Prioritization models in humanitarian operations: systematic review of the literature

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ABSTRACT
The need for prioritization models was highlighted in several circumstances of recent relief operations regarding both material and operations. This work aims to identify prioritization models in humanitarian operations according to a systematic review of the literature identifying models, object of prioritization and criteria.

Keywords: prioritization model, disaster, humanitarian logistics.

INTRODUCTION

According to the International Federation of the Red Cross, disasters are sudden and calamitous events that disrupt the normal functioning of a society or community, causing economic, human, environmental or material losses which exceed the community's resilience (IFRC, 2012). Data collected by the Centre for Research on the Epidemiology of Disasters (CRED) and consolidated in the database Emergency Events Database (EM-DAT) shows that, between 1990 and 2014, 9,336 disasters were recorded worldwide with 2.3 million deaths during this period and about 209 million affected annually. The types of disasters with most affected people were floods and droughts (CRED, 2015).

Besides the characterization by event type, a disaster can be classified as having a rapid onset - such as earthquakes, hurricanes and terrorist attacks - or slow onset - as famine, drought and refugee crisis (Van Wassenhove, 2006); special tools are needed for each context as preparation time and strategies of response are different for each type of disaster and onset occurrence.

In addition, disasters are divided into four phases: mitigation, preparedness, response and reconstruction. The goal of the mitigation phase is to prevent the occurrence or, at least, to

reduce possible damage to the population to be affected by a disaster; for example, residents of risk areas can be moved and dams can be built. By preparing the response, actions are taken in order to make the disaster response to be as efficient as possible; thus, for example, pre-positioning of assets can be done as well as allocation of resources and training of personnel. The response phase begins as soon as the disaster occurs and aims to alleviate the suffering of the community; recurring activities at this stage are the transport of supplies and rescue and search operations. Finally, at the reconstruction phase long-term actions are taken which provide tools with the purpose of reinstating the previous condition of the community (Altay and Green, 2006).

Regardless of the analyzed phase, it is essential that while structuring the plan of action the scope of humanitarian logistics is taken into account, as has been specified by Thomas and Kopczak (2005). Kovács and Spens (2007) report that humanitarian logistics is an area that only recently has been highlighted in humanitarian aid. Studies are still in its early stages and emphasis has been given on the need for research in the process of planning humanitarian operations. Leiras et al. (2014) - in their literature review on humanitarian logistics - also underscore as a research gap the planning process at the tactical and operational levels; the authors point out as challenge the conflicting interests of different stakeholders and the chaotic environment which hampers coordination between actors and often prevents better results in the supply chain.

A difficulty in the majority - if not in all – of disasters of great magnitude and which involves both planning at the tactical level and conflict of interest of different stakeholders is the management of donations (Holguín-Veras et al., 2012.). Coordination in this environment is difficult or even unfeasible, especially given the total lack of communication from some actors (there have been reports of cases in which international actors do not identify themselves to the national government (Moore et al., 2003)) and because of a number of complicating factors that affect effective coordination, as discussed by Balcik et al. (2010).

The responses to the 2010 earthquake in Haiti and the Typhoon Haiyan in the Philippines in 2012 can be cited as examples of this complex environment; in both cases the donor response was quick, however the sudden assistance with materials and personnel of humanitarian agencies, private institutions and governments quickly surpassed the processing capacity at the airports - both with regard to equipment and human resources (Moline, 2013). The number of stakeholders in Haiti reached 4000 organizations and in response to the typhoon over 40 governments and 50 american corporations made donations (US Chamber of Commerce Foundation, 2012) - not to mention non-governmental organizations (NGOs) and corporations from other countries; the number of stakeholders and the amount of supplies to be considered were overwhelming. Prioritized were items related to water both in Haiti and the Philippines, however prioritization did not meet adequately the needs of affected populations – e.g., lack of critical items for medical care was reported (WHO, 2010) – and it went against the interests of donor organizations.

To prioritize items partially solves the problem because it reduces the need for good coordination between agents in the operation. However the absence of well-defined criteria through which prioritization is implemented to date undermines the effectiveness and efficiency of humanitarian aid as shown in the examples cited. Thus, this study aims to identify prioritization models used in the academic literature on humanitarian operations in order to, in a future study, propose a model of management of donations.

The paper follows as described. First, concepts regarding the prioritization and existing

models are addressed. The following section describes the methodology used to obtain a systematic literature review. Then, the literature review on the use of prioritization models in humanitarian aid operations is presented and results are discussed. Finally, conclusions and suggestions for future work are identified.

PRIORITIZATION MODELS

The process of prioritizing means to list and rank alternatives in an order of priority, according to a particular perspective (Vaz, 2015). Prioritization can be done in several ways and in the following sections approaches found in literature related humanitarian logistics are described.

Multi-criteria

Multi-criteria models started to be developed in the 1970s as opposed to mono-criteria methods which were previously used. The goal of a multi-criteria analysis is to incorporate multiple aspects to be considered in a decision-making process helping to choose, order and / or rank alternatives (Ensslin et al., 2001).

The single-criterion synthesis approach is also known as the multi-attribute model. According to the experience of the decision maker a value, between 0 and 100, is given for each criterion of the options; then weights are defined for each criterion and, finally, the value of each alternative is given by Equation 1:

$$V(x) = w_1 v_1(x) + w_2 v_2(x) + \cdots + w_n v_n(x) \tag{1}$$

With *V(x)* as the aggregating function of alternative *x*, *w* as the weight assigned to each criterion and *v(x)* as the value function (or utility) for each criterion. AHP (Analytic Hierarchy Process) is an example of this approach (Ensslin et al., 2001).

Because the single-criterion synthesis approach requires large amount of data which may be inaccurate, the outranking approach was proposed in which the alternatives are compared pairwise. The prioritization that is reached when using this method does not produce a relative value of significance among the alternatives. It may be difficult to apply, but less specific data is needed for the model (Ensslin et al., 2001).

The multi-objective approach optimizes simultaneously more than one objective function, that is to say there is not made a global aggregation as in the former approaches. To this end, alternating stages of calculation and iteration are held with decision makers. At the calculation phase the computer searches for a viable solution and at the iteration phase the decision makers specify which direction the optimization should take (Ensslin et al., 2001).

The algebraic multi-objective optimization model can be written as:

$$
\begin{aligned}
&\textit{Min/Max} && z = f(x) = \big(f_1(x), f_2(x), \dots, f_r(x)\big) \\
&\textit{Subject to} && g(x) = (g_1(x), g_2(x), \dots, g_p(x)) \le b \\
&&& x = (x_1, x_2, \dots, x_n) \in X \\
&&& z = (z_1, z_2, \dots, z_n) \in Z
\end{aligned}
\tag{2}
$$

With $Z = f(x)$ as the image of x called objective space, x as the decision vector, z as the object vector and X and Z denoting the spaces of decision and objective vector, respectively (Campos, 2011).

In multi-criteria optimization a comprehensive aggregation of criteria is done, the criteria being subject to several restrictions (Victorian, 2011). Thus, this approach is a hybrid of the single-criterion synthesis approach and the multi-objective approach.

On the fuzzy approach a certain criterion has not only the values of belonging or not belonging (0 or 1), but there is a range between these absolute values. The goal may also be "fuzzy", not only the criteria. First the classification of attributes of each alternative is made by decision makers. Then the alternatives are prioritized according to the aggregated result (Kahraman, 2008).

Heuristics

To use heuristics is to implement rules aimed at accelerating the process of identifying a solution close to the optimal - in the ideal case it is the optimal − which meets the needs of the decision maker. Generally this approach is used for problems that would require too much processing time using common optimization methods (Rayward-Smith et al., 1996). In the case of metaheuristics an element is added so that the search for an optimum is not restricted and the global optimum can be found (Cotta, 2011).

Empirical Prioritization

In addition to the models discussed above, lists can be compiled empirically with priority given to each of the listed items according to the know-how of the organization. The result is not properly a model of prioritization, yet through feedback mechanisms implicit to human activities - during and after humanitarian operations - the relevance of each item is determined. To deepen the understanding of dynamics of feedbacks see Sterman (2000). This approach is particularly observed for objectives which are difficult to measure or regarding political elements.

METHODOLOGY

The steps outlined by Benedict (2012) were followed for the literature review and elements of the methodology proposed by Leiras et al. (2014) were also used.

The publication channels chosen for the research were national and international journals related to logistics and humanitarian operations published between 1991 and 2015 which are available at Portal de Periódicos CAPES/MEC. The keywords searched for were "prioritization" along with "disaster", "humanitarian" and "relief". After the initial search by keywords secondary sources were revised, including congress articles, symposia and theses / dissertations. Articles had their general information listed including title, authors, publication channel and year. Next elements were characterized according to disaster - type of disaster, disaster phase - approached decision level and country of the application (when applicable). Finally, the scope was analyzed regarding the prioritization by identifying object of prioritization, quantity of criteria and model used.

LITERATURE REVIEW

There have been found 16 relevant articles for this study. In Figure 1 the amount of publications for different periods of time since 1991 is shown.
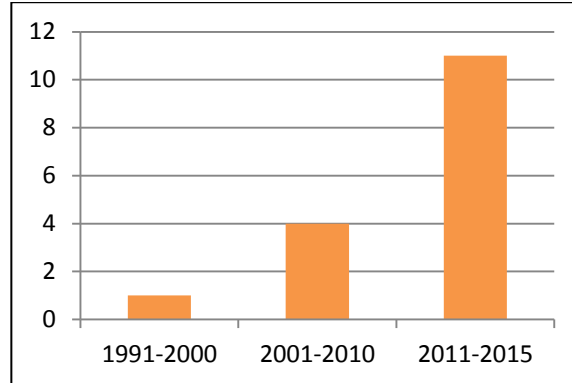

Figure 1: Amount of publications per period

The publications channels found were journals (13), master's thesis (2) and report (1). Regarding the journals, articles have been published in Fuzzy Sets and Systems, Omega, Journal of Global Optimization, Production and Operations Management, OR Spectrum, Accident Analysis and Prevention, Journal of Bridge Engineering, Knowledge-Based Systems, Risk Analysis, Health Care Management Science, Socio-Economic Planning Sciences, Networks and Spatial Economics and Water Resource Management.

In Figure 2 the number of disasters is specified according to the classification of type of disaster. Most studies do not determine (ND) the type of disaster studied, i.e., it presupposes that the study is comprehensive enough for any type of event. Next there is prevalence of studies addressing earthquakes.
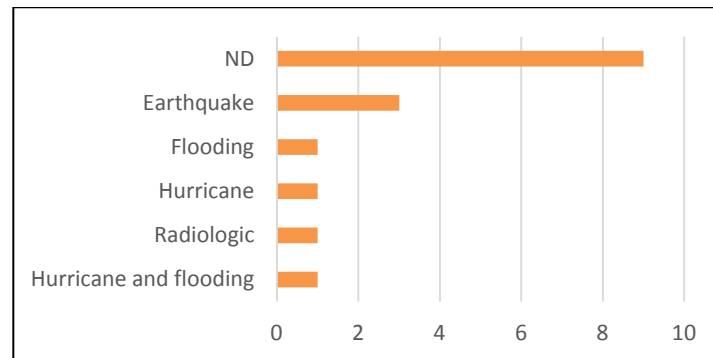

Figure 2: Amount of publications by type of disaster

The most studied disaster phase was the response and then the phases of mitigation and preparation - Figure 3. A single study may address more than one phase, so the sum of the phase count does not necessarily correspond to the total number of publications.
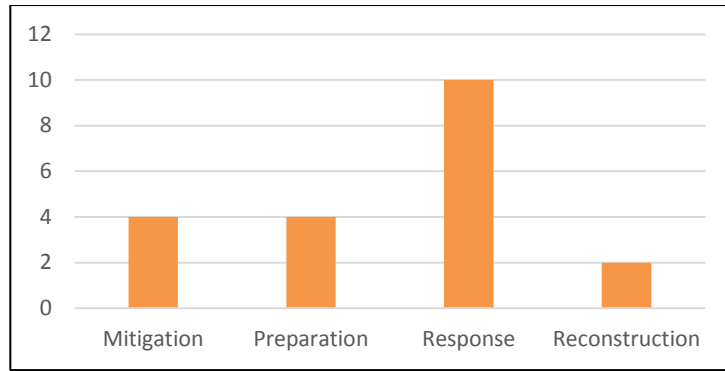
Figure 3: Amount of publications by disaster phase

Regarding the decision level (Figure 4), a number of the highest level of management studies were found - strategic (8) and tactical (5) - and 3 studies addressing prioritization in operational decision level.

Figure 4: Amount of publications per decision level

Applied to real cases were found 43% of the studies, in two cases having as context the earthquake in Haiti, two application cases in Iran, two in America and one case in Portugal.

In Table 1 publications are characterized according to the prioritization object, the prioritization model and the amount of criteria used. The multi-attribute models were the most studied (5), with some contributions from multi-objective models (4), multi-criteria optimization (2) and heuristics (2). The most frequent prioritization object in the studies was the prioritization of operations in three publications. The amount of criteria varied between 2 and 36 with approximately 70% of the studies using 10 or less criteria.

Table 1: Publication characteristics regarding prioritization

Publication	Prioritization Object	Prioritization Model	Number of criteria
Ibrahim e Ayyub (1992)	Components of systems	Fuzzy multi-criteria	6
Park (2007)	Operations	Multi-objective	12
Bana e Costa *et al.* (2008)	Renovation of bridges/tunnels	Multi-attribute	5
Weinberger (2010)	Air transport	Empirical	-
Bocchini e Frangopol (2010)	Renovation of bridges	Multi-objective	2
Cotta (2011)	Patients	Metaheuristics	3
Lin *et al.* (2011)	Routes	Multi-objective	9
Vitoriano *et al.* (2011)	Distribution location	Multi-criteria optimization	6
Parlak *et al.* (2012)	Improvement in operations	Multi-attribute	10
Ressurreccion e Santos (2012)	Sectors of the economy	Multi-objective	2
Childers *et al.* (2014)	Patients	Heuristics	4
Gralla *et al.* (2014)	Operations	Multi-attribute	5
Du e Peeta (2014)	Infrastructure	Multi-criteria optimization	3
Cavalcanti (2015)	Operations	Multi-attribute	36
Bozorgi-Amiri e Asvadi (2015)	Logistical assistance centers	Multi-attribute	5
Chitsaz e Banihabib (2015)	Alternatives to mitigate flood damage	Comparison of models	11

Ibrahim and Ayyub (1992) studied in a general way the relevance of particular component for a system analyzing 6 criteria: probability of failure, magnitude of fatality, magnitude of damage, economic risk, human risk and uncertainty in predicting the consequences.

Park (2007), Gralla et al. (2014) and Cavalcanti (2015) addressed the prioritization of operations. Park (2007) addressed the humanitarian aid at the strategic level maximizing the amount of rescued people, supply provision, provision of shelter, sanitation system provision, crime prevention / chaos, answers to health requirements, satisfaction with public economic activities, prevention of environmental damage and minimization of deaths, damage to transport infrastructure, damage to public infrastructure and damage to public services. On the other hand Gralla et al. (2014) preferred the operational approach using the most common criteria in the area: delivered amount, amount of each type of delivered item, amount delivered to places with high or low priority, delivery speed, cost of operation. Cavalcanti (2015) details more criteria, already used by Gralla et al. (2014), and adds others which comprise available budget and comparison of operations between points served, e.g., "worse unsatisfied demand rate among all points". In addition, Parlak et al. (2012) prioritize the operation that most needs improvement

according to the public health and safety criteria, estimated cost, information sharing, preparedness and public planning, environmental considerations, coordination between NCR and localities, coordination amid the emergency support, shelter capacity and evacuation in multiple geographical and temporal scales, effective assistance of the private sector, innovation, learning and adaptation in emergency planning. Weinberger (2010) conducted the only study of empirical prioritization in which the air transport priorities in the event of disaster were analyzed, especially being observed prioritization of operations related to the political agenda.

Both Bana and Costa et al. (2008) and Bocchini and Frangopol (2010) observed the importance of functional bridges after the occurrence of a disaster. The first ones identified five criteria - vulnerability, public safety, emergency response time, economic impacts, interference with other critical public services - and the last ones had the simultaneous goal of maximizing resilience and minimizing costs. Du and Peeta (2014) also identified the need for critical infrastructure studies by analyzing the importance of a link of a network, the function of the link and the marginal increase in survival of infrastructure due to increases in pre-disaster investment. In this respect Chitsaz and Benhabib (2015) studied alternatives that could be undertaken, especially with regard to infrastructure, to mitigate the environmental effects of floods by analyzing recovery rate criteria, gradual rate, EAD, feeling of security, employment, participation , protection and improvement of the natural landscape, protection of wildlife habitat, protection of water quality, technical feasibility and speed of construction. Ressurreccion and Santos (2012) prioritized sectors of the economy according to economic loss and inoperability time.

Vitorino et al. (2011) addressed the location of distribution centers according to cost, weather, equity, priority, reliability and security. Bozorgi-Amiri and Asvadi (2015) aimed to locate logistics service centers according to availability, risk, technical considerations, cost and coverage. Lin et al. (2011) developed a multi-objective model to minimize: unmet need, travel time of all routes and vehicles and rate of satisfaction among nodes (equity); the criteria were time period index that pending applications are delivered, delay severity index, set of nodes traveled by the vehicle per route, travel time per route, delivery time windows without prejudice to the item, cost of trip per route, available working time per period, maximum weight capacity of the vehicle, maximum vehicle volume capacity.

Childers et al. (2014) aimed to study the priority evacuation of patients (urgent and non-urgent) using the criteria: death rate during shipment, death rate during waiting, patient evacuation rate and amount of remaining patients; greedy and hybrid heuristics were used. In Cotta (2011) the sorting of patients is made according to the average life span, the number of deaths during operation for the group and the time in which the operating room will be free; metaheuristics were used.

CONCLUSION

It was found that there are few studies about humanitarian logistics on prioritization models in the literature; there was significant development on the issue only as of 2010. There is particular need for prioritizing studies for the reconstruction phase, in line with the lack of research identified by Leiras et al. (2014).

The preponderance in prioritization is given to models with less than 10 criteria in the strategic and tactical levels. Also, it is observed that multi-attribute and multi-objective models can be applied in a reasonable manner in various situations in the humanitarian context.

For future work it is suggested to check the consistency of the criteria used by the studies on humanitarian operations by comparison and to deepen studies in prioritizing specific objects in order to increase the understanding of difficulties and opportunities related to the objects.

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