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An enhanced reverse auction framework for relief procurement management

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ABSTRACT

An enhanced reverse auction framework is developed for procuring excess required relief items for humanitarian organizations at post-disaster. Given the input data tainted with epistemic uncertainty, two novel possibilistic models are developed to support the bidders and the auctioneer who is a coordinating platform (CP), regarding the bid construction and bid evaluation, respectively. First, using the bid construction model, competing suppliers determine their suggestions regarding the unit prices, quantities, and delivery times of relief items as well as the most appropriate transportation modes. Afterwards, the CP runs the bid evaluation model to assess the submitted bids by which the best portfolio of suppliers and their allocated orders are determined. An illustrative numerical example inspired by a real practice is provided to demonstrate the applicability of the proposed decision models. Several sensitivity analyses are also conducted on key parameters from which useful managerial insights are drawn.

1. Introduction

In recent years, the humanitarian logistics has attracted the attention of many researchers and practitioners because of the necessity for delivering effective and efficient disaster relief operations. The International Federation of Red Cross (IFRC) has recorded the happening of 7184 disasters worldwide in the period of 2000–2009 with more than 2.5 billion affected people [1]. For example, on 26 December 2004, the Indian Ocean tsunami killed 225,000 people [2]. On 12 January 2010, the Haiti earthquake killed 200,000 people, injured 300,000 and made about one million people homeless [3].

Providing sufficient relief items in a timely manner at post-disaster plays a key role in the performance of humanitarian relief chains (HRCs). As Thomas and Mizushima [4] defined, humanitarian logistics (HL) includes different tasks such as preparedness, procurement, planning, warehousing, transport, tracking and tracing, and clearance. Implementing HL in a proper configuration can mitigate the negative impact of disasters. McLoughlin [5] classifies HL operations into four categories including the activities related to the preparedness, mitigation, response, and recovery. Preparedness and mitigation related activities account for the pre-disaster phase while the activities related to the respond and recovery address the post-disaster phase. It is worth noting that, mitigation aims to prevent from occurring disasters, while preparedness relates to those operations with getting prepared for possible disasters. In addition, response stage associates with managing the limited resources for emergency purposes in order to save lives (e.g. relief item distributions). Also, recovery stage concerns with controlling the affected areas and returning the HRC back to the normal situation (e.g. debris removal).

At the preparedness stage, humanitarian organizations (HOs) usually purchase and preposition the critical relief items (e.g. medical kits, blanket, shelters, foods, etc.) at pre-disaster so that they can be distributed to affected areas immediately after a disaster strikes [6], while extra needed relief items should be procured at post-disaster. Taupiac [7] expresses that about 60% of expenditures during the post-disaster phase, which is the main domain of this paper, is assigned to the procurement of required relief items. Falasca and Zobel [8] argue that 65% of HL expenditures are devoted to the procurement processes, 15% for transportation, 10% for field personnel and 10% for administrative affairs. Van der Laan et al. [9] investigate on the importance of procurement process in HRCs. They clarify that order process in HOs is usually originated from a centralized decision shared between the logistics and medical teams. The department which is responsible to convert the relief items' forecasts into the orders and procure the required relief items, can be known as the coordinating platform (CP). In addition, Ertem et al. [10] declare that the procurement is a necessary and complex part of relief operations by which the required relief items are provided. The complexity of the relief items procurement within the context of humanitarian logistics might be increased with involving the monetary values, donor funding, unpredictable disasters, and lack of resources [10]. According to these data and facts, it is obvious that the procurement process of relief items in the setting of humanitarian aids should be improved in order to decrease the relief response time and also related logistical costs as much as possible.

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Despite the abundant literature about the design of procurement contracts and auctions in the setting of commercial supply chains; surprisingly, there is a very limited literature in the field of humanitarian logistics. Nevertheless, there is a strong need for designing appropriate contracts and auctions in the relief context while accounting for the special features of relief supply chains (RSCs) such as inherent uncertainty in both demand and supply data [11] and the competing environment in which the relief bidders compete together.

Auctions are classified into two categories: traditional (or forward auctions) and reverse auctions. In the forward auctions, an auctioneer (i.e. the seller) sells a number of products or services to the bidder (i.e. the buyer) with the highest offered price among the bidders. While in a reverse auction, a buyer announce for supplying a number of products or services in particular quantities for which a number of bidders may send their bids to the buyer and the final supplier(s) is (are) selected using the pre-designed bid-evaluation process [12]. Online reverse auctions are very useful in reducing the procurement cost of services and goods [13]. An additional advantage of using reverse auctions in the setting of humanitarian logistics is their applicability in the different phases of the so-called disaster management cycle including the preparedness, response and recovery phases. A reverse auction process is usually divided into the announcement construction, bid construction and bid evaluation stages. Reverse auctions are often performed in one of the sealed bid, open bid or semi-sealed bid types [12]. In the sealed bid auctions, bidders are unaware about the prices submitted by the other bidders while in an open bid auction, all prices offered by bidders are visible for all competitors. In a semi-sealed bid auction, bidders are allowed to know their current ranks according to their submitted offers but they are not allowed to know the content of their competitors' bids.

As mentioned earlier, very limited works exist in the literature of procurement management within the context of humanitarian operations (which are reviewed in Section 2). Scarcity of research in this area as well as the urgent need of Iranian Red Crescent Society (IRCS) to a reverse auction framework for procuring required relief items in both the pre- and post-disaster phases were our main motivations to develop an enhanced reverse auction framework for the relief procurement setting. The main contributions of this paper are briefly as follows:

- Accounting for the epistemic uncertainty of input data (i.e. the lack of knowledge about the exact values of uncertain parameters) and developing two possibilistic programming models to help the bidders and the CP in the bid construction and evaluation phases.
- Providing a suitable suite for making the trade-off analysis between the cost-efficiency and responsiveness of the concerned HRC using a multi-objective approach.
- Providing an illustrative example inspired by a real case study to demonstrate the applicability of the proposed reverse auction models.

The remainder of this paper is organized as follows. Related works are reviewed in Section 2. Problem description and model formulation are presented in Section 3. Solution procedure is provided in Section 4. An illustrative example inspired by a real case study is presented in Section 5 by which a number of sensitivity analyses are carried out. Main findings and managerial insights are provided in Section 6. Finally, the concluding remarks and further research directions are presented in Section 7.

2. Literature review

Balcik and Ak [6] proposed a framework agreement (FA) to facilitate the procurement activities at the post-disaster phase. A two-stage stochastic integer programming model was developed to select the most appropriate suppliers for making procurement agreements with them in the first stage (i.e. at pre-disaster), and placing the required orders in the second stage (i.e. at the post-disaster). Liang et al. [14] developed an option contract for the disaster relief setting. Their proposed contract had two delivery steps and a binominal lattice was exploited to estimate the value of option contract for the members of the supply chain under consideration. Wang et al. [15] developed an option contract for pre-purchasing required relief items (either perishable or imperishable) in a relief supply chain. They showed that pre-purchasing with an option contract is more profitable than the buy-back contract and instant-purchasing using a return policy. Rawls and Turnquist [16] proposed a scenario-based model which accounts for procurement and pre-positioning of emergency supplies. Bozorgi-Amiri [17] presented a robust scenario-based model to make the robust decisions about the relief procurement levels from different suppliers as well as their pre-positioning and distribution levels. In another work, Bozorgi-Amiri et al. [18] proposed a scenario-based model for relief prepositioning in which the procurement decisions in the pre-disaster phase are also incorporated. Van der Laan et al. [9] provided a comprehensive framework for demand forecasting and order planning in the context of humanitarian logistics. They also discuss about the impact of several factors on forecasting and order planning performances. Nagurney et al. [19] developed an optimization model with focusing on procurement and distribution of relief items. They tried to integrate the pre-positioning of relief supplies in the pre-disaster phase with the post-disaster procurements. Pradhananga et al. [20] proposed a two-stage stochastic programming model that integrates the preparedness and response planning related decisions with the purchasing decisions. Alem et al. [21] presented a two-stage stochastic network flow model which accounts for a number of pre- and post-disaster related decisions such as the budget allocation, procurement, and fleet sizing. They assumed that the pre-disaster procurements would be pre-positioned in warehouses and HOs are able to procure excess required relief items during a multi-period horizon in the post-disaster. Morrice et al. [22] concerns about purchasing goods for hurricane events and proposed an inventory management model to help retailers, who are responsible to provide supplies, estimate demands and be prepared in the pre-disaster phase. Acimovic and Goentzel [23] propose novel HL metrics in order to evaluate the response capacity. They state the importance of incorporating real limitations such as procurement budget while designing efficient disaster relief operations.

Noteworthy, relief items are typically divided into the three categories in the literature by defining three different priority levels [24–26]. The first priority level includes the urgent-immediate items (such as medical kits and shelters). The second level is related to those items with the lower-priority (e.g. food items), and finally the third level includes the relief items with the least priority (e.g. clothes).

There are also some auction-based research works in the relief setting. Trestrail et al. [27] proposed a mixed integer programming model from the perspective of bidders to enhance their bidding policy. They specifically contributed for food aid bids to response disasters and hunger. Ertem et al. [28] provided an auction-based framework, which consists of the announcement construction, bid construction and bid evaluation phases in a two-echelon humanitarian supply chain with multiple-buyers and multiple-bidders. In order to help the bidders and auctioneers to make their optimal decisions, two mathematical models were presented for the bid construction and bid evaluation phases, respectively. In another study, Ertem and Buyurgan [29] developed another auction-based procurement framework to coordinate a relief chain involving one auctioneer, which is a CP and multiple bidders (i.e. suppliers). Two mathematical models were also presented for making required decisions during the auctioning operations. As Özdamar and Ertem [30] clarified, non-governmental organizations, such as CPs, aim to enhance the performance of emergency operations by utilizing the information and communication technology (ICT). Disaster relief operations like the procurement and online ordering could be under the control of CP by using ICT. Ertem et al. [10] contributed to the bid construction phase of procurement reverse auctions in the context of HL. They presented an integer programming model to help the bidders