Decision Support Systems 66 (2014) 160–169

Contents lists available at ScienceDirect

Decision Support Systems

journal homepage: www.elsevier.com/locate/dss

A decision support system for post-disaster interim housing

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ARTICLE INFO

Article history:
Received 12 December 2013
Received in revised form 12 May 2014
Accepted 21 June 2014
Available online 1 July 2014

Keywords:
Decision support systems
Integer programming
Heuristics
Disaster management

ABSTRACT

The Northridge earthquake of 1994 displaced almost 10,000 families and destroyed major transportation infrastructure within Southern California, and Hurricane Katrina created the largest national housing crisis since the Dust Bowl of 1930, destroying over 300,000 homes and leaving over one million people seeking shelter. Numerous smaller disasters each year such as tornados, costal or inland flooding, and less severe earthquakes also destroy homes and displace families, although on a much smaller scale. Arranging housing for disaster victims ranks as a top priority after the immediate needs for food and medical care are met. This task becomes more challenging as families are displaced for a longer period of time due to increases in costs, government involvement, and expectations of the victims. In early 2009, FEMA released the first-ever National Disaster Housing Strategy which calls for improved planning and outlines the key principles and policies guiding disaster sheltering, interim housing, and restoration of permanent housing. While all three housing problems are very difficult, the provision of adequate temporary or interim housing is perhaps the most challenging. A few researchers have addressed the issue of optimal allocation of temporary housing, but have focused primarily on the first part of the problem which focuses on the selection of adequate capacity from among available interim housing alternatives. The second part of the problem, which consists of recommending housing alternatives to individual families from the pool of temporary housing units selected in phase one such that educational, healthcare, and socio-economic needs are met, has not yet been addressed to the best of our knowledge. We propose a decision support system for assigning families to housing units which addresses these needs. We develop a benchmark integer programming model for developing a balanced housing plan, and then use the model to evaluate three heuristics which could be practically applied with our system. We use a prototypical example to illustrate the model and evaluate the heuristics, and to demonstrate their appropriateness for the development of realistic real-time housing recommendations.

1. Introduction

Natural disasters such as hurricanes, earthquakes, fires, floods, and tsunamis, and man-made disasters such as terrorists' attacks, have the potential to disrupt lives and displace families in enormous numbers. When homes are destroyed and families are displaced, providing shelter and housing is essentially a three-phase process. First, short-term emergency shelters must be located to provide safe space, food, and emergency medical care for the displaced families. These shelters may also serve as processing centers where information can be gathered about the families and their immediate and longer term needs. Once the sheltering phase is complete, which could last for a few days up to a few weeks, families are sometimes able to return home if the disaster damage is minimal and their previous homes are structurally and environmentally safe. However, this is often not the case. Disasters, especially large-scale events, commonly cause lasting structural and environmental damage to many homes and business, in which case families may be displaced for much longer periods of time. In the case of Hurricane Katrina, many families are still unable to return home eight years later.

In this situation, we enter the second phase of the problem, providing interim or temporary housing for families. It is important to note that the definition of family in relation to housing is very broad, and may consist of a housed group which is based on a traditional nuclear family, an extended family, or simply a co-residence arrangement. Although interim housing may last for several years, the goal of disaster relief planners is to limit the length of this phase as much as possible in order to minimize the adverse effects which families experience when separated from their socio-economic, medical, and educational support structures. If this interim period lasts too long or involves moving families too far from their previous neighborhood, families may never return to rebuild their old neighborhoods because of broken social ties or a general feeling of not belonging. The goal of interim housing is to allow the family to live a normal life until they can return to their home or to other permanent housing, which FEMA identifies as the

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http://dx.doi.org/10.1016/j.dss.2014.06.012
0167-9236/

focus of the third phase. While all three phases of this housing problem are very difficult, the provision of adequate temporary or interim housing is perhaps the most challenging.

In early 2009, The Federal Emergency Management Authority (FEMA) published its National Disaster Housing Strategy which outlines their guidelines for planning and providing housing in all three phases [9]. Their report states that "the needs and expectations of disaster victims in interim housing are greater than those in shelters, and our experience has taught us the importance of addressing these issues early in disaster response and throughout the recovery process." They also affirm that "housing is the connector to how we live our lives and interact with the social networks within our communities. While interim housing cannot replicate a household's pre-disaster conditions, it can be planned to integrate delivery of essential support or 'wrap-around' services, such as referrals for mental health, emotional, and spiritual support; job placement; childcare; social services; and other resources that can help make temporary housing viable."

Researchers have long understood the importance of socio-economic impacts on displaced families [2,12,14]. When families are forced to live isolated from their familiar surroundings and friends, they may experience emotional difficulties and broken social ties which could ultimately lead to a reluctance to return and rebuild the former community. El-Anwar and El-Rayes [2] discussed the importance in this regard of minimizing the distance between the displaced family's preferred location and its assigned temporary housing location. Other factors which affect the level of socioeconomic disruption include the capacity of temporary housing alternatives to support the economical, medical, educational, and safety needs of displaced families [3,27,31].

While many researchers have explored these effects, little attention has been given to the development of quantifiable methods for recommending housing alternatives to families in consideration of these factors. In a series of three studies, El-Anwar et al. develop a model, and eventually an automated system, for identifying desirable housing alternatives [3–5]. While their research is a major step forward, they do not suggest any mechanism for recommending the best alternatives to families from the identified housing pool. Without a mechanism for matching families with alternatives, it is likely that many families will choose an area that either is far removed from their area of preference or does not have the necessary healthcare and educational support services which allow them to function properly. The only housing matching mechanism we are aware of is the FEMA Housing Portal [8] which allows web users to query a database of available temporary housing alternatives. However, FEMA's mechanism does not provide any information on nearby availability of hospitals and schools, nor does it allow planners to balance the needs of numerous displaced families. This portal is essentially a "multiple listing service" for housing alternatives which leaves users to sort through numerous housing options with little support and feedback. What seems to be needed is a decision support system for matching families with specific housing alternatives. Decision support system design for disaster management has been a popular topic in the literature [10,11,22,23,25], and systems have been developed for many areas of disaster management, including nuclear and radiological emergencies [28], earthquakes [7], and health emergencies [13,16,26]. While such free and open source decision support systems for disaster management certainly benefit from public–private collaboration to deploy and maintain [20], the first step is the development of a prototype system.

The purpose of this paper is to present a decision support system for making specific recommendations to families with respect to their interim housing alternatives. First, we develop an integer programming model which serves as a benchmark for our system development. The model solution represents a "greater-good" set of housing assignments that would balance the aforementioned objectives across all families. The model also serves as a learning tool to better understand the housing problem, and could serve as a planning tool for determining whether the available alternatives allow for feasible housing of all families. However, the model solution is impractical as a real-time decision aid as each family is interested in the best housing alternative relative to their needs only, and families present themselves for assistance sequentially as opposed to as a group. Next, we present a set of heuristics which can approximate the benchmark solution while serving each family on an individual basis, and we evaluate the heuristics through a hypothetical example. Next, we discuss the DSS design for the implementation of the best heuristic. Finally, we offer conclusions and possible areas for future research.

2. The interim housing model

The interim housing model is designed to minimize the total distance from the family's preferred neighborhood and the distances from necessary support services across all displaced families while making sure that there are sufficient housing units to accommodate the families and sufficient school capacity in a given area. In this example, we consider educational and healthcare support services, although other important services such as spiritual support and childcare services could also be included. Consider the following definitions:

Variables

X_{ij} assignment of family i to housing alternative j ($1 =$ yes, $0 =$ no).

Parameters

W_{if} relative weight for each family i on the importance of factor f ($f = 1$ for socioeconomic area, $f = 2$ for healthcare services, $f = 3$ for educational services)

F_{sj} maximum number of families of size s which can be housed by alternative j

A_i area of preference (original neighborhood or locus of socio-economic support structure) for family i

$D_{A_i j}$ distance from area A_i to alternative j

H_{jt} distance to the nearest healthcare facility type t from alternative j ($t = 1$ for hospital, $t = 2$ for mental health services facility, $t = 3$ for clinic)

E_{jk} distance to within-district educational facility type k from alternative j ($k = 1$ for pre-k, kindergarten, or elementary school, $k = 2$ for middle school, $k = 3$ for high school)

N^H_{it} healthcare need matrix (1 indicates a need in family i for healthcare type t, 0 indicates no need)

N^E_{ik} educational need matrix derived from B_{ik} (1 indicates a need in family i for educational service type k, 0 indicates no need)

B_{ik} number of school-age children in family i at level k

C_{kd} additional capacity of school(s) of type k in school district d

L_d set of housing alternative locations in school district d

S_i size of family i

$smax_j$ maximum size of a family that can be housed at alternative j

s' lower size limit designed for a housing alternative of size s.

The parameter s' is the minimum size family that an alternative is *designed* for, but not necessarily that it can accommodate. Suppose we have alternatives that have 2, 3, or 4 bedrooms so that they are designed for a maximum of 4, 6, or 8 people, respectively. The resulting values of s' would be 1, 5, and 7, respectively. That is, a two-bedroom unit would be designed to handle a minimum of one person and a maximum of 4. A three-bedroom unit would be designed to handle from 5 to 6 people (although, as we will see later, a three-bedroom unit could house less than 5 people if necessary to provide enough temporary housing for all families). A four-bedroom unit would be designed to handle 7 or 8 people, although again it could house fewer if necessary. Thus, s' is the family size at which we must move up to the next largest capacity unit.