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Humanitarian logistics and disaster relief research: trends, applications, and future research directions

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Abstract: *The increase in the number of people impacted by natural and man-made disasters has required more efforts of humanitarian organizations. In this context, research on disaster operations management and humanitarian logistics has grown in terms of publications and importance in recent years. This paper presents a literature survey of humanitarian logistics studies that aims to observe trends and ideas for future research directions. First, the reviews by Altay and Green (2006) and Natarajarathinam et al. (2009) are updated and detailed. In addition to the updated review and the classification criteria adopted by the previously-mentioned papers, other criteria are proposed in order to have more information about them. Two hundred one (201) that were published in the HL area are reviewed and listed in a companion website. The studies are classified according to criteria such as research method, disaster type, decision level, and the database of publication. The conclusions point out to some literature gaps and research opportunities in the area of study.*

Keywords*: Supply chain risk management, Humanitarian supply chain, Humanitarian logistics, Disaster Relief, Literature Survey,*

1 Introduction

Natural disasters (such as floods, droughts, earthquakes, hurricanes, famine) or man-made disasters (such as wars, conflicts, and refugee crisis) have increasingly impacted communities and nations around the world in recent decades, and forecasts suggest that the trend will continue (EMDAT, 2011). According to the International Federation of Red Cross and Red Crescent Societies (IFRC), disasters can be defined as sudden, calamitous events that disrupt the activities of a society or community and causes human, material, economic, or environmental losses that exceed the recovery capacity of the affected community or society using only its own resources (Natarajarathinam *et al*., 2009). The main factor used to measure the intensity of a disaster is the site's vulnerability. Such disasters as the earthquake and tsunami in Asia in 2004 and in Japan in 2011, the earthquake in Pakistan in 2005, in China in 2008, in Chile in 2010, and in New Zealand in 2011; and the floods occurred in Brazil in 2008, 2009, and 2011, among others, have demonstrated the vulnerability of the societies which requires more efforts of humanitarian organizations to provide disaster relief.

Considering the urgency, the uncertainty, and the complexity of the global supply chain that is driven by humanitarian entities, usually non-governmental, at the onset of a disaster anywhere in the world, enhancements in logistics and supply chain management directly affect the ability of humanitarian organizations to respond to disasters and improve its overall effectiveness. In this sense, humanitarian logistics (HL) can be defined as the process of planning, implementing, and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption, in order to meet beneficiary's requirements (Thomas and Mizusjima, 2005). Humanitarian operations encompass the lifecycle of a disaster including preparedness, response, and recovery. So, the ability to conduct efficient and

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effective humanitarian operations is a critical element of a disaster relief process.

Academic research of disaster operations management and humanitarian logistics is relatively new but has grown in terms of quantity and relevance in the last years (for example, Beamon, 2004; Thomas, 2004; Beamon and Kotleba, 2006; Thomas, 2007; Van Wassenhove, 2006; Van Wassenhove *et al*., 2008). Until 2005, there was a limited set of research on HL (Beamom and Kotleba, 2006), as indicated by the literature reviews by Natarajarathinam *et al*. (2009) and Altay and Green (2006). Most of the papers on HL were published in practitioner journals. Since then, however, HL has been included as special tracks at prominent conferences such as INFORMS – *Institute for Operations Research and the Management Sciences* and POMS – *Production and Operations Management Society* (Kovacs and Spens, 2009). Special issues on the subject were published by such journals as OR Spectrum (2011), the International Journal of Production Economics (2010), the International Journal of Physical Distribution & Logistics Management (2009, 2010), the International Journal of Services Technology and Management (2009), International Journal of Risk Assessment and Management (2009), Management Research News (2009), and Transportation Research Part E (2007) (Kovacs and Spens, 2011). In 2011, the first journal on HL, the *Journal of Humanitarian Logistics and Supply Chain Management*, was published. Additionally, research groups dedicated to the topic – for example, the Fritz Institute, the INSEAD (*Institut européen d'administration des affaires*), and the MIT (Massachusetts Institute of Technology) groups – and graduate programs on the topic have been created at several universities (Kovacs and Spens, 2011) which indicates that the humanitarian logistics research line has evolved in the past few years.

In this context, the purpose of this work is to deepen the knowledge about disasters and humanitarian crises by surveying current research in logistics and supply chain management in these types of crisis situations. Papers published in the area of HL were reviewed and classified to observe trends, identify literature gaps and, then, propose ideas for future research.

The first literature review in disaster operations management was conducted by Altay and Green (2006). These authors reviewed 109 papers that were published in operations research (OR) and management science (MS) journals from 1980 to 2004, in which papers were included papers that covered such situations as computer network emergencies. Logistics and supply chain management journal were not included in their work. Natarajarathinam *et al*. (2009), conversely, extended the scope of the previous work and reviewed papers dealing with supply chain management during a crisis, including such situations as a supplier bankruptcy and the loss of key clients. These researchers considered 118 papers published in 48 journals from 1975 to 2008. However, these interesting contributions, which include the proposal of several criteria to classify the literature, both works have a more general scope than the one proposed in the present paper, which focuses solely on disaster relief and humanitarian logistics. Therefore, given the increasing number of works published in the HL field, there is a need for updated and detailed review of the current literature that requires further investigation. In addition to the updated review additional the classification criteria adopted to those by the abovementioned papers, other criteria are proposed in order to better detail the different contributions.

Both Altay and Green (2006) and Natarajarathinam *et al*. (2009) stated their objectives to point out issues and provide ideas and directions for future research in the area. Thus, the literature review presented in this work may lead to the identification of publication trends and identify application opportunities (Altay and Green, 2006), that are key information for analysis of the relevance and originality of future projects.

The remainder of this paper is organized as follows. The scope covered by this paper is described at section 2. Section 3 presents the research methodology used to classify the papers. Next, section 4 offers results and discussions of the literature review. The paper ends with concluding remarks in section 5. Because of space constraints in this paper, see the following website for the complete list of references of the reviewed papers: http://cislog.poli.usp.br/download/get/ils-references/109/.

2 Scope of the paper

The scope of the literature review presented is this paper is limited to academic peer-reviewed journals because of their academic relevance and their ease of searching. Books, conference proceedings, and practitioner journals are outside the scope of this work. In addition, the review considers only papers that were published after 1980, as that is the period when the first works on disaster operations management (Sheffi *et al*., 1982; Sampson and Smith, 1982) appeared.

The keywords "disaster", "relief" and "humanitarian logistics" were used for the literature searches in several journal databases and for content analysis in journal special issues in HL. The searches were then extended by using the reference lists of the papers found.

Finally, this paper is focused on disaster relief.Studies of daily responses to routine emergency calls are excluded from this paper, and the interested reader can refer, for example, to the work by Swersey (1994).

The research method used in this paper is presented in the next section.

3 Research Methodology

The method used to classify the literature is based on the ten criteria presented in Table 1. Several of these criteria (1 to 5) were used in previous literature, as Altay and Green (2006) and Natarajarathinam *et al*. (2009). Additionally, other criteria are proposed (6-10) in order to detail organizational level, type of modeling used in the OR-oriented studies, and real case applications.

#	Criteria	Description	Source
1	General paper information	Journal, author affiliation, publication year, country of the university	Natarajarathinam *et al*. (2009)
2	Research method	Conceptual; analytical; empirical; applied	Natarajarathinam *et al*. (2009)
3	Disaster type	(1) Hurricanes, cyclones and typhoons; (2) Floods; (3) Drought, (4) Earthquakes; (5) Volcanic eruption; (6) Epidemics; (7) Famine and food insecurity; (8) Man-made disasters; (9) Population movement; and (10) Technological.	Altay and Green (2006)
4	Disaster lifecycle stage	Mitigation; preparedness; response; recovery	Altay and Green (2006)
5	Technique	Math programming; simulation; statistics etc.	Altay and Green (2006)
6	Decision level	Strategic; tactical; operational	Our contribution
7	Problem type	Facility location; inventory management; network flows and scheduling	Our contribution
8	Optimization type	Deterministic; stochastic	Our contribution
9	Model type	Linear (LP); nonlinear (NLP); mixed-integer linear (MILP); mixed-integer nonlinear programming (MINLP)	Our contribution
10	Actual application	Yes; no. If yes, location of the application	Our contribution

Table 1: Research method

First, general paper information was collected such as the journal title, the publication year, the author affiliations, country of the universities..

The research method classification follows the approach of Natarajarathinam *et al*. (2009). Papers can be classified as conceptual or analytical. The conceptual works consider a new method, a technique, or an approach to disaster relief and are not justified with any additional work such as modeling, a case study, or empirical research. Literature review works are additionally classified as conceptual research. The analytical category considers research methods such as simulation or mathematical modeling. These papers are further classified as empirical or applied. Empirical works include collection and the evaluation of data and observations. Case studies, opinions, and interviews are included in the applied research category.

Disasters are categorized into 10 types (listed in Table 1), following the classification proposed by the IFRC and adopted by Altay and Green (2006). These authors divided the disaster lifecycle in 4 stages: mitigation; preparedness, response, and recovery. In the mitigation stage measures are applied either to prevent the onset of a disaster or to reduce the impacts. Hence, risk measurement and risk analysis articles were classified in the mitigation stage. Preparedness activities train the community to respond when a disaster strikes. The resources and the emergency procedures employed immediately after the disaster occurs comprise the response stage. Recovery involves the actions taken in the long term after the immediate impact of the disaster.

Next, the techniques are listed following a similar classification of the one used by Altay e Green (2006).

The last five criteria were not used in the previous reviews. Papers are divided according to the decision level because humanitarian logistics services require good strategic (long term), tactical (medium term), and operational (short term) decisions to ensure the efficient allocation of resources. For the OR-oriented papers, the relevant academic literature falls into three problem types: (1) facility location, (2) inventory management, and (3) network flows and scheduling. According to Duran *et al*., 2011The first type focuses on the spatial aspects of operations; the second type focuses in estimating demand at various nodes of a supply chain; whereas the third type focuses in delivery of goods and sequence of activities . In addition, optimization type, model type, and actual application are described to provide more detail about the use of mathematical programming in the HL field.

The results of the application of these criteria to the literature are presented below.

4 Results and Discussion

The literature review resulted in 201papers published in 75 journals – see http://cislog.poli.usp.br/download/get/ils-references/109/ for the complete reference list. First, the characteristics of the reviewed papers are presented, and analysis and discussions appear subsequently.

4.1 Papers classification and analysis

Figure 1 displays a histogram of the reviewed papers by databases. The Science Direct database is pointed out as the major source of papers, corresponding to almost 30% of the papers analysed.

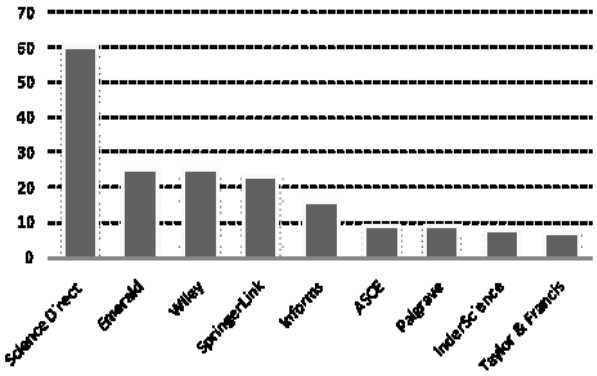

Figure 1: Number of papers per database

A comparison between the number of victims of major disasters (for the period 1980-2010) (EM-DAT, 2011) and the publication profile by the disaster type is shown in Figure 2 (the man-made and famine categories are not covered by EM-DAT). The largest number of academic publications deals with the type of events that cause the largest number of victims (especially earthquakes). On the other hand, an inverse relationship in terms of academic publishing and actual data is observed for floods, epidemics, and drought events.

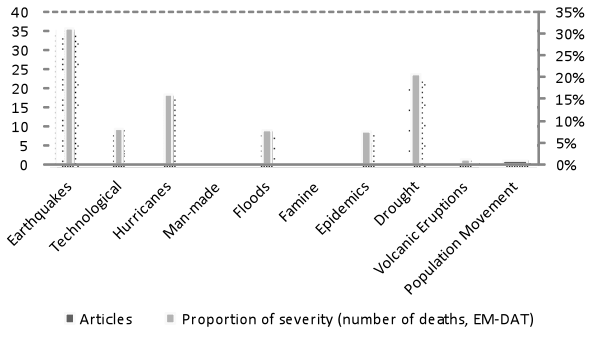

Figure 2: Number of papers by disaster type

Van Wassenhove (2006) proposed a classification of natural and man-made disasters according to the speed with which the disaster strikes: slow-onset and sudden-onset. Famine, drought, political, and refugee crises are examples of the former category, whereas the latter includes, for example, earthquakes, hurricanes, technological, and terrorist attacks. The division of papers according to this approach is summarized by Table 2, where sudden-onset disasters can be viewed as the category that has gained more attention from academia.

	Natural disaster	Man-made disaster	Undefined	Total
Slow-onset	9	3	2	14
Sudden-onset	77	35	26	138
Undefined	4	0	45	
Total	90	38		201

Table 2: Papers according to Van Wassenhove (2006) approach

Figure 3 illustrates the distribution of papers per year, according to the disaster lifecycle stage. The results indicate an emphasis on the mitigation stage from 1998 to 2003 and the growth of research into the response stage from 2006 to 2011. Figure 2 additionally shows the scarcity of literature on HL prior to the 1990, indicating that it was as rarely explored field the figure indicates a sharp increase in the number of publications on the subject in the past few years, especially after 2009, when journals published special issues.

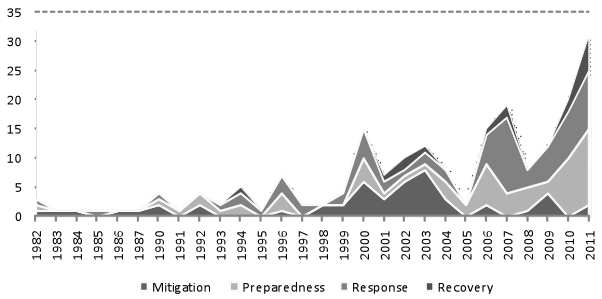

Figure 3: Annual paper distribution by disaster stage

The distribution of papers by research method and disaster lifecycle stage is illustrated in Figure 4. It is important to note that the articles are divided into categories of conceptual or analytical and empirical or applied. Thus, more than one category can be assigned to a paper and, as a consequence, the total of papers shown in Figure 4 is higher than the 201 papers reviewed in this work.

The results suggest that the analytical work is predominant to conceptual work and that the number of empirical and applied papers is well distributed. The publication profile by disaster lifecycle stage has changed since the Altay and Green study was published. In these researchers review, the mitigation stage accounted for 44% of the papers, followed by response, preparedness, and recovery, in decrease order. From Figure 4, however, it can be observed that preparedness and response are currently the most addressed phases of the disaster lifecycle. The lack of work on recovery efforts has remained since the Altay and Green review.

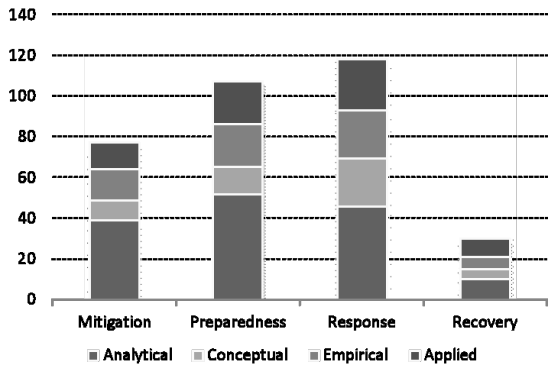

Figure 4: Papers by research method and disaster stage

Few papers are applied to humanitarian organizations which suggest the need to strengthen relationships between academia and these entities. Among the applied papers IFRC, World Food Programme (WFP), *Medecins Sans Frontieres* (*MSF* – Doctors without Borders), and Federal Emergency Management Agency (FEMA) are the ones that the most appear in publications, especially the IFRC.

The top ten journals in number of publications are presented at Table 3 which also lists the journal's impact factor from Journal Citation Report (JCR). These journals are responsible for 49.25% of the total reviewed papers.

As mentioned previously, Altay and Green (2006) studied the OR/MS literature exclusively; whereas Natarajarathinam *et al*. (2009) considered crisis supply chain management in a broader scope. As a result, only four (4) of the top ten journals listed in Table I are featured in Altay and Green review (EJOR, JORS, Interfaces, and Comp. & OR) and only five (5) are featured Natarajarathinam *et al*.'s reviews (IJPDLM, Interfaces, EJOR, JORS, and IJPE). The journals OR Spectrum, Risk Analysis, Transportation Res.-E and Management Res. News did not appear in the previous reviews. This finding confirms the new trend of publications in the HL area.

#	Journal	Papers	JCR
1	International Journal of Physical Distribution & Logistics Management (IJPDLM)	15	2.62
2	OR Spectrum	14	2.03
3	Interfaces	12	0.83
4	International Journal of Production Economics (IJPE)	12	1.99
5	European Journal of Operations Research (EJOR)	11	2.16
6	Risk Analysis	10	2.10
7	Journal of the Operational Research Society (JORS)	9	1.10
8	Transportation Research - Part E	6	1.95
9	Computers & Operations Research	5	1.77
10	Management Research News	5	Not available

Table 3: Top ten journals

The analysis of the research methods employed in the top 10 journals, as shown in Figure 5, highlights the conceptual line of journal oriented toward logistics- and supply chain management- (such (as IJPDLM and IJPE), in contrast to the analytical feature of OR oriented journals (such as EJOR and JORS).

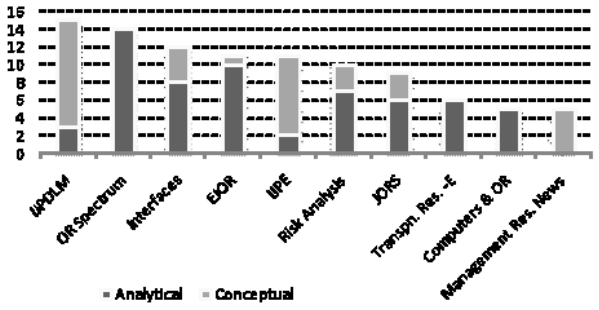

Figure 5: Research methods of the top 10 journals

Table 4 presents the list of countries with at least 4 publications. The paper distribution by author's work-country shows the USA and Europe in the top of the list. This trend is also seen in the previous studies (Altay and Green, 2006; Natarajarathinam *et al*., 2009).

Country	Papers	Country	Papers
United States (USA)	106	Finland	5
United Kingdom (UK)	19	Netherlands	5
Germany	11	Japan	5
France	11	Switzerland	5
Turkey	10	Austria	4
Spain	7	Taiwan	4
Canada	5		

Table 4: Publications by country

Despite the US lead in the number papers, the author ranking leader in publication comes from a French institution (INSEAD), as indicated in Table 5 (only authors of at least 4 papers are presented).

Author	Papers	Affiliation	Country	References
Luk N. van Wassenhove	7	INSEAD	France	Van Wassenhove (2006); Tomasinia and Van Wassenhove (2009); Charles et al. (2010); Van Wassenhove and Martinez (2010); Besiou et al. (2011); Martinez and Van Wassenhove (2011)
William A. Wallace	6	Rensselaer Polytechnic Institute	USA	Belardo et al. (1984); Harrald et al. (1990); Mendonça et al. (2000, 2001); Mendonça and Wallace (2007); Dowty and Wallace (2010)
Benita M. Beamon	5	University of Washington	USA	Beamon and Kotleba (2006a, 2006b); Balcik and Beamon (2008); Balcik et al. (2008, 2010);
James H. Lambert	5	University of Virginia	USA	Haimes et al. (1998); Frohwein et al. (1999); Frohwein and Lambert (2000a, 2000b); Lambert and Patterson (2002)
Stephen Pettit	5	Cardiff University	UK	Petitt and Beresford (2005, 2009); Banomyong et al. (2009), Beresford and Pettit (2009); Taylor and Pettit (2009)
Yacov Y. Haimes	5	University of Virginia	USA	Haimes et al. (1998); Frohwein et al. (1999); Haimes and Jiang (2001); Haimes and Longstaff (2002); Leung et al. (2003)
Begoña Vitoriano	4	Complutense University	Spain	Rodríguez et al. (2010, 2011a, 2011b); Vitoriano et al. (2011)
Javier Montero	4	Complutense University	Spain	Rodríguez et al. (2010, 2011a, 2011b); Vitoriano et al. (2011)
Gyöngyi Kovács	4	Hanken School of Economics	Finland	Kovacs and Spens (2007, 2009, 2011); Tatham and Kovacs (2010)
Anthony Beresford	4	Cardiff University	UK	Petitt and Beresford (2005, 2009); Banomyong et al. (2009); Beresford and Pettit (2009);

Table 5: Top authors (at least 4 papers)

However, in terms of performance per institution, U.S. not only led back but also occupies the top three positions of the ranking, as listed at Table 6 (only institutions with at least 4 publications are presented).

Institution	Country	Papers
Rensselaer Polytechnic Institute	US	8
University of Washington	US	8
University of Virginia	US	7
INSEAD	France	7
Georgia Tech	US	6
Cardiff University	UK	5
Massachussets Intitute of Technology	US	5
Delft University of Technology	Netherlands	4
Complutense University	Spain	4
Hanken School of Economics	Finland	4

Table 6: Top institutions (at least 4 papers)

Figure 6 presents a classification of the literature according to the techniques used in the papers. To establish a base for comparison this classification is similar to the one proposed to Altay and Green (2006),. The classification by techniques follows a profile similar to that followed by Altay and Green's (2006) review, especially in the large number of conceptual papers and mathematical programming papers.

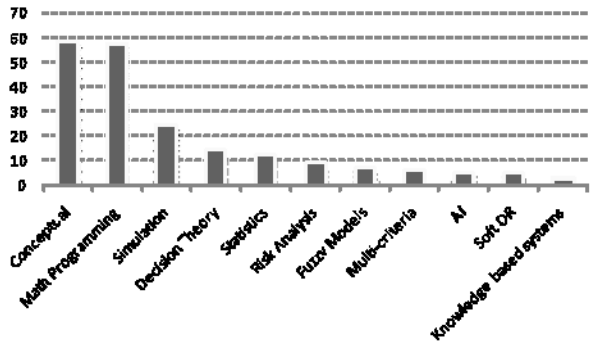

Figure 6: Papers by technique

Although mathematical programming was traditionally developed with well established deterministic models, decisions to support HL activities for disaster operations management are challenging due to the uncertainties of events. In this regard, stochastic programming is an appropriate tool to support decision due to its ability to handle uncertainty. Actually, the results suggest a rise in the stochastic applications over the years, reaching the total of 16 studies (in contrast with 42 deterministic studies).
The predominance of deterministic studies can be seen in Figure 7, where the articles are also classified by type of problem. Networks flow problems appear as the most common problem type. Routing problems related to delivery of goods and scheduling of activities after a disaster onset are included in this category.

In addition, LP and MIP models are the most commonly applied in the literature and have been found in 10 and 55 articles, respectively. The emphasis on MIP models is attributed to the use in the strategic problem of facility location. Prepositioning of warehouses and determining the inventory level of resource allocation (critical commodities for immediate relief) are typical preparedness activities for disaster operations management. The need for preparedness is confirmed by the high number of papers that cover strategic decisions (88), followed by operational (44), and tactical papers (28).

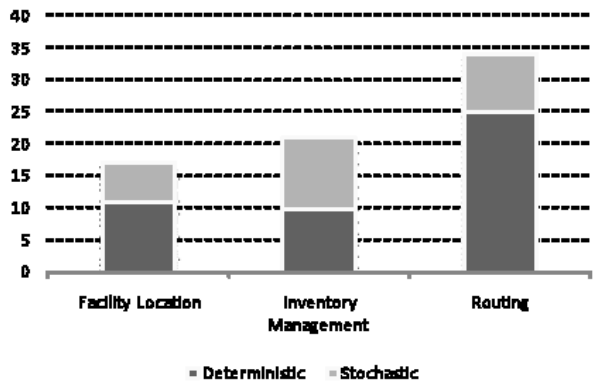

Figure 7: Papers by problem type

The gaps in the literature and future research directions are summarized in the next section.

4.2 Trends and future research directions

From the results of the literature survey, it can be concluded that research on the proactive and immediate reaction stages of the disaster lifecycle such as mitigation, preparation, and response is more widespread than research on the recovery stage. The recovery of a site after experiencing a disaster has received little attention. The need for a recovery plan to return to normal operations and that this process may take a long time (for example, nearly one year alter the floods in Rio de Janeiro, life has not yet returned to normal conditions in the affected area), more research in recovery planning is needed.
The imbalance in academic efforts and actual needs was confirmed by contrasting the number of papers by disaster type in Figure 2. According to EM-DAT (2011), drought and epidemic disasters have caused significant number of deaths and yet academic studies regarding these crises are seldom .

Additionally, Altay and Green (2006) indicated that papers linking theory and practice were rarely explored. This situation still exists. In our review, only 24 of the 130 analytical papers included a case study (not only a model or a numerical example to test the model with historical and geographical data). Therefore, there is a need for closer collaboration with non-profit humanitarian organizations such that more case studies and empirical research can be conducted, as previously stated by Van Wassenhove (2006). It could be beneficial for scholars and practitioners to exchange data and knowledge about the process of providing humanitarian aid.

The United States has been the major contributor since in the HL research since the Altay and Green (2006) review. More than 50% of the papers reviewed involved US scholars . Therefore, the involvement of the academic community from other parts of the world is essential to share knowledge about the local characteristics of HL problems.

Productivity and efficiency studies are challenging issues that have gained importance in humanitarian operations because of pressure from donors on humanitarian organizations to deliver aid to beneficiaries in a cost-effective way. This trend can be observed in the research history. Whereas Altay and Green (2006) concluded that disaster operations management did not have lacks widely accepted measures of productivity and efficiency, there are more recent papers tracked parallels between the performance indicators of business logistics and humanitarian logistics (for example, Schulz and Height, 2009).

Natarajarathinam *et al*. (2009) also suggest that disaster relief logistics should learn from business logistics.
A predominance of works focused on strategic decision level was identified in the literature. Operational level is concentrated on routing problems. Thus, there is a need to extend the analysis to the other decision levels (tactical and operational). These decision levels are conventionally viewed as being related in a hierarchical fashion with strategic planning decisions imposing goals, targets, and constraints on tactical decisions, which are in turn implemented and supported via a number of operational execution functions. One way to emphasize the need for integration is by recognizing the natural hierarchy among these steps and the fact that they may not operate with the same level of information. Thus, the political hierarchy in emergency response organizations is well suited for hierarchical planning and multi-attribute, multi-objective approaches (Altay and Green, 2006).

Finally, humanitarian logistics is a multidisciplinary field of both a social and a political nature and presents problems that are suitable for conceptual, analytical, empirical, and applied research. Despite several interesting contributions to humanitarian logistics listed in all the revised papers, the humanitarian relief chain management is still an open issue, which is therefore relevant for mathematical modeling, research methods, and actual applications.

5 Conclusions

This paper presented a literature survey of humanitarian logistics and disaster operations management and showed an increase in the number of publications on the subject over the past five years. The number of papers published in the subject has significantly increased since the previous Altay and Green (2006) and Natarajarathinam *et al* (2009) literature reviews in this research area. Two hundred and one (201) published papers in the area of HL were surveyed, classified, and some gaps were identified, allowing suggestions for future research. In the last years, most publications have focused on strategic decisions, thus tactical and operational decisions could be more explored. The main conclusions are the need for more studies into the disaster recovery phase; and need for closer relationship between the academia and humanitarian organizations in order to generate more applied research. The authors agree that a closer collaboration between universities and humanitarian organizations may lead to a greater development of applied research at the tactical and operational decision levels.

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