547
Extermination supplies	-0.788	-0.660	-0.287	-0.610
Primary raw materials for extermination supplies	-0.352	-0.932	-0.652	-0.624
Extermination equipment	-0.860	0.069	-0.238	-0.385
Protective supplies	0.355	-0.528	1.278	0.313
Primary raw materials for protective supplies	0.582	-0.927	0.543	0.073
Electronic instruments and meters	-0.641	0.474	-0.973	-0.363
Key components	-0.451	1.174	-0.837	-0.019
Diagnostic medical devices	1.527	0.576	-1.176	0.483
Therapeutic medical devices	1.582	0.781	-0.225	0.829
First-aid medical devices	1.251	1.333	0.916	1.188

4.3. Hierarchical cluster analysis

Based on the factor analysis, a cluster analysis of the demand for emergency medical materials was carried out, which was divided into four levels according to the hierarchy. The especially significant needs (level I) are first-aid medical devices and therapeutic medical devices; the significant needs (level II) are two types, namely primary raw materials for protective supplies, and key components; the large needs (level III) are three types, namely drugs for the treatment of general and heavy cases, protective supplies and diagnostic medical devices; seven types of general needs (level IV), namely ambulances of various types, novel coronavirus test kits, medications for the treatment of Chinese medicine, extermination supplies, primary raw materials for extermination supplies, extermination equipment, and electronic instruments and meters.

5. Conclusion

This paper takes the early stage of COVID-19 as the research background. It summarizes the factors affecting the demand for emergency medical materials as suddenness, uncertainty, timeliness, irreplaceability, and diversity, thus constructing a demand grading evaluation indicator system and establishing a comprehensive evaluation model. The paper selected representative emergency medical materials from the 2020 Hubei COVID-19 for empirical analysis. Using the method of factor analysis, the twelve evaluation indicators were re-divided into three hands by extracting three factors: the application benefit factor, the difficulty of obtaining factor, and the dynamic change factor of emergency medical materials, which achieved a good state of expression, from which the total score of each material under the model was calculated and graded through clustering with good results. In practice, the grading of material requirements also needs to be dynamically adjusted according to the

phase of the task. Considering more complex influences such as dynamics would be a direction for extended research.

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