

Decision alternatives between expected cost minimization and worst case scenario in emergency supply – Second revision



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ABSTRACT

Emergency supply chain management is often in the focal point of public scrutiny. Expected cost minimization may result in unacceptable high shortage for scenarios with small probabilities that is hardly tolerated by the public. To decrease the loss for the worst-case scenario, the min–max regret criterion could be applied for the pre-positioning decision. This alternative could get public support but results in high pre-positioning cost and large amount of unused resources since an unfavorable scenario with very low chance would dominate the solution. We suggest a compromising decision criterion and apply it for hurricane supply of commodities (like bottled water and canned food) in the Louisiana Gulf Coast. We coordinate the two stages, the preparedness and response decisions, in a large hierarchical emergency supply chain. The decision makers can utilize the major advantage of our parametric decision model providing a set of solution alternatives that dominate the decisions on different reliability levels.

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1. Introduction and literature review

A critical component of emergency response is the resource supply chain of providing commodities (like bottled water and canned food). Lacking sound analysis of how supply chains operate during disasters, organizations continue to underestimate disruption risk and fail to take appropriate approaches to mitigate these risks proactively. The Federal Emergency Management Agency (FEMA) summarized the status of disaster supply in the USA: “The sourcing for disaster response is fragmented; the lack of integrated and coordinated supply management results in supply delays on one hand and waste on the other hand.” How could the *pre-positioning* of resources in the preparedness phase and the supply of commodities in the *response phase* after the hurricane hit be better coordinated? We built different two-stage optimization models for this problem.

Disaster supply chain management is often in the focal point of public scrutiny. The pre-positioning of resources based on *expected cost minimization* may result in unacceptable high shortage cost for some disaster scenarios with small probabilities. This may be a major disadvantage, since any chance for huge loss is hardly tolerated by public opinion. However, planning for the worst case scenario can be too expensive.

The potential loss for a specific scenario is the *regret*, the difference between the cost of the overall optimal solution and the cost of the best solution for that specific scenario. To decrease the loss for the worst-case scenario, the common approach is to minimize the maximum regret, which is the *min–max regret criterion*. The min–max regret decision could get a public support but it results in an unacceptable high pre-positioning cost and high potential for unused resources since an unfavorable scenario with low chance would dominate the solution. We seek a compromise between the worst-case and average cost criteria. What kind of compromise should provide a reasonable cost and public support at the same time?

The so-called *p*-reliable regret criterion we use is a trade-off between the expected value and the min–max regret criteria. To avoid the dominance of a single or multiple worst case scenarios with very low probabilities of occurrence, we propose to disregard the lowest-chance scenarios and consider only the highest chance scenarios up to a total probability of *p* chosen close to 1. The disregarded scenarios can be selected in increasing order of probability starting with the lowest probability scenario and continue until the $1 - p$ cumulative probability is reached. Instead, we apply an optimization model that endogenously selects a subset of the scenarios whose collective probability of occurrence is at least *p* and disregards the other scenarios. So we minimize the maximum regret with a chance *p* that the regret will be not more than the one found by the model. The decision makers can utilize the major advantage of our parametric decision model providing a set of

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solution alternatives that dominate the decisions on different reliability levels.

We apply the above decision criteria to a disaster supply chain problem for hurricane scenarios in the Louisiana Gulf Coast area. We coordinate the two stages, the preparedness and response decisions, in a large hierarchical emergency supply chain model. In the first stage decision the expected cost of the second stage is included which is influenced by the first stage decision.

The literature is rich in papers related to the disaster SCM area. Articles surveying disaster supply chain papers include an OR methodology survey by Altay and Green (2006), a risk management survey by Tang (2006), a Special Issue on OR recovery planning (edited by Osei-Bryson and Joseph, 2009), and a Special Issue on disaster SCM (edited by Boin et al., 2010). Most papers dealing with disaster supply chain are focusing either on the evacuation or on the supply part. The recent papers in the specifics of *evacuation and sheltering* planning include the following papers. Yi and Ozdamar (2007) present an integrated location-distribution model for coordinating logistics support and evacuation operations in disaster response activities. Saadatesresht et al. (2009) address the use of multi-objective evolutionary algorithms and a geographical information system for evacuation planning. Stepanov and Smith (2009) are dealing with the optimal design of evacuation routes. An et al. (2013) propose a reliable emergency facility location model that determines both pre-emergency facility location planning and the evacuation operations afterwards, while facilities are subject to the risk of disruptions. Hadas and Laor (2013) published a model that integrates evacuation time and costs within the network design problem. A recent paper by Murray-Tuite and Wolshon (2013) provides a review of highway based evacuation modeling and simulation. In our paper we connect the evacuation and sheltering to the resource allocation and distribution problem and we examine the integrated decision problem.

Several papers are dealing with *resource allocation and pre-positioning*. Mete and Zabiski (2010) used a stochastic program to decide the locations and inventory levels of medical supply in preparedness and distribution in response under given scenarios. Taskin and Lodree (2010) solve a stochastic inventory control problem for manufacturing and retail firms who face challenging procurement and production decisions associated with hurricane seasons. Rawls and Turnquist (2010) used a stochastic program to determine the locations and quantities of emergency supplies during the preparedness stage. Campbell and Jones (2011) include

the risk of the location if the disaster occurs. Considering these risks, they determine the optimal stocking quantity and the total expected costs. Rawls and Turnquist (2012) extend their previous research and include requirements for reliability in the solutions that all demands are met in scenarios comprising at least $100\alpha\%$ of all outcomes. Galindo and Batta (2013) also include the possible destruction of supply points during the disaster event. The above mentioned papers are all dealing only with supply planning. These papers do not integrate the evacuation and sheltering phase into the supply problem like we do it in our paper.

Integrated evacuation and resource allocation was published first by Li et al. (2011). We extended the integrated modeling approach with additional complexities in supply chain structure in Kelle et al. (2011). While the Kelle et al. (2011) paper is based on minimizing the expected value as decision criterion, in our current paper the same supply chain structure is considered but the decision criterion has been changed to find the appropriate compromise between the worst-case and average cost consideration.

Stochastic programming is one of the most frequently used methods for disaster supply chain management (see Altay and Green, 2006). We apply also stochastic programming methodology but for a more complex, integrated demand–supply model not considered before. Most papers use the expected value criterion to find the optimal solution. First Barbarosoglu and Arda (2004) applied stochastic programming in disaster supply management. Balcik and Beamon (2008) determine the number and locations of distribution centers in a relief network by stochastic programming. Liu et al. (2009) applied two-stage stochastic programs in long-term transportation planning to minimize a mean-risk objective of the system loss while considering the interdependencies of individual facilities. Revealing the problems of the expected value criterion, different alternative criteria were applied for disaster supply. The mean-risk criterion (considering a weighted mean-risk objective) was applied by Ahmed (2006) and the Conditional Value at Risk criterion was used by Fábíán (2008) and Noyan (2012). The Conditional Value at Risk (CVaR) is defined as the expected loss exceeding Value-at-Risk that is the quantile of potential losses. Similar to our decision criterion, the α -reliable min–max regret criterion has been applied by Daskin et al. (1997) for a stochastic facility location problem. The model minimizes the expected regret with respect to a subset of worst-case scenarios whose collective probability of occurrence is no more than $1 - \alpha$.

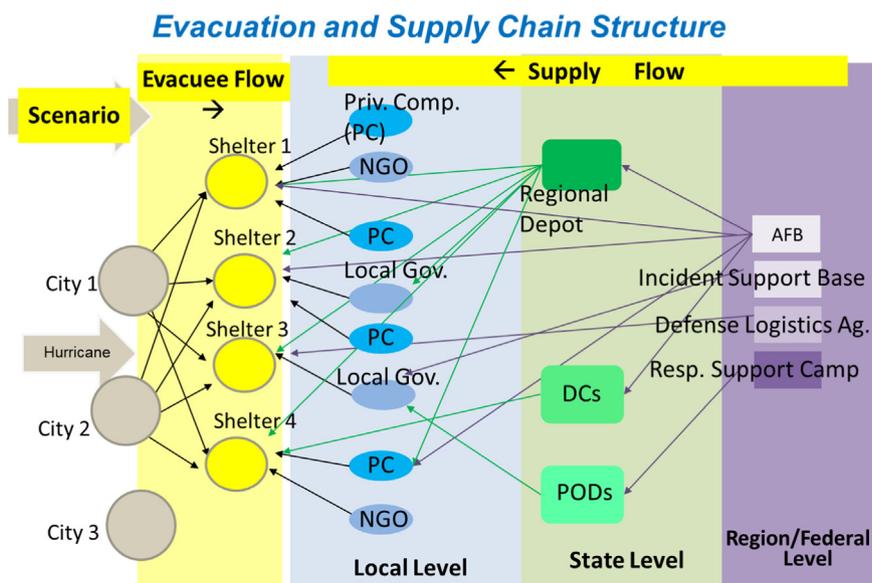


Fig. 1. The disaster preparedness and response network.

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