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Relief Distribution Networks: A Systematic Review

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Abstract. Emergency Management has received increasing attention from the scientific community in the past 20 years and, as a result of this interest, an abundance of articles on disaster management are available in the literature. In particular, the number of recently published OR/MS contributions to the field has literally exploded. This paper presents a systematic review of contributions related the relief distribution networks in response to disasters. It tries to gather and consolidate the many different studies available in order to give an up-to-date survey of the research in relief distribution networks, show the advancement in this discipline, and highlight the most significant contributions in the literature.

Keywords. Emergency logistics, humanitarian logistics, emergency management, response optimization, systematic review.

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Introduction

From the beginning of time, disasters and catastrophes have been part of the world's reality. The number of victims and economic loss after a disaster is huge, even today when technology and advancements in disaster planning are playing in our favor. For instance, Japan's earthquake and tsunami in March 2011 resulted in more than 15800 deaths and 3600 missing people[1] in the Tohoku district only, and over 210 billions of dollars of economic loss[2]. Due to the multiple catastrophes, both natural and manmade, happening in different corners of the planet, the scientific community is increasingly interested in developing Emergency Management (EM). The main goal of emergency management is to help communities to prepare themselves for disasters and, eventually, be able to respond to extreme events. Emergency management can be divided into four phases. The mitigation and preparedness phases take place before the disaster. These phases try to reduce the probability of the disaster or to minimize its possible effects (Altay & Green, 2006; Haddow et al., 2007; McLoughlin, 1985). The phases of response and recovery are post-disaster phases. The response phase seeks to minimize the effects of the disaster by helping people as quickly as possible and preventing any more loss, while the recovery phase tries to support the community in order to re-establish their normal state.

In recent years, many academic publications have joined the group of contributions to the research in one or more of these four phases. According to Altay & Green (2006), a total of 109 EM scientific articles were published between 1980 and 2004, with 46.8% of them appearing after 2000. This growing researcher interest in this field is not only due to its urgency and its relevance, but also to the challenge that it represents. Even though logistics network design is a widely-studied discipline, business logistics methods cannot be directly applied in an emergency management framework.

Many authors in the literature have acknowledged that the particularity of the emergency management context imposes some new challenges to logistics optimization (Kovács & Spens, 2009; Kovács & Spens, 2007; Sheu, 2007b; Tzeng, 2007; Van Wassenhove, 2005). For instance, in a crisis context, the humanitarian logistics seek to minimize loss or to maximize need satisfaction, instead of focusing on minimizing the costs. What is more, distribution agility is a challenge, especially during the first days following the disaster. Again, the stochastic and dynamic aspects of demand require a

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[1] Damage Situation and Police Countermeasures associated with 2011 Tohoku district - off the Pacific Ocean Earthquake - November 22, 2011 - http://www.npa.go.jp/archive/keibi/biki/higaijokyo_e.pdf

[2] EM-DAT data base, Disaster profile: Earthquake (seismic activity): http://www.emdat.be/result-disaster-profiles?disgroup=natural&period=1900%242011&dis_type=Earthquake+%28seismic+activity%29&Submit=Display+Disaster+Profile

special analysis. If there is a distinction between humanitarian supply chain and business supply chain, the cost related to demand under covering in relief distribution is definitely higher, because the risk is the loss of human lives. In addition, there are lots of participants, which means higher demand for coordination efforts, and a greater restriction of resources. New propositions are thus needed in order to give a rapid, efficient response.

This paper presents a systematic review of contributions related the relief distribution networks in response to calamity. Thus, we pay special attention to the response phase. We firmly believe that research in this area is an opportunity to reduce the human and economic loss by improving the reaction ability in a crisis. The Altay & Green review (2006) highlighted many articles in the pre-disaster phases (65% of the total), leaving room for response and recovery research.

To the best of our knowledge, four reviews have been done in Emergency Management in the past years: Altay & Green (2006), Kovács & Spens (2007), Caunhye et al. (2012), and de la Torre et al. (2012). Altay & Green (2006) were one of the first to show a concern for the subject. They presented a review of the articles written between 1980 and 2004 over the four phases. They made a classification system and statistical analyses over the different contributions of this large domain. However, the number of contributions has grown significantly between 2004 and 2011. Later, Kovács & Spens (2007) made a topical review of academic and practitioner journals, with some guidelines over the humanitarian relief chain and the specific challenges that need to be faced. The authors propose a general framework to the relief supply chain and the relationships between its stakeholders.

In the emergency logistics field, two literature reviews were published in 2011. Caunhye et al. (2012) analyzed the optimization papers in a pre-disaster and post-disaster context. This recent review fills the time gap for the Altay & Green review (2006), although our results showed that these authors' methodology (Content Analysis) left a good number of papers out their review. Likewise, de la Torre et al. (2012) present a review of academic and practitioner papers on the Vehicle Routing Problem (VRP). The main characteristics of the papers reviewed and their relationship with the academic/practitioner's point of view are presented. However, due to the difference in the motivation and in the scope, many academic papers were left out. Even though these reviews made important contributions, we still see the need to consolidate and present the actual state of art in the relief distribution networks.

Two main objectives motivate our work. First, a systematic review will allow us to gather and consolidate the many different studies available. In this way, the recent studies will provide an overview of new optimization tools in the hands of emergency managers. In addition, this systematic review will become a powerful tool for introducing the students or other interested people to the discipline. It will give an up-to-date survey of the research in relief distribution networks in a clearly defined scope. Second, the evolution of this discipline needs to be studied. This review will allow us to present the state of art, show the advancement in this discipline, and highlight the most significant contributions in the literature. More importantly, analyzing the evolution of this discipline will lead us to identify new research areas that still need to be explored.

The rest of this article is organized as follows. Section 2 describes the process used to find and select the studies considered by this review. Section 3 reports our research results, in which the research topics in humanitarian logistics are summarized. The next four sections (4 to 7) present the papers' trends in each one of the identified research topics. Section 8 gives a general discussion of our research results and future research recommendations, and section 9 draws our global conclusions.

2. Methodology: Selection process

In order to cover as many pertinent documents as possible, given the variety of scientific papers in emergency logistics and the growing number of contributions, a systematic procedure is needed. This section presents the methodology used to guide the selection process of the articles: the systematic review methodology. Although the systematic review methodology started in the medical field, it has been recently applied to management topics (Tranfield et al., 2003). The main difference between a systematic and a traditional literature review is the objective transparent procedure, so researcher subjectivity and bias can be minimized (Tranfield et al., 2003; Staples & Niazi, 2007; Kitchenham, 2004; Carter & Easton, 2011). This systematic methodology maximizes the possibility of replicability (Carter & Easton, 2011).

The methodology applied to this review can be summarized as follows:

1. This review's needs and its general goals were established. This systematic review is about the relief supply chain deployed in response to disasters. This means that, in the literature reviewed, an Operational Research (OR) component is desired, with a goal of optimizing the distribution center location, resource allocation, or humanitarian aid transportation after a disaster, as well as others logistics tasks. Although other reviews are available for an even larger scope, a real state of art is needed in these specific topics.

2. With this general thought, six relevant databases were selected as search engines. Three of them are related to administration sciences: ABI/Inform Global, Academic Search Premier and Business Source Premier. Two others were OR oriented: Compendex for engineering and technology, and

Inspec for calculations in physics, electronics, and information science. A multi-disciplinary database was included: ISI' Web of Science.

3. Based on our knowledge and expertise in the domain, as well as the revision of 20 well-recognized references from the literature, a set of key words was selected to define two search chains. These search chains were identified in the title, abstract, citation and/or subject of the articles. The words in our search chains are emergenc*; disaster*; catastroph*; "Extreme Events"; Humanitarian*; Aid; Assistanc*; Relief*; Logistic*; Supply Chain; Response; Distribution. The word "optimization" showed an enormous restriction of the results, so it was not considered in our search chains.

4. To help us to restrict our search results, a date range was defined. We took only the publications between 1990 and 2011. This decision was justified by the fact that the most significant advancements in the EM research field were done in the last decade. In addition, the previous studies focused on nuclear emergency response, which was a strong trend in the 1980s. At the time, emergency management was not really structured or formalized (Altay & Green, 2006).

5. The great number of search results and the variety of contributions required establishing of boundaries to limit the number of "hits". Different inclusion and exclusion criteria were defined and applied in our selection process. But before presenting these criteria, it is worth mentioning that this paper does not intend to be an exhaustive bibliographic study, but the result of a systematic scientific method that minimizes the researcher subjectivity and bias, with well-defined range of our interest: the relief distribution networks in response to disasters.

The inclusion and exclusion criteria used to narrow the search are presented:

Inclusion and exclusion criteria

We chose to limit our search to academic publications with a peer review process. We excluded from our selection all governmental or military reports, all practitioner reviews or the research of private organizations as well as conference acts, congress papers, theses and dissertations.

This review was limited to logistics optimization in the broadest sense, including operational research papers. The social sciences aspect of our research problem was thus not considered. Therefore, papers discussing human resources management challenges or coordination were excluded. In addition, to reflect our interest in the response phase, the contribution proposed by the articles selected has to be designed to be applied in the aftermath of an extreme event. This aspect is sometimes difficult to evaluate precisely because some papers can be applied in either the preparedness phase or the response phase, depending on whether or not the input data were predictions or real observations. In the latter case, they were included in this review.

Furthermore, given the large number of papers and the context particularities, we limited our search to papers considering sudden-onset disasters only (Van Wassenhove, 2005), such as the 9/11 terrorists attacks in NYC or the earthquake in Haiti in January 2010. This means that the relief distribution in a slow-onset disaster context (e.g., famine or drought) is out of our scope. Other papers (e.g., case studies, response performance analysis or reports from EM organizations, such as the Federal Emergency Management Agency (FEMA), the United Nations (UN) or the International Committee of the Red Cross (ICRC)) were excluded as well.

Studies about preparedness activities, which are intended to be applied in advance of a disaster (e.g., evacuation planning, congestion analysis problems, provision sourcing selection and stock prepositioning for a long-term context) were also excluded from our review. Likewise, we excluded the research on the recovery phase, in which the planning horizon defined for the problem is longer than for the response phase and the research objective has more a strategic sustainable perspective. However, although not considered in this review, we tend to point out the interest of these papers and the importance of their contributions.

After establishing the review's boundaries, the search process was executed in the different databases. A total of 4169 papers was found in the search engines. From this first result, a total of 89 papers were retained for deeper inspection after a selection by title and reading the abstract. We consulted other external sources in order to make the research as rich as possible. A previous search in the references of well-known articles led to the addition of 22 new references, and 5 papers in press that were available to us during our search process (e.g., the two 2011 literature reviews cited above) were added to the list of papers for further inspection. In addition, our research led to discover five previously published special issues in emergency management: International Journal of Physical Distribution & Logistics Management, Vol. 40, No. 8-9, "Transforming humanitarian logistics," 2010; International Journal of Physical Distribution & Logistics Management, Vol. 39, No. 6, "SCM in time of crisis humanitarian," 2009; International Journal of Production Economics, Vol. 126, No.1, 2010; OR Spectrum, Vol. 33, No. 3, 2011; and Transportation Research, Part E, Vol. 43, No. 6, 2007. A total of 46 papers were found. Eighteen of these papers were found in the databases with our search system. The other 28 new references were explored, and 3 of them were retained for a more profound inspection. The references from the 16 articles of OR Spectrum, as well as the references from the five papers in press, were explored to add 27 new references.

In most cases, the mix of the keywords defined by the authors was the reason that excluded those references from our search results. A total of 146 papers was set apart for a more conscientious reading. The 146 papers selected were read, analyzed and then compared to our inclusion/exclusion criteria. This article reviews a final set of 57 papers.

3. Research topics in the emergency logistics literature

To approach the research topics in the emergency logistics literature, a general description of the response activities is presented as the Crisis Manager (CM) executes them. Once the emergency alert is given, the relevant authorities on the scene evaluate the situation. The authorities might be regional, national or even international, depending on the size and gravity of the crisis. After this, the affected zone is delimited, and the logistics deployment is begun.

The first decision is the network design. The set of logistics centers, shelters and distribution centers that will be used in the relief operations have to be selected. The site location needs to be chosen both inside and outside the affected zone, also called the hot zone and the cold zone, respectively. This means that the CM needs to select sites at different network levels. Inside the disaster zone, humanitarian aid distribution centers (HADCs) need to be located to supply the points of demands (PODs) directly. In addition, selecting the larger distribution centers (DCs) outside the disaster zone is mandatory. These DCs will be responsible for recollecting and sorting the different products to supply the HADCs later. Normally, the selection of sites of the DCs and HADCs is done from a set of pre-selected sites that were marked, and even prepositioned, during the preparedness phase.

There is also a location decision to made in the preparedness phase, but on a larger scale. For instance, Non-Governmental Organizations (NGOs) and international organizations, such as the ICRC and the UN, usually select a set of strategic locations around the world to prepare themselves to respond to all kinds of extreme events. These sites are used as major DCs, where non-perishable food, rescue materials and other materials will be prepositioned, ready to be dispatched to the affected zone.

The second step in the logistic deployment problem is the allocation of the available resources. After the HADCs and DCs are established inside and outside the affected zone, they need to be provided with the required resources, rescue teams, humanitarian aid, and wherewithall to make reparations for machinery and the working infrastructure, equipment and technology. Then, the relief distribution to the victims is started.

In an emergency logistic network, there are two major flows. From one side, there is an entering flow of disaster relief. In this case, humanitarian aid is transported from the outside to the inside of the disaster zone (i.e., from major contributors to the DC to the HADC). Finally, the disaster relief commodities need to be dispatched to the victims in order to satisfy their urgent needs. On the other hand, there is a flow of people from the disaster zone towards the safe areas. It could mean wounded people who need emergency transportation to a hospital or care center, but also transporting survivors towards shelters or help centers. Figure 1 presents a diagram of the general emergency logistic network.

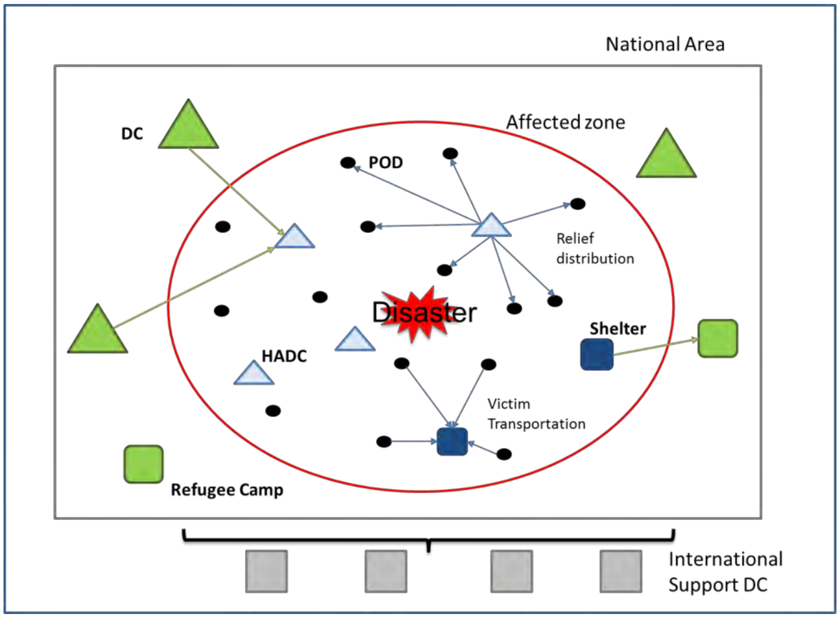

Figure 1: Emergency Response Logistic Network

The papers reviewed were divided in three major logistics decision categories: (1) location and network design problems, (2) transportation problems, and (3) other less popular, but still important, topics in relief distribution. Given that our interest is limited to the relief distribution network, the resource allocation problem is only defined for the commodities and capacity assignments in the DCs. In most cases, this aspect is covered in the network design decisions.

Table 1 presents the articles found in each category. From the 57 papers selected, the location and network design problem category has 17 articles, while the research in transportation problems has 25 articles, thus making the second category more popular. This is an expected result given the importance of the transportation problem to distribute relief, but also because of the traditional orientation of other categories. In fact, as important as they are, the location problem and resource allocation problem are usually addressed as a strategic problem for a long-term horizon, thus is solved in the preparedness phase. On the other hand, we can identify a small group of 6 articles that tackle both problems either in an integrated or a sequential manner. Those papers are reviewed in both categories. Finally, nine papers are contained in the category other important topics, which includes articles concerning dynamic demand management, prevision and road repairing, among other subjects. Each one of these categories is presented in the following sections.

Table 1: Research topics in emergency logistics

Research Problem	Total	Articles
Location and Network Design	17	Horner & Downs, 2007; Horner & Downs, 2010; Iakovou et al., 1996; Jia et al., 2007a; Jia et al., 2007b; Lee et al., 2009; Balcik & Beamon, 2008; Campbell & Jones, 2010; Chang, 2007; Görmez et al., 2011; Lee et al., 2009; Rawls & Turnquist, 2010; Rawls & Turnquist, 2011; Wilhelm & Srinivasa, 1996; Kongsomsaksakul et al., 2005; Li et al., 2010; Sherali et al., 1991
Transportation (Relief distribution & Casualty transportation)	25	Adivar & Mert, 2010; Balcik et al., 2008; Barbarosoğlu & Arda, 2004; Berkoune et al., 2012; Campbell et al., 2008; Chen et al., 2011; Gu, 2011; Haghani & Oh, 1996; Hu, 2010; Huang et al., 2012; Lin et al., 2012; Özdamar et al., 2004; Shen et al., 2009; Sheu, 2007a; Tzeng, 2007; Vitoriano et al., 2010; Vitoriano et al., 2009; Yuan & Wang, 2009; Jotshi et al., 2009; Barbarosoğlu et al., 2002; Chern et al., 2010; Özdamar & Yi, 2008; Özdamar, 2011; Yi & Özdamar, 2004; Yi & Kumar, 2007
Location and Transportation	6	Mete & Zabinsky, 2010; Nolz et al., 2010; Ukkusuri & Yushimito, 2008; Yi & Özdamar, 2007; Zografos & Androutsopoulos, 2008; Nolz et al., 2011
Other important topics	9	Minciardi et al., 2007; Rottkemper et al., 2011; Feng & Wang, 2003; Maya Duque & Sörensen, 2011; Viswanath & Peeta, 2003; Yan & Shih, 2009; Yan & Shih, 2007; Sheu, 2010; Xu et al., 2010

Classification taxonomy

Before going into the details of each category, we present the taxonomy used to classify the articles according to some general OR characteristics. With this taxonomy, we define the first research trends in emergency logistics, highlighting the different types of problems and the way that academics represent the reality of the crisis response.

First, we define the type of data modeling used by the authors, which means the model's inputs are deterministic or stochastic. In most cases, the problem context is represented by demand characterization, PODs or catastrophe impacts. These aspects can be modeled as a known static or dynamic input. In addition, to show the environment variability, some of the authors choose to represent these inputs as a stochastic process with random variables, or even as a fuzzy problem with fuzzy variables.

Second, we define their problem characteristics. We highlight whether or not the research problem (i.e., location, transportation or other problem) is a single- or a multi-objective optimization case, one or more periods for the planning horizon, and a single- or a multi- commodity network.

Third, we define the resolution method proposed by the authors (i.e., the model can be solved by an exact method or a heuristic algorithm). The exact resolution method provides the optimal solution to the problem. However, as it is well-known in the OR context, most of the models proposed are NP-hard, and their exact resolution is limited only to small instances. In fact, because of the combinatorial nature of the problem, an exhaustive exploration of the decisional space is long and difficult. To deal with this difficulty, many authors have proposed heuristic methods (e.g., genetic algorithms, ant colony algorithms, or local search heuristics) to solve real-life instances. Clearly, many other classification taxonomies may be used, but we think that ones used represent a good compromise and correspond to the most desired information.

The general classification that we have just presented is done for all the articles reviewed. Some other considerations, which are more specific to the research topic, will be presented further on.

4. Location and Network Design

In logistics deployment, network design is the first decision faced by the Crisis Manager (CM). Right after the disaster occurs and when the first alert is given, the affected region is restricted. The CM has to select the HADC location(s) from a set of possible locations. Table 2 presents the different contributions found in this field. In addition to the classification features defined in the previous section (i.e., data modeling, number of objectives, periods & commodities, and resolution method), we added three additional features that are important to location and network design problems: capacity limits, sourcing considerations and the resource allocation approach.

The column capacity limits shows whether or not the model deals with a capacity limit in potential location sites. This consideration will evidently add constraints to the problem and can increase its solution difficulty. The column sourcing will show us whether or not the authors restrict the supply sources. A single-sourcing restriction means that a client is forced to be supplied from one depot and one only, which means an implicit single client allocation at most one particular depot or shelter. On the contrary, a multiple sourcing points means that a client can be reached from various depots, allowing to the model to assign more than one depot or shelter to a point of demand. Last, the column resource allocation (RA) let us know whether or not the authors include resource allocation decisions (e.g., capacity allocation, stock prepositioning, or client's assignment) in their model.

Three types of papers are reviewed under this section. The first type are the location decisions that are defined for a post-disaster context. This hypothesis creates a steady environment that allows the propositions in this category to define the demand and the location of clients, as well as the disaster impacts, as an input known a priori in the model. In the general case, they seek to optimize a single objective and have a single period. In addition, most of the location and network design problems are directed for a single commodity relief distribution, represented by a global demand.

These articles present a more traditional facility location problem (FLP) structure, adapted to the crisis context through their objectives, such as Jia et al., 2007a & b, or their model's scope, such as Horner & Downs (2010), who presented a multi-echelon network design. Horner & Downs (2007) proposed a multi-objective model, minimizing assignment cost for each network's level. As a practical case, Iakovou et al. (1996) presented strategic and tactical decisions to locate the cleanup equipment for oil spill disaster, unifying the location and allocation decisions. Other authors dealt with the location-allocation decision with a covering objective, and they integrated their model in a complete Decision Support System (DSS): Lee et al., 2009a and Lee et al., 2009b. This feature allows their model to be applied in preparedness and training phases.

The second group contains the propositions with a pre-disaster setting. The strategic nature of the location problem has encouraged many authors to prepare for a disaster. However, these models can also be applied in an immediate response to the disaster. For this reason, even though our article selection process is limited to the relief distribution network in response to disasters, these propositions are included in this review. For instance, some of the papers presented stochastic models, in which the site location is chosen to satisfy demand under different possible disaster impacts: Balcik & Beamon (2008); Campbell & Jones (2010); Chang (2007); Rawls & Turnquist (2010); and Rawls & Turnquist (2011).

Table 2: Location and Network Design Problem

	Article	Data Modeling	Problem characteristics						Resolution Method
			Objective	Period	Commodity	Capacity Limits	Sourcing	RA	
Post-disaster context	Horner and Downs, 2010	Static	Single	Single	Single	Yes	Single	Yes	Exact
	Horner and Downs, 2007	Static	Multi	Single	Single	No	Single	No	Exact
	Iakovou et al., 1996	Static	Single	Single	Multi	Yes	Multi	Yes	Heuristic
	Jia et al., 2007	Static	Single	Single	Single	No	Multi	No	Exact
	Jia et al., 2007	Static	Single	Single	Single	No	Multi	No	Exact
	Lee et al., 2009	Static	Single	Single	Single	Yes	Single	Yes	Exact
	Lee et al.,, 2009	Static	Single	Single	Single	Yes	Single	Yes	Exact
Pre-disaster context	Balcik and Beamon, 2008[3]	Stochastic	Single	Single	Multi	Yes	Multi	Yes	Exact
	Chang et al., 2007	Stochastic	Single	Single	Multi	Yes	Multi	Yes	Heuristic
	Campbell and Jones, 2010	Stochastic	Single	Single	Single	No	Single	Yes	Exact
	Görmez et al., 2011	Static	Multi	Single	Single	Yes	Multi	Yes	Exact
	Rawls and Turnquist, 2011	Stochastic	Single	Single	Multi	Yes	Multi	Yes	Exact
	Rawls and Turnquist, 2010	Stochastic	Single	Single	Multi	Yes	Multi	Yes	Heuristic
	Wilhelm and Srinivasa, 1996	Stochastic	Single	Multi	Single	Yes	Single	Yes	Heuristic
	Kongsomsaksakul et al., 2005*	Static	Single	Single	Single	Yes	Multi	Yes	Heuristic
	Li et al., 2010*	Stochastic	Single	Single	Multi	Yes	Multi	Yes	Exact
	Sherali et al., 1991*	Static	Single	Single - Multi	Single	Yes	Multi	Yes	Heuristic and Exact

* Shelter location-allocation problem

[3] both pre and post-disaster contexts

In addition, these papers dealt with stock prepositioning decisions, and the expected demand that needs to be satisfied in response phase were modeled by a set of scenarios or a distribution function.
We would like to point out that, even after the disaster has hit the zone, the information about demand is hard to obtain, and so a stochastic modeling approach can be useful to represent the incertitude attached to the process of the impact's estimation. Wilhelm & Srinivasa (1996) focus on the risk related to the reliability of the relief distribution network, which is still present in a post-disaster context. The stochastic feature for the designed network is as robust as possible to support the changes on the real demand. This was modeled by Görmez et al. (2011) with a single deterministic model, which is executed under different scenarios. The selected sites are those which are selected in most of the scenarios.
Three papers in a pre-disaster context proposed for the sheltering location (and allocation) problem. These papers were retained, even though they are evacuation-oriented, because location decisions for the evacuation problem at this level are the same for the distribution context. Kongsomsaksakul et al. (2005) and Sherali et al. (1991) defined the optimal sheltering network that will minimize the evacuation time (i.e., distribution time), while Li et al. (2010) proposed a two-stage stochastic model to consider the shelter supply. Section 6 discusses the location and transportation problems in detail.

5. Transportation Problems

After the logistic network has been established, the relief delivery plan has to be constructed. This review shows that this topic is the most popular in emergency logistics research, by the number and also the variety of propositions.
Since the transportation problem's characteristics changed, the table structure proposed in the previous section was modified, leading to Table 3. The first four columns show the general characteristics that have been defined already. In the fifth column Depot, the problem is defined as a single depot or multiple depots. This characteristic usually increases the difficulty of the problem. In addition, it shows the type and complexity of logistic network that the authors modeled. Then, some vehicle's characteristics of the model are observed. The column capacity limits summarizes whether or not the proposition limits the vehicle's capacity. Unlike the location and network design problem,

the transportation problem is quite common for authors to consider some kind of limits in the available resources. This column shows the limitation considered: in the volume capacity, in the weight capacity, in the distribution time of the driver's shift, in the cost, in the number of vehicles available, or in the number of units.

Table 3: Transportation Problem in Emergency Logistics

	Article	Data Modeling	Problem characteristics: Objective	Periods	Commodity	Depots	Capacity Limits	Fleet Comp.	Tr. Mode	Resolution Method
Relief Distribution	Adivar and Mert, 2010	Fuzzy	Multi	Multi	Multi	Multi	Weight	Hetero	Multi	Exact
	Balcik et al., 2008	Dynamic	Single	Multi	Multi	Single	Volume/Time/ Fleet	Hetero	Ground	Exact
	Barbarosoğlu et al., 2004	Stochastic	Single	Single	Multi	Multi	Units	Hetero	Multi	Exact
	Berkoune et al., 2012	Static	Single	Single	Multi	Multi	Weight/Volume//Fleet	Hetero	Ground	Heur.
	Campbell et al., 2008	Static	Single	Single	Single	Single	None	Homo	Ground	Heur.
	Chen et al., 2011	Static	Single	Single	Single	Multi	Units	Homo	Ground	Exact
	Gu, 2011	Static - Fuzzy	Single	Single	Single-Multi	Multi	Units±	Homo	Single	Exact
	Haghani and Oh, 1996	Static	Single	Multi	Multi	Multi	Units/Fleet	Hetero	Multi	Heur.
	Hu, 2011	Static	Multi	Single	Multi	Single	None	Hetero	Multi	Exact
	Huang et al., 2012	Static	Single	Single	Single	Single	Units	Homo	Ground	Heur.
	Lin et al., 2011	Static	Multi	Multi	Multi	Single	Weight/Volume//Fleet	Hetero	Ground	Heur.
	Özdamar et al., 2004	Dynamic	Single	Multi	Multi	Multi	Weight/Fleet	Hetero	Multi	Heur.
	Shen et al., 2009	Stochastic	Single	Single	Single	Single	Units/Fleet	Hetero	Ground	Heur.
	Sheu, 2007	Dynamic	Multi	Multi	Multi	Multi	Units/Fleet	Hetero	Ground	Exact
	Tzeng et al., 2007	Static	Multi	Multi	Multi	Multi	Volume	Hetero	Ground	Exact / Sim.
	Vitoriano et al., 2010	Stochastic	Multi	Single	Single	Multi	Units/Fleet/ Budget	Hetero	Ground	Exact
	Vitoriano et al., 2009	Stochastic	Multi	Single	Single	Multi	Units/Budget	Hetero	Ground	Exact
	Yuan and Wang, 2009	Static	Single-Multi	Multi	Single	Single	None	Homo	Ground	Heur. / Sim.
	Jotshi et al., 2009*	Static	Multi	Single	Single	Multi	Units/Fleet	Homo	Ground	Heur./ Sim.
Distribution and Evacuation	Barbarosoğlu et al., 2002	Static	Multi	Single	Multi	Multi	Weight/Fleet/Time	Hetero	Air	Heur.
	Chern et al., 2010	Dynamic	Multi	Multi	Multi	Multi	Units/Fleet	Hetero	Multi	Heur.
	Özdamar and Yi, 2008	Static	Single	Multi	Multi	Multi	Units/Fleet	Hetero	Ground	Heur.
	Özdamar, 2011	Static	Single	Single	Multi	Multi	Weight/Time/Units	Homo	Air	Heur.
	Yi and Kumar, 2007	Stochastic	Single	Multi	Multi	Multi	Weight/Fleet	Hetero	Ground	Heur.
	Yi and Ozdamar, 2004	Fuzzy	Single	Multi	Multi	Multi	Weight/Fleet	Hetero	Multi	Exact

The seventh column Fleet Composition shows whether or not the model uses a heterogeneous fleet of vehicles or homogeneous fleet to construct the route. This is an important feature in humanitarian logistics, in which there are several organizations involved in emergency response activities and having numerous types of resources (i.e., vehicles) is very common. Finally, the column Transportation Mode shows whether or not the problem is stated as a multi-modal problem or the specific type of transportation mode (i.e., ground, air or water). The different papers concerned with relief transportation decisions are presented in Table 3.

In general, the transportation and routing problems are very difficult. Even in the industrial context, academics and practitioners have been working for decades on this optimization problem. The problem's difficulty increases as the model's level of detail increases. If, all at the same time, stochastic data, heterogeneous vehicle fleet, multi-modal problem in a multi-period and multi-commodity network context are dealt with (which is probably the closest to reality), the resulting model will be extremely hard to solve. For this reason, the authors will normally choose the factors that adapt best to their study context and will establish hypotheses on the other features to simplify the model.

For instance, some of the authors have a traditional approach for the data type (e.g., a deterministic static or dynamic data model) in order to consider a multi-period planning horizon (Yuan & Wang, 2009) or a multi-commodity network (Berkoune et al., 2012; Gu, 2011; Hu, 2010), or even both (Balcik et al., 2008; Haghani & Oh, 1996; Lin et al., 2012; Özdamar et al., 2004; Tzeng, 2007). Even though their data setting is deterministic, these papers define a complex distribution network, as close as possible to the reality for relief distribution, with a proper level of detail to reflect crisis manager's challenges.

Some of the authors have a more traditional approach in their problem's characteristics (i.e., static data, single commodity and single period considerations) but with the objective of exploring new approaches to the relief distribution problem. For example, Campbell et al. (2008) and Huang et al. (2012) define more appropriate objectives to the relief distribution challenge (i.e., minimize distribution time, equity, efficacy and efficiency). Chen et al. (2011) define a distribution problem integrated in a DSS with the support of a Geographic Information System (GIS). Many authors consider the uncertainty related to the relief distribution context, reflecting the uncertainty in demand, arc capacity, travel time or network reliability, through random or fuzzy variables (Barbarosoğlu & Arda, 2004; Shen et al., 2009; Vitoriano et al., 2010; Vitoriano et al., 2009; Adivar & Mert, 2010; Sheu, 2007a).

Besides the relief distribution models, Jotshi et al. (2009) dealt with the casualty transportation problem. Unlike the evacuation planning problem, the casualty transportation problem is sort of a "reverse distribution problem," which allowed us to review them in this paper. Certainly, the evacuation planning decisions demand another type of analysis in operational level (i.e., traffic assignment problem and congestion analysis, among others), which are out of the scope of our review. Some of the authors tackle both relief distribution and casualty transportation problems in their optimization model. In this case, the proposed model finds the optimal route to distribute relief products and transport victims from the danger zone to health centers, resulting in a much more complex network problem, which is a multi-commodity problem and most of them are also multi-period planning horizon. Some of them have a static data setting, planning helicopter scheduling (Barbarosoğlu et al., 2002; Özdamar, 2011) or a heterogeneous vehicle problem (Özdamar & Yi, 2008). Others present a dynamic problem (Chern et al., 2010) or a fuzzy stochastic problem (Yi & Özdamar, 2007; Yi & Özdamar, 2004). A heterogeneous vehicle fleet is one of the relief distribution's characteristics more commonly implemented; some authors even consider a multi-modal problem.

6. Location - Transportation Problems

Some articles have tackled two of the main distribution problems together: location and transportation. These articles and their characteristics are presented in Table 4. Some of them address the problem in an independent sequential manner (Mete & Zabinsky, 2010; Zografos & Androutsopoulos, 2008), with a stochastic or static data setting. Nolz et al. (2010, 2011) present a tour-covering problem in which the routes are constructed, integrating the site selection decisions inside the covering zone. Ukkusuri & Yushimito (2008) and Yi & Özdamar (2007) present an integrated Location-Routing Problem (LRP). Ukkusuri & Yushimito (2008) use this modeling approach for the stock prepositioning and distribution problem, considering the path's reliability. Yi & Özdamar (2007) solve a complex distribution problem, including casualty transportation. Based on dynamic updates of the demand, the model will decide to open new care centers.

Table 4 : Location and transportation problems

	Article	Data Modeling	Problem characteristics							Resolution Method
			Objective	Periods	Commodity	Depots	Capacity Limits	Fleet Composition	Transp. Mode	
Location / transportation	Mete and Zabinsky, 2010	Stochastic	Single	Single	Multi	Multi	Units/Fleet	Hetero.	Ground	Exact
	Nolz et al., 2010	Static	Multi	Single	Single	Single	Units/Fleet	Hetero.	Multi	Heuristic
	Nolz et al., 2011	Static	Multi	Single	Single	Single	Units/Fleet	Homo.	Ground	Heuristic
	Ukkusuri and Yushimito, 2008	Stochastic	Single	Single	Single	Single	Budget/Fleet	Homo.	Ground	Exact
	Yi and Özdamar, 2007	Dynamic	Single	Multi	Multi	Multi	Weight	Hetero.	Multi	Heuristic
	Zografos and Androutsopoulos, 2008	Static	Multi	Single	Single	Single	Units/Fleet	Homo.	Ground	Heuristic

7. Other contributions

Some articles highlight a research problem that is less popular than the location or routing problem, but still represent an important advancement in relief distribution networks. Besides the basic information columns (data modeling, objectives, periods, commodity and resolution method), these articles are classified by their Research Problem. Minciardi et al. (2007) and Rottkemper et al. (2011) deal strictly with the resource allocation problem, where the real-time dynamic aspects in the resource allocation problem is approached. Feng & Wang (2003), Maya Duque & Sörensen (2011), Viswanath & Peeta (2003), Yan & Shih (2009), and Yan & Shih (2007) propose the problem of planning the urgent repairs in the response network.

Sheu (2010) and Xu et al. (2010) present a very interesting and useful proposition to manage and forecast demand. Clearly, this is one of the major challenges in emergency logistics response, and it is often ignored in the literature propositions. Sheu (2010) proposes a complete system that forecasts, groups and ranks the demand after a disaster, with the help of multicriteria analysis. Xu et al. (2010) forecast demand using a hybrid method and having better results than traditional statistics methods. Table 4 summarizes these articles.

8. Future research perspectives and other results

The systematic review presented in this article make it possible to reassess the most relevant works for optimizing relief distribution networks, understand its evolution, and thus define the state of the art. From the set of articles reviewed, even though humanitarian logistics is a recent field, it has experienced a significant evolution, especially in the last decade. It is known that the first contributions to this area were really focused in just one kind of disaster, such as oil spills in 1970s (Caunhye et al., 2012) or nuclear disasters in 1980s (Altay & Green, 2006).

In 2000s, researcher interest started to grow. However, the discipline was not well-defined, and we were not really aware of their challenges and implications. The first propositions started to define general response models that represented those challenges in a network, mostly with a multi-commodity setting (Barbarosoğlu & Arda, 2004; Barbarosoğlu et al., 2002; Özdamar et al., 2004;

Viswanath & Peeta, 2003; Yi & Özdamar, 2004; Haghani & Oh, 1996). The first articles explored these challenges and the differences with business logistics. Nowadays, our knowledge and comprehension level is greater, and the articles present models more sophisticated, detailed and adapted to action needs: Berkoune et al. (2012), Lin et al. (2011), Özdamar (2011), Gu (2011), Yan & Shih (2009) and Lee et al. (2009). There is increasing interest in tackling new subjects, such as the international scheme in response effort, service quality or the integration of technological advances, for instance: Adivar & Mert (2010), Rawls & Turnquist (2011), and Chen et al. (2011).

Many of the models proposed for a pre-disaster phase can be easily applied during the response phase too. The location and network design problems present a clear example of this. Unlike the traditional approach in EM literature, the location and network design problem is not exclusively for the pre-disaster phase. Clearly, it is a major concern in preparedness phase; however, during response phase, a rapid efficient decisions need to be made from the preselected set of DCs about the opening of HADCs. A good-quality decision is needed to satisfy the demand effectively and satisfactorily.

We made two observations about the resolution methods. First, the location and network design problem has a significant number of papers that used an exact resolution method (12 out of 17). This is mostly because of the exploratory character of those papers, in which a model initiative is more significant (Horner & Downs, 2010; Jia et al., 2007a; Li et al., 2010; Rawls & Turnquist, 2011). Second, in the transportation problem section, the number of heuristics is bigger (14 out of 25). This result is expected, given the difficulty of the Vehicle Routing Problem. Obviously, even in the business logistic context, a real-size instance is hard to solve to optimality. For this reason, a trade-off is required, accepting a good-quality solution to gain efficiency for the resolution time. Even though most of the papers reviewed are mainly contributing a model, some of the others focus purely on the resolution method (Nolz et al., 2010; Yi & Özdamar, 2007), given the new hints for optimizing the emergency response.

After analyzing the state of art in emergency logistics, it is possible for us to give a brief outline of the future research perspectives. Several features can be highlighted. First, the line of separation that is broadly accepted between preparedness and response is really fuzzy in OR language. In fact, a response model, adapted to a DSS, can be used in a training and preparedness process. Similarly, once the data has become available, a preparedness model can lead to an optimal response plan. We encourage the researchers in emergency logistics to explore the validity of their research in both phases to maximize the benefits of their scientific contributions.

Second, analyzing emergency logistics is already an important contribution. Relief distribution networks are better defined if their context particularities are widely known. The next natural step is to continue the development of models even more complete and faithful to the emergency logistics context. For instance, the stochastic and dynamic propositions are still rare. Similarly to business logistics, these propositions best reflect reality. Even in response phase, the level of uncertainty is high, and a deterministic static modeling approach can easily lead to a low performance, after the demand variation, route reliability, impact estimation and reliability of the sites, work teams or equipment have been taken into account. This is particularly true for the location problem, in which there is a great need of response models. A stochastic and/or dynamic modeling approach can thus lead us to a more robust network design.

On the other hand, a multi-schema modeling approach, which represents the coordination challenges between the different participants, is a problem that has not been explored in logistics optimization. Some preliminary contributions in other support activity problem can still be explored. Many logistics challenges can be dealt with, especially in a dynamic real-time context (e.g., demand estimation, inventory management and personal management). More proposals for stock relocation and stock management (e.g., Rottkemper et al., 2011) will better support daily operations in response phase. Furthermore, the research in casualty transportation is still very limited. Besides Jotshi et al. (2009) with the combined models, this problem has been ignored; they gave the challenge for the fleet capacity. New approaches that support the assistance given by hospitals and care centers could be also useful.

There is also plenty of room for integrated contributions, in which the different stages of logistic deployment are addressed through multi-level optimization models. The final objective in this research field is to increase the CM response capacity, supporting the decision-making process. Integrated DSS models, which allows CMs to interact in the field, are greatly desired. Finally, in order to support these integrated models, newer resolution methods are needed, in which the heuristic methods support the interactive decision-making process, thus solving the optimization problems in a reasonable time.

9. Conclusions

This article presents a systematic review from the literature in relief distribution networks. A scientific research process was designed and executed to explore more than 4000 references. A transparent, systematic selection process was applied to highlight 57 relevant articles to be reviewed. Our research shows that scientific community has developed a growing interest in optimizing relief distribution systems in response to disasters, with two major focuses: (1) location and network design problems and (2) transportation and routing problems. The first problem is usually situated in disaster preparedness phase, but it can be extended to response phase. The second problem adapts traditional vehicle routing problems to the context of relief distribution.

The challenge to the academic community is now turning to designing more complex but realistic models, with stochastic and dynamic considerations. In addition, we recognize the need for integrated models, which better support the CM's decisions, considering other logistic activities, such as demand management, resource allocation or inventory management. Finally, there is still a challenge for the resolution methods, in which advanced heuristic proposals can enhance the complex modeling process to support decision-makers in the race for an efficient relief distribution.

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References

Adivar, B. & Mert, A., 2010. International disaster relief planning with fuzzy credibility. Fuzzy Optimization and Decision Making, 9(4), pp.1-21.

Altay, N. & Green III, W.G., 2006. OR/MS research in disaster operations management. European Journal of Operational Research, 175(1), pp.475-493.

Balcik, B. & Beamon, B., 2008. Facility location in humanitarian relief. International Journal of Logistics Research and Applications, 11(2), pp.101-121.

Adivar, B. & Mert, A., 2010. International disaster relief planning with fuzzy credibility. Fuzzy Optimization and Decision Making, pp.1-21.

Altay, N. & Green III, W.G., 2006. OR/MS research in disaster operations management. European Journal of Operational Research, 175(1), pp.475-493.

Balcik, B. & Beamon, B., 2008. Facility location in humanitarian relief. International Journal of Logistics Research and Applications, 11(2), pp.101-121.

Balcik, B., Beamon, B. & Smilowitz, K., 2008. Last mile distribution in humanitarian relief. Journal of Intelligent Transportation Systems, 12(2), pp.51-63.

Barbarosoğlu, G. & Arda, Y., 2004. A two-stage stochastic programming framework for transportation planning in disaster response. Journal of the Operational Research Society, 55(1), pp.43-53.

Barbarosoğlu, G., Özdamar, L. & Cevik, A., 2002. An interactive approach for hierarchical analysis of helicopter logistics in disaster relief operations. European Journal of Operational Research, 140(1), pp.118-133.

Berkoune, D., Renaud, J., Rekik, M., & Ruiz, A., 2012. Transportation in Disaster Response Operations. Socio-Economic Planning Sciences, 46(1), pp. 23-32.

Campbell, A.M. & Jones, P.C., 2010. Prepositioning supplies in preparation for disasters. European Journal of Operational Research, 209(2), pp. 156-165.

Campbell, A.M., Vandenbussche, D. & Hermann, W., 2008. Routing for relief efforts. Transportation Science, 42(2), pp.127-145.

Carter & Easton, P., 2011. Sustainable supply chain management: evolution and future directions. International Journal of Physical Distribution & Logistics Management, 41(1), pp.46-62.

Caunhye, A.M., Nie, X. & Pokharel, S., 2012. Optimization Models in Emergency Logistics: A Literature Review. Socio-Economic Planning Sciences, 46(1), pp. 4-13.

Chang, M.S. et al, 2007. A scenario planning approach for the flood emergency logistics preparation problem under uncertainty. Transportation Research Part E: logistics and Transportation Review, 43(6), pp.737-754.

Chen, A., Pena-Mora, F. & Ouyang, Y., 2011. A collaborative GIS framework to support equipment distribution for civil engineering disaster response operations. Automation in Construction, 20(5), pp. 637-648.

Chern, C.C., Chen, Y.L. & Kung, L.C., 2010. A heuristic relief transportation planning algorithm for emergency supply chain management. International Journal of Computer Mathematics, 87(7), pp.1638-1664.

Feng, C.M. & Wang, T.C., 2003. Highway emergency rehabilitation scheduling in post-earthquake 72 hours. Journal of the 5th Eastern Asia Society for Transportation Studies, 5.

Görmez, N., Koksalan, M. & Salman, F., 2011. Locating disaster response facilities in Istanbul. Journal of the Operational Research Society, 62(7), pp.1239-1252.

Gu, Y., 2011. Research on Optimization of Relief Supplies Distribution Aimed to Minimize Disaster Losses. Journal of Computers, 6(3), pp.603-609.

Haddow, G.D., Bullock, J.A. & Coppola, D.P., 2007. Introduction to emergency management, Butterworth-Heinemann.

Haghani, A. & Oh, S.C., 1996. Formulation and solution of a multi-commodity, multi-modal network flow model for disaster relief operations. Transportation Research Part A: Policy and Practice, 30(3), pp.231-250.

Horner, M.W. & Downs, J.A., 2010. Optimizing hurricane disaster relief goods distribution: model development and application with respect to planning strategies. Disasters, 34(3), pp.821-844.

Horner, M.W. & Downs, J.A., 2007. Testing a flexible geographic information system-based network flow model for routing hurricane disaster relief goods. Transportation Research Record: Journal of the Transportation Research Board, 2022(-1), pp.47-54.

Hu, Z.H., 2010. A container multimodal transportation scheduling approach based on immune affinity model for emergency relief. Expert Systems With Applications, 38, pp.2632-2639.

Huang, M., Smilowitz, K. & Balcik, B., 2012. Models for relief routing: Equity, efficiency and efficacy. Transportation Research Part E: Logistics and Transportation Review, 48(1), pp. 2-18.

Iakovou, E., Il, C.M., Douligeris, C. & Korde, A., 1996. Optimal location and capacity of emergency cleanup equipment for oil spill response. European journal of operational research, 96(1), pp.72-80.

Jia, H., Ordóñez, F. & Dessouky, M., 2007a. A modeling framework for facility location of medical services for large-scale emergencies. IIE Transactions, 39(1), pp.41-55.

Jia, H., Ordóñez, F. & Dessouky, M., 2007b. Solution approaches for facility location of medical supplies for large-scale emergencies. Computers & Industrial Engineering, 52(2), pp.257-276.

Jotshi, A., Gong, Q. & Batta, R., 2009. Dispatching and routing of emergency vehicles in disaster mitigation using data fusion. Socio-Economic Planning Sciences, 43(1), pp.1-24.

Kitchenham, B., 2004. Procedures for performing systematic reviews. Keele, UK, Keele University, 33.

Kongsomsaksakul, S., Yang, C. & Chen, A., 2005. Shelter location-allocation model for flood evacuation planning. Journal of the Eastern Asia Society for Transportation Studies, 6, pp.4237-4252.

Kovács, G. & Spens, K., 2007. Humanitarian logistics in disaster relief operations. International Journal of Physical Distribution & Logistics Management, 37(2), pp.99-114.

Kovács, G. & Spens, K., 2009. Identifying challenges in humanitarian logistics. International Journal of Physical Distribution & Logistics Management, 39(6), pp.506-528.

Lee, E.K. et al., 2009a. Modeling and optimizing the public health infrastructure for emergency response. Interfaces, 39(5), pp.476-490.

Lee E.K., Smalley, H.K., Yang Zhang, Pietz, F., & Benecke, B., 2009b. Facility location and multi-modality mass dispensing strategies and emergency response for biodefence and infectious disease outbreaks . International Journal of Risk Assessment and Management, 12(2), pp.311–351.

Li, L., Jin, M. & Zhang, L., 2010. Sheltering network planning and management with a case in the Gulf Coast region. International Journal of Production Economics, 131, pp.431-440.

Lin, Y., Batta, R., Rogerson, P.A., Blatt, A., Flanigan, M., 2012. A logistics model for emergency supply of critical items in the aftermath of a disaster. Socio-Economic Planning Sciences, 45(4), pp.132 - 145.

Maya Duque, P. & Sörensen, K., 2011. A GRASP metaheuristic to improve accessibility after a disaster. OR Spectrum, 33(3), pp.1-18.

McLoughlin, D., 1985. A framework for integrated emergency management. Public Administration Review, 45, pp.165-172.

Mete, H.O. & Zabinsky, Z.B., 2010. Stochastic optimization of medical supply location and distribution in disaster management. International Journal of Production Economics, 126(1), pp.76-84.

Minciardi, R., Sacile, R. & Trasforini, E., 2007. A decision support system for resource intervention in real-time emergency management. International Journal of Emergency Management, 4(1), pp.59-71.

Nolz, P.C., Doerner, K.F. & Hartl, R.F., 2010. Water distribution in disaster relief. International Journal of Physical Distribution & Logistics Management, 40(8/9), pp.693-708.

Nolz, P.C., Semet, F. & Doerner, K.F., 2011. Risk approaches for delivering disaster relief supplies. OR Spectrum, 33(3), pp.1-27.

Özdamar, L., 2011. Planning helicopter logistics in disaster relief. OR Spectrum, 33(3), pp.1-18.

Özdamar, L. & Yi, W., 2008. Greedy neighborhood search for disaster relief and evacuation logistics. Intelligent Systems, IEEE, 23(1), pp.14-23.

Özdamar, L., Ekinci, E. & Küçükyazici, B., 2004. Emergency logistics planning in natural disasters. Annals of Operations Research, 129(1), pp.217-245.

Rawls, C.G. & Turnquist, M.A., 2010. Pre-positioning of emergency supplies for disaster response. Transportation Research Part B: Methodological, 44(4), pp.521-534.

Rawls, C.G. & Turnquist, M.A., 2011. Pre-positioning planning for emergency response with service quality constraints. OR Spectrum, 33(3), pp.1-18.

Rottkemper, B. et al., 2011. Inventory relocation for overlapping disaster settings in humanitarian operations. OR Spectrum, 33(3), pp.1-29.

Shen, Z., Dessouky, M.M. & Ordóñez, F., 2009. A two-stage vehicle routing model for large-scale bioterrorism emergencies. Networks, 54(4), pp.255-269.

Sherali, H.D., Carter, T.B. & Hobeika, A.G., 1991. A location-allocation model and algorithm for evacuation planning under hurricane/flood conditions. Transportation Research Part B: Methodological, 25(6), pp.439-452.

Sheu, J.B., 2007a. An emergency logistics distribution approach for quick response to urgent relief demand in disasters. Transportation Research Part E: Logistics and Transportation Review, 43(6), pp.687-709.

Sheu, J.B., 2007b. Challenges of emergency logistics management.

Sheu, J.B., 2010. Dynamic relief-demand management for emergency logistics operations under large-scale disasters. Transportation Research Part E: Logistics and Transportation Review, 46(1), pp.1-17.

Staples, M. & Niazi, M., 2007. Experiences using systematic review guidelines. Journal of Systems and Software, 80(9), pp.1425-1437.

de la Torre, L.E., Dolinskaya, I.S. & Smilowitz, K.R., 2012. Disaster Relief Routing: Integrating Research and Practice. Socio-Economic Planning Sciences, 46(1), pp. 88-97.

Tranfield, D., Denyer, D. & Smart, P., 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management, 14(3), pp.207-222.

Tzeng, G.H., Cheng, H.J., Huan, T.D., 2007. Multi-objective optimal planning for designing relief delivery systems. Transportation Research Part E: Logistics and Transportation Review, 43(6), pp.673-686.

Ukkusuri, S.V. & Yushimito, W.F., 2008. Location Routing Approach for the Humanitarian Prepositioning Problem. Transportation Research Record: Journal of the Transportation Research Board, 2089(1), pp.18-25.

Viswanath, K. & Peeta, S., 2003. Multicommodity maximal covering network design problem for planning critical routes for earthquake response. Transportation Research Record: Journal of the Transportation Research Board, 1857(1), pp.1-10.

Vitoriano, B., Ortuño, T. & Tirado, G., 2010. A multi-criteria optimization model for humanitarian aid distribution. Journal of Global Optimization, 51, pp.1-20.

Vitoriano, B., Ortuño, T. & Tirado, G., 2009. HADS, a goal programming-based humanitarian aid distribution system. Journal of Multi-Criteria Decision Analysis, 16(1-2), pp.55-64.

Van Wassenhove, L.N., 2005. Humanitarian aid logistics: supply chain management in high gear†. Journal of the Operational Research Society, 57(5), pp.475-489.

Wilhelm, W. & Srinivasa, A.V., 1996. A Strategic, Area-wide Contingency Planning Model for Oil Spill Cleanup Operations with Application Demonstrated to the Galveston Bay Area*. Decision Sciences, 27(4), pp.767-799.

Xu, X., Qi, Y. & Hua, Z., 2010. Forecasting demand of commodities after natural disasters. Expert Systems With Applications, 37(6), pp.4313-4317.

Yan, S. & Shih, Y.L., 2007. A time-space network model for work team scheduling after a major disaster. Journal of the chinese institute of engineers, 30(1), pp.63-75.

Yan, S. & Shih, Y.L., 2009. Optimal scheduling of emergency roadway repair and subsequent relief distribution. Computers & Operations Research, 36(6), pp.2049-2065.

Yi, W. & Kumar, A., 2007. Ant colony optimization for disaster relief operations. Transportation Research Part E: Logistics and Transportation Review, 43(6), pp.660-672.

Yi, W. & Özdamar, L., 2007. A dynamic logistics coordination model for evacuation and support in disaster response activities. European Journal of Operational Research, 179(3), pp.1177-1193.

Yi, W. & Özdamar, L., 2004. Fuzzy modeling for coordinating logistics in emergencies. International Scientific Journal of Methods and Models of Complexity-Special Issue on Societal Problems in Turkey, 7(1).

Yuan, Y. & Wang, D., 2009. Path selection model and algorithm for emergency logistics management. Computers & Industrial Engineering, 56(3), pp.1081-1094.

Zografos, K.G. & Androutsopoulos, K.N., 2008. A decision support system for integrated hazardous materials routing and emergency response decisions. Transportation Research Part C: Emerging Technologies, 16(6), pp.684-703.