



A hybrid multi-objective decision model for emergency shelter location-relocation projects using fuzzy analytic hierarchy process and goal programming approach

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Abstract

This paper presents a hybrid algorithm for efficiently managing location and relocation projects by proposing a hybrid multi-objective decision model based on analytic hierarchy process (AHP), fuzzy set theory and goal programming approach. The objectives of proposition are to minimise distance, risk, number of sites and uncovered demand and simultaneously maximise suitability based on qualitative factors while taking into consideration demand, capacity, utilisation and budgetary constraints. Since the problem is of multi-objective decision making, we solve it by converting all objectives into a single objective function using goal programming approach. Project managers can benefit from collective expertise of multiple decision makers as proposed model leverages their knowledge into automating shelter site selection and relocation process. The model attempts to achieve a compromise solution to multiple objectives in disaster recovery projects involving shelter location decisions. The results are validated by considering two real case studies of Nepal earthquake.

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1. Introduction

Disaster is defined as a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources (IFRC, 2015). The increase in number and impact of disasters over the past few years has been very significant; from fewer than 50 disasters per year reported in 1950 to more than 400 disasters in 2010 (EM-DAT, 2015). They lead to vast devastation and destruction of physical infrastructure. Every year, a number of people become homeless due to natural disasters like earthquakes, hurricanes,

etc. Dealing with adverse effects of these disasters requires better planning and implementation (Trivedi et al., 2015). Humanitarian logistics focuses on efficient management of flows of goods, information and services, to meet the urgent needs of affected people under emergency conditions. Its contribution towards overall relief operations is 80% (Trunick, 2005), which makes it a critical element for a successful relief operation (Sheu, 2007). Temporary Shelters provide immediate accommodation, medical care and food to affected people (Bayram et al., 2015). Since their locations are of paramount importance, they must be strategically selected for an efficient disaster recovery. Disaster recovery projects are initiated in dynamic environment involving high uncertainty and risks due to accumulation of many factors. One of the major goals of these projects is to ensure that affected people are relocated to areas at a safe distance from threat zones and may have easy access to other essential service facilities. In non-routine

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projects, project manager must handle multiple conflicting goals in an uncertain environment with incomplete or unavailable information (Xu et al., 2012). These goals focus on minimization of project completion time, and/or minimization of total project cost through crashing or shortening of activities time duration (Akkan et al., 2005; Eshtehardian et al., 2009; Leu et al., 2001). Moreover, quality of a disaster recovery project is determined to a large extent by the degree of safety provided to people. Most of the researches have successfully addressed emergency shelter location problem using quantitative factors. However, to the best of our knowledge, no study has collectively taken into account both quantitative as well as qualitative factors in emergency facility location problem. Hence, in present research work this aspect has been addressed. This work focuses on improving efficiency of disaster recovery projects by proposing a hybrid methodology based on fuzzy AHP and goal programming for emergency shelter site location and relocation problem. Rest of the paper is organised as follows.

Section 2 provides review of related literature along with research issues identified from it. Section 3 presents an overview of adopted methodology while Section 4 presents the problem for study along with proposed mathematical model. Section 5 highlights the applicability of model with the help of two case studies of Nepal earthquake. Implications for managers are highlighted in Section 6. The last Section summarises the study along with future research directions.

2. Review of literature

This section starts with an overview of different facility location issues in humanitarian relief contexts that have been addressed in previous studies. Reported research works on temporary shelter site location are further reviewed to identify research objectives of study. A brief review of literature is given in subsequent sub-sections.

2.1. Facility location in humanitarian relief

Facility location in humanitarian relief has been addressed by several researchers. It has been extensively reviewed in few studies (Başar et al., 2012; Li et al., 2011a, 2011b; Trivedi and Singh, in press). It can broadly be classified into three categories; namely, warehouse location for relief materials, emergency medical centre location, and shelter site location problem (Kılıcı et al., 2015). The reported research on these issues has been discussed below.

2.1.1. Warehouse location for relief materials

Relief materials such as food, medicines, tents, tools, equipment, etc. are pre-purchased and stocked at strategic locations in advance to be distributed to aid recipients in the aftermath of a disaster. These locations are strategically selected to carry out response activities rapidly. A number of research efforts have been carried out to address warehouse location decision. Hale and Moberg (2005) formulated a deterministic set covering problem and presented a four step process for site

decision that included recommendations from FEMA's disaster management guide. A prepositioning problem for CARE International was addressed by Duran et al. (2011). In addition to location decision, number of distribution centres also needs to be minimised considering limited availability of funds. Balcik and Beamon (2008) proposed a maximal-covering type model that simultaneously established number and locations of distribution centres in a relief network. They also determined amount of relief supplies to be stocked at each centre. A variant of this model was used by Murali et al. (2012). Since disaster recovery projects are restricted by limited funds, cost becomes an important criterion. Construction cost efficiency was considered by Zhu et al. (2010) while determining storage locations and optimum level of a single commodity. Modelling of real life location problems is complex, resulting in longer solution times. Thus, a number of heuristic approaches have been proposed. Li et al. (2011a, 2011b) proposed a heuristic algorithm that covers all demand points and minimises urgency. Rath and Gutjahr (2014) proposed a math-heuristic for a three-objective warehouse location–routing problem in disaster relief. Yushimito et al. (2012) proposed a heuristic based on Voronoi diagrams to locate distribution centres while Salman and Yücel (2014) used Tabu search heuristic to select locations of emergency response facilities in pre-disaster stage. Risk of demand points was considered by Akgün et al. (2015) in their optimization model. Further, to address randomness and uncertainty associated with disasters, a few stochastic formulations have also been proposed. Campbell and Jones (2011) and Jia et al. (2007a) used a stochastic approach to address location decision. Another approach for location and inventory problem was adopted by Rawls and Turnquist (2010) and Mete and Zabinsky (2010). A few studies have attempted to address multiple objectives in their location models. Doerner et al. (2009) developed a multi objective mathematical model to locate facilities like school, etc. in tsunami prone area using coverage, risk and costs as criteria. Rath and Gutjahr (2014) considered cost and demand functions to address location issue in their study.

Stock pre-positioning and warehouse location have been extensively studied by several researchers. Most of the works on facility location in humanitarian relief are based on warehousing decisions that involve pre-positioning of critical supplies at strategic distribution centres to meet the needs of affected population.

2.1.2. Emergency medical centre location

Emergency centres are healthcare establishments to provide medical assistance to disaster affected people. Since injured people should be provided medical facilities at the earliest, locations of these centres are vital for an effective response. Set covering models have been proposed by Dekle et al. (2005) and Ablanedo-Rosas et al. (2009) for medical centre locations. Huang et al. (2010) considered response failure of centre at a node and based on it, proposed a variation of p-median model. Jia et al. (2007b) attempted to address uncertainty by analysing different scenarios. A two stage stochastic programming model was developed by Verma and Gaukler (2011) while Lu (2013) addressed randomness in ambulance location and dispatching

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