A System Dynamics Approach to Humanitarian Logistics and the Transportation of Relief Supplies

Yesenia Cruz-Cantillo, Civil Engineering and Surveying Department, University of Puerto Rico at Mayagüez, Mayagüez, PR, USA

ABSTRACT

A system dynamics model was developed for the forecasting, prioritization, and distribution of critical supplies during relief operations in case of a hurricane event, while integrating GIS information. Data was obtained from operational reports gathered during Hurricane George from agencies such as: Puerto Rico Department of Housing (PRDOH), Puerto Rico National Guard (PRNG), Civil Defense State Agency of Puerto Rico, Puerto Rico Department of Transportation and Public Works (PRDOTPW) and Puerto Rico Highway & Transportation Authority (PRHTA), along with reports from other U.S. agencies. Information about travel times, roadway classification, and geometric characteristics of the roads as well as the location of distribution centers, shelters, points of distribution and kitchens facilities were also gathered through visual field inspections and interviews with local residents. The model developed is able to (1) establish the people’s decision and transportation characteristics that determine the time of evacuation; (2) simulate the behavior of key variables due to the relation between level of hazard and people’s decision to evacuate; (3) estimate for each level of natural hazard the time frequency to order and the order size of each relief supply to be needed in shelters and points of distribution; and (4) reveal which routes cause more delays during distribution of relief supplies. It was demonstrated that the number of people that leave the disaster site increases despite their concerns about the road conditions and that a Category 3 hurricane will produce the higher amount of people that will evacuate.

Keywords: Humanitarian Logistics, Relief Supplies, System Dynamics, Transportation, Vehicle Routing Procedure

INTRODUCTION

When an extreme and/or unanticipated natural event occurs, such like a hurricane, the safety and efficiency of transportation systems are seriously affected as well as the people and the infrastructure. Successful distribution of critical resources in emergency relief depends on volumes, response time and inventory level replenishment of supplies (medical materials and personnel, specialized rescue equipment and teams, food, etc.). For this reason, forecasting commodity and...
transportation demand becomes essential for logistics planning in emergency situations. Nowadays, the logistics of providing emergency response and relief to distribution of aid is subject to intense study; therefore, emergency logistics is classified as one of the most complex elements of relief operations (United Nations Development Programme, 1993).

Logistics is the work needed to move and position inventory within a company’s supply chain management. It is a subset of and happens inside the wider framework of a supply chain, and it is the process that creates value by timing and positioning inventory. It is the grouping of a company’s order management, inventory, transportation, warehousing, materials handling, and packaging as integrated all over a facility network (Bowersox, 2002).

Logistics refers to the planning, implementation and control of the goods and materials from a point of origin to a point of consumption with the purpose of meet the beneficiary requirements (Thomas and Mizushima, 2005). From the humanitarian’s point of view, logistics is the processes and systems involved in mobilizing people, resources, skills and knowledge, to help vulnerable people affected by the disaster (Wassenhove, 2006).

Logistics is crucial to the performance (effectiveness and speed) of existing and future operations and programs. It provides a rich source of data, since it is this department that manages the tracking of goods, which could be used to analyze post-event effectiveness. In a disaster relief operation is the most expensive part and means the difference between a fruitful or unsuccessful operation (Wassenhove, 2006). Therefore, logistics operations have to be designed in such way that they get the right supplies to the precise place and allocate them to the correct people at the precise time.

Being better prepared permits humanitarian organizations better their response. Logistics has to be identified and understood as an inherent element of any disaster relief operation in order to be better prepared (Wassenhove, 2006).

The term “logistics” refers to, how are obtaining, distributing, maintaining and replacing the material and personnel (Logistics World, 2014). Supply chain management (SCM) is a term often used reciprocally with logistics; it refers to the acquisition, manufacture, and distribution of goods in commercial, military, and humanitarian sectors (Tabbara, 2008). Prior research has shown that distribution of critical supplies is a hard task due to the very limited or non-existent transportation capacity in the affected areas and the severe damages to the physical infrastructures (Holguín-Veras et al., 2007). In addition, the demands of critical resources and transportation have the tendency to change depending on the time of day and the size and location of the evacuation area.

Due to the wide variety of factors that influence emergency logistics, it becomes a challenge to optimize the critical resource logistics and distribution during a hurricane event. Therefore, identifying, inventorying, dispatching, mobilizing, and transporting critical supplies throughout emergency relief operations are necessary to preserve the life of those affected by these events. Currently there is no known model that takes into account the elements of a disaster and their dynamic interactions that aims to improve the distribution of critical resources while allowing the corresponding organizations to react in real time based on the disaster situation.

System dynamics are able to account for the interrelations and dynamics of evacuated people, traffic flow, response time, inventory level, reorder points, transportation and supplies demand, among other elements. In addition, the creation of an information technology framework that helps to collect data in real time about the conditions of the roads and supply levels in shelters and points of distribution during the event could help improve the operations of the agencies in charge of emergency relief. Therefore, the consideration of these relationships and the establishment of an information technology framework can help enhance the behavior of emergency logistic operations during unanticipated natural events.