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IFAC-PapersOnLine 49-12 (2016) 520–525

A Multiple Objective Mathematical Program to Determine Locations of Disaster Response Distribution Centers

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Abstract: Every year, natural disasters kill thousands of people and affect millions of people as well as causing economic damages. This increasing number of affected people by disasters reveals the need for effective and efficient disaster response operations. This study focus on one of the important disaster response operations: the location of disaster response distribution centers. A multiple objective decision model is proposed to locate the main and local distribution centers simultaneously. The objectives of the model are minimizing distance among demand points, local, and main distribution centers, and minimizing the number of local distribution centers and main warehouses. The proposed model is solved for different instances (different number of candidate demand points, local and main distribution centers) using a goal programming approach. Although the initial results are promising, the completion time increases dramatically as the size of the problem increases.

Keywords: Multiple objective optimization, Disaster Management, Decision making, Location.

1. INTRODUCTION

Although technological advancements solved many problems, it is still widely believed that the capacities of many societies are not enough to cope with the massively destructive effects of natural and human-made disasters. Millions of people suffer from natural disasters every year. According to the Office of U.S. Foreign Disaster Assistance and the Center for Research on the Epidemiology of Disasters, in 2010 more than 297,000 people were killed and over 217 million were affected by natural disasters. The economic damage has been estimated at over US$ 123.9 billion (Guha-Sapir et al., 2011). This increasing effect of disasters over recent years revealed the need for effective and efficient disaster response operations.

Disaster management is defined as a composition of systems that is designed for reducing and preventing the effects of disasters, during, before and after disaster (Nikbakhsh and Farahani, 2011). Also in the literature, disaster management studies are usually grouped as either pre-disaster or post-disaster studies. Pre-disaster studies include assessing and analyzing potential dangers and mitigation of possible damages before occurring of it. Post-disaster studies are interested in events starting with disaster such as relocation of depots, management and coordination of available resources (Altay and Green, 2006). One of the most important parts of disaster response is humanitarian logistics including processes and systems involved in resources such as food, tent, water, equipment etc. to help vulnerable people affected by disasters. It consists of a range of activities such as supply, tracking, transportation, warehousing, and last mile delivery and has a critical importance in terms of efficiency of relief operations (Nikbakhsh and Farahani, 2011). Balcik and Beamon (2008) states differences between humanitarian and commercial logistics as follows:

- Additional uncertainties (unusable routes, safety issues, changing facility capacities, demand uncertainties);
- Complex communication and coordination (damage to communication lines, involvement of many third parties, government, and civilians, inaccessibility to accurate real-time demand information)
- Harder-to-achieve efficient and timely delivery,
- Limited sources often overwhelmed by the scale of the situation (supply, people, transportation capacity, fuel)

One of the most critical issues of pre-disaster phase is selecting distribution center locations for disaster relief operations. Humanitarian relief organizations pre-position essential relief items and equipment in central distribution centers, local distribution centers and permanent relief facilities. After occurring disaster, pre-positioned relief items such as medicine, food, water and equipment are delivered to victims of disasters. Since the delivery time of relief items has a vital importance after a disaster, location selection for these kinds of facilities is a key issue for relief operations.

This study proposes a multiple objective decision model to locate disaster response distribution centers. The objectives of the model are minimizing distances among local

10.1016/j.ifacol.2016.07.682

distribution centers, demand points and main warehouses, and minimizing numbers of local distribution centers and main warehouses. The proposed mathematical programming model is solved for different scenarios (different number of candidate demand points, local and main distribution centers).

The paper is organized as follows: Section 2 examines location problem in disaster management and gives information about some related studies in the literature. Proposed model for locating disaster response distribution centers and an experimental study is given in Section 3. Conclusions of the study and future research suggestions are given in Section 4.

2. LOCATION PROBLEM IN DISASTER MANAGEMENT

In disaster management, the facilities considered for location are referred to as distribution centers and they can be thought as warehouses or shelters (Caunhye et al., 2012). The location problem in disaster management aims at designing a network for distributing humanitarian aid (e.g. water, food, medical goods and survival equipment). It mainly includes determining number, position and the mission of required humanitarian centers within the disaster region. Central distribution centers are constructed permanently and usually it is assumed that they are not in the hot (disaster affected) zone. However, local distribution centers are constructed in the hot zone after a disaster and relief goods are delivered to victims from these temporary centers. Figure 1 shows logistics chain structure for both pre and post disaster phase.

Humanitarian logistics chain structure has three main stages: supply, purchasing and procurement, pre-positioning /warehousing and transportation. Acquisition and procurement of relief goods and equipment is the initial stage in a humanitarian logistics chain. Any relief organization has to obtain necessary relief goods from local or global suppliers via different procurement techniques. Reducing the purchasing costs, ensuring the availability of supplies in essential situations, reducing lead times and coordinating in-kind donations with respect to other acquired items are the main challenges at this stage. After acquiring necessary items and equipment for the pre-disaster and post-disaster periods, related relief organizations have to pre-position and store their items and equipment in suitable locations considering the location of disaster-prone areas. High costs of opening and operating permanent warehouses, inventory holding costs, and possible deterioration of items are the main challenges at this stage (Balcik et al., 2010). Also decision makers need to consider disasters such as earthquakes, floods and even non-natural events such as terrorist bomb attacks on certain target structures that may have devastating effects on large geographical areas while deciding appropriate locations for pre-positioning warehouses (Verma and Gaukler, 2014). Disasters may also adversely affect infrastructure, especially to highways and roads. Predicting accessibility to demand points from the supply points by a systematic model would lead to more effective emergency facility location decisions (Salman and Yucel, 2015).

The last stage of a humanitarian logistics chain is transportation. During this stage, required human personnel, equipment, and essential goods are sent to predefined main distribution centers, distribution intermediary points, local distribution centers, and finally regions affected by the disaster. Transportation during the post disaster period is somehow the most difficult stage of humanitarian logistics even if different kinds of preventive measures and plans have been taken into account (Balcik and Beamon, 2008).

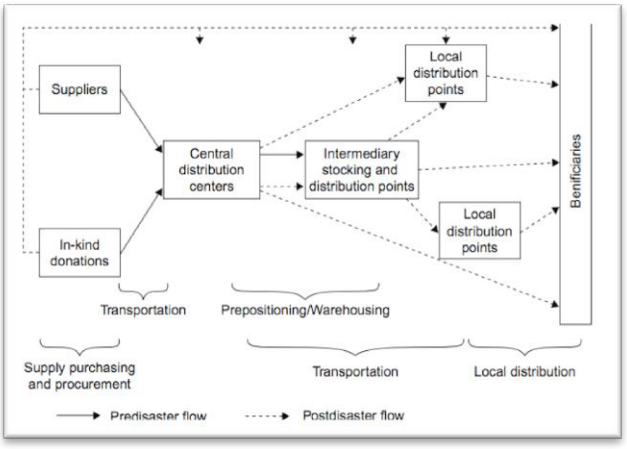

Fig. 1. Humanitarian logistics chain structure (Balcik et al., 2010).

Minimizing transportation time and maximizing covered demand are key issues in saving victims` lives. Therefore, location decisions are quite critical for increasing the performance of relief operations, since they affect the response time and cost directly in disaster management.

Facility location is one of the main categories of emergency logistics (Caunhye et al., 2012) and in the facility location literature, some studies are only examining the process of location - building new facilities or choosing among existing ones while some others combine this process with other disaster operations such as stock pre-positioning and relief distribution. Also interested readers can check Caunhye et al. (2012) for more detailed classification of optimization models in emergency logistics.

Studies on facility location in disaster management can be split into three categories in terms of focusing on distribution center types: local distribution center, main distribution center and both of them. Naji-Azimi et al. (2012), Salman and Yucel (2015) determine only location decisions of local distribution centers while Verma and Gaukler (2014) and Ye et al. (2015) focus on only main warehouse location. Gormez et al. (2011) determine both main and local distribution center locations in Istanbul. They decompose the problem by a two-stage approach. In the first stage, they solve an integer programming model for each district to locate the local distribution centers in its neighborhoods and in the second stage, they take the local distribution centers as the demand points and locate the main distribution centers to service the demand points with minimum total weighted distance.