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Review and Prospect of Studies on Emergency Management

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Abstract

In China, the occurrence of a series of disasters and the tremendous loss in human lives expose the vulnerability the emergency system and the incomplete of the methodology. Faced with the needs of the practice, this paper conducted a comprehensive review both from the system and the methodology prospective. From the system prospective, this paper aims at analyzing the existing problems and the solution finding. From the methodology prospective, emergency facility location problem, emergency resource allocation problem, and emergency management technical support problem are examined.

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Keywords: Unexpected Events; Emergency Management; Review

1. Introduction

Emergency management has attracted the public attention globally as there is a series of disaster occurred in the last decade such as 911 terrorist attack (2001), Sichuan Earthquake (2008), Hurricane Sandy (2012), and the recent Tianjin explosion（2015), to name a few. It is a decision making process that develops and implements policies dealing with four main aspects including mitigation, preparedness, response and recovery [1]. Emergency refers to events which suddenly take place, causing or having the possibility to cause intense death and injury, property loss, ecological damage and social hazards. By its nature, emergency can be divided into four categories: natural disasters, accidents disasters, public health incidents and social safety incidents. The nature of a disaster can often be characterized as destructive, uncertainty, urgent. In addressing to these features, emergency management is a decision making process that is intended to mitigate the level of harm.

In the US, Emergency Management started much earlier which can be traced to 1930s when President Franklin

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Roosevelt set out Emergency Banking Relief Act (1933) to rebuild confidence in the nation's banking system. The need for emergency management in natural disaster was not highlighted until 1960s. In the 1970s, the Disaster Relief Act of 1974 was passed which raise the nationwide focus on emergency management. In 1978, Federal Emergency Management Agency (FEMA) was established as a federal emergency management organization to consolidate emergency preparedness, mitigation, and response activities. As for Japan, it has been equipped with specialized crisis management mechanism totally, and it has established the central and local disaster prevention and mitigation information systems and emergency response systems, focusing on the use of science and technology in safety and hazard mitigation. In 1993, the first international organization on Emergency Management, The International Emergency Management Society (TIEMS), came into being, which has greatly contributed to emergency management research development.

In China, control of SARS (2003) evidenced the strength of different agencies in dealing with emergency, but also exposed the weakness and vulnerability as a lacking of the integrated emergency management system for disaster prevention and mitigation system [2]. The recent Tianjin explosion（2015）again reveals the fragility of the emergency system in dealing with such outbreak of emergencies. In the light of this, the purpose of this paper carries out a review on existing researches of emergency management in China from both system and methodology prospective.

2. System prospective

The study on the system prepositive focuses on the relevant national emergency management systems, mechanisms and institutions. It aims at analyzing the existing problems and the solution finding.

Identification of emergency management stages is crucial in the process of emergence management. According to the laws of emergency development, an early identification of the emergency management stage is vital for holding the entire macroscopic system. Thus we can determine what to be done in a specific stage. Robert Heath (2004) [3], a US scholar, devised 4R crisis management models, namely: reduction, readiness, response and recovery. Another phase classification method is defined by Norman R. Augustine (1995) [4] who proposed a six-stage theory of crisis management including prevention, preparation, confirmed, management, resolution and crisis learning. Research on classification and grading is even importance. In general, defining the emergency stage is the prior step of selection any response plan

Yang Jing [5] linked the emergency classification and grading to the level of resources protection, highlighting the influence of time on the classification and grading. In the field of emergency management, there still exist to be many problems in terms of mechanisms, institutions, rules of law. These problems restrict the effective implementation and operation of the emergency management system.

Ma Kai summarized the problems as [6]:

emergency management institutions, mechanism and the legal system need to be strengthened;

emergency management system is not perfect, and the emergency rescue support capacity is relatively weak;

the study of the formation mechanism of some major natural disasters and forecasting is not deep enough, and there is a wide gap between the use of science and technology disaster preparedness and mitigation;

the disaster prevention and mitigation of urban and rural infrastructure construction is lagging behind, and the basic capability to prevent all types of emergencies is yet to be improved;

The risk awareness in certain localities and departments is not strong, and the public disaster prevention awareness and knowledge of first aid are in great lack.

Tsinghua University Xue Lan identified four major characteristics of current problems in the China Emergency Management: (a) There is no permanent institution or agency for heavy or light emergency management; (b) Conflicts among human widely exists as a result of inefficient coordination. (c) The long-term anti-crisis strategies and plans are incomplete. (d) Conflicting as a result of inefficient coordination; (e) incomplete of the long-term anti-crisis strategies and plans; and (f) There is few synergies among various agencies and department. Zhen-Ming Chen [7] pointed that the legal system of emergency management should also be strengthened. Confronted with the problems existing in the emergency management system in China, scholars also attempted to address this issues, and brought forward comments and suggestions. Zhen-Ming Chen argued that when dealing with emergencies, a unified command, responsive, harmonious and orderly efficient operation should be established to improve the system of

emergency operations. Xiao-Ping Gao [8] pointed out six critical needs for emergency management including: (1) integrating of emergency management system, (2) clarifying the command relationship, (3) establishing of specific and authoritative emergency command protocol, (4) determining the responsibility of relevant agencies, (5) classifying management function and (6) scientifically representing the emergence management problem. He also highlighted that the responsibility of different agencies should be enhanced as a result of an integration of organization, resource, information and operations. Li Wan [9] proposed the emergency law to complement the legal system as a lesson learned from United States, Japan and other countries. This suggestion also shared with Chun-Chang Shan [10] who also pointed to the need of emergency response law as well as national emergency preplans. Other studies focus on the improvement of the emergency systems. Zhang Xinmei [11] stated a more consistent system including the whole process of decision making, commanding and the power of disposal.

In summary, from the system prospective, the internal mechanism of emergency management should be analyzed, together with further design and rule mechanisms, institutional and laws mentioned above, to provide assistance and protection for the emergency management. For the mechanism level, phasing and classification of emergency management and emergency response agencies grading have been studied respectively. In terms of classification and grading, the present studies are more partial to the emergent events, but relatively less concerned the emergency facilities. Gao Xiaoping [8] emphasis the essential of clarifying the command relationships, management functions and management responsibilities for the emergency management in China. In another report by Development Research Center of the State Emergency Management, a reinforced and integrated system is proposed to enhance the coordination among agencies.

3. Methodology prospective

In this chapter, emergency facility location problem, emergency resource allocation problem, and emergency management technical support problem are examined to analyze the current situation of emergency management in China.

3.1 Emergency facility location problem

Emergency facility location problem is tantamount to investigate how to locate the emergency facilities so as to satisfy the demand with a minimized cost under some set of constraints. Location problem is first proposed by Weber who tries to select a depot in the plane so as to minimize the total distance between the customers and the depot, known as the famous Weber problem. And that is the official start of the location choice theory research. Shier D R and Dearing P M discussed the optimized location of a single facility location, and then put forward the Absolute center model of a single facility. The model is substantially to find the point, the distance from which each point in the network is minimum, i.e. absolute center [12]. Wlodzimierz in 2001 studied the double- objective emergency services location model which considered two objective functions named the minimax (center) and the minimum (median) and put it into single objective model with parameters λ and points out the shortcomings of the single-objective model when applied to normal network [13]. Fang Lei, Jian-min He combines analytic hierarchy process (AHP) and Objective programming. They not only discussed the factors in location decision-making, but solved the problems of different units of measurement and conflicting goals of multi-objective decision-making. In general, location problems are classified into three categories, that is: P-center problem, P- median problem and Covering problem [14].

3.1.1 P-center problem

The P-center problem is known as the minimax problem, because its objective function is to minimize the maximum distance between the demand points and the facilities. First proposed by Hakimi in 1964 [15], P-center problems are applied to emergency facility location problems such as fire stations and hospitals. Handler put forward to the discrete facility location problem when dealing with the p-center problem [16], he argued that we should consider the location problem under the assumption that demand for the required service originating from a

finite set points. But, in many cases, it is unrealistic to consider in that way. Atsuo Suzuki, in 1991, proposed a continuous facility location model on the basis of the former studies, assuming that an area represents the set of demand points. We can divide p-center problem in two type by judging whether there are some constraints on the capacity of the emergency facilities or the demand of demand points. Most scholars focus on the uncapacitated p-center problem, for example, Elloumi S and Pochet Y (2004) proposed an extensive review of the literature [17]. When it comes to the capacitated p-center problem, the research has been more limited. The most representative contributions on this aspect are Albareda-Sambola(2010). In his study each demand point has a known demand and each potential emergency facility a known capacity [18].

The model for P-center problem [19] can be formulated as follows:

$$\min z$$

$$s.t.\begin{cases} \sum_{j\in J} c_{ij}x_{ij} \le z, \forall i \in I & (1) \\ \sum_{j\in J} y_j \le p, \forall j \in J & (2) \\ \sum_{j\in J} x_{ij} = 1, \forall i \in I & (3) \\ \sum_{i\in I} h_i x_{ij} \le s_j y_j, \forall j \in J & (4) \\ x_{ij} \in \{0,1\}, \forall i \in I, \forall j \in J \\ y_j \in \{0,1\}, \forall j \in J \end{cases}$$

he notions of the model are introduced as follow:

is a set of demand points
is a set of facilities T
is the transportation cost from demand to facility
is demand of
is capacity of facility

$$x_{ij} = \begin{cases} 1 & \text{if demand point } i \text{ is assigned to facility } j \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

$$y_j = \begin{cases} 1 & \text{if facilitiy } j \text{ is opened} \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

The objective function is to minimize the maximum transportation cost between demand points and the facilities they are assigned to. Constraint (1) makes sure that z in the objective function is the maximum transportation cost. Constraint (2) limits the number of the opened facilities. Constraint (3) ensures that each demand points is assigned to some facilities. Constraint (4) ensures that the total demands assigned to a facility do not exceed the facility's capacity.

3.1.2 P- median problem

The p-median problem was proposed by Hakimi in 1967 [15], the problem is to choose some facilities in order to achieve a goal of global optimization, such as cost, time, distance and so on. One of the most striking features in emergency problem characterized by the urgency of the time, so it is meaningful to consider the sum of the minimal distance with a weight between the demand points and facilities when satisfying the time urgency.

Canós M J utilized fuzzy techniques to tackle the external data in the *p*-median problems. He believed that we only considered the transport costs as the main influence factors in optimal solution in the standard version of the p-median problem. However, there usually exist other external information which can also affect the optimal solution. When we take the external information into consideration, we can use the fuzzy methods [20]. Enrique Domínguez proposed a neural model for the p-median problem in 2008. He presented a new technique which always provides feasible solutions and removes the tuning phase since the constraints are incorporated in the neural architecture instead of the energy function, so that the tuning parameters are unnecessary [21]. X Weng and L Zhang studied the emergency material storage facility location problem on Anhui Province based on theP-Median Location [22]. ND Pizzolato proposed a heuristic approach for large-size p -median location problems and applied the model to the school location problem [23]. The model for p-median problem can be formulated as follows:

$$\min \sum_{i\in I}\sum_{j\in J} a_i d_{ij} x_{ij}$$

$$s.t.\begin{cases} \sum_{j\in J} x_{ij} = 1, \forall i \in I & (7) \\ \sum_{j\in J} x_{ij} = p & (8) \\ x_{ij} \le y_j, \forall i \in I, j \in J & (9) \\ x_{ij} \in \{0,1\}, \forall i \in I, j \in J & \\ y_j \in \{0,1\}, j \in J & \end{cases}$$

The notions of the model are introduced as follow:

is the weight of demand point

is the distance between the demand point and facility

$$x_{ij} = \begin{cases} 1 & \text{if demand point } i \text{ is assigned to facility } j \\ 0 & \text{otherwise} \end{cases} \quad (10)$$

$$y_j = \begin{cases} 1 & \text{if facility } j \text{ is opended} \\ 0 & \text{otherwise} \end{cases} \quad (11)$$

The objective function is to minimize the total demand-weighted distance between customers and facilities. Constraint (7) ensures that each demand points is assigned to some facilities. Constraint (8) limits the number of the facilities. Constraint (9) allows assignment only to sites at which facilities are opened.

3.1.3 Covering problem

While the former two methods are widely studied, when it comes to some facilities that provide emergency services (e.g. fire station, hospitals), the covering problem is more applicable. C. S. Re Velle and H. A. Eiselt P believes that the service radius of facility service is standard, such as no more than a certain distance or a certain time in emergency facility location problem. For instance, the fire truck or ambulance should arrive in the site of accident within a specific time. In order to satisfy these kinds of demand, the facilities must be located in a set of points which can cover the demand points. As we can see, the former model can't achieve such goal, so the location set covering problem (LSCP) [24] is proposed. In short, the LSCP aims to satisfy all demands with minimal facilities. When resources can't satisfy all demands, decision makers have to seek alternative methods, such as limiting the number of facilities, controlling the cost, to meet the demand. Under this condition, Church and Revelle proposed the maximal covering location problems (MCLP) [25]. This model does not require covering all of the demand points, but maximizes the amount of demand covered within certain service distance S by locating a finite number of new facilities. Some scholars generalized the MCLP to introduce a generalized maximal covering

location problem (GMCLP) [26]. We only introduce the basic model of the problem [27]:

$$\min z = \sum_{j \in J} x_j \tag{12}$$

$$s.t. \begin{cases} \sum_{j \in N_i} x_j = 1, i \in I \\ x_j \in \{0,1\}, j \in J \end{cases} \tag{13}$$

The notions of the model are introduced as follow:
is the be the distance between the demand point and facility
S is the maximal distance within which a facility can provide service
is the set of potential facilities locations within S so that

$$x_j = \begin{cases} 1 & \text{if facility } j \text{ is located at point } j \\ 0 & \text{otherwise} \end{cases} \tag{14}$$

The objective function is to minimize the total number of located facilities. Constraint (1) is to ensure each demand points being covered.

3.2 Emergency resource allocation problem

The Emergency resource allocation problem is a special class of resource allocation problems. Resource allocation problem refers to the allocation of limited resources to some main objectives or activities of competition for optimizing certain goals. Based on the definition of problems about resource allocation, it can be given that the emergency resource allocation problem refers to that, in the emergent situation, allocating limited emergency resource to some of those competitive affected points or rescue activities in order to minimize losses of the disaster. Emergency resource allocation problem refers to management decisions of disaster relief resources in the whole emergent rescue activities after sudden natural disaster, it is always the key of effectively implementing rescue measures, also the core work of emergent management of sudden natural disaster and one of the most important measures of weighing emergent management capacity. Existing literatures with respect to the distribution of emergency supplies mainly concentrated in two areas, i.e. the distribution of static and dynamical supplies.

3.2.1 Statistical resource allocation problem

Distribution of static emergency resource is a normal condition of emergency resource distribution. According to the past condition and the probability of disaster occurrence in the future before the disaster occurring, relevant organizations put a certain number and type of emergency resource in an appropriate reservation location. In the problem of static resource allocation, one of the most important research issues is the choice about storage location of emergency resources, which is closely related to the location problem in the last section.

3.2.2 Dynamical resource allocation problem

With the development of the disaster, the demand of emergency resource will change in different stages of relief work, which forms a dynamic relationship between supply and demand, and need to consider unified distribution of emergency supplies. Therefore, the static collocation of materials resource converts to dynamic allocation of supplies after the disaster. For "more than one" situation, Fiouccci discussed how to allocate emergency resource and make schedules for the fire accident, and constructed a dynamic model [28]. Sheu treated the allocation of emergency resource as two-phase materials resource scheduling and allocation dynamic optimization problems based on disaster degree. In the first stage, the decision-making objectives are based on time-varying to meet the maximum of meeting the resource demand and the minimum of distribution costs; in the second stage, the decision-

making is about all the resources from multiple supply departments to the distribution center. Sun Ying et al analyzed the potential disaster possibility of emergency resource demand sites in stricken areas and its impact on the demand for emergency resource, taking into account the impact of disasters on the traffic situation in the affected areas, and indicated that the deployment of emergency supplies need to work under uncertainty interference and obstruction of roads.

3.3 Emergency management technical support problem

Emergency management technical support problem refers to a technical system which helps the decision making when faced with emergency.it can also be called decision making support system. If decision makers only depend on personal experience, it is easy to make wrong judgments, causing serious consequences. The use of advanced technology combined with decision-making process to form a decision-making system is very important. Emergency decisions not only need to rely on physical, social perception of information and data analysis, but also need to rely on models, data, system integration calculation and analysis, and we also need to consider the impact of psychological and behavioral characteristics of individuals and groups on the development of events and emergency response.

At present, many scholars make the research from the perspective of emergency management decision support system. Qinjun Chang put forward major tasks of emergency decisions and make the conceptual design of the system based on the characteristics of DSS [29]. Cosgrave, on the base of the characteristics of the emergency management environment, decided the emergency decision process, and gave some simple decision rules [30]. IPhigenia used the GIS and integrated range of personal assistant software in handling oil spill in the decision support system that can provide the necessary tools for quick response [31]; A. Ertug Gunes described the use of GIS in emergency support system and established a GIS-based decision support system, focusing on emergency prevention and preparedness [32]. Zhan Yong-song used web GIS technology to build a distributed urban emergency decision support model with function designed and integrated by an expert system for the emergency evacuation.

From the decision support systems point of view, the research focused on the following three aspects: 1) Decision Support System designed for specific disasters, such as water pollution, oil spills; 2) Decision support systems designed based on a specific technical, such as those based. GIS platform; 3) Explore a certain part of decision Support System, such as database, model base. To design a complete and comprehensive practical decision support system, we need to start from all aspects, from data collection to design Model Base, from method base to the design and implement of interactive platform. Every part needs a further discussion and study.

In short, to establish a complete emergency management system, and to improve the efficiency and level of emergency management, the research on the decision support is necessary. According to "gather information, analyze information, assess grade, analyze requirements, develop model, design plan, simulation comparison and selection" and other decision-making processes, select the decision-making techniques and methods in every stage to build decision support platform thus to form emergency management decisions support system.

4. **Conclusion**

Emergency research is a type of multi-disciplinary research; it is also a developing research. From the experience in SARS and Tianjin explosion, the weakness and vulnerability of the emergency system is exposed. In addressing to this issue, in this paper, a review is conducted to look deep into the existing policies and methodology for emergency management in China. The objective of this paper is to analysis the weakness loop of the system by reviewing the literatures and seek methods to solve it.

From the analysis, the problems can be majorly concluded in the following aspects:

- needs for permanent integrated emergency management;
- collaboration among different agencies need to be enhanced;
- gaps between current emergency management studies and emergency preparedness and mitigation practice;

From the methodology prospective, emergency facility location problem, emergency resource allocation problem,

and emergency management technical support problem are examined. These models proposed by researchers mentioned above well address to the resource allocation problems under certain hypotheses. However, in real practice, the process is dynamic, which does not necessary meet all the hypotheses. The link between models and practice weak and need to be further addressed.

To sum up, while great progress has been made in emergency management in China in recent year, there is still a long way to go. From the authors' prospective, this problem could be further improved by more in-depth researches, an integrated emergency response system and an effort to link them together.

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