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Research of Regional Emergency Logistics Support Capability Evaluation: A Case of Typhoon Disaster in Zhejiang Province

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Abstract: Logistics support capability evaluation and constructions are key issues in emergency logistics efforts, with the objective of preventing or controlling the emergency events, to minimize systematic loss. In this paper an emergency logistics support capability evaluation system was proposed. Firstly, the factors influenced emergency logistics support capability were analyzed with lecture reviews and expert questionnaire and an evaluation index system was presented. Then with the application of fuzzy analytic hierarchy process, a model of regional emergency logistics support capability evaluation model was proposed. Finally, a case study of evaluating typical cities affected by typhoon in Zhejiang Province was given, with the results that Ningbo, Zhoushan, Wenzhou, Hangzhou and Jinhua have better logistics support capability than other cities in Zhejiang, which should put more hard work on the construction of emergency logistics in case to minimize the loss of typhoon disaster.

Key words: Emergency logistics, support capability, capability evaluation system, FAHP

INTRODUCTION

Recent years, there are more explosions of large-scale paroxysmal events and natural disasters, such as earthquakes, typhoons, floods, droughts. All of them will cause huge relief resource demands to avoid economic disruptions and human injuries. Emergency logistics plays an important role in the rescue efforts of disaster relief operation system. Emergency logistics should and could guarantee the supply of relief materials and save injured people before, during and after the explosion of paroxysmal events and natural disaster. Therefore, if the Emergency Logistics Support Capability (ELSC) is in a low level, the affected area will suffer from a huge loss when disasters encounter. There is no doubt that it is necessary to improve emergency logistics support capability.

In recent decades, the emergency logistics researches in domestic and abroad mainly focus on the purpose of construction, principles, system structure and scheduling models of the emergency logistics. For instance, some of the scholars proposed natural disaster emergency logistics decision support system or focus on the characteristics of emergency logistics. Li and Mu (2012) proposed an emergency logistics support capability evaluation model based on the analysis of the Hilbert space vector norm. Yu and Zhou (2008) put forward the emergency logistics support capability evaluation method with network analytic hierarchy process (ANP). Lin *et al.* (2010) studied the influence factors of natural disaster emergency logistics capability from three dimensions, proposed a natural disaster emergency logistics capability evaluation index system with ANP to get index's weight and evaluated emergency logistics capability with multilevel gray evaluation. Zhang and Fu (2012) built an index of logistics system, calculated the weight of each layer index using the AHP method and obtained the relative efficiency of each system of indicators for each layer separately with the method of using the DEA. Chen *et al.* (2012) proposed assessment model of drought disaster based on entropy-weight gray fuzzy clustering method according to the gray and fuzziness characteristics of regional drought disaster. With the aim of natural disasters risk reduction performance evaluation in tourism industry, Tsai (2011) proposed a default risk-based probabilistic decision model.

However, in these articles there is no complete and all-round evaluation index to examine the emergency logistics support capability performance or the results aren't related to reality. So this study proposed an emergency logistics capability performance evaluation index, Applied Fuzzy Analytic Hierarchy Process (FAHP) to accommodate the inherent uncertainty and taken Zhejiang province as an example to demonstrate the index system and evaluation model by analytical research. The structure of the rest of the paper is as follows.

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EMERGENCY LOGISTICS SUPPORT CAPABILITY EVALUATION INDEX SYSTEM

Identification of emergency logistics support capability: Based on a questionnaire survey and the emergency logistics support capability factors analysis, a classification of emergency logistics support capability is proposed, which includes:

- **Organizational coordination capability:** Emergency logistics organization system is a special temporary logistics command center that aims to help the country or region in dealing with natural disasters, public health and other sudden crisis, to make materials financing, scheduling, transportation and distribution. Professional emergency command center in its nature is the executive institution of authority in disaster relief operation (Yao and He, 2012), which can guarantee emergency logistics activities operating in an efficiency and smooth matter. After the disaster, the disaster relief operation usually requires the participation of many departments from central government, local authority and NGO (Non-government Organization), which will inevitably produce conflict. So the coordination of the relief resource and forces becomes very important and has a significant impact on the result of logistics operation, for example, the improper coordination may delay the relief process and cause huge losses. Therefore, organization and coordination capability in natural disaster emergency logistics activity plays a very important role (Lin *et al*., 2010)
- **Information management capability:** A high level of information processing is a powerful guarantee for emergency logistics operation. Processing information accurately and efficiently can help to select useful information and conduct the emergency logistics activities. In addition, letting the public know disaster information in time, actively motivate all social resources to support the disaster relief activities. Without the information system's support, disaster relief efforts will be blindness to expand and even have no way to deal with
- **Emergency response cost:** An important feature of emergency logistics operation is "time efficiency is the first goal" and the economic benefit is not obvious, therefore the construction of emergency logistics work can't be done by enterprise under market economy condition. So the cost factor is not a key consideration in emergency logistics and the weight is small, but it does mainly can be taken as a reference, for ideal emergency logistics should be economic efficiency
- **The public effect:** Government needs to notify the public about disaster information. Including time, place, type of disaster, scope of disaster and the difficulties in relief work, etc. Meanwhile, mobilize people through various channels, to improve the enthusiasm of public to participate in disaster relief. The degree of public effect and public satisfaction can and should be used to measure the effectiveness of the emergency logistics support capability
- **Emergency preparation capability:** Government is the leader of relief operation activities; responsible for coordinating and organizing all kinds of resources to help the disaster relief work. It is also vital for the government to carry out counter measures and plans to deal with natural disasters. One of the most important efforts is preparation work. Without full preparation of pre-arranged planning, foods, manpower and rescue equipment, it will be difficult to perform rescue work
- **Emergency logistics response operation capability:** The research of emergency logistics response operation capability can be divided into the macro and micro level, microscopic level can be considered to be concentrated on the logistics operation. In enterprise level, logistics operation capability is the service capability, so emergency logistics activities can also be understood as a service that the authorities and organizations depend to save people's life and guarantee property safety. Logistics service capability can refer to general logistics enterprise, such as materials, supplies and raise scheduling materials transportation, which is also the so-called micro logistics response operation capability
- **After-disaster management capability:** After-disaster reconstruction work and information statistical work is often overlooked in previously research. However, well-done after-disaster information collection and statistical analysis can do support evaluation for the emergency logistics support capability; also can find the deficiency to help to improve and to do better for next disaster relief operation

The system of emergency logistics support capability evaluation: Based on the related literatures (Liu and Xie, 2008; Zeng *et al*., 2009; Ju *et al*., 2012; Gong *et al*., 2012) and discussion with experts and employees from related authorities, an index system of emergency logistics support capability evaluation is proposed, as Table 1 shows.

This index system is made of seven criterions and fifty index level indexes. Comparing with other research,

Table 1: Emergency logistics support capability evaluation index

Purpose (W)	Criteria (U)	Index (V)
Emergency logistics support capability evaluation index	Organizational coordination capability (A)	1. Levels of emergency logistics response organization (A1)
		2. Inner staff's coordinate capability of the organization (A2)
		3. Coordinate capability with related organizations (A3)
		4. Using the rights and obligation that the laws endowed (A4)
		5. Construction level of emergency logistics information system (A5)
	Information management capability (B)	6. Fluent level of inner information (B1)
		7. Capability of monitoring the disaster (B2)
		8. Capability of predicting the disaster (B3)
		9. Capability of gathering information about the disaster (B4)
		10. Capability of analyzing the information of the disaster (B5)
		11. Capability of preserving the information about the disaster (B6)
		12. Timely level of release the disaster information (B7)
		13. System's software and hardware level (B8)
		14. Safety of the system (B9)
	Emergency response cost (C)	15. Storage cost (C1)
		16. Handling cost (C2)
		17. Transport cost (C3)
		18. Package cost (C4)
		19. Labor cost (C5)
	The public effect (D)	20. Level of public's knowledge about the disaster (D1)
		21. Satisfactory level of public (D2)
	Emergency preparation capability (E)	22. Construction level of storage network (E1)
		23. Emergency materials preparation capability (E2)
		24. Emergency rescue equipment preparation capability (E3)
		25. Capability of maintain the emergency rescue equipment (E4)
		26. Purchase capability of emergency goods and materials (E5)
		27. Scope of the emergency plan (E6)
		28. Feasibility of the emergency plan (E7)
		29. Construction level of after-disaster arrangement plan (E8)
		30. Construction level of emergency shelters (E9)
		31. Condition of emergency drill (E10)
	Emergency logistics response operation capability (F)	32. Emergency plan execution time (F1)
		33. Administrative department's capability of scheduling people (F2)
		34. Decision-making time of emergency plan (F3)
		35. Distribution capability of emergency resource (F4)
		36. Transport capability of emergency resource (F5)
		37. Gathering capability of emergency resource (F6)
		38. Storage capability of emergency resource (F7)
		39. Dispatch capability of emergency resource (F8)
		40. Supply capability of emergency resource (F9)
		41. Emergency-dealing capability of urgency (F10)
		42. Capability of mobilizing the police (F11)
		43. Capability of mobilizing the populace (F12)
		44. Maintenance capability of social order (F13)
	After-disaster management capability (G)	45. Summary and research work after-disaster (G1)
		46. Capability of reconstruction of infrastructure (G2)
		47. Recalling capability of the emergency resource (G3)
		48. Capability of storing the information of the disaster (G4)
		49. Capability of satiating disaster information (G5)
		50. Capability of analyzing the disaster information (G6)

it is a fairly comprehensive index. This index system is able to reflect the factors which influence emergency logistics support capability.

ELSC EVALUATION MODEL BASED ON FAHP

The influencing factors of the emergency logistics support capability evaluation include qualitative and quantitative indexes. While fuzzy mathematics can put the qualitative problem into quantitative description. Emergency logistics activity itself is a typical grey system which has the characteristics of fuzzy and gray. Fuzzy mathematics and grey theory are integrated to draw a comprehensive evaluation.

In the analysis of general problem, structure comparison between two judgment matrix usually doesn't consider people's fuzzy judgment, but only consider the judgment of the two possible extreme cases: Using the membership 1 to choose an index and at the same time use membership 1 to negate (or membership 0 selection) other scale value. However, in practical problem, a lot of decision information is very difficult to use accurate quantitative values to depict; some qualitative estimation and judgment can only be got from the expert consultation, so the decision information is fuzzy. However, Fuzzy comprehensive decision method is a very effective multi-factor decision method to make comprehensive evaluation of the various-factors affected things. The mainly characteristic is that the evaluation result is not absolutely sure or negative, but showed with a fuzzy set. Fuzzy decision-making method is more accurate to evaluate fuzzy indexes, reveal a clear understanding of various-factors fuzzy things, making multi-level fuzzy scientific and quantitative.

FAHP can over come the defect that in various-factors affected things. AHP method is difficult to meet the consistency and large operation for each comparison between two standards. So this paper the fuzzy method is introduced to improve AHP algorithm.

Expert questionnaire survey: In the above evaluation index system, evaluation criterion U_i and index V_i has different important degree to the evaluation purpose W, which means they have different weights. In order to determine the weights, Analytic Hierarchy Process (AHP) is introduced, with the importance comparison of two pairs of different criterion U_i and different index V_i, establish the judgment matrix and determining the weight of U_i and V_i by using the matrix Eigen value method.

In expert questionnaire survey, experts are required to rate the designated area emergency logistics support capability, fill in the expert rating scale. A total of 52 expert questionnaires were sent, which involves logistics experts in the field and social logistics staff from related organizations. The 44 questionnaires were sent back totally, 41 of the questionnaire are effective, 3 of the questionnaire are invalid. Questionnaire effective rate reached 78%.

Structure fuzzy consistent judgment matrix: Here, the method proposed by Van Laarhoven and Pedrycz (1983) is applied. In this method the triangular fuzzy number is used to represent fuzzy judgment, as following:

- **Definition 1:** Set M as a fuzzy number of filed R, M's membership function μ M: R- [0, 1] is expressed as:

$$\mu_M(x)=\begin{cases}\frac{1}{m-x}x-\frac{l}{m-l} & x\in[l,m]\\ \frac{1}{m-u}x-\frac{u}{m-u} & x\in[m,u]\\ 0 & x\in(-\infty,l]\cup[u,+\infty)\end{cases}$$

In this formula, $l\le m\le u$, l and u represent the lower bound and upper bound value of M. m is the medium value when M's membership degree equals to 1. General triangle Fuzzy number M is expressed as (l, m, u). Triangular Fuzzy number's geometric interpretation: triangular Fuzzy number M is expressed as (l, m, u), when x = M, x completely belongs to M, l and u were lower bound and upper bound. Outside of l, u, it completely do not belong to the fuzzy number M. The operation method of two triangular fuzzy numbers M_1 and M_2:

$$M_1=(l_1,m_1,u_1);M_2=(l_2,m_2,u_2)$$
$$M_1+M_2=(l_1+l_2,m_1+m_2,u_1+u_2)$$
$$M_1\otimes M_2\approx(l_1l_2,m_1m_2,u_1u_2)$$
$$\frac{1}{M}\approx(\frac{1}{u},\frac{1}{m},\frac{1}{l})$$

In the index evaluation between two matrixes, in order to consider the fuzziness, triangular fuzzy M_1, M_3, M_5, M_7, M_9 is used to represent the traditional number 1, 3, 5, 7, 9.While M_2, M_4, M_6, M_8 is the median. M_1~M_9, respectively represent integer from 1~9. Specific definition is expressed in Table 2.

Research group use fuzzy number (M_1-M_9) to express their preference. Here this article hypothesizes there are three research members. Each of them get a fuzzy number from a group of comparison (such as C_1 and C_2 comparison), respectively are (l_1, m_1, u_1) (l_2, m_2, u_2) (l_3, m_3, u_3).

In this study, in the process of given the fuzzy number, in order to make the operation convenient, l, m, u is calculated, respectively. Taken criterion layer index weight as an example, below are the results:

(l,m,u)	A	B	C	D	E	F	G
A	(1,1,1)	(0.89,1.03,1.31)	(0.41,0.63,0.77)	(0.52,0.68,0.92)	(0.92,1.00,1.13)	(0.99,1.19,1.46)	(0.79,0.89,1.12)
B	(0.80,0.99,1.15)	(1,1,1)	(0.39,0.61,0.68)	(0.51,0.67,0.83)	(0.90,1.06,1.10)	(0.94,1.15,1.31)	(0.75,0.85,0.96)
C	(1.39,1.66,2.44)	(1.47,1.66,2.56)	(1,1,1)	(0.89,1.16,1.81)	(1.53,1.68,2.30)	(1.62,1.89,2.85)	(1.28,1.37,2.10)
D	(1.15,1.54,2.04)	(1.24,1.52,2.01)	(0.57,0.89,1.25)	(1,1,1)	(1.31,1.56,1.85)	(1.36,1.73,2.37)	(1.11,1.32,1.82)
E	(0.90,1.00,1.09)	(0.96,1.03,1.15)	(0.470.61,0.66)	(0.58,0.68,0.83)	(1,1,1)	(1.02,1.16,1.27)	(0.86,0.93,0.94)
F	(0.72,0.86,1.03)	(0.77,0.87,1.06)	(0.35,0.53,0.63)	(0.46,0.59,0.75)	(0.80,0.88,1.19)	(1,1,1)	(0.67,0.75,0.95)
G	(0.99,1.21,1.35)	(1.08,1.21,1.39)	(0.50,0.74,0.80)	(0.67,0.84,1.02)	(1.12,1.25,1.31)	(1.16,1.39,1.54)	(1,1,1)

Table 2: Importance comparison between fuzzy judgment matrixes

Index A and B's importance comparison	Definition	Illustration
M_1	Equal importance	Two factors are of equal importance
M_3	A bit importance	Two factors compare with each other, A is a bit important than B
M_5	Obviously importance	Two factors compare with each other, A is obviously important than B
M_7	Much importance	Two factors compare with each other, A is much important than B
M_9	Very importance	Two factors compare with each other, A is extremely important than B
M_2,M_4,M_6,M_8	Medium importance	Medium status corresponding value

Integrate three fuzzy numbers into one:

$$(\frac{l_1+l_2+l_3}{3},\frac{m_1+m_2+m_3}{3},\frac{u_1+u_2+u_3}{3})$$

Repeat the steps until all the comparison turns into a fuzzy number. The result of calculating the fuzzy number of Criterion layer index is (44.96, 52.10, 64.10).

Calculate index comprehensive weights: The comprehensive fuzzy value D_i^k (initial weight) of K layer element is calculated as following:

$$D_i^k=\frac{\sum_{j=1}^{n}a_{ij}^k}{\sum_{i=1}^{n}\sum_{j=1}^{n}a_{ij}^k}, i=1,2,...,n$$

The comprehensive fuzzy rule layer value is as following:

	A	B	C	D	E	F	G
l	0.11	0.12	0.06	0.07	0.12	0.13	0.1
m	0.16	0.16	0.1	0.11	0.16	0.18	0.13
u	0.22	0.23	0.13	0.16	0.22	0.26	0.2

Defuzzification and find out the final weight of C1 to C4, the fuzzy number comparison principle:

Definition 1: M1 (l1, M1, u1) and M2 (l2, M2, u2) are triangular fuzzy number. The possible degree of M1> = M2 can be defined with triangular fuzzy function as:

$$V(M_1\geq M_2)=\mathrm{Sup}_{x\geq y}[\min(u_{M_1}(x),u_{M_2}(y))]$$

$$V(M_1\geq M_2)=\mu(d)=\begin{cases}1 & m_1\geq m_2\\ \frac{l_2-u_1}{(m_1-u_1)-(m_2-l_2)} & m_1\leq m_2, u_1\geq u_2\\ 0 & \text{otherwise}\end{cases}$$

Definition 2: The possible digress of a fuzzy number is greater than the other K numbers can be defined as:

$$V(M\geq M_1, M_2, \ldots, M_k)=\min V(M\geq M_i), i=1,2,\ldots,k$$

Standardize the above weight value then get the final weight of each index. The final weight calculation results of criterion layer index of are as following:

A	B	C	D	E	F	G
0.18	0.19	0.01	0.07	0.19	0.23	0.14

After calculation with the help of EXCEL, the index weight calculation results are marked in Table 3.

From Table 3 we can see that, the largest weight is A5 (4.03%). It means the construction level of emergency logistics information system plays the most important role in emergency logistics support capability. This result reflects the actual situation exactly. For example, the missing important information will cause much confusion and have negative impact on emergency logistics efforts in disaster relief operation. High level of information collecting and transmitting capability, as an important guarantee of emergency logistics, can make the logistics activations response quickly and efficiently. If there is a complete information system and the information from affected areas can be transferred and shared immediately, then the timeliness of emergency logistics will be improved and guaranteed. For the same and similar reasons, index A2, A3, A4 also get a high weight, respectively.

On the opposites side, it is interesting to find that index C1, C2, C3, C4, C5 all get much lower weight, with the average weight as 0.14%. The cause of this phenomenon is that emergency response cost is barely important comparing to other indexes. As for its essence, emergency logistics has the characteristics of weak economy. Emergency logistics is different from business logistics. Business logistics emphasizes the efficiency and the economic benefits. While in emergency logistics the efficiency is more important than economic benefits.

In a summary, the index weight calculation results in Table 3 are consistent with reality and can be helpful to the following case study of typhoon disaster in Zhejiang Province.

Table 3: Emergency logistics support capability performance evaluation index weights ($*10^{-2}$)

Index (V_i)	Weight	Index (V_i)	Weight	Index (V_i)	Weight	Index (V_i)	Weight	Index (V_i)	Weight
A1	3.48	B6	1.52	D2	3.40	E10	1.95	F10	1.92
A2	3.98	B7	2.11	E1	1.99	F1	1.84	F11	1.76
A3	3.92	B8	1.80	E2	1.94	F2	1.90	F12	1.57
A4	3.00	B9	1.96	E3	1.93	F3	1.79	F13	1.73
A5	4.03	C1	0.14	E4	1.79	F4	1.79	G1	2.27
B1	2.25	C2	0.14	E5	1.82	F5	1.83	G2	2.70
B2	2.36	C3	0.15	E6	1.68	F6	1.71	G3	2.30
B3	2.21	C4	0.13	E7	1.93	F7	1.58	G4	1.85
B4	2.05	C5	0.13	E8	1.82	F8	1.74	G5	2.00
B5	2.40	D1	3.60	E9	1.85	F9	1.67	G6	2.61

CASE STUDY OF TYPHOON DISASTER IN ZHEJIANG PROVINCE

Zhejiang province is one of the provinces in which natural disasters take place frequently every year in China. The number of storm, flood, typhoon, landslide and other natural disasters that happens every year is also increasing. The long continental coastline, wide shallow shelf sea area, not only often makes the typhoon land in Zhejiang coastal, but also the specific dynamics environment sets a favorable condition for the development of storm surges. In 1949-2009,40 typhoons landed in Zhejiang province, at an annual average of 0.66, mainly appeared in May to October (Jiang, 2011). So the government pays highly attention on emergency logistics support for typhoon disaster.

Here this article sets a scoring rule as followings, in which the score points are divided into 5 degrees, according to the emergency logistics performance quality:

- Five points means that according to the index the work has been done very perfect and this city can be used as a benchmarking city to other regions for reference
- Four points means that according to the index, the work was relatively perfect, but comparing to the 5 points it still has some aspects to be improved
- Three points means that there is a construction of the index, but it is not perfect and need to take rectification measures
- Two points means the city has only a preliminary concept, there is no unified integration planning
- One point means that according to the index this city's performance is bad, need large rectification or due to special circumstances, such as the typhoon disasters seldom happens so they don't need to input a large number of finance

With the above scoring rule, the score of each index within eleven cities is calculated based on the data from Zhejiang province's yearbook.

After a statistics of each city's marking result, the weight proportion and marking results are multiplied to get each city's comprehensive score which is shown in Table 4.

As illustrated in Table 4, the total score of the 11 cities in Zhejiang province are all above 2.5 points, which means that Zhejiang province's emergency logistics support capability is above the average level. Among the 11 cities, Wenzhou got the highest score (4.4906) while Lishui got the lowest score (3.3678). Here, 11 cities are divided into two groups. The first group includes Wenzhou, Hangzhou, Ningbo, Zhoushan and Jinhua, they scored more than four points. The second group include Jiaxing, Shaoxing, Huzhou, Quzhou and Lishui, scored between 3 to 4 points. Based on this classification, for each city, different construction opinions and improving advices can be suggested, in order to improve its emergency logistics support capability.

Table 4: Final scores of the 11 cities

	Wenzhou	Hangzhou	Jinhua	Zhoushan	Ningbo	Jiaxing
Total score	4.4906	4.3299	4.1885	4.1704	4.1546	3.9427
	Shaoxing	Huzhou	Taizhou	Quzhou	Lishui	
Total score	3.9259	3.9065	3.6056	3.5618	3.3678	

For it has the highest score, Wenzhou is chosen as a benchmarking city for the emergency logistics support capability construction in Zhejiang province. Compared to Wenzhou, some improvements for emergency logistics support capability construction can be proposed, respectively. Taking Huzhou for example, the internal staff scheduling, the information management capability, the disaster information processing work are not good enough, emergency response cost is higher than other cities. So the authority in Huzhou should put more efforts in the standardization construction in staff scheduling and information management.

CONCLUSION

In this study, an emergency logistics support capability evaluation index system was proposed based on lecture reviews and expert questionnaire. FAHP was applied to assessment the weights of the indicators of the evaluation index system. And the case study of typhoon disaster in Zhejiang Province was given, the result showed that the emergency logistics support capability evaluation index system and FAHP method were applicable and had potential advantages in improving emergency logistics support capability construction.

Nevertheless, there are still a great potential and lots of problems in emergency logistics support capability evaluation research. One extension is to consider more complicated and the real situation in different disaster relief operations and to build more suitable evaluation indexes for different disasters. Furthermore, there is an urgency effort for the statistical work, because in this research it is a great challenge to carry out the study without a reliable and authentic source of the data.

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