PERFORMANCE EVALUATION OF EMERGENCY LOGISTICS BASED ON DEA-AHP ALGORITHM

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Abstract: In recent years, much more natural disasters, public health events and a variety of disasters, accidents have occurred. This paper proposes an index system for the evaluation of the performance of emergency logistics. Performance evaluation of a group of entities is frequently based on the values of several attributes and usually requires the weights of the attributes to be set in advance. After an index of logistics system being built and with the Data Envelopment Analysis (DEA) algorithm and Analytical Hierarchical Process (AHP) algorithm being integrated. This hybrid model takes the best advantages of both AHP and DEA and at the same time, avoids either the subjectivity of AHP or the dichotomy of DEA. The results show that the evaluation method can measure the emergency logistics performance more effective and feasible.

1 INTRODUCTION

2011.3.11, the earthquake and tsunami disasters have brought great suffering to the Japan. In the process of disaster relief, the importance of emergency logistics becomes the focus of people again.

With the rapid development of science and technology, the ability of predicting natural disasters has been significantly improved. However, heaven decides the weather. Localized, regional, even global emergencies have occurred, serious threat to human life and property safety.

The emergency logistics just meet the need to complete sudden logistics demand from the various situations.

1.1 Research Significance

The purpose of evaluating the performance of emergency logistics is to identify the weak links of the emergency operation in the logistics. Then, with continuous improvement of the emergency logistics system can make the system more efficient.

Currently, the assessment of emergency logistics performance is still in the exploratory stage. The most correspondingly published literature focus on the study of response to emergency situation and the logistics system itself. There are few studies on the evaluation of the methods to evaluate the performance of the emergency logistics system. Now the main measurement methods are as follow: Fuzzy Comprehensive Algorithm, Analytical Hierarchy Process (AHP), Data Envelopment Analysis (DEA). These methods are flawed during the process.

In this text, the first step is to calculate the weight of each layer index using the AHP method. The second step is to obtain the relative efficiency of each system of indicators for each layer separately with the method of using the DEA. Finally, integrate the weight of each index and the relative efficiency to calculate the overall efficiency of the emergency logistics system and sorting. The method effectively combines the advantages of both DEA and AHP, at the same time, is good to make up for the lack of the two methods. All of this makes the method applicability and operability.

2 DEA-AHP EVALUATION PRINCIPLES

2.1 Basic DEA Methodology

Built upon the earlier work of Farrell (1957), DEA is a well established methodology to evaluate the relative efficiencies of a set of comparable entities by some specific mathematical programming

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models. These entities, often called decisions making units (DMU_s), perform the same function by trans- forming multiple inputs into multiple outputs. A main advantage of DEA is that it does not require any prior assumptions on the underlying functional relationships between inputs and outputs (Seiford and Thrall, 1990). It is therefore a nonparametric approach. In addition, DEA is a data-driven frontier analysis technique that floats a piecewise linear surface to rest on top of the empirical observations (Cooper et al., 2004).

Since the work by Charnes et al. (1978), DEA has rapidly grown into an exciting and fruitful field, in which operations research and management science (OR/MS) researchers, economists, and experts from various application areas have played their respective roles (Førsund and Sarafoglou, 2002, 2005). For DEA beginners, Ramanathan (2003) provided an excellent introductory material. The more comprehensive DEA expositions can be found in the recent publication by Cooper et al. (2006). In the sections that follow, we shall briefly introduce the basic DEA methodology.

Assume that there are K DMU_s, e.g. electricity distribution utilities, to be evaluated that covert N inputs to M outputs. Further assume that DMU_k consumes $x_{nk}>=0$ of input n to produce $y_{mk}>=0$ of output m and each DMU has at least one positive input and one positive output (Fare et al., 1994b; Cooper et al., 2004). Based on the efficiency concept. in engineering, the efficiency of a DMU, says DMU_o (o=1,2,...,K), can be estimated by the ratio of its virtual output(weighted combination of outputs) to its virtual input(weighted combination of inputs). To avoid the arbitrariness in assigning the weights for inputs and outputs, Charnes et al. (1978) developed an optimization model known as the CCR in ratio form to determine the optimal weights for DMU_o by maximizing its ratio of virtual output to virtual input while keeping the ratios for all the DMU_s not more than one.

2.2 Basic AHP Methodology

Analytic Hierarchy Process(AHP) is theorized by U.S. Operations Research Professor Saaty TL. It is a simple, flexible and practical method for multiple criteria decisions making. It is based on a hierarchy of multi-objective, subjective judgments based on a range of options for calculating the relative importance, followed by a top down basis, through the decision-makers for each sub-index layer and index layer provided by the importance of subjective judgments in pairs, for each unit down to the pairwise comparison matrix to establish. Comparison of first through calculating the feature vector matrix elements get the same level on a level for the relative importance of the same unit, and then in accordance with the order from the bottom up Yici, calculate aggregate importance, end up ranking value of each option. AHP process was people's thinking process by fully reflect the preferences of decision makers, decision makers experience will be quantified, so as to provide decision makers with quantitative forms of decisions making. But its limitations can not be ignored: it relies heavily on people's experience, subjective factors is large, it can only rule out the thought process up to the serious non-compliance, but can not rule out the possible existence of individual decision-makers A serious one-sidedness.

2.3 Evaluation of the Significance of AHP-DEA

The above method of DEA-AHP method described shows, DEA methods for assessing the results of the program is totally dependent on the objective evaluation of indicator data, without considering the preferences of decision makers, and can only be divided into units based on the dichotomy of decision-making both active and inactive Part of effective decision-making unit of the information given is too small, can not be a reasonable sort; and simple AHP, due to the characteristics of semi-qualitative semi-quantitative determined by its lack of strict objectivity, subjective factors, too. Taking into account the practical problems of evaluation reflects the degree of importance among may vary, so the decision makers in order to reflect the preferences of the different level of evaluation, so that the evaluation of a more comprehensive and reasonable, considering the above two methods the author Advantages and disadvantages in use of data envelopment analysis and analytic hierarchy process method are combined to establish the subjective and objective integrated multi-objective comprehensive evaluation model. The model make up the traditional method of data envelopment analysis does not consider the lack of decision-makers preferences, and overcome the many levels of analysis and decision making the current weakness of subjectivity, the evaluation results more comprehensive and more realistic.

3 THE STEPS OF OPERATION

3.1 Determine the Comprehensive Evaluation Index System

After the disaster, need to provide emergency support by emergency logistics. Information systems in the process of the establishment may be abreast of the situation and help the government and relief workers to better organize the relief work. After the disaster, a different geographic location should adopt different means of transportation, but they are time efficient in order to achieve the ultimate goal. Organize and direct the work of the emergency logistics, largely depends on the functioning of the Government, pragmatic and efficient government departments to organize and command the emergency key to the success of logistics. Emergency funds management, resource availability, quality, utilization, efficiency is the focus of government management. The performance of government logistics performance directly affects the level of emergency. Greater chance of sudden disasters, as in emergency logistics will face many problems can not be predicted, which requires the strain relief workers have the ability to act decisively, through peacetime training and exercises in dealing with real problems can be quickly and effectively. A state of emergency to deal with emergency incidents is the key to effective functioning of government functions and coordination. When the disaster occurred, the government needs through statistical property loss rate, affected by the number and scope of post-disaster disaster feedback, documentation kept facilitate future reference to justice. We can set up an emergency measure logistics performance evaluation system, see Table 1.

Table 1: Emergency Evaluation System of logistics performance measurement.

Framework Elements	Index name	Form and Content
Emergency Information System A_1	Normative B_{11}	Index
	Timely feedback B_{12}	Index
	Safety and secrecy B_{13}	Index
Condition Of Disaster A_2	Natural Factors B_{21}	Level
	Human factors B_{22}	Level
Location A_3	City B_{31}	Index
	Rural B_{32}	Index
	Natural Area B_{33}	Index

Table 1: Emergency Evaluation System of logistics performance measurement (cont.).

Traffic A_4	Port Facilities B_{41}			Level
	Road Facilities B_{42}			Level
	Aviation facilities B_{43}			Level
	Pipeline facilities B_{44}			Level
Government Administrati-on A_5	Emerge-ncy Logisti-cs Costs B_{51}	Transportation costs		Proportion
		Warehousing costs		Proportion
		Handling costs		Proportion
		Labor costs		Proportion
	Avail-ability of Suppl-ies B_{52}	Availability	Convenience	Index
			Timely	Index
			Complete	Index
		Resource call	Usually reserves	Proportion
			Proportion	Proportion
			Social contributions	Proportion
			Emergency Procurement	Proportion
	Quality B_{53}	Quality materials		Index
		Shipping Quality		Index
	Utilization of Supplies B_{54}	Type		Proportion
		Quantity		Proportion
		Specifications		Index
		Recycling		Rate
	Efficien-cy B_{55}	Material Delivery Time		Time
		People Arrival Time		Time
Rescue workers A_6	Organizers B_{61}			Index
	Training B_{62}			Level
	Experts B_{63}			Proportion
Government coordination mechanism A_7	Advantage of Government Coordination B_{71}			Index
Aftermath A8	Loss of Property B_{81}			Proportion
	Number of People Affected B_{82}			Proportion
	Areas B_{83}			Proportion

3.2 Determine the Weight of Each Index System

As the special nature of emergency logistics, emergency logistics management capabilities in building evaluation system should be strengthened in terms of speed indicators, and weakening economic indicators system, it can be reflected by the weight.

The index weight was determined by expert evaluation of. The determination of one, two weight is show in Table 2, Table 3.

Table 2: Logistics performance indicators weight determination of level 1.

N	Mea-sure	E1	E2	…	En	Mean	Normalized
1	A_1	A_{11}	a_{12}	…	a_{1n}	$a_1 = \sum_{i=1}^{n} a_{1i} / n$	$c_1 = a_1 / \sum_{i=1}^{8} a_i$
2	A_2	a_{21}	a_{22}	…	a_{2n}	$a_2 = \sum_{i=1}^{n} a_{2i} / n$	$c_2 = a_2 / \sum_{i=1}^{8} a_i$
…	…	…	…	…	…	…	…
8	A_8	a_{81}	a_{82}	…	a_{8n}	$a_8 = \sum_{i=1}^{n} a_{ni} / n$	$c_8 = a_3 / \sum_{i=1}^{8} a_i$

Table 3: Logistics performance indicators weight determination of level 2.

L1	L2	E1	..	En	Mean	Normalized
A_1	B_{11}	b_{111}	..	b_{11n}	$b_{11} = \sum_{j=1}^{n} b_{11j} / n$	$d_{11} = b_{11} / \sum_{j=1}^{3} b_{1j}$
	B_{12}	b_{121}	..	b_{12n}	$b_{12} = \sum_{j=1}^{n} b_{12j} / n$	$d_{12} = b_{12} / \sum_{j=1}^{3} b_{1j}$
	B_{13}	b_{131}		b_{13n}	$b_{13} = \sum_{j=1}^{n} b_{13j} / n$	$d_{13} = b3 / \sum_{j=1}^{3} b_{1j}$

Table 3: Logistics performance indicators weight determination of level 2 (cont).

…	…	…	..	…	…	…
A_8	B_{81}	b_{811}	..	b_{81n}	$b_{81} = \sum_{j=1}^{n} b_{81j} / n$	$d_{81} = b_{81} / \sum_{j=1}^{3} b_{8j}$
	B_{82}	b_{821}	..	b_{82n}	$b_{82} = \sum_{j=1}^{n} b_{82j} / n$	$d_{82} = b_{82} / \sum_{j=1}^{3} b_{8j}$
	B_{83}	b_{831}	..	b_{83n}	$b_{83} = \sum_{j=1}^{n} b_{83j} / n$	$d_{83} = b_{83} / \sum_{j=1}^{3} b_{8j}$

3.3 Quantify the Indicators of Level2

Use interval [0, 1] as indicate the pros and cons of each index. 0 is the worst, 1 is the best.

Index system can calculate the value of the index should be calculated by using actual data, for data can not be quantified or non-comparable should deal with expert evaluation.

Table 4: Logistics performance measurement indicators of level 2.

NO.	Indicators	Pros and cons of degree
1	B_{11}	e_{11}
2	B_{12}	e_{12}
…	…	…
24	B_{83}	E_{83}

The value of A_1, A_2, …, A_8 are set with Q_{01}, Q_{02}, …, Q_{08} .

$$Q_{01} = (d_{11}, d_{12}, d_{13}) \bullet \begin{pmatrix} e_{11} \\ e_{12} \\ e_{13} \end{pmatrix}$$

…

$$Q_{08} = (d_{81}, d_{82}, d_{83}) \bullet \begin{pmatrix} e_{81} \\ e_{82} \\ e_{83} \end{pmatrix}$$

Q_0= (Q_{01}, Q_{02}, …, $Q_{\cdot}$)

This problem can be further transformed into an equivalent output maximization linear programming problem as follows:

$$\max = \sum_{m=1}^{M} u_m y_{mo}$$

s.t.

$$\sum_{m=1}^{M} u_m y_{mk} - \sum_{n=1}^{N} v_n x_{nk} \le 0 \quad k=1,2,\ldots,K.$$

$$\sum_{n=1}^{N} v_n x_{n0} = 1 \qquad (1)$$

u_m, $v_n \ge 0$, m= 1,2,…,M;

n= 1,2,…,N.

Model (1) is known as the CCR in multiplier form. The efficiency scores of DMU_1 to DMU_K can be derived by solving K such models. Despite the linear form of (1), efficiency score is usually calculated based on its dual problem:

$$\text{Min } \theta$$

s.t.

$$\sum_{n=1}^{N} x_{nk}\lambda_k \le \vartheta x_{n0} \quad n=1,2,\ldots,N;$$

$$\sum_{m=1}^{M} y_{mk}\lambda_k \ge y_{m0} \quad m=1,2,\ldots,M; \qquad (2)$$

$$\lambda_k \ge 0 \quad k=1,2,\ldots,K.$$

Input units include A_1-A_7, Output unit includes A·. Bring the data into the formula (2).

4 CONCLUSIONS

In this paper, the establishment of logistics system performance bases on evaluation index system. Propose the method DEA-AHP. Firstly, use AHP to assessment the weights of the indicators of the performance. Secondly, use DEA to calculate the relative efficiency of indicators for each level of the system. Last, sort the weight of each index and the relative efficiency of the logistics system. The method combines well the advantages of DEA and AHP. Make up the problem of DEA method which can not consider the preferences of decision maker, and the problem of AHP is too subjective. Further analysis of the results of evaluation of each program can be obtained and the corresponding improvement of weak links in each program.

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