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Designing an efficient humanitarian supply network

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ABSTRACT

Increasingly, humanitarian organizations have opened regional warehouses and pre-positioned resources locally. Choosing appropriate locations is not easy and frequently based on opportunities rather than rational decisions. Dedicated decision-support systems could help humanitarian practitioners design their supply networks. Academic literature suggests the use of commercial sector models but rarely considers the constraints and specific context of humanitarian operations, such as obtaining accurate data, high uncertainties, limited budgets and increasing pressure on cost efficiency. We propose a tooled methodology to properly support humanitarian decision makers in the design of their supply chains. Our contribution is based on the definition of aggregate scenarios to reliably forecast demand using past disaster data and future trends. Demand for relief items based on these scenarios is then fed to a mixed-integer linear programming model in order to improve current supply networks. The specifications of this model have been defined in close collaboration with humanitarian workers. The model allows analysis of the impact of alternative sourcing strategies and service level requirements on operational efficiency. It provides clear and actionable recommendations for a given context, bridging the gap between academics and humanitarian logisticians. The methodology was developed to be useful to a broad range of humanitarian organizations, and a specific application to the supply chain design of the International Federation of Red Cross and Red Crescent Societies is discussed in detail.

1. Introduction

Humanitarian organizations (HOs) need to respond quickly to crises, providing medical aid, shelter, food, and water to victims. Disaster relief largely depends on logistics, so improvements in this area have major impacts on the three performance dimensions of relief operations: effectiveness (quality), responsiveness (time), and efficiency (cost). In order to improve their operations, organizations "have to work hard not only during disasters but also between disasters" (Van Wassenhove, 2006). Consequently, most organizations have recently reexamined their logistics networks or are considering doing so.

Research on supply networks is well-established and discusses both centralized and decentralized systems. Centralized systems enable risk pooling and are generally better in terms of safety stocks, overhead costs, and economies of scale (Simchi-Levi et al., 2003). Decentralized systems have better lead times and therefore seem to fit well with the humanitarian need for quick response. A swift response is vital for victims but also essential for favorable media coverage which has a strong impact on funding. Advanced and decentralized stockpiling of a variety of resources is crucial for a fast, adequate, and efficient response, given the cost of intercontinental airlifts.

Most HOs have transited to decentralized supply networks, capitalizing on improved delivery service by getting closer to the field (Gatignon et al., 2010). The Pan American Health Organization (PAHO) lists short delivery times, reduced transportation costs, and building local capacity as the major advantages of a decentralized system. It also points out that local shipments normally require less documentation than international consignments. In addition, a decentralized system increases the quality and predictability of local purchases and supports the local economy (PAHO, 2001). According to the International Federation of Red Cross and Red Crescent Societies (IFRC), decentralized networks also increase visibility and coordination with national societies and other local nongovernmental organizations (NGO).

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However, HOs have historically behaved rather opportunistically in reconfiguring their logistics networks. They have built their stocks where they already had operations or have identified convenient locations based on proximity to an airport or special customs and tax advantages in some countries. By failing to systematically consider all options, they may have missed out on better locations.

Designing an optimal supply network is a major challenge for humanitarian practitioners. The trend toward more frequent medium-sized disasters imposes a simultaneous management of multiple relief operations around the world. A performing supply network is therefore crucial to HOs. In addition, donors are pledging millions in an economic context that demands rationalization. They seek more accountability and cost efficiency and are less tolerant to the old fire-fighting mentality that characterized many relief operations.

The IFRC recognized these issues as early as 2007, during a meeting at its Geneva headquarters, shortly after the reorganization of its logistics network. The organization faced critical questions: "What stock should we hold? How much, and where?" (IFRC, 2007). They needed answers to these questions, and they also wanted to know which parameters impact the decision process. Despite clear improvements with their decentralized supply network, these questions remain relevant today.

Recent academic publications on facility location have applied commercial approaches to the context of disaster relief (see Section 2 for details). Our review shows that this strategy has reached its limits. First, the research frequently uses fictitious scenarios and data to compensate for the lack of realistic information. This approach is no longer sufficient to validate whether decision support systems can be successfully applied in the actual context of disaster relief. Real cases with accurate data are necessary to enable HOs to start using the results of academic studies. Our first research objective is to carefully generate realistic data based on past and future disaster trends, as suggested by Galindo and Batta (2013) and Pedraza-Martinez and Van Wassenhove (2013). Second, research (see section 2 for details) has focused on effectiveness (quality) and responsiveness (time) of humanitarian networks. We asked HOs about their real concerns regarding network design, using semi-structured interviews, and consistently got the same response. Starting the interview with an open question, effectiveness is indeed mentioned as the key objective. But after discussion, once we explained the difference between "what is the most important" and "what is the right objective function", interviewees agreed that effectiveness (quality) and responsiveness (time) are a target to be met for the organization, e.g. reaching x beneficiaries with y essential relief items within z days. However, the real concern of HOs in building their supply networks is how to achieve this target, and how to do so in the most cost efficient way.

It may help to understand this better when one considers the fact that HOs have a limited budget to respond to disasters. Cost efficiency simply allows these organizations to reach more beneficiaries. Consequently, we develop a model that reflects these priorities, i.e. in which cost efficiency is the objective and quality (effectiveness) and timeliness are constraints. In sum, our research follows the recommendations of Schmenner et al. (2009): "focus on what appears to be important to know, what we understand about it, and what we can do to understand it better". Facility location problems have received much attention, so the main goal was not to propose a fundamentally novel method but a dedicated model capable of ensuring that HOs find relevant answers to their problems. The study provides answers regarding the optimal configuration (one-stage or two-stage network), the optimal number, size and location of warehouses and the impact of alternative sourcing strategies on decisions.

2. Literature review and research statements

2.1. Gap between needs and research in the humanitarian sector

The number of scientific and managerial publications on humanitarian logistics has increased considerably in recent years. Yet few, if any, HOs actually use optimization-based decision-support systems. Authors such as Galindo and Batta (2013) and Van Wassenhove and Pedraza Martinez (2012) have argued that, to bridge this gap, research should be more realistic and consider real-world problems and data on past, present, and future disaster trends. However, researchers find it difficult to obtain accurate and, above all, reliable data (Van Wassenhove, 2006; Peres and Brito, 2012).

More research should be done in close collaboration with HOs. Academics need to learn about the challenges and priorities of this specific sector. We have interviewed a dozen logistics decision makers from various HOs (IFRC, Médecins Sans Frontières (MSF), World Vision International (WVI), Word Food Program (WFP)). Objectives, constraints, availability and accuracy of data were discussed. Interviewees notably insisted that their problem is not maximizing coverage because (i) plane deliveries allow them to quickly cover large distances, and (ii) search-and-rescue activities and needs assessment are the priorities in the first hours after disasters. HOs need to ensure that relief items reach affected areas at the most appropriate times to correctly prioritize actions in the field, and to avoid bottlenecks and needless competition for scarce transportation resources.

To formulate models that use realistic assumptions and produce more applicable research, Galindo and Batta (2013) argue that it is necessary to conduct a formal analysis with a solid statistical basis. Research in the humanitarian sector will be applied by HOs only if they trust the findings. Altay and Green (2006), Simpson and Hancock (2009), Lettieri et al. (2009), and Galindo and Batta (2013) recently conducted reviews of disaster management literature and identified its strengths and weaknesses. They propose clear directions to increase the relevance and impact of research on HOs. In particular, they suggest: (i) building realistic assumptions and scenarios, (ii) improving the efficiency capabilities of humanitarian networks and (iii) considering the effect of data uncertainty on the results. Our approach is aligned with these recommendations.

2.2. Facility location problems in disaster relief

2.2.1. Choice of the objective function: effectiveness, responsiveness, or efficiency?

Facility location models dedicated to the not-for-profit sector mostly focus on the response phase (Barbarosoglu et al., 2002; Ozdamar et al., 2004; Yi and Ozdamar 2007 and Campbell et al., 2008). More than one-third of research papers focus on early response (Galindo and Batta, 2013). Another often-studied problem concerns setting up a local, pre-positioning system (Hale and Moberg, 2005; Salmeron and Apte, 2010; Rawls and Turnquist, 2010; Mete and Zabinsky, 2010). Among the facility location articles dedicated to disaster relief, only a small proportion adopt a preparedness perspective and consider the global supply network (Akkihal, 2006; Lodree and Taskin, 2007; Balcik and Beamon, 2008; Ukkusuri and Yushimito, 2008; Campbell and Jones, 2011; Duran et al., 2011; Yushimito et al., 2012).

All these papers focus on maximization of effectiveness or responsiveness. Effectiveness is defined as the "ability to deliver the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct user" (Supply Chain Council, 2006), while responsiveness is the "ability to evaluate and take

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