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OPERATIONS RESEARCH ON LOGISTICS DECISIONS

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ABSTRACT

The decision-making process on humanitarian logistics deals with variables related to the flow and quality of supplies, since the receipt of emergency relief items, its classification, stock, separation and delivery. Consequently, this decision-making process is crucial for seeking the best results in the allocation of scarce resources for storage and transportation in humanitarian operations, while preventing the flow of unnecessary products, which leads to losses and costs that may have consequences in the effectiveness of the operation.

KEY WORD- *natural disasters, humanitarian logistics; optimization;*

INTRODUCTION :

Natural events can be characterized as natural disasters when they occur in populated areas, causing the destruction of local infrastructure and population leading to a state of deprivation and suffering. In the last three decades, the occurrence of natural disasters has increased significantly.

Immediately after the occurrence of disasters, humanitarian operations are initiated with the intent to provide rapid assistance to victims in different ways, such as salvaging those who are wounded and/or stranded, collecting and disposing corpses, resource allocation, provision of food aid, shelter and medical care, and restoring access to remote locations. In humanitarian actions, delays in delivery or relief can cost lives. Therefore, efficiency in logistics is a key success factor, because it ensures the smooth flow of goods and services in a complex supply chain.

Logistics plays a key role in disaster response operations; it serves as a link between disaster preparedness and response, between procurement and distribution, and between headquarters and the field, and is crucial to the effectiveness and responsiveness to major humanitarian programs such as health, food, shelter, water and sanitation (Thomas, 2003).

Decisions on humanitarian logistics are usually taken in urgency, based on the experience of the practitioners involved in the disaster response. According to Beamon and Balcik (2005), the decision-making process during a disaster response may differ from conventional decision-making, since important attributes of the problem are uncertain and needs change rapidly, besides there is little time and information may not be available for making a decision. Considering this context, we identified in the literature existing mathematical models, based on Operations Management (OM) and Operations Research (OR) techniques that can be applied to solve logistics challenges in disaster relief operations and thus helping the decision-making process. We believe that these models can be adapted to support logistics procedures to be applied in response operations for natural disasters in Brazil.

This paper analyzes logistics models that can be applied to help humanitarian logistics decisions regarding activities such as procurement, storage and handling, and transportation and distribution in natural disaster relief operations

OPERATIONS RESEARCH AND OPERATIONS MANAGEMENT MODELS IN HUMANITARIAN LOGISTICS

The scope of the paper consists in analyzing the existing Operations Research and Operations Management models found in the humanitarian logistics literature that can be applied to help the decision-making process regarding the following activities in disaster relief operations: procurement; storage and handling; and transport and distribution.

1. Procurement: consider the activities relating to supply chain preparation, planning and evaluation, supply chain optimization and pre-positioning of products (allocation problem).
2. Storage and handling: operational issues regarding to storage and movement of materials and inventory planning - supply network design, determination of inventory levels, facilities location (location problem) and personnel allocation.
3. Transport and distribution: associated with the delivery of the product to the end user or a point to redispatch - routing of deliveries and distribution flow coordination.

In the bibliographical research, a limited amount of work related to applications of operations research (OR) for relief operations and disaster management was found on the recent literature (Beamon and Balcik, 2005; Altay and Green III , 2006). Perez et al. (2010) reinforce this small amount of studies published, showing that the field is still incipient with opportunities of research.

Only forty-four articles related to humanitarian logistics process modeling, or associated to its theoretical basis were found and twenty-five were organized and classified in accordance to the scope of this study, as their contents address the activities defined for the object of the study, offering specific optimization models for application in operating conditions of emergency relief responses (urgency, lack of resources, limited availability of data, variable demand). Table I presents the researched articles classified according to the scope of the study and to the logistics activity it focus. Articles that address more than one logistics activity are marked with asterisks.

Table I - Classification of articles studied in accordance with the logistics scope of the study

Logistics Process Stages	Logistical Activities	Authors
Procurement	Supply Chain Optimization	Nagurney *et al.* (2012)
		Nagurney *et al.* (2010)
		Salmeron and Apte (2010)
		Clark and Culkin (2007)
	Inventory Pre-positioning	Rawls and Turnquist (2009)
		Mete and Zabinsky (2009)
		Yushimito and Ukkusuri (2007)
Storage and Handling	Supply Chain Project	Beamon and Balcik (2005)
		Barbarosoglu and Arda (2004)
	Inventory Planning	Wyk *et al.* (2011)
		Emmett and Lodree (2011)
		Ozbay and Ozguven (2007)
		Balcik and Beamon (2008)*
		Beamon and Kotleba (2006)
	Facilities Location	Jaller and Holguín-Veras (2011)
		Balcik and Beamon (2008)*
		Günnec and Salman (2007)
		Yi and Özdamar (2007)**
		Huang *et al.* (2012)
	Staff Allocation	Falasca *ei al.* (2009)
Transport and Distribution	Deliveries Routing	Lin *et al.* (2011)
		Lin *et al.* (2010)
		Perez *et al.* (2010)
		Lin *et al.* (2009)
		Campbell *et al.* (2008)
		Yi and Özdamar (2007)**
	Distribution Flow Coordination	Özdamar *et al.* (2004)

Procurement

Regarding the logistics process of procurement, the existing mathematical models focus on decisions related to supply chain optimization and inventory pre-positioning. The OR/OM techniques applied in these models are discussed as follows.

Supply Chain Optimization

Most supply chain optimization problems, developed in the context of humanitarian logistics apply Linear Programming (LP) techniques. Nagurney et al. (2012), applying Linear Programming techniques, developed a multiproduct supply chain network design model, solved as a variational inequality problem (adjusted for computational purposes), so that the total cost in the humanitarian operation is minimized and the demands are satisfied as nearly as possible. To solve the variational inequality formulation, the Euler method and Lagrange multipliers are used.

Salmeron and Apte (2010) proposed a stochastic optimization model to guide strategic resource allocation for cyclic disasters in geographical areas. It is a Prepositioning multiobjective Optimization Model, solved in two stages, applying both mixed-integer programming and simulation techniques.

Clark and Culkin (2007) develop a mathematical transshipment multi-commodity and multiobjective supplychain network model, using LP with an objective function that minimizes transportation and inventory costs, weighted according to the component cost reduction priority. The Cplex 9.1 solver was used.

Inventory Pre-positioning

For facility location, Rawls and Turnquist (2009) proposed a two-stage stochastic mixed integer program (SMIP) model, which can be formulated as an optimization problem to decisions regarding stocking levels for emergency supplies and distribution. The proposed model uses the L-shaped method to reduce the number of second-stage problems, and also a Lagrangian Relaxation. For the same purpose, Mete and Zabinsky (2009) also proposed a stochastic optimization approach with a two-stage stochastic programming model, with a mixed-integer programming (MIP) model, that is a reduce capacitated vehicle routing problem (CVRP) in the second stage, solved with Cplex solver. Nonetheless, Yushimito and Ukkusuri (2007) used a combination of the most reliable path and an Integer Programming to model the pre-positioning of supplies for disasters as a facility location problem that accounts for the vehicle routing to minimize both the fixed costs and the routing costs.

Storage and Handling

Regarding the logistics process of storage and handling in the context of humanitarian operations, the existing mathematical models focus on decisions related to supply chain project, inventory planning, facilities location and staff allocation. The OR/OM techniques applied in these models are discussed as follows.

Supply Chain Project

Beamon and Balcik (2005) modeled a facility location problem for small-scale emergencies, through the minimization of the sum of the expected response times of items over all scenarios, with the objective of finding the best distribution network configuration for the relief chain (the number, location and the capacity of the DCs) Looking for planhing the transportation of vital first-aid commodities to disaster-affected areas during emergency response, Barbarosoglu and Arda (2004) propose a two-stage stochastic programming model. As Beamon and Balcik's (2005) model, this one also was solved using GAMS/OSL and SLPIOR solver.

Inventory Planning

Wyk et al. (2011) proposed a stochastic inventory model to help anticipate the types and quantities of aid supplies to be kept in a pre-positioned facility, minimizing the overall cost of inventory kept; using LINGO version 8.0 for the solution.

The study of Emmett and Lodree (2011) focused in the local retailer's inventory management problem that emerges upon recognition of a possible pre-storm demand surge; evaluating the reactive and proactive strategies over inventory level for a fast-moving item. They use the minimax decision criterion (the decision rule that optimizes the worst case scenario that does not require any probabilistic information) for the classic economic order quantity (EOQ) model.

Ozbay and Ozguven's (2007) paper is concerned with the development of a model which can determine the safety stock that will prevent disruptions at a minimal cost. They mathematically formulate the humanitarian inventory management problem as a version of Hungarian Inventory Control Model (convex nonlinear programming problem); and then propose a solution to this time-dependent stochastic model using pLEPs algorithm (p-level efficient points - pLEPs), after converted the continuous distribution functions into discrete distributions.

Beamon and Kotleba (2006) treated the development of an inventory management policy to improve the effectiveness and efficiency of emergency relief during long-term humanitarian responses, through a multi-supplier inventory model, as an extension of the standard (Q, r) inventory policy that allows for two different lot sizes and two different reorder levels. They developed a mathematical model that optimised the reorder quantity and reorder level based on reordering, holding and back-order costs.

Balcik and Beamon (2008) proposed a maximal-covering type model that determines the number and locations of the distribution centres in the relief network and the amount of relief supplies to be stocked at each distribution centre, developping an inventory strategy for stocking different types of supplies. The results were obtained using GAMS/Cplex solver.

CONCLUSIONS

There is a tendency to use mental models, based on the experience and intuition of practitioners, in the complex decision-making processes. This reality also occurs in response operations to natural disasters.

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