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Systems Engineering Procedia 5 (2012) 240 – 247

Procedia Systems Engineering

International Symposium on Engineering Emergency Management 2011

Research on efficiency of collaborative allocation system of emergency material based on synergetic theory

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Abstract

Emergencies increasingly become so comprehensive covering large areas and derivative that a single organization can not meet the requirement of emergency disposition. Therefore, collaborative allocation of emergency material involving multi-organizations becomes one of the key content of emergency management. The collaborative allocation system of emergency material has the characteristics of complex system. Based on synergetic theory of systems engineering and the actual problem of low efficiency of collaborative allocation of emergency material in our country, the key factors influencing efficiency improvement are analyzed in respect of people, organization, material, information, technology and strategy. By adopting and improving QSIM (qualitative simulation method), the inner action mechanism is studied and the conclusion is that the responsibility and authority definition, the coordination ability of decision-makers and information transmission efficiency are the most important factors for the efficiency of collaborative allocation. The measures set forth in this paper are for the reference of relevant decision-makers and we hope it can be helpful for their decision making.

Key words: Synergetic theory; Emergency material allocation; Qualitative simulation; Action mechanism;

1. Introduction

In recent years, emergencies have become comprehensive and derivative and have gone beyond the disposition capability of single type organization. From SARS, our study field, society and government have been attaching great importance to emergency system construction and achieve significant results. Especially in recent years, the emergency offices have been increasingly perfected. Emergency management system and joint-action mechanism have been established, but the problems of undefined responsibilities and authority of different departments, action of different departments only from its own view, redundant construction still exist. The collaborative allocation system of emergency material has the characteristics of complex system involving multi-type and multi-grade departments and organizations and all kinds of factors, which results in the low efficiency of collaborative allocation of multi-departments. The important way and core task is to analyze the relevant factors influencing the efficiency of collaborative allocation of emergency material and distinguish key factors and improve the key factors.

Scholars at home and abroad have been studied the collaborative efficiency of emergency management from different aspects and put forward factors influencing emergency collaborative efficiency accordingly. But most literatures only pay attention to the importance of the organization and people. For example, Comfort (1990)

 doi:10.1016/j.sepro.2012.04.038

proposes the organizations conflict among main bodies of the emergency management has influenced with emergency collaborative [4], Chen Xing et al (2010) consider that emergency collaborative decision-making is a multi-objective process [5]. Quarantelli (1982) believes that to a large extent the inter-organizational differences from emergency response objectives [6] affect the collaboration efficiency. Comfort (2001) [7] and Waugh (2003) [8] believe that cultural differences from organizations bring the effect of emergency collaborative efficiency. With researching from the perspective of disaster organizational behaviour, scholars propose that the effective factors of collaborative efficiency include the close degree of inter-organizational relationships (Trebilcock, 2006) [9], the close degree of relationships within the organization (Mendonca, Jefferson and John Harrald, 2007) [10]. From case studies, McEntire (2002) [11] and Scott E. Robinson (2006) [12] analyze tornado happening in the city of Fort Worth, Texas in U.S., and hurricane Katrina and other disasters, they believe that the lack of the exchange among new entrants to the emergency response, organizational authority conflicts, language barriers and the relationship among organizations affect the efficiency of emergency collaboration to a different extent. Chen R (2008) also concerns highly about the relationship among organizations [13]. Michael McGuire (2010) thinks that simplification of the structure of emergency organizations, efficient execution of emergency staff, the consistency for decision-makers to understand the seriousness of emergencies and emergency response abilities have an impact on the emergency organizations synergy [14].

Most scholars believe that materials or resources are security factors of emergency collaboration. The resource availability (type and quantity) (Comfort, 2004) [15], the deficiency of emergency equipments (McEntire, 2002) [11] and the adequacy of emergency resources (Chen R, 2008) [13] have an important impact on the efficiency of emergency collaboration.

In terms of information and technology on emergency collaboration, scholars study emergency collaboration respectively from the channels and effectiveness of the information transmission, technology and knowledge sharing or learning and other perspectives. Some factors may affect the efficiency of collaboration. They are effective emergency information transmission (Comfort, 2001) [7], the effective channels of information transmission (Kapucu, 2008) [16], information transmission efficiency (Chen R, 2008) [13]. Drabek (1985) thinks that improving the emergency plans, multi-agent decision-making model, and emergency decision-making, emergency command center, multi-agent emergency drills all have an impact on the synergy of emergency response [17]. Multi-agent normalization learning (Ali Farazmand, 2007) [18], efficient emergency interactive learning (Margaret T. Crichton, 2009) [19], the effective use of related technologies (Kapucu, 2008) [16]and the knowledge sharing of emergency response (Lalonde & Marincioni F, 2007) [20][21] can improve the efficiency of emergency collaboration; Also, timely and accurate decision-making knowledge (Zhao Lindu, 2009) can provide intellectual support and information security for inter-city emergency collaboration[22].

With the analysis on the disposal process and the disposal strategies of emergencies, some scholars propose that the condition of new tasks and disasters [6] [23], the dynamic changes of the disasters [7], the severity of disasters [15], the difference from emergency response phases [12] cause some influence on collaborative disposal.

There are a large number of collaborative influence factors mentioned above. But they do not be pointed out that the differences from their influences on the efficiency of emergency collaboration, and so it is difficult to identify the work priorities of improving emergency management method in practice. Secondly, there are no study on the relevance among these factors in a unified system angle, and regarding them as an organic whole together to achieve the ultimate goals. Thirdly, there is no literature about the efficiency of emergency material collaborative allocation. In this paper, we analyze the elements affecting collaborative allocation of emergency material at first, and then analyze the influence factors relating to each element, so that we can do a comprehensive and systematic study. Getting the actual data to analyze the important degree of the influence factors and cooperative mechanism is very difficult or can't get. Therefore, to resolve this problem using qualitative model and simulation methods have important practical significance. However, such problems have high complexity and a variety of constraints. To deal with them conveniently, we must be based on the actual situation to distinguish the key factors. Erasing the relatively minor factor is the equivalent of erasing many constraints, which causes the expansion of the combination results obtained by qualitative simulation; this makes it difficult to deal with conventional simulation. In this paper, we put forward the improvement methods of qualitative simulation technology-QSIM algorithm according to the need of the question in this paper, analyze the action mechanism of the key factors, and study the strategies and measures of improving the efficiency of collaborative allocation.

2. Analysis on the core elements and the influence factors

The collaborative allocation system of emergency material has several main elements, including people, organization, material, information, technology, strategy, and so on. People and organization are the most critical elements in the process of emergency material collaborative allocation, involving the decision makers, the executives of materials allocation and daily and "wartime" situation of organizations. People and organizations are decision-makers and executants of all measures and actions. They have a close contact and a complex relationship. They not only learn and assimilate knowledge and technology each other, but also exchange and assimilate information and culture each other; they complement each other, share risk together and the act of any part can not be ignored. Considering the simplification and practical use of the models, in this paper we mainly studies four factors, which are the collaboration abilities of policy makers, executants' cooperation abilities, complexity of organization structure and the daily tightness of the organizational relationships.

"Material" is the support elements in the collaborative allocation system of emergency material, and also is the tools and objects of the collaborative allocation. All kinds of emergency material are made co-allocation in response to emergency disposal, with the support of information platform, in the scheduling of the command center, and under the guidance of the scene allocation command system. The main factors about "Material" influencing the efficiency of emergency material collaborative allocation are the advance of equipment and facilities, the material complete condition of support and supplies. These two factors can describe the "Material" elements from two angles of the sufficient conditions and advancement of materials, and they can fully reflect the physical security condition of allocation system.

The timely and accurate information is essential for the emergency material allocation. And the complexity of emergency material allocation makes new demands for information and technology. Facing significant emergencies, the first question is that how to achieve a comprehensive monitoring and control, and to understand the condition of the emergency scene rapidly and dynamically, then convey the original information accurately to the relevant departments. The second question is that facing different conditions of disasters, how to predict the trends and consequences scientifically, then identify the demand quantity of material, and convey this information to the executive branch. The third question is that for cross-departmental emergencies, how to make decision scientifically, coordinate comprehensively and dispose efficiently, determine the temporary mechanism and program, adjust the original plan according to the practical situation. Considering the characteristics of the collaborative allocation process, we select four factors including the effectiveness of information transfer, technology sharing and adaptability, completeness of original plans, multi-organizational drill maturity.

"Strategy" element is the "software" support environment of collaborative allocation system. It means a series of laws and policies, institution, measures and standards or rules involved in the process of emergency material collaborative allocation. "Strategy" elements include three factors: collaborative policy and mechanism, target consistency, definition of responsibilities and authority.

3. The improved qualitative simulation analysis method

Figure 1 is the comprehensive model of the causal relationship between the main parameters of the collaborative allocation system. The model reflects the structural relationship between the influencing factors involved in the process of emergency material collaborative allocation.

In the emergency material collaborative allocation system, decision-making, adopting policies and mechanisms, the state of facilities and equipment, improving and exercising plans, organizational structure and organizational relationships between the relevant agencies and organizations involved in the allocation process have a quite close relationship with the collaboration allocation efficiency. We regard the change of emergency material collaborative allocation factors as a continuous optimization of the dynamic process and forecast the collaborative allocation effect after a specific time period by the simulation. Because of the representation and the relative independence of factors, the model does not include the factors that influence the collaborative allocation process less such as the degree of the similarities and differences between organizations cultural, the regulation of the action consistency in the organizations because these factors won't change too much in the short term. What's more, considering the actual situation of emergency management, we choose the responsibility and authority definition, organization structure complexity.

In Figure 1, the "+" indicates that the increase of the arrow tail variables will result in the increase of the arrow variables, "-" indicates that the increase of the arrow tail variables can lead to the decrease of the arrow variable. The symbols "+","-" are not only the significance of positive and negative related but also the cause and effect relationship between the actions. The arrow tail variable is the cause and the arrow variable is the result. For example, the higher the advancement of the equipment and facilities is, the stronger the flexibility of the system is. And technology sharing and adaptability are more likely to be improved. We should make organizational structure as simple as possible, then the information transmission "journey" is relatively short, the information transmission time corresponding is less and the error rate is low, so we can improve the effectiveness of information transmission. The change of the structure of organization can directly affect the ability of cooperation of executives because the complicated organizational structure makes departmental level more. And it will be easy to disorder in the link of approval. If the subjective effect factors increase, the implementation of collaborative activities is affected. All of these factors influence each other and ultimately affect the efficiency of material collaborative allocation directly or indirectly.

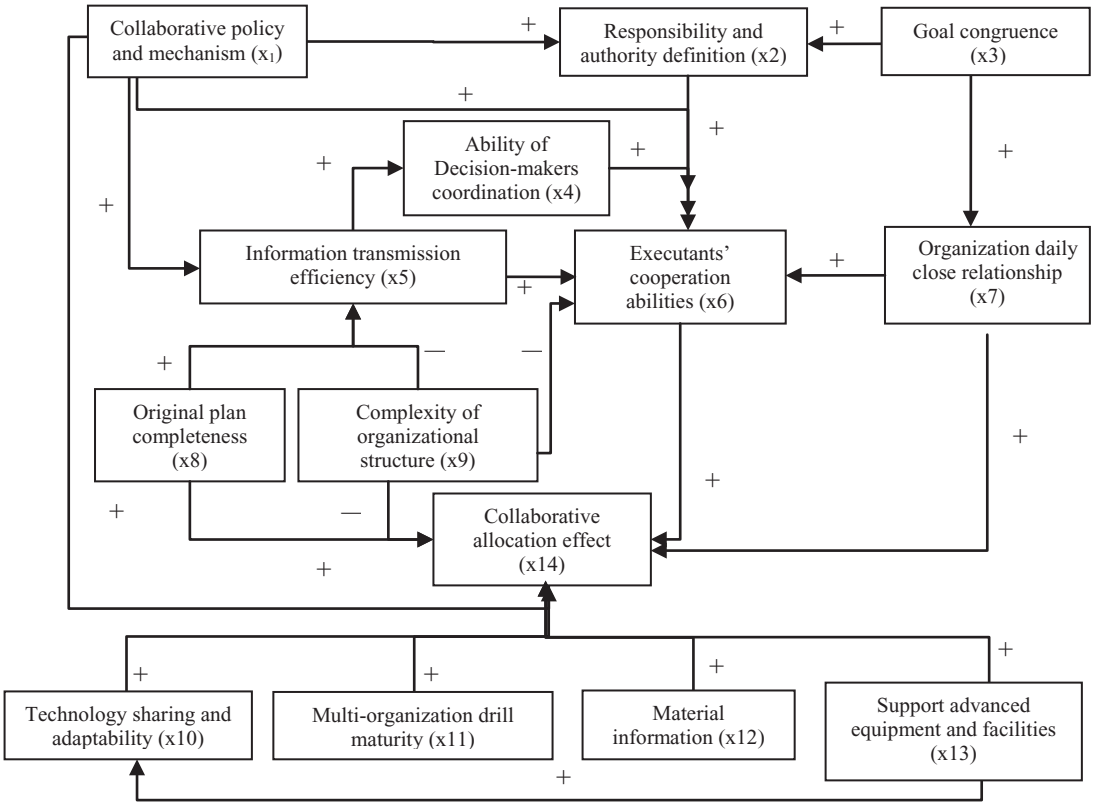

Figure 1. The cause-effect relationship model of main parameters in emergency material collaborative allocation

It's quite difficult to describe the development of most parameters quantitatively. We can not establish a precise mathematical model, and can only get the qualitative knowledge of the changes of the system. At first, we determine the states of each link and related factors based on the analysis of emergency material collaborative allocation system. Then we need to simulate the states of each link and relevant factors after some time. Due to the state of allocation development and the dynamics of all aspects and factors, the effect of changes in the allocation process is improved. By the results we propose improvement measures about the original state of the system.

The QSIM algorithm is adopted to simulate the process of emergency material collaborative allocation. In terms of time, the simulation of the time period from t_0 tot_1 is carried out, the quantity of state results are from 14 to 37. Table 1 shows the state results of the key factors from t_0 tot_1, and indicating that with the qualitative simulation proceeding, the results have a continued "inflation" phenomenon of combinations. The reason is that the defined

constraints are too few, which leads to not tight constraint, and this makes “filtering” ineffective. For example, the variable of "information transfer effectiveness" turn into the better state, in fact, it is affected by many constraints including natural and man-made conditions. The adverse weather conditions may interrupt the signal transduction, and the personnel’s identification may have error, and so on. If we can define more constraints, especially if there are algebraic constraints existing, the combinations of the simulation process are reduced greatly and the decision is to be more beneficial. However, the study will be made complicated very much, and does not have operability in practice. Of the 13 key factors influencing the efficiency of emergency material collaborative allocation, which factors play a decisive role and need be improved mainly, which factors should be given general concern, thus we need improve the QSIM algorithm for further discussion and analysis about the problem.

We get the initial value of all the factors in time t_0 (state scores and change trends) according to expert knowledge and experience evaluation. After a time period from t_0 to t_1, owing to the development of the collaborative allocation system and surroundings, the factors states have a certain degree of change. They affect the efficiency of collaborative allocation directly or indirectly. In order to study the change magnitude of the factors and the important degree for the efficiency of collaborative allocation, first of all, we define the standard of the degree of state changes. It’s defined that the change from the point value to the interval value is regard as "0.5 box", the change from the point value to an adjacent integer point value is regard as "1 box", the trend toward the positive (changes speed up or get better) is regard as "0.5 box", that to the negative (changes slow down or get worse) is regard as "-0.5 box". If changes are not obvious the trend is regard as the "0". If the new situation comes up, the change from the point value to the interval value is regard as "<0.5 box", that from the point value to an adjacent integer point value is regard as "<1 box". In this way the standard value that each variable state changes can be calculated. And for several successor states of the variable, we make the value of the minimum state changing as the standard. In Table 1, the values behind the variables in the first column are the final calculation results. Taking the results for the judgement, we analyze the action mechanism of the influence factors.

Table 1. The main simulation results

variable	$t=t_0$	$t\in(t_0,t_1)$	$t=t_1$
X_1(△<0.5)	<-1,+>	<(-1,0),+>	<0,0> <0,+> <(-1,0),+> <l^*,0>,$l^*\in$(-1,0)
X_2(△=1.5)	<-1,0>	<(-1,0),+>	<0,+> <0,0>
X_3(△=0)	<0,0>	<0,0> <(0,1),+>	<1,0> <1,+> <(0,1),+> <l^*,0>,$l^*\in$(0,1)
X_4(△=1.5)	<1,0>	<(1,2),+>	<2,+>
X_5(△=1.5)	<0,0>	<(0,1),+>	<1,+>
X_6(△=1)	<0,+>	<(0,1),+>	<1,+>
X_7(△=1)	<0,+>	<(0,1),+>	<1,+>
X_8(△<0)	<(0,1),+>	<(0,1),+>	<1,0> <1,+> <(0,1),+> <l^*,0>,$l^*\in$(0,1)
X_9(△=0)	<(0,1),->	<(0,1),->	<0,0> <0,-> <(0,1),-> <l^*,0>,$l^*\in$(0,1)

$X_{10}(\triangle=1.5)$	<-1,0>	<(-1,0),+>	<0,+>
$X_{11}(\triangle=0)$	<1,0>	<1,0> <(1,2),+>	<1,0> <2,0> <2,+> <(1,2),+> <l^*,0>,$l^* \in (1,2)$
$X_{12}(\triangle<0)$	<(0,1),+>	<(0,1),+>	<1,0> <1,+> <(0,1),+> <l^*,0>,$l^* \in (0,1)$
$X_{13}(0<\triangle<1.5)$	<1,+>	<(1,2),+>	<2,0> <2,+> <(1,2),+> <l^*,0>,$l^* \in (1,2)$
$X_{14}(\triangle=1.5)$	<-1,0>	<(-1,0),+>	<0,+>

4. Analysis on the action mechanism and discussion of the improving measures

Based on the above calculation results, the factors influencing the efficiency of collaborative allocation are divided into four categories. The first category (the variation is less than"0 box") includes original plan completeness and material completeness. Their status values are relative to the present condition of the environment, the bodies' endurance when facing disasters, the disposal ability of disaster resistant bodies, as well as the destruction ability of disasters, which turn bad. This shows that, for the two factors, the speed of turning a good trend is lower than the speed of emergencies to turn bad trend (or more difficult to dispose, or stronger destruction ability). This is accord with the present actual situation. Taking the effectiveness influencing collaborative allocation into consideration, since the two factors turn bad, the increasing of collaborative allocation efficiency is still apparent. Therefore, it shows that the importance of the two factors, for collaborative allocation system, is limited.

The second category (the variation is equal to "0 box") includes goal consistency, complexity of organizational structure, and multi-organization drill maturity. They do not be improved too much for the current level of disposing emergencies. Within a short time this kind of factors is not easy to be changed.

The third category (the variation of the status values is at middle level) includes collaborative policy and mechanism, executives' cooperation abilities, organization daily close relationship, advancement of equipment and facilities. After development and adjustment within a span there is a little improvement for them. The improvement of executives' cooperation abilities and organization daily close relationship of the four factors is more obvious. The two factors are easy to improve. However, collaborative policy and mechanism and advancement of equipment and facilities do not change significantly. On the one hand, because these two factors have a better foundation, obvious change is not easy to appear. On the other hand, it is due to more difficult to implement in practice. The factor of Collaborative policy and mechanism pertain to this kind of situation. For the target variable (collaborative allocation effect), these factors is more important, and we should continue to intensify efforts to improve them.

The fourth category (the variation is equal to "1.5 box") includes responsibility and authority definition, abilities of decision-makers collaboration, information transmission efficiency and technology sharing and adaptability. They are improved significantly. These four factors are the most important factors for the efficiency of collaborative allocation. The obvious improvement of the four factors, and with the gradual improvement of other factors can eventually make the efficiency of emergency material collaborative allocation improved significantly.

The effectiveness of collaborative allocation is the target variable of the research, whose variation is "1.5 box". The calculation result is more optimistic. Through the above analysis, we put these factors from the most important to the least important in order as follows: Responsibility and authority definition, Abilities of decision-makers collaboration, Information transmission efficiency, Technology sharing and adaptability, Collaborative policy and mechanism, Executives' cooperation ability, Organization daily close relationship, Advancement of equipment and

facilities, Goal congruence, complexity of organizational structure, Multi-organization drill maturity, Original plan completeness, Material completeness.

Emergency material collaborative allocation is a systematic engineering. Promoting the efficiency of collaborative allocation can't be isolated and simply rely on improving a single aspect of the problem, also can't divide all the resources to implement measures. From the entire system perspective, we should in different time, according to the different geographical characteristics, economy and technological development stage, select the key and then perfect the system with focus and in order. The basic principles to enhance collaborative allocation efficiency of emergency material are: (1) Regard the development characteristics of emergencies as the direction and criteria to improve; (2) According to the key point, take reasonable solution to improve the efficiency of collaborative allocation step by step; (3) Improve the effect of emergency material collaborative allocation based on science and technology; (4) Consider the regional characteristics to improve the efficiency of emergency material collaborative allocation. In view of emergency management system for China's actual situation, first of all, set up the "four-chain network" of emergency material collaborative allocation system. The management modes that different departments only acts in their own view and benefits without interaction among departments must be broken and the collaborative allocation system with systemic network management must be established. Secondly, do well on daily work for disposition of emergencies and promote the overall quality of staffing and improve the function of emergency material collaborative allocation system.

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