Risk-averse models for earthquake preparedness and response

Komlanvi Parfait Ametana[1,2], Mehdi Amiri-Aref[3], Olga Battaïa[3], Francois Clautiaux[1,2], Boris Detienne[1,2]

[1] Université de Bordeaux, Institut de Mathématiques de Bordeaux UMR 5251, Talence, France
[2] Inria Bordeaux - Sud-Ouest, Talence, France
{boris.detienne,francois.clautiaux,komlanvi-parfait.ametana}@u-bordeaux.fr
[3] The Centre of Excellence for Supply Chain Innovation and Transportation (CESIT), Kedge Business School, Bordeaux, France
{olga.battaia,mehdi.amiri-aref}@kedgebs.com

Keywords : *Disaster management, blood supply chain, robustness, finite adaptability.*

1 Introduction

Disasters can be classified into several categories, namely natural, man-made and industrial disasters. When addressed from an operations research point-of-view, disaster management is often split into two phases [7]. The preparation phase consists of building the most resilient system to face a disaster, anticipating the random disaster and the way the infrastructure will be optimally used to assist the victims in the so-called response phase.
This work focuses on the case of earthquakes. In the short term, one of the most important issues for areas affected by an earthquake is the emergency treatment of injured victims. Treating the severe wounds implied by such an event requires large amounts of blood, typically more than the regular stock at hospitals. It follows that an emergency blood supply-chain must be designed and operated, whose efficient management is complicated by the uncertainty over the blood demands and donor availability at the time of preparedness phase. In 2003, after a devastating earthquake in Iran, only about 23% of the blood collected reached the affected people [1]. This motivates us to investigate the problem of building resilient blood supply chains and defining appropriate recourse actions in accordance with the designed system, in order to mitigate the risk of such situations to occur.

In the literature, this type of problems is usually described using two-stage stochastic models. Some authors address the uncertainty through the paradigm of possibilistic programming [5], which is designed to handle rare random events for which stochastic probabilities are not well known. Another approach is risk-neutral stochastic programming [3], which minimizes the mean blood delivery time and the economic cost of preparedness and response. The authors of [4] address the problem using the concepts of solution and model robustness [6], which is designed to reduce the variability of the second stage cost on one hand, and the infeasibility of the second-stage solutions on the other hand.

2 Problem description

We have a set of possible locations for blood collection sites and donors divided into several groups. In the preparation phase, we are setting up the fixed collection center and the number of mobile collection sites that will be used after the earthquake. At the same time, an initial stock of blood is established in existing hospitals with limited capacity. The primitive uncertainty (locations and magnitudes of the tremors) is translated in our models to the uncertain demand of blood at each location and time period. In the response phase, the decisions are related to the management of the blood flow in the network and the routes of the mobile collection sites. This includes the assignment of donor groups to collection sites and the amount of blood collected at the collection sites for hospitals. The collections have to satisfy the capacity of the collection sites and the supply of donor groups. During the response phase, it is also decided what blood stock to maintain for the next period of time. The objective is to minimize the amount of unmet blood, which is a decision of the response phase, throughout the response horizon.

3 Contribution

In the purpose of placing the risk incurred by human lives at the heart of our study, we propose to address the blood supply chain design problem using two risk-averse optimization models. First, similarly to [8], we use a model based on a set of discrete scenarios, which optimizes the conditional-value-at-risk measure of the unserved demand. Second, we use a polyhedral-based uncertainty set inside a finite adaptability model [2] that minimizes the unserved demand in the worst case. We perform a numerical comparison of these approaches with the method of [4], in the objective of evaluating their relevance for minimizing the unserved demands when human lives are at stake. We used data from [4] and generated new random data sets.

References

[1] M. Abolghasemi, H.and Radfar, M. and Tabatabaee, M. and Hosseini-Divkolayee, N. and Burkle, F. Revisiting Blood Transfusion Preparedness: Experience from the Bam Earthquake Response. *Prehospital and Disaster Medicine*,23(5):391-394, 2008.

[2] D. Bertsimas and C. Caramanis. Finite Adaptability in Multistage Linear Optimization. *IEEE Transactions on Automatic Control*, 55(12):2751–2766, December 2010.

[3] Behnam Fahimnia, Armin Jabbarzadeh, Ali Ghavamifar, and Michael Bell. Supply chain design for efficient and effective blood supply in disasters. *International Journal of Production Economics*, 183:700–709, January 2017.

[4] Armin Jabbarzadeh, Behnam Fahimnia, Stefan Seuring. Dynamic supply chain network design for the supply of blood in disasters: A robust model with real world application. *Transportation Research Part E: Logistics and Transportation Review*, 70:225-244, 2014.

[5] Fazli-Khalaf Mohamadreza, Khalilpourazari Soheyl ,Mohammadi Mohammad. Mixed robust possibilistic flexible chance constraint optimization model for emergency blood supply chain network design. *Annals of Operations Research*, 283(1/2):1079-1110, 2019.

[6] John M. Mulvey, Robert J. Vanderbei and Stavros A. Zenios. Robust Optimization of Large-Scale Systems. *Operations Research*, 43(2):264-281, 1995.

[7] Scaparra, Maria Paola and Church, Richard L. Location Problems Under Disaster Events. *Location Science*, 631-656, Springer International Publishing, Cham, 2019.

[8] Nilay Noyan. Risk-averse two-stage stochastic programming with an application to disaster management. *Computers & Operations Research*, 39(3):541–559, March 2012.