Humanitarian Supply Chain Management – An Overview

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Disasters recently received the attention of the Operations Research community due to the great potential of improving disaster related operations through the use of analytical tools, and the impact on people that this implies. In this introductory article, we describe the main characteristics of disaster supply chains, and we highlight the particular issues that are faced when managing these supply chains. We illustrate how Operations Research tools can be used to make better decisions, taking debris management operations as an example, and discuss potential general research directions in this area.

Introduction

From improving the performance of fire and police departments, optimizing the public transportation system, programming delivery of blood to hospitals, planning housing projects, analyzing drug policies, to improving delivery of meals to senior citizens, there are many examples of how Operations Research (OR) addresses community needs (Kaplan, 2008). Public sector OR deals with solving public interest problems through the application of analytical tools. One of the public sector OR application areas is humanitarian OR, which particularly deals with the problem of delivering relief to people affected by a disaster. Hence, natural and man-made disasters are the most common subject of attention for humanitarian OR.

There were 6,637 natural disasters between 1974 and 2003 worldwide, with more than 5.1 billion affected people, more than 182 million homeless, more than 2 million deaths, and with a reported damage of $1.38 trillion USD (Center for Research on the Epidemiology of the Disasters (CRED)). In 2005 alone, over 180,000 deaths and $200 billion USD economic losses have occurred due to disasters according to the Disaster Resource Network Humanitarian Relief Initiative (HRI). The September 11 attacks (2001), tsunami in South Asia (2004), Hurricane Katrina (2005), earthquakes in Pakistan (2005) and Java (2006), are just some examples of the deadliest disasters witnessed by humankind in the past few years.

The consequences of these events are enormous, not only in the short term with injuries, loss of life, and damaged infrastructure, but also in the long term with changes in social and economic conditions. Even though the occurrence of these events could not have been avoided, the impact could have been reduced by different means including humanitarian OR. For example, adequate warning systems could have prevented injuries and fatalities during the 2004 tsunami and help could not reach Pakistani earthquake victims due to logistics difficulties with limited infrastructure. Humanitarian OR differs from other OR applications because it deals with particularly unique and highly variable events, often in resource-poor and limited infrastructure environments, with multiple organizations trying to work together in response activities simultaneously. These factors increase the complexity of responding to these events.

Dagstuhl Seminar Proceedings 09261
Models and Algorithms for Optimization in Logistics
http://drops.dagstuhl.de/opus/volltexte/2009/2181

The focus of this article is on supply chain related issues in humanitarian operations, with a greater focus on "disasters" rather than ongoing conditions. We discuss differences between regular supply chains and supply chains used for disaster planning and response, "humanitarian supply chains". First, we describe characteristics of supply and demand of disaster supply chains, followed by a discussion on the particularities of the execution and management of these supply chains. Next, an application of OR in humanitarian operations is examined in more detent, and finally main challenges and future research directions are presented.

Supply: Supplies consist of relief items, personnel/volunteers, and transportation and construction resources, among others. Most of the supplies fall into the relief items category. There are specific challenges related to supplies that come from in-kind donations. First, since the quantity and mix of the supplies depend at least to some degree on the donor, there is a high uncertainty of what is going to be received. Moreover, the timing of these supplies might not be appropriate: for example, consumables that arrive too early and cannot be stored for a long time, or non-consumables that arrive after the operation was set up are wasted. There are many cases in the recent history where donated items were not needed and were not deployed to people affected by the disaster. Autier *et al.* (1990) discuss the case of drug supplies after the 1988 Armenian earthquake, when at least 5,000 tons of drugs and consumable medical supplies were sent by international relief operations, but only 30% were immediately usable (sorted, relevant for the emergency situation, and easy to identify), and 20% of these supplies had to be destroyed by the end of 1989. Unsuitable donations caused bottlenecks in the supply chain, making storage and transportation processes more inefficient.

Demand: The customers in a disaster supply chain include the population at the affected area, as well as intermediate customers at local or global storage facilities. Their needs change significantly according to disaster types and the phases in the disaster timeline. Dependency of demand in disasters on these hard to measure factors and its high uncertainty are the main differences from the demand in regular supply chains. Unlike logisticians in the private sector, humanitarian workers are always faced with the unknown: when, where, what, how much, where from and how many times; in short, the basic parameters needed for an efficient supply chain setup are highly uncertain (Van Wassenhove, 2006). Disaster demand forecasting is also difficult due to the lack of historical data. Even though there do exist some databases from the past experiences prepared by both NGOs and governments such as the EMDAT: Emergency Events Database by the Center of Research on the Empidemiology of Disasters, they are occasionally inadequate because of inconsistent and/or insufficient data collection and reporting problems. Additionally, disasters are unique even if they occur in the exact same location, since other factors such as population structure or economic conditions could have changed since the previous occurrence. Hence, historical data is not always very useful for predicting future demand.

Disaster Supply Chains: Supply chains link the sources of "supply" (suppliers) to the owners of "demand" (end customers). In a typical humanitarian supply chain, governments and NGOs are the primary parties involved. Governments hold the main power with the control they have over political and economical conditions and directly affect supply chain processes with their decisions. After the 2004 tsunami, for instance, the Indian government did not invite international aid agencies to participate at all in the first 60 days of the relief effort, and functioned during that period with the local sources of supplies (Thomas and Fritz, 2006). Donors, military and the media are the other significant players in the humanitarian supply chains.

Coordination and management of disaster supply chains has challenging problems. The supply network is huge and complicated with numerous players (donors, NGOs, government, military, and suppliers), and it is hard to coordinate all of them along with all the items that need to be delivered. Despite the different cultural, political, geographical and historical differences among them, collaboration and specialization of the tasks between NGOs, military, government and private business are increasingly needed in the humanitarian supply chains (Van Wassenhove, 2006). Despite being experienced and aware of the key points in humanitarian supply chains, people in charge of logistics and supply chain management in most NGOs or other humanitarian organizations are not often specialized in this area, thus they are not experts in the tools for solving the problems that might occur during the operations. There could also be domestic barriers such as the need of excessive paper work, and specific policies of the region that may cause additional delays, as well as external complications due to foreign relations.

Goals and performance metrics of humanitarian and regular supply chains differ notably. Unlike the humanitarian supply chains, which do not have any profit targets and rely heavily on volunteers and donors, in regular supply chains, stakeholders are the "owners" of the chain. Nevertheless, the numerous models based on minimizing cost (or equivalently, maximizing profit) for building efficient supply chains can be applied to the humanitarian supply chains directly or with modifications. One example is an integrated multi-objective supply chain (SC) model that uses fill rate, cost and flexibility as measurement factors for simultaneous strategic and operational SC planning (Sabri and Beamon, 1999). Lodree and Taskin (2009) work on stochastic production/inventory control models for recovery planning, specifically for hurricanes, to determine how long to postpone decision making to optimize the trade-off between logistics cost efficiency and hurricane forecast accuracy.

An illustrative example - Debris Management Operations (Carbajal *et al.* (2008))

Depending on the nature and severity of the disaster, and the characteristics of the affected area, there could be massive amounts of debris. The resources required to collect the debris might be limited, debris could be blocking roads and obstructing aid supply, and some types of waste can endanger community health and safety; therefore, resources have to be allocated adequately to speed up the debris collection and disposal process, while minimizing its impact.

During the pre-event stage forecasts are made to predict the quantities and location of debris prior to disasters. Debris forecasts are used to plan for the resources, to design debris management sites for temporary storage, and to develop adequate strategies for debris final disposal. During the response stage, having access to injured people and to critical facilities such as hospitals or police stations is crucial. Roads and streets that are essential for the emergency operations might be obstructed, and debris must be removed to facilitate rescue efforts. A network model can determine how resources should be allocated and which roads should be cleared first. Such a model takes into account the priority of the facilities to be connected in order to maximize the supplied relief, as well as the available quantity of workforce and equipment.

The longest phase of the debris collection process occurs during the recovery stage of a disaster, once emergency and other major routes are cleared from debris. After the disaster, community residents begin to take debris to public rights-of-way, and this debris along with what was left after the response stage has to be collected. Debris such as white goods (containing refrigerants and other regulated machine fluids) and hazardous waste has to be handled with special care due to environmental and health safety impact. Scheduling and routing models for the debris collection resources can be developed to minimize the impact of the remaining debris while using the available resources efficiently to reduce costs. A model of this nature assigns each resource to loading tasks at the debris sites and unloading tasks at the debris management sites. After the debris is collected, it may go through some reduce or recycle processes, and then be taken to its final destination. Deciding the best policies to follow for each debris type is not a trivial problem when different constraints such as environmental regulations, available capacities, budget, etc., are taken into account. A mathematical model can help the decision maker to find an optimal trade-off of cost and environmental impact.

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