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An interactive approach for designing a robust disaster relief logistics network with perishable commodities

Mohammad Rezaei-Malek [a,b], Reza Tavakkoli-Moghaddam [a,b,*], Behzad Zahiri [c], Ali Bozorgi-Amiri [a]

[a] *School of Industrial Engineering and Engineering Optimization Research Group, College of Engineering, University of Tehran, Tehran, Iran*
[b] *LCFC, Arts et Métiers ParisTech, Metz, France*
[c] *Department of Operations Management & Strategy, School of Management, State University of New York at Buffalo, Buffalo, NY, USA*

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ABSTRACT

Pre-positioning of relief commodities in appropriate locations and quantities at a pre-disaster phase assists a disaster relief logistics network in order to efficiently distribute the commodities to demand points; however, a disaster may occur after a long time, and generally perishable commodities (*e.g.*, medical commodities and packed milk) have a fixed lifetime for use. Hence, this paper aims at developing a new integrated model in order to determine the optimum location-allocation and distribution plan, along with the best ordering policy for renewing the stocked perishable commodities at the pre-disaster phase. The uncertain nature of the problem leads to the utilization of a scenario-based robust stochastic approach. The proposed model simultaneously seeks to minimize: (1) the average of the weighted response times and (2) the total operational cost at the pre-disaster phase and the penalty costs of unmet demand and unused commodities at a post-disaster phase. The reservation level Tchebycheff procedure (RLTP) as an interactive approach is also applied to cope with the presented bi-objective model. The significance of the presented model and the efficiency of the RLTP method are then tested via a real case study in Iran.

1. Introduction

Casualties from natural disasters have significantly increased in recent years. Based on the most recent statistics, approximately 70,000 people die and 200 million people are injured annually (Duran, Gutierrez, & Keskinocak, 2011). The Indian Ocean tsunami in 2004 and the significant role of logistics during this disaster attracted the interest of both researchers and practitioners (Kovács & Spens, 2007). According to Van Wassenhove (2006), "*Logistics is the part [of any disaster relief] that can mean the difference between a successful or failed operation.*" Disaster relief logistics (DRL) can be defined as "*the process of planning, implementing and controlling the effective, cost-efficient flow and storage of goods and materials as well as related information, from the point of origin to the point of consumption for the purpose of meeting the end beneficiary's requirements*" (Thomas & Mizushima, 2005).

To increase the agility of the DRL operations, pre-positioning has been suggested as one of the most efficient approaches (Trestrail, Paul, & Maloni, 2009). Generally, associated organizations in charge of relief operations can properly handle the emergency situations if a pre-positioned network at the pre-disaster phase is efficiently established (Duran et al., 2011). In this field, Caunhye, Nie, and Pokharel (2012) reviewed studies concerning location with relief distribution and stock pre-positioning (LRDSP), in the DRL network at the pre-disaster phase. Moreover, Hoyos, Morales, and Akhavan-Tabatabaei (2015) surveyed published papers in the LRDSP category that address the inherent uncertainty of the disaster area using stochastic components. In this respect, McCall (2006), Chang, Tseng, and Chen (2007), Jia, Ordonez, and Dessouky (2007), Balcik and Beamon (2008), Rawls and Turnquist (2010), Mete and Zabinsky (2010), Rawls and Turnquist (2011), Duran et al. (2011), Tofighi, Torabi, and Mansouri (2011), Lin, Batta, Rogerson, Blatt, and Flanigan (2011), Rawls and Turnquist (2012), Bozorgi-Amiri, Jabalameli, Alinaghian, and Heydari (2012), Döyen, Aras, and Barbarosoglu (2012), Bozorgi-Amiri, Jabalameli, and Mirzapour Al-e-Hashem (2013), Barzinpour and Esmaeili (2014), Rezaei-Malek and Tavakkoli-Moghaddam (2014), Garrido, Lamas, and Pino (2014), Lee, Kim, and Opit (2014), Ahmadi, Seifi, and Tootooni (2015), Rodriguez-Espindola and Gaytan (2015), Bastian, Griffin, Spero, and Fulton (2015), and Tofighi, Torabi, and Mansouri (2015) tackled the LRDSP problem in the DRL network with a mathematical modeling approach. All of the above-mentioned studies addressed

* Corresponding author.
E-mail address: tavakoli@ut.ac.ir (R. Tavakkoli-Moghaddam).

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Table 1
Probabilities of scenarios.

Scenario	Magnitude ⩽ 6 (Richter)			6 ⩽ Magnitude ⩽ 8 (Richter)			Magnitude ⩾ 8 (Richter)		
	W	R	N	W	R	N	W	R	N
Probability	0.0857	0.0536	0.1607	0.1429	0.0893	0.2679	0.0571	0.0357	0.1071

Notes: N, Non-working hours; W, Working hours; R, Rush hours.

related issues on non-perishable relief commodities (*e.g.*, tent, blanket, clothing and non-perishable food), while addressing special products (most especially the perishable ones), which has become a concern in real-world applications. These specialty products in the disaster relief networks are mainly referred to as the perishable products (*i.e.*, medical commodities, blood products and packed milk, etc.) with strict and fixed lifetimes. Some of these relief items (*e.g.*, medical commodities, blood products) perish because of their characteristics and others perish because of insufficient warehouse facilities (Yadavalli, Sundar, & Udayabaskaran, 2015). On the other side, a disaster may take a long time to strike. Therefore, if the DRL network does not have a proper ordering policy for renewing the perishable commodities, the risk of expired commodities will be high when a disaster strikes. For instance, in the Bam earthquake in Iran in 2007, a high percentage of stored antibiotics in the warehouses of the DRL were expired (nearly 30%) and the network faced a huge shortage and an increased response time at an alarming rate (JICA, 2010).

In conclusion, preparing a periodic ordering policy for perishable commodities in disaster management is quite vital (Jaller, Ukkusuri, & Holguín-Veras, 2008). To address this concern, the present work considers fixed lifetime commodities and proposes a robust dynamic bi-objective mathematical model that further incorporates the important issues of the LRDSP problem (*e.g.*, location-allocation and distribution of commodities) regarding to the probable post-disaster conditions. Indeed, handling the afore-mentioned issue in this paper results in a more reliable DRL network by reducing the risk of expired relief commodities in the network and by preventing managerial problems such as the disposal of the expired commodities in the disaster area.

Briefly, the main contributions of this paper (which differentiate our efforts from the other efforts dedicated to the LRDSP category) are as follows:

- Proposing a new integrated multi-objective model for location-allocation, ordering policy and the distribution of relief commodities to design a DRL network under uncertainty.
- Considering the dynamic environment of the DRL network in the pre-disaster phase.
- Considering the fixed lifetime of perishable commodities by adjusting certain time windows.

It is expected that this paper and its proposed approach assists the decision-makers of DRL networks by providing appropriate solutions regarding the strategic issues (*i.e.*, the location-allocation problem) and the tactical issues (*i.e.*, ordering policy problem) in preparation for a disaster.

The remainder of this paper is presented as follows. The case study is described in Section 2. The most relevant literature is reviewed in Section 3. The DRL problem is described and a new integrated mathematical model is developed in Section 4. In Section 5, the robust stochastic scenario-based programming model is proposed, and the RLTP method, which is an interactive solution procedure, is described. The computational results are presented in

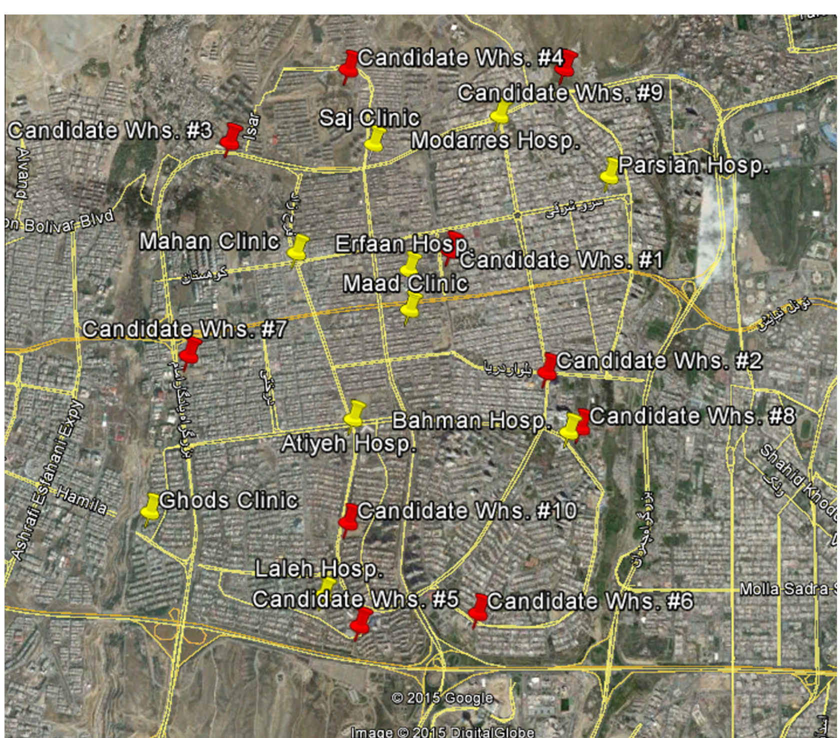

Fig. 1. Sadatabad-Shahrakegharb map: Hospitals and candidate warehouses.