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Determination of relief supplies demands and allocation of temporary disaster response facilities

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Abstract

Distribution of relief supplies and allocation of the facilities to store these supplies are important pre- and post-Disaster Operations Management (DOM) activities. In this study, we propose a simulation-based approach to determine the demands of relief supplies until the governmental and/or central humanitarian organizations (i.e., the Turkish Red Crescent - TRC) reach to the affected area. We then develop a plan to allocate the so-called temporary-disaster-response (TDR) facilities and distribute the relief supplies stored in these facilities. An earthquake case study is constructed for the Yildirim district of Bursa-Turkey including 64 neighborhoods. Corresponding relief supplies demands are determined by analyzing the time it takes for the TRC to reach the affected area using the simulation model with two different system designs. The two-phase integer program is then used to develop a pre-positioning plan, i.e., allocation of TDR facilities and distribution of relief supplies.

Keywords: Disaster operations management; Relief supplies distribution; Facility allocation; Simulation; Integer programming

1. Introduction

Disaster Operations Management (DOM) is about the managerial activities performed before, during and after a disaster in order to reduce the unwanted effects of a disaster. According to a common classification in literature there are four phases in DOM as mitigation, preparedness, response and recovery (Altay and Green, 2006; Galindo and Batta, 2013). In this study, our solution approach to the problems of (i) determination of relief supplies demands and (ii) allocation of temporary-disaster-response (TDR) facilities and distribution of these relief supplies involves two of these phases; preparedness and response.

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In DOM, it is generally assumed that it is not possible to reach the affected area in the first 72 hours due to the destructive effects of the disaster, especially in areas with high infrastructure complexities. It is hence very important to provide relief supplies to disaster victims in this critical time period (Koehler, 1996). Therefore, humanitarian logistics and disaster supply chain studies gain more attention recently. Some related studies focus on providing relief supplies for disaster victims, representing an example of such humanitarian operations (Barbarosoglu and Arda, 2004; Wei and Ozdamar, 2007; Natarajarathinam et al., 2009; Rawls and Turnquist, 2010; Nagurney et al., 2011; Rawls and Turnquist, 2011; Ozdamar and Demir, 2012). Although simulation-based studies are commonly used for planning evacuation operations in DOM studies (Zou et al., 2005; Georgiadou et al., 2007; Chen and Zhan, 2008; Chiu and Mirchandani, 2008), it is also possible to use simulation for analyzing different type of DOM activities, such as resource allocation and mass decontamination (Albores and Shaw, 2008) and, as we also consider in this study, relief supplies distribution operations (Lee et al., 2009). Facility allocation is also another important DOM problem. Although it is mostly a pre-disaster decision, facility allocation requires the consideration of both pre- and post-disaster operations (Rawls and Turnquist, 2010; Gormez et al., 2011; Rawls and Turnquist, 2011; Murali et al., 2012; Salman and Gul, 2014; Kilci et al., 2015), since for an optimal allocation it is necessary to consider the post-disaster activities, such as the distribution of relief supplies.

In general, DOM activities are coordinated with some kind of governmental and/or central humanitarian organizations, such as the Federal Emergency Management Agency (FEMA) or the Red-Cross. In Turkey, we note that the corresponding organizations for such purposes are the Prime Ministry Disaster and Emergency Management Authority (AFAD) and the Turkish Red Crescent (TRC), respectively. In this study, we analyze the time it takes for these organizations (in particular the TRC since it is directly responsible for humanitarian relief supplies distribution operations) to reach the affected area via a simulation model using an earthquake case study developed by AFAD for the Yildirim district of Bursa-Turkey including 64 neighborhoods. There are three types of relief supplies considered in this study as water, meal ready-to-eat (MRE) and medical kit. After running the simulation model we determine the demands of these relief supplies for the corresponding time period representing the time it takes for the TRC to reach the affected area. Decisions involving the allocation of TDR facilities and distribution of relief supplies are then performed via a two-phase integer programming model.

2. Methodology

We estimate the amount of relief supplies required to satisfy the demands of disaster victims using the results of the simulation model. Pre-positioning of the corresponding TDR facilities are then performed via a two-phase integer programming model where the total cost (distance) of distributing relief supplies and the total number of facilities are minimized in the first and second phases, respectively. The overall solution approach is shown in Figure 1.
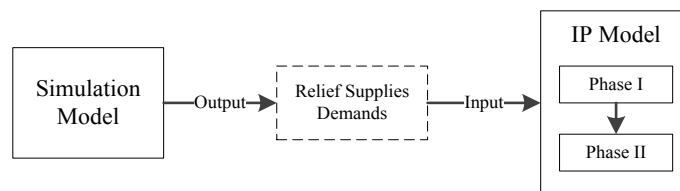

Fig. 1. Overall Solution Approach

2.1. Simulation model

Our model simulates the arrivals of all related resources (i.e., mobile kitchens etc.) of the TRC to the affected area to determine the corresponding relief supplies demands to be satisfied from the TDR facilities. We use ProModel to build the simulation model. There are totally 20 locations in our simulation model. One of them represents the affected area whereas the 19 disaster management centers of the TRC in Turkey are modeled as the other locations. We define the service units (i.e., mobile kitchens etc.) in these disaster management centers as the resources of our model. A dummy entity "Disaster" is used to request the resources in the locations representing the 19 disaster management centers. A path network is used to define the paths between the possible origin-destination