Bi-objective Network Optimization in Disaster Relief Logistics

Authors : Katharina Eberhardt, Florian Klaus Kaiser, Frank Schultmann

Abstract : Last-mile distribution is one of the most critical parts of a disaster relief operation. Various uncertainties, such as infrastructure conditions, resource availability, and fluctuating beneficiary demand, render last-mile distribution challenging in disaster relief operations. The need to balance critical performance criteria like response time, meeting demand and cost-effectiveness further complicates the task. The occurrence of disasters cannot be controlled, and the magnitude is often challenging to assess. In summary, these uncertainties create a need for additional flexibility, agility, and preparedness in logistics operations. As a result, strategic planning and efficient network design are critical for an effective and efficient response. Furthermore, the increasing frequency of disasters and the rising cost of logistical operations amplify the need to provide robust and resilient solutions in this area. Therefore, we formulate a scenario-based bi-objective optimization model that integrates pre-positioning, allocation, and distribution of relief supplies extending the general form of a covering location problem. The proposed model aims to minimize underlying logistics costs while maximizing demand coverage. Using a set of disruption scenarios, the model allows decision-makers to identify optimal network solutions to address the risk of disruptions. We provide an empirical case study of the public authorities' emergency food storage strategy in Germany to illustrate the potential applicability of the model and provide implications for decision-makers in a real-world setting. Also, we conduct a sensitivity analysis focusing on the impact of varying stockpile capacities, single-site outages, and limited transportation capacities on the objective value. The results show that the stockpiling strategy needs to be consistent with the optimal number of depots and inventory based on minimizing costs and maximizing demand satisfaction. The strategy has the potential for optimization, as network coverage is insufficient and relies on very high transportation and personnel capacity levels. As such, the model provides decision support for public authorities to determine an efficient stockpiling strategy and distribution network and provides recommendations for increased resilience. However, certain factors have yet to be considered in this study and should be addressed in future works, such as additional network constraints and heuristic algorithms.

Keywords : humanitarian logistics, bi-objective optimization, pre-positioning, last mile distribution, decision support, disaster relief networks
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