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Effect Evaluation of Emergency Resource Integration Configuration Based on Fuzzy Analysis Hierarchy Process

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Abstract: Emergency resource integration configuration includes multiple stages and steps, each stages and aspects of the collaboration with each other constitutes an emergency resource integration configuration system. Running effect evaluation can build integrated configuration system by establishing a five-level index system, 16 secondary index system, the application of fuzzy analytic hierarchy process to determine the conclusions of the interval, the effect of the level of the final determination based on the principle of maximum membership.

Key words: Emergency resource, integration, configuration, fuzzy analytic hierarchy process, evaluation

INTRODUCTION

The emergency resource allocation is a process of close coherence which needs take many procedures into consideration, including production, storage, transportation and consumption. The purpose is to achieve the dynamic balance between aggregate supply and total demand (including species and quantity), the balance between production rate, transportation rate and consumption rate and also the balance between forward configuration and inversion recovery. Among them, the first two balances are in view of the rescue efficiency while the third one reflects the economic principle of the distribution and consumption of resources.

DEFINE OF THE INTEGRATION OF EMERGENCY RESOURCE ALLOCATION

With continuous reinforcement of the dependency between many individuals and links, people pay more and more attention to the “gathering”, among which “integration” is used more frequently. From small aspects, like an enterprise that includes distribution integration, forward integration and backward integration, etc., from large aspects, like between countries that includes regional integration, economic integration, monetary integration and so on. We also emphasize integration of different links of the same kind things, such as the integration of project management, logistics integration and so on.

So, the concept of integration can be understood from two perspectives: One is using appropriate methods to integrate two or more different and inharmonious items as a whole and establish synergy which can achieve organizational goals (Wang *et al*., 2010). The other is that different aspects of the same item can be connected, according to systematic principles, to cooperate with and promote each other which can form an integrated supporting system.

For features of the object in this study, we use the second expression method to define emergency resources integration as follows: it is a process to hit the intended target. It means that in emergency management, we regard emergency rescue as the goal, connect and coordinate different stages and links of resource allocation process according to systematic principles. This definition considers two layers of integration: the integration of emergency resources allocation process and the integration of single phase and internal process (Zhou, 2011a):

- **Integration of whole process:** That is the connections of periods which include normal period and dynamic period. Normal period is the fundament and assurance of the integration and its emergency point is the key node; dynamic period is actions and results, whose cores are multiple supply points and multiple demand points and it also includes reversing resources allocation. Implementation of the integration of whole process is not natural, so it

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needs more management aspects which is the key of implementation of the coordination between the periods

- **Integration of internal parts of periods and integration of management process:** That is the relationships of links which is reflected in two different periods and management processes. Every period and process covers many links and the integration of links is called secondary integration which is the key of the integration of period

The above integrations aim at the allocation process. There are many similar allocation processes in different regions which can produce the relationship between the path and the path, namely the horizontal relationship. According to the needs of disasters, an allocation path may not achieve all desired effects, so it also needs many multiple paths and requires certain elasticity of different allocation paths.

INFLUENCE FACTORS AND CHOICES OF EVALUATION METHODS OF THE INTEGRATION OF EMERGENCY RESOURCE ALLOCATION

Emergency management process includes four processes-prevention and emergency preparedness, monitoring and early warning, emergency disposal and rescue, afterwards restoration and reconstruction. As the main reflect of the ability of emergency management, the integration of emergency resource allocation is affected by many factors.

First is the accurate prediction and analysis of the demands for disasters. Before the disasters come, according to the regional social environment, traffic and disaster history data, an applicable model should be set up to meet the possible resource requirements and on-site demands should be simulated through the computer.

Second is the adequacy and sustainability of the supply of resources. Integration of emergency resources allocation is the inherent requirement of emergency management and the base of the success of disaster relief, whose goal is to achieve dynamic fuzzy balance of the total demand and total supply.

Third is to achieve harmonization of "Three Points and One Line". Three points are disaster area, emergency point and production site; one line refers to the transport routes. With the support of GIS (Geographic Information Systems), DSS (Decision Support System) and MIS (management information system), information sharing and synchronization of execution between these points and line can be achieved (Zhou, 2011b).

Fourth is the dynamic coordination in the forward supply and backward allocation. The backward allocation of resources is also an integral part of integration. Emergency resources allocation emphasizes timeliness and weakens economic effects. Providing disaster relief resources at the lowest cost is the best idea on the premise that the rescue is guaranteed. Forward transporting system is designed to be controllable in elasticity and flow which can adjust the frequency, type and quantity of allocation and transport according to the different disasters and on-site needs, in order to reduce in-transit cost and recycling and reallocation cost of resources.

Evaluation of effects of the integration of emergency resources allocation is a relatively complex process, as the quantity and span of indicators referred to, including first and second class indicators, are huge. More difficult thing is that the evaluation is a combination of static and dynamic states. The evaluation of usual resources allocation is easier because of its relatively static state of the data and the relatively simple availability and processing of the data. While the evaluation of resources allocation in emergency response phase is relatively complex, because resources also change with the changes of the frequency, time and path of the demand and the data has a strong dynamic state.

In Fuzzy Analytic Hierarchy Process, fuzzy consistent matrix is first constructed. It determines the comprehensive evaluation values of different options which can be considered as the basis for selecting the optimal solution, through hierarchical sorting to calculate the weight of each indicator. The evaluation results are not absolutely positive or negative, but in a fuzzy set.

The evaluation of effect of emergency resources integrated allocation selects FAHP (Fuzzy Analytical Hierarchy Process) as an analysis tool, considering mainly from the following points:

- The features of evaluation method itself. The method pays attention to the influences of humans and reflects experts' advice on the evaluation of single factor. With management integration in the balanced position in it, the resource allocation highlights eight main parts, in which responsibility entity and management entity take the responsibility for scheme designing. The foundation of decision-making lies in the fusion of self experience, obtained firsthand materials and related analysis methods
- The requirements of emergency resources allocation itself. There is a big difference of resources allocation between emergency state and normal state. Due to

sudden matters, the designed indicator has no specific corresponding data, so the indicator must be evaluated. Furthermore, many indicators present in qualitative and blurry forms, hindering the final judgment. However, the FAHP overcomes these restrains

- The result of evaluation can be elastic. The result of FAHP is not a fixed data, but a range which is corresponding to pre-set goals. The result can be determined according to the maximum subordination principle which avoids the program only having "good" or "bad" evaluation standard. Evenmore, for each program the matching degree will be judged, so that policy makers can adjust the program according to the disaster in a timely manner to achieve the desired objectives

ANALYSIS OF EVALUATION INDICTOR SYSTEM

The integration of emergency resources allocation is an orderly and coordinated complex system which has numerous steps and links. Its effectiveness evaluation can be divided into five first grade indictors according to its constitutions and flows: the ability to produce emergency resources and the deliver ability to emergency points, the layout of the emergency points and the internal control ability, the dispatch ability from emergency points to demand points, the ability to secondarily dispose and control the resource on site, the operation capacity of established recourse allocation system. Each first grade indictor can be divided into several second grade indictors. This indictor system which includes the key element of normal integration, dynamic integration and management integration can represent resources allocation better and has a sufficient representation.

Production and supplying ability of emergency resources: The orderly production is the guarantee of adequate supply. The production sites that are established by the various procedures should be in accordance with the emergency storage requirements to organize the corresponding daily production and supply; When disaster occurs, it can quickly adjust and transform the production and provide rapid consumption of resource needs. The specific indicators include the production layout and quantity, the production capacity, the distribution capacity between production sites and emergency sites.

Layout and internal control of emergency spots: In general, the emergency resources that have been produced should stay for some time in emergency spots and then they should be handled properly in the picking area to carry on the reasonable shipment according to the needs of disasters. Specific indicators include the number of emergency spots and their location layout, the linkage of the multi-emergency-spots, the type and quantity of resource that emergency spots can call and the internal disposal ability of emergency spots.

Transport between emergency spots and destinations: In general, the emergency points are often laid out those areas that disasters may occur which have the characteristics of scientific rationality and can well meet the needs of the scene. But when severe disasters are severe, the environment will be greatly damaged, so transport will be a big problem, such as the Wen Chuan Earthquake. Specific indicators include callable integrity rate of the vehicle, road.

Second-time allocation and control ability of resource on scene: After disasters occur, the scene is very chaotic. The analysis of the disaster, organization of the disaster relief personnel, arrangement of victims, prevention and control of epidemic and so on all need specific physical resources, so as to keep the scene smooth and orderly. Specific indicators include the organization of resource allocation personnel, the location of the shelter, the concentration degree of the demands on site and the comprehensive management on site.

Ability to run of emergency resource system: The implement ability is the key point for the integration system of resource allocation to achieve the abilities mentioned above. The smooth and efficient operation of the system is a guarantee of other abilities which is mainly reflected in the management integration. Specific indicators include the coordination of phases and links, technical support and information processing.

According to the kinds and contents of the index, the effect of the integration of disaster emergency resource allocation can be determined evaluation index structure diagrams, as shown in Table 1. The performance of integrated resource allocation (A_1) is the goal layer, the primary indicators (B_1-B_5) belong to the criterion layer, the secondary indicators (C_1-C_{16}) are the secondary criterion layer and the decision-making units for performance evaluation system belong to the solution layer.

CALCULATION OF EVALUATION RESULTS OF FUZZY ANALYTIC HIERARCHY PROCESS

According to index hierarchy frame, the fuzzy complementary judgment matrix can be constructed. The matrix A represents the importance of every factor on this level relative to that of last level that is:

Table 1: Index system and the fuzzy hierarchy frame

Target	First-level index	Second-level index	
Effect of integrated resource allocation A_1		Resource production and supply capacity	
	B_1	Layout and quantity of production points	C_1
		Productivity of production points	C_2
		Distribution between production points and emergency points	C_3
		Layout and internal control of emergency points	
	B_2	Quantity and layout of emergency points	C_4
		Linkage among multi-emergency points	C_5
		Callable resources at emergency point	C_6
		Handling capability inside emergency points	C_7
		Dispatching between emergency points and demand points	
	B_3	Callable vehicles	C_8
		Serviceability rate of the road	C_9
		On-site resource configuration and control	
	B_4	Personnel organization of resource allocation	C_{10}
		Location of shelters	C_{11}
		Demand concentration at disaster scenes	C_{12}
		On-site general management	C_{13}
		Operating capability of the system	
	B_5	Coordination among stages and aspects	C_{14}
		Technical support	C_{15}
		Information processing	C_{16}

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

Thereinto, a_{ij} represents the importance evaluation of c_i and c_j relative to that of last level.That is given by using the subjection degree of fuzzy relation between these two factors. The matrix A satisfies the following constraint:

$$a_{ij}+a_{ji} = 1;\ 0<a_{ij}<1;\ a_{ii} = 0.5 \quad (2)$$

After establishing the comparison scale from 0.1-0.9, the value of a_{ij} can be worked out by using the above Delphi method and by doing questionnaires to the experts.

Therefore, with the purpose of transforming the fuzzy complementary judgment matrix to the fuzzy consistent matrix $R = (r_{ij})_{n\times n}$, the following method can be used:

$$\begin{cases} r_i = \sum_{j=1}^{n} a_{ij} \\ r_{ij} = \dfrac{r_i - r_j}{2(n-1)} + 0.5 \\ i, j = 1, 2, \cdots, n \end{cases} \quad (3)$$

According to the calculated fuzzy consistent matrix R, calculate the weight of every index:

$$w_i = \frac{\sum_{j=1}^{n} r_{ij} + \frac{n}{2} - 1}{n(n-1)} \quad (4)$$

Based on data from Delphi method, calculate the weight of every factor relative to factors superior to them. According to the affiliation of every evaluation index, multiply the weight of the index layer by that of the criterion layer to get the total weights of every factor relative to the total evaluation goal(Yang *et al*., 2011).

Thereupon, based on the calculated index weights and scores, the total score S which represents the effect of emergency resource integration configuration can be worked out. Then, the final evaluation and the related information of every index come out:

$$S = (s_1, s_2, \ldots, s_n)\,(w_1, w_2, \ldots, w_n)^T \quad (5)$$

Thereinto, S_i is the score of the i index and w_i is the weight.

Then, the writer will evaluate the designed integration solution (without considering the reverse configuration of resource) 20 experts of this field are invited to evaluate the givesn indexes, in the meantime, to process the related data. Subsequently, results are shown as Table 2.

Confirmation of all indicator weights: “Performance of integration” itself is a vague concept and the 16 relevant factors have different influences on the “performance” and contain various practical implications. Hence, fuzzy comprehensive evaluation method can be used to process the above data to give a proposal.

Concerning the interrelation between the factors, they can be classified into four main-factor levels (principle factors): Configuration of production points:

$$A = (C_1, C_2, C_3)$$

Table 2: Evaluation of single indicator by experts

Assessme index		Excellent	Good	Medium	Poor	Very poor
Layout and quantity of production points	C1	5	6	8	1	0
Productivity of production points	C2	5	10	4	1	0
Distribution ability between production and mergency points	C3	6	6	6	1	1
Quantity and layout of emergency points	C4	7	7	5	1	0
Linkage among multiple emergency points	C5	6	7	5	1	1
Available resources at emergency points	C6	9	9	2	0	0
Internal disposal ability of emergency points	C7	4	8	6	1	1
Available vehicles	C8	4	11	5	1	0
Serviceability rate of the road	C9	5	10	4	1	0
Organization of resource allocation personnel	C10	3	5	7	3	2
Location of shelters	C11	4	6	8	2	1
Demand concentration degree at disaster scenes	C12	3	8	6	3	0
On-site comprehensive management	C13	2	11	6	1	0
Coordination between the links	C14	3	7	8	1	1
Technical support	C15	4	10	4	2	0
Processing of information	C16	5	9	5	1	0

Table 3: Value of each factor

Dominant factors	Secondary factors		Weight
(A) Configuration of production points 0.2	Layout and quantity of production points	C_1	0.3
	Production capacity	C_2	0.4
	Distribution ability between production and emergency points	C_3	0.3
(B) Configuration of emergency points 0.3	Quantity and layout of emergency points	C_4	0.2
	Linkage among multi-emergency points	C_5	0.2
	Available resources at emergency points	C_6	0.3
	Internal disposal ability of emergency points	C_7	0.3
(C) Traffic capacity 0.1*	Available vehicles	C_8	0.6
	Serviceability rate of the road	C_9	0.4
(D) Organization and management capacity 0.4	Organization of resource allocation personnel	C_{10}	0.1
	Location of shelters	C_{11}	0.1
	Demand concentration degree at disaster scenes	C_{12}	0.1
	On-site comprehensive management	C_{13}	0.2
	The coordination between the links	C_{14}	0.2
	Technical support	C_{15}	0.2
	The processing of information	C_{16}	0.1

*The weight of transport capacity differs in different types of disasters, for example, earthquake demands for high level weight of transport capacity. In home destructiveness of general disasters toward roads is relatively less, so set the weight being 0.1 is reasonable

configuration of emergency points:

$$B = \{C_4, C_5, C_6, C_7\}$$

transport capacity:

$$C = \{C_8, C_9\}$$

organization and management capacity:

$$D = \{C_{10}, C_{11}, C_{12}, C_{13}, C_{14}, C_{15}, C_{16}\}$$

According to practice and suggestions given by concerned experts, Delphi method can work out the weight of every factor just as Table 3 and make out membership degree of the principle factors. Thereby, we can evaluate effect of emergency resources integration configuration objectively.

Confirmation of multistage fuzzy comprehensive evaluation vector: Substituting the statistic data of evaluation given by 20 experts on given every single index, then we can compute Vector of fuzzy comprehensive evaluation at all levels:

- Evaluation vector of configuration of production points:

$$A_1 = a \circ R = \begin{bmatrix}0.3 & 0.4 & 0.3\end{bmatrix} \circ \begin{bmatrix}0.25 & 0.3 & 0.4 & 0.05 & 0\\ 0.25 & 0.5 & 0.2 & 0.05 & 0\\ 0.3 & 0.3 & 0.3 & 0.05 & 0.05\end{bmatrix} \tag{6}$$
$$= \begin{bmatrix}0.2650 & 0.3800 & 0.2900 & 0.0500 & 0.0150\end{bmatrix}$$

- Evaluation vector of configuration of emergency points:

$$B_1 = \begin{bmatrix}0.2 & 0.2 & 0.3 & 0.3\end{bmatrix} \circ \begin{bmatrix}0.35 & 0.35 & 0.25 & 0.05 & 0\\ 0.3 & 0.35 & 0.25 & 0.05 & 0.05\\ 0.45 & 0.45 & 0.1 & 0 & 0\\ 0.2 & 0.4 & 0.3 & 0.05 & 0.05\end{bmatrix} \tag{7}$$
$$= \begin{bmatrix}0.3250 & 0.3950 & 0.2200 & 0.0350 & 0.0250\end{bmatrix}$$

- Evaluation vector of transport capacity:

$$C_1 = [0.6 \quad 0.4] \circ \begin{bmatrix} 0.2 & 0.55 & 0.25 & 0.05 & 0 \\ 0.25 & 0.5 & 0.2 & 0.05 & 0 \end{bmatrix} \quad (8)$$
$$= [\ 0.2200 \ \ 0.5300 \ \ 0.2300 \ \ 0.0500 \ \ 0]$$

- Evaluation vector of organization and management capacity:

$$D_1 = [0.1 \quad 0.1 \quad 0.1 \quad 0.2 \quad 0.2 \quad 0.2 \quad 0.1] \circ$$
$$\begin{bmatrix} 0.15 & 0.25 & 0.35 & 0.15 & 0.1 \\ 0.2 & 0.3\ 0.4 & 0.1 & 0.05 & \\ 0.15 & 0.4 & 0.3 & 0.15 & 0 \\ 0.1 & 0.55 & 0.3 & 0.05 & 0 \\ 0.15 & 0.35 & 0.4 & 0.05 & 0.05 \\ 0.2 & 0.5 & 0.2 & 0.1 & 0 \\ 0.25 & 0.45 & 0.25 & 0.05 & 0 \end{bmatrix} \quad (9)$$
$$= [\ 0.1650 \quad 0.4200 \quad 0.3100 \quad 0.0850 \quad 0.0250]$$

- Comprehensive evaluation vector:

$$A = [0.2 \ \ 0.3 \ \ 0.1 \ \ 0.4] \circ \begin{bmatrix} 0.265 & 0.380 & 0.290 & 0.050 & 0.015 \\ 0.325 & 0.395 & 0.220 & 0.035 & 0.025 \\ 0.220 & 0.530 & 0.230 & 0.050 & 0 \\ 0.165 & 0.420 & 0.31 & 0.085 & 0.025 \end{bmatrix} \quad (10)$$
$$= [\ 0.2385 \quad 0.4155 \quad 0.2710 \quad 0.0595 \quad 0.0205\ ]$$

- Ranking the comprehensive scores

Experts define 5 measurement levels with semantics scale: Excellent, good, moderate and poor, very poor. To facilitate the calculation, they quantify semantics scale of subjection and number them 5, 4, 3, 2 and 1 successively. Subjective measurement takes advantage of semantics scale of the five levels. The quantitative evaluation criterion is as follow:

$$\begin{aligned} V_A &= 5\times 0.265 + 4\times 0.380 + 3\times 0.290 + 2\times 0.050 + 1\times 0.015 = 3.8300 \\ V_B &= 5\times 0.325 + 4\times 0.395 + 3\times 0.220 + 2\times 0.035 + 1\times 0.025 = 3.9600 \\ V_C &= 5\times 0.220 + 4\times 0.530 + 3\times 0.230 + 2\times 0.050 + 1\times 0 = 4.0100 \\ V_D &= 5\times 0.165 + 4\times 0.420 + 3\times 0.31 + 2\times 0.085 + 1\times 0.025 = 3.6300 \end{aligned} \quad (11)$$

Table 4: Quantified ranking standards of evaluation

Score	Measurement level	Rating
	Excellent	E1
	Good	E2
	Medium	E3
	Poor	E4
	Very poor	E5

According to Table 4,the above calculation shows that the evaluation result of "configuration at production points" is "good", belonging to E_2 level according to the above rating standard and the evaluation results of the other three indicators are "good", also belonging to E_2 level. Based on the rating scores of each index those four can be sorted. The evaluation result of "Transportation ability" is a little higher than that of other indicators. And the score of comprehensive evaluation is:

$$\begin{aligned} V &= 5\times 0.2385 + 4\times 0.41455 + 3\times 0.2710 + \\ & 2\times 0.0595 + 1\times 0.0205 = 3.8070 \end{aligned} \quad (12)$$

It is indicated that the performance of designed resources integration configuration is "good", belonging to E_2 level.

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