



Disaster relief routing: Integrating research and practice

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ABSTRACT

Disaster relief presents many unique logistics challenges, with problems including damaged transportation infrastructure, limited communication, and coordination of multiple agents. Central to disaster relief logistics is the distribution of life-saving commodities to beneficiaries. Operations research models have potential to help relief agencies save lives and money, maintain standards of humanitarianism and fairness and maximize the use of limited resources amid post-disaster chaos. Through interviews with aid organizations, reviews of their publications, and a literature review of operations research models in transportation of relief goods, this paper provides an analysis of the use of such models from the perspective of both practitioners and academics. With the complexity of disaster relief distribution and the relatively small number of journal articles written on it, this is an area with potential for helping relief organizations and for tremendous growth in operations research.

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1. Introduction

Just days after the 2010 earthquake in Haiti, the United Nations (UN) called the earthquake the worst it had encountered [1]. Six months later, UN Secretary General Ban Ki-Moon said the same about devastating floods in Pakistan, and called for half a billion dollars of support just for short-term relief [2]. In addition to these catastrophes, the past decade has seen many other large disasters including the 2004 Indian Ocean earthquake and tsunami, in 2005 Hurricane Katrina, the 2005 Pakistan earthquake, in 2008 Cyclone Nargis and the 2008 Sichuan earthquake. The destruction from disasters can leave populations without shelter, food and water, and in need of urgent medical care. In these situations, it can be necessary to supplement local capacity with regional or international aid. For example, within the first 30 days of the 2001 Gujarat, India earthquake, the International Federation of the Red Cross and Red Crescent (IFRC) arranged delivery of hundreds of thousands of blankets, tents and plastic sheets. Additionally, over 300 other non-governmental organizations (NGOs) and UN agencies provided assistance [3]. The Gujarat earthquake is just one of many large disasters that have required international assistance, and is far from the largest. A contains a table of the top five (by number of lives lost) earthquakes, cyclones, and floods from 1980 to 2009.

Tables are derived from data at EM-DAT, a global database of disaster information [4].

Disaster relief requires efforts on many fronts: providing rescue, health and medical assistance, water, food, shelter and long term recovery efforts. Much of successful and rapid relief relies on the logistical operations of supply delivery. In 2005, the United Nations established the Logistics Cluster as one of nine inter-agency coordination efforts in humanitarian assistance, recognizing the key importance of logistics in aid operations. The Pan American Health Organization (PAHO), a regional division of the World Health Organization (WHO), states in its publication *Humanitarian Supply Management and Logistics in the Health Sector* ([5]) that “countries and organizations must see [humanitarian supply logistics] as a cornerstone of emergency planning and preparedness efforts.”

In this paper we focus on reviewing the problems related to routing of vehicles within disaster-affected regions to deliver goods and services to distribution points and beneficiaries.

We analyze the representation of these problems in current operations research models for disaster relief, and identify outstanding related research questions. Mathematical models related to emergencies have a long history. In 1955, Valinsky [6] published one of the earliest papers in emergency assistance, on locating fire fighting resources. Work related to non-daily emergencies started in the 1980s, in assessing the risk of rare events such as large natural disasters (Sampson and Smith [7]) and simulations of traffic patterns to improve the flow of emergency evacuation (Sheffi et al. [8]). Disaster relief transportation also saw its start in the 1980s with a routing model developed by Knott in 1987 [9]. In order to better understand the ways in which operations research

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models are helping and can continue to help relief organizations, we have conducted a series of interviews with representatives from organizations involved in disaster relief. These include small and large NGOs, local, state and federal governmental relief organizations and commercial partners of relief organizations. In addition, we discuss findings from publications of relief organizations on logistical procedures for disaster relief. We have also conducted a comprehensive literature review of operations research models in disaster relief transportation and distribution. We review findings from these studies and discuss areas where models can continue to expand and capture characteristics of relief distribution. Our literature review focuses on papers specifically in relief transportation and their modeling characteristics. Other surveys in humanitarian logistics have been published previously. [10] gives an overview of academic literature in disaster operations management, discussing work in disaster operations not limited to routing. Kovács and Spens [11] provides a survey of both academic and practitioner literature in disaster operations. From their in-depth survey of practitioner literature, the authors find many challenges in disaster operations similar to what we found from our interviews: destabilized infrastructure; uncertainty in demand, supply, and the time and effort needed to distribute goods; a need for academic work that considers dynamics; and fundamental differences in goals and objectives between commercial and non-profit logistics. Simpson and Hancock [12] also provides a broad recent survey of work in all areas of emergency response, including disaster relief along with other categories such as daily fire and medical emergencies, evacuation, and search and rescue operations.

1.1. Information collection methodology

To collect papers on operations research models for this review, we searched journal search engines such as ISI Web of Science, the INFORMS journal database, Transportation Research Board publication database, Science Direct, Springer Journal Database and various individual journals' search engines. These were queried using the keywords "disaster", "emergency", "catastrophe", "humanitarian", and other forms of the words such as "disastrous". The search engines' filters were used to narrow results to operations research models for disaster relief. Within these results, papers were kept that specifically address the transportation and routing of goods. Finally, the reference sections of these papers were searched to find additional relevant papers. Many of the papers selected model additional characteristics, including asset pre-positioning, facility location, infrastructure repair following

a disaster, or evacuation and rescue and evacuation, but all include transportation of goods as a significant component.

To learn about current practices and challenges in disaster relief transportation and distribution, we interviewed representatives from governmental organizations, NGOs, and commercial partners of organizations. We interviewed 32 representatives from 21 organizations over the phone or in person with follow-up questions by email. Interviewees were not all asked the same set of questions. All interviews began with similar initial questions and progressed based on the responses and expertise of the interviewee. From these interviews, we share responses that have an impact on modeling disaster relief transportation and distribution problems. To protect the confidentiality of interviewees, we use the conventions similar to those of Holguín-Veras et al.'s [13] review of logistics issues during Hurricane Katrina. Government agencies are referred to only as "state" or "federal" depending on their jurisdiction. Those from non-profit organizations not under the jurisdiction of a government are identified as volunteer organizations. Some of the organizations interviewed work primarily in countries other than the US, which we describe as international organizations. Those from commercial partners are referred to as "commercial partners". We interviewed three commercial partners, eight international volunteer organizations, four volunteer organizations working primarily in the US; three volunteer organizations that work in both the US and internationally; one US federal government organization and one US state government organization.

In addition to interviews, we include findings from the general media, trade publications and other publications in disaster relief and humanitarian logistics.

In the next sections, we review these papers concurrently with our findings from interviews and relief organization publications. We categorize papers by problem characteristics and discuss these characteristics with related findings. Tables 2 and 3 provide a summary of transportation-related modeling characteristics in the papers reviewed. Table 2 defines the terms used in Table 3.

2. Relief transportation in practice and operations research models

2.1. Allocation policies

A critical and challenging component of relief distribution is the allocation of goods to beneficiaries. In many situations, beneficiary needs exceed the available supply of goods and relief organizations must allocate limited goods. Published humanitarian guidelines do

Table 1
Top five disasters by number of lives lost from 1980–2009 (plus 2010 Haiti earthquake) and number of disasters 1980–2009 (source: [4]).

Type	No. of disasters, 1980–2009	Year	Country	Lives lost	No. of people affected	Damage (Millions \$)
Earthquake	756	2010	Haiti	222,570	3,700,000	8000
		2004	Indonesia	165,708	532,898	4451.6
		2008	China P Rep	87,476	45,976,596	85,000
		2005	Pakistan	73,338	5,128,000	5200
		1990	Iran Islam Rep	40,000	710,000	8000
Cyclone	2516	1991	Bangladesh	138,866	15,438,849	1780
		2008	Myanmar	138,366	2,420,000	4000
		1985	Bangladesh	15,000	1,810,000	50
		1998	Honduras	14,600	2,112,000	3793.6
		1999	India	9843	12,628,312	2500
Flood	3120	1999	Venezuela	30,000	483,635	3160
		1980	China P Rep	6200	67,000	160
		1998	China P Rep	3656	238,973,000	30,000
		1996	China P Rep	2775	154,634,000	12600
		2004	Haiti	2665	31,283	

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