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A Study on Emergency Supply Chain and Risk Based on Urgent Relief Service in Disasters

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Abstract

In order to make the affected areas receive urgent relief service timely and accurately after the disasters, the effective operation of emergency logistics and quick response to the urgent demands in the affected areas is very critical. In this paper, firstly, the emergency supply chain management in disasters is presented, and the risk of disasters and urgent relief decision-making are analyzed, then the support mechanism of emergency logistics including infrastructure support, unified command and network coordination, law guarantee, contingency plan and emergency transportation channel is analyzed. Secondly, the evaluating indicators are specified by introducing the salvable degree concept, the salvable degrees of the affected areas which lie on the impact degrees of relief demands in the corresponding affected areas are analyzed and evaluated by the extension technique, and then a two-objective optimization model with the urgent relief demand time-varying fill rate maximization and the urgent relief distribution time-varying window minimization is developed in order to distribute urgent relief to the identified affected area sets. Finally, a numerical example demonstrates our conclusions.

Keywords: Emergency supply chain; Emergency logistics distribution; Salvable; Extension technique; Two-objective optimization

1. Introduction

In recent years, there are various kinds of serious disasters either natural occurring (e.g., earthquake, typhoons, floods, drought) or man-made (e.g., the 9.11 event in the USA) around the world, such as the tsunami in the Indian Ocean (2004), the Katrina Hurricane in the US (2005), as well as the Sichuan earthquake in China (2008) (Ergonul S., 2005; Chandre, Monerawela, Baskett., 2007). These disasters have caused severe damage to our world. For instance, in the Sichuan earthquake and its aftershocks in 2008 in China, 69,185 people died, 18,403 people went missing and a large number of houses were destroyed, and a large number of people were homeless unable to secure livelihoods (Lefei L, Shuming T., 2008). In order to support rescue operation after disasters, the urgent relief service must be delivered to the affected areas as quickly as possible, i.e., the quick-responsive emergency logistics system is needed for the relief service operations. For example, in the Sichuan earthquake, in the first day, 19 helicopters and 6 cargo-transport planes were assigned to the affected areas. Approximately 150 tons of relief resources including foods, waters, drugs, and so on were delivered to the affected areas. In a sense, emergency logistics became the lifeline in the affected areas associated with Sichuan earthquake. From a global point of view, over the last several years, changes in environment and society relationship have raised the requirement for effective emergency logistics to a new level, and emergency logistics issues lie in justifiable concerns and research interests.

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Different from general business logistics, emergency logistics is unique in the following four aspects that may increase the relative complexity and difficulty in solving the induced emergency logistics issues, particularly in terms of emergency logistics distribution problem, i.e., (1) *The urgent relief services are very diverse and urgent.* Generally, disasters often cause serious casualties and make many buildings severely damaged, so various kinds of urgent relief service goods such as waters, foods, medicines, shelters, medical equipments are needed to deliver to the affected areas in the immediate way, which maintain the daily needs of the corresponding survivals and alleviate the disaster impact. Furthermore, for emergency logistics, the timely availability of urgent relief service has a direct effect on the survival rate in the affected areas after the disasters. So the quick response to urgent relief services supplied for the affected areas is very critical. (2) *The accurate and real-time urgent relief demand information is almost inaccessible*. Unlike general business logistics in which the demand information (e.g., product orders) is provided actively and directly by end customers or the entire supply chain, the sources of on-the-spot relief demand information may be limited and almost unidentifiable in the immediate aftermath. In most disasters, such on-the-spot affection information may not be actively and timely provided by the affected people under the emergency conditions. (3) *The benefits of emergency logistics operation are always weakened.* Commonly, the general business logistics pursues the objectives of maximizing both efficiency and profits of logistics operation. However, for emergency logistics, the goal associated with the service benefits is often weakened. Sometimes, emergency logistics only focuses on the logistics service efficiency, regardless of the profits. For example, in order to distribute urgent relief to the affected areas quickly after disasters, the transportations (such as plane) with higher costs but higher speed are always needed, which will increase transport costs greatly. (4) *Government and the market participate in the emergency logistics service together.* The urgent relief service in emergency logistics is usually supplied by government, public organizations, firms, individuals and so on, which has decentralized storage. Under this circumstance, government who acts as a coordinator or organizer should take effective measures to integrate the urgent relief activities and resources, i.e., the government should efficiently collaborate with corporations and individuals to respond to the disasters.

While there are a variety of theoretical considerations for general business logistics from the presented literatures, there is still a lack of a theory for the emergency logistics, particularly with regard to the emergency logistics distribution. The main research works are expatiated as follows: The significance of issues on urgent relief service supply to the affected areas suffering from disasters, e.g., drought, earthquakes, typhoon etc., which can result in emergency logistics problems are addressed previously (Kembell C.D., Stephenson R., 1984; Ardekani S.A., Hobeika A., 1988; Long D.C., Wood D.F., 1995), Brown G.G. & Vassilion A.L.(1993) based on the diverse linear programming models presented for emergency logistics planning. However, a clear definition of emergency logistics has not yet been well clarified, unlike general business logistics which has been clearly defined in the previous literatures (Bowersox D.J., Closs D.J., 1996; Ballou R.H., 1999; Johnson J.C., Wood D.F., 1999). Usually, the emergency logistics is a process of planning, managing and controlling the efficient flows of urgent relief, information and services from the origin point to the destination points to meet the urgent needs of the affected areas under emergency conditions (Jiuh-Biing Sheu, 2007). In this paper, considering the urgent relief service, the emergency logistics is defined as: A process of planning, managing and controlling the efficient flows of urgent relief service, information and resources from the origin point to the destination points to meet the urgent service needs of the affected areas under emergency conditions. Obviously, considering the emergency logistics, quick and feasible response to the urgent relief services in affected areas after disasters is a critical objective. From the quantitive research, the presented literatures are reflected: Most formulate the corresponding urgent relief distribution problems as multi-commodity multi-modal flow problems with time windows (Rathi A.K. Church R.L., Solanki R.S., 1992; Haghani A, Oh S.C., 1996). Fiedrich *et al.* (2000) develop a dynamic combinatorial optimization model to find the optimal resource rescuing schedule with the objective of minimizing the total deaths during the search and rescue period. Barbarosoglu *et al*. (2002) propose a bi-level hierarchical decomposition approach for helicopter plan during a disaster relief service operation, where the top-level programming model is formulated to solve the tactical decision problems, involving the helicopter fleet management, crew assignment and the tour number undertaken by each helicopter. Özdamar *et al.* (2004) point out that the emergency logistics plan can be obtained by solving the dynamic time-dependent transportation problem, where the objective aims to minimize unsatisfied demands of all commodities throughout the planning horizon. The emergency logistics plan includes the optimal pick-up and delivery schedules for vehicles within the considered planning time horizon as well as optimal quantities and types of loads picked up and delivered on these routes. Wei *et al.* (2007) propose an ant-