OPTIMAL ALLOCATION OF PREDETERMINED SAFE PLACES TO CITIZENS IN DISASTER MANAGEMENT BASED ON GIS

R. A. Abbaspour* and F. Samadzadegan

Surveying and Geomatics engineering Dept., Faculty of Engineering, University of Tehran, Tehran, Iran
(abaspour, samadz,)@ut.ac.ir

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ABSTRACT:

One of the main tasks in the pre-disaster phase of integrated natural disaster management is settlement of people in safe places. To improve the efficiency of this task, it is necessary to prepare a plan in advance. Determination of the safe areas and planning to allocate these places between people plays the main role during a disaster management. In this research, an allocation procedure, which is based on supply and demand model, is proposed to allocate temporary places for residents after a natural disaster such as earthquake. This model uses an exact operational research technique. An evaluation of residents' allocation in pre-determined temporary places for a moderate complicated map of the city of Tehran is conducted. The results show the efficiency of the algorithm and support the proposed modelling.

1. INTRODUCTION

Now, when most of the countries do the best to achieve a sustainable development, the natural disasters are considered as the main threat against this attempt. Under this situation, the policy of most of the governments is concentration on the implementation of a comprehensive strategic plan to cover the different sorts of natural disasters before, during and after disaster, in order to reduce the risk factors (Hodgkinson et al., 1991). To have an integrated disaster management, knowledge about the life cycle of disaster management is necessary.

Disaster management comprises of five important phases: disaster prevention, disaster mitigation, disaster preparedness, emergency management, and disaster recovery (Figure 1). These phases can be divided into two broad groups of pre-disaster and post-disaster phases. Pre-disaster includes the process of preparation in advance to encounter a coming disaster, while the post-disaster process is the set of activities to return to the normal situation, which was before disaster. Each of the phases of disaster management is different for different disasters. Thus, the determination of type of disaster is important.

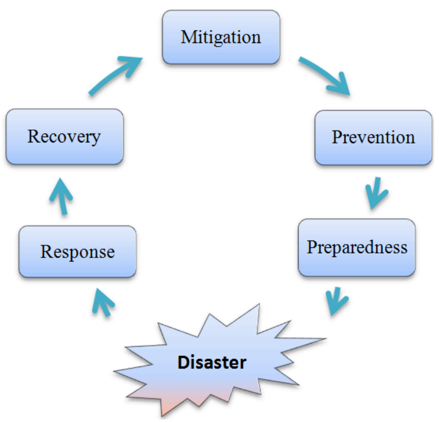

Figure1. Life cycle of a disaster management

Among the different types of natural disasters, earthquake is of considerable importance due to its unpredictable nature and high frequency of happenings. The recent statistics about the damages of earthquakes in cities and villages leads the disaster management teams to consider it especially (Fiedrich et. al, 2000). Since both this phenomenon and its consequences are geospatial, using Geospatial Information Systems (GIS), which are well known as the spatial data analyst and management tools, during the integrated disaster management may improve the monitoring and management (Cardenas and Whitaker, 2000).

One of the valuable capabilities of GIS is the modelling of the spatial optimization problems (Fotheringham and Rogerson, 1994). Combination of optimization techniques with tools for spatial analysis provide the decision makers with vast capabilities to find the most satisfactory and optimum solutions (Malczewski, 2006). Different types of this combination emerge during the integrated disaster management.

One of the main problems in integrated disaster management especially in unpredictable events is modelling the problem of locating the citizens' residential places and allocating these places to citizens before disaster (Fiedrich et. al, 2000; Hanta, 2002). Conducting these two important tasks, everybody knows about his/her temporary accommodation place and the way to that place in advance. This information facilitates the evacuation during the first hours after disaster. Finding a satisfactory solution for the allocation problem, therefore, will be an important step towards the effective disaster management.

The allocation problem can be considered as an optimization problem that is subject to several constraints (Cooper, 1963). Due to the diversity of affecting parameters and factors, modelling of allocation is a complex problem especially in urban areas (Yeh and Chow, 1996; Hanta, 2002). Complexity in spatial distribution of people and buildings besides the other major urban infrastructures especially in big cities made the classic optimization and multi-criteria decision-making problem to consider the uncertainty as well.

* Corresponding author.

In this research, an allocation procedure, which is based on supply and demand model, is proposed to allocate temporary places to the residents after an earthquake. This model uses an exact operational research technique. The objective of allocation modelling in this study is minimization of distance (time) between parks and buildings subject to capacity constraint for parks and population of buildings.

2. PROPOSED METHOD

The proposed method, in this research, is based on general supply and demand model (Densham and Rushton, 1992). Supply presents the amount of resources or services in the centres, and demands show the potential capabilities of units to use the resources (Kim and Openshaw, 2002). A transportation network is necessary to connect the supply and demand centres. The positions of supply centres may be static or dynamic. For example, production of electrical power in powerhouse and its transformation to users is a sample of static supply and demand.

In addition to mentioned three main elements of this model, some other parameters should be considered during the allocation. On these factors is impedance (Klinkenberg, 1997). Impedance in a network refers to difficulty of transportation or the cost of transfer of products/services from supply centres to demand points. There are several methods for calculation of impedance values in a network that are different based on type of network and type of services offered by supply points. For instance, in allocation of students of a region of a city to a set of primary schools, impedance may be assumed as the time takes to travel between students' home and school. In other words, impedances play the same role that the weights play in the network analysis for finding the shortest path between two specific points (Ghosh and Rushton, 1987).

When the problem of allocation is supposed to be solved using a relational GIS, the centres may be assumed as the nodes of the network, and the supply values may be presented as the attribute data that are related to nodes or arcs. Impedances are also the attributes assigned to the arcs of network.

In this research, the allocation of safe shelters to residents after an earthquake is solved. Either these safe places might be determined by solving a location problem using a GIS or using other approaches such as multi-criteria decision making procedure. Finding a satisfactory solution for the allocation problem provides several benefits among them we may refer to the facilitation of evacuation during an earthquake and mitigation after this disaster.

The proposed solution for allocating temporary shelter for residents after an earthquake is illustrated in Figure 2. After determination of allocation parameters, they are entered into the allocation module together with prepared dataset. After applying the algorithm, the results are presented both in text and in graphic format. In the following, the determination of parameters and implementation is discussed.

1. *Determination of main elements of allocation*: the first step to solve the allocation problem is determination of main elements such as supply and demand centres, network, and impedance. In this research, open areas like parks, which are considered as the safer places after an earthquake, are assumed the supply centres. Since the open areas are supposed to be used for accommodation after a disaster, it is obvious that the area of usable parts is used as the volume of supply. The building in which the citizens live compose the set of demand centres. The population who lives inside the building is assumed as the amount of demand. The urban transportation network plays the role of connecting network. The impedances assigned to this network are the temporal distances between the buildings and nearest parks to them. Under these assumption, the objective function of the problem is allocating part of nearest park to a building to the residents of that building subject to some constraints such as capacity of parks and buildings.

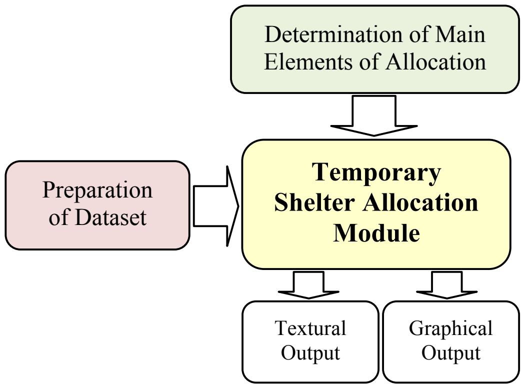

Figure2. The workflow of proposed method

2. *Implementation of optimization algorithm:* when the elements of the problem are defined, some other minor points are applied to the problem. The supply and demand centres are assumed as points ignoring the area of these places in the classic allocation problems. In this problem, however, the sizes of these centres are of importance because they affect the temporal distance between supply and demand points. The other point considered is the direction of arcs in the transportation network. Because the paths from home to parks are supposed to be walked, the directions for arcs are meaningless. Having all the parameters of the problem, it was prepared as a spatial optimization problem. A program in the ArcGIS 9.1 software, which has the capabilities to analysis of both spatial data and attributes, was developed independent of the input data.

3. EVALUATION AND RESULTS

To evaluate the workability and efficiency of proposed methodology, some tests were carried out over the data of a part of city of Tehran, the capital city of Iran. Since on one hand this city is the main centre of political and economical activities, and on the other hand it has a population about 10 millions, the preparation phase of disaster management in this city is of crucial importance. The evaluation phase of this research consists of two parts: preparation of dataset in a suitable and desired format and evaluation of implemented algorithm over this dataset.

3.1 Preparation

Tehran comprise of 22 districts. The data set of this research includes three districts of 12, 15, and 16. In addition to selection of study area, preparation step consists of selection of digital maps and extraction of required information layers. Since the base 1:2000 scale digital maps of the city contains 10 main classes and more than 50 subclasses of objects, the necessary information layers have been extracted. Sample part of the base maps of study area is presented in Figure 3. The selected layers are prepared and cleaned to input into the GIS system, which is ESRI ArcGIS software in our case study. Then the format of inputted layers changed to GeoDB and finally the following spatial data layers were used:

- Residential area (includes residential units like buildings),
- Park (includes green and open areas like parks),
- Pathway (includes all pathways of area such as highways, avenues, streets, alleys, etc.).

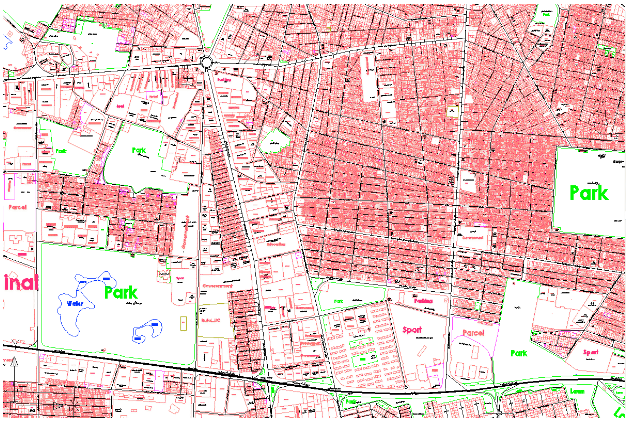

Figure3. A schematic presentation of part of case study area

The suitable topology is built for each layer. Afterwards, the attributes such as the population of each building and capacity of parks are assigned to the spatial information. These attributes are also used during allocation. Some residential buildings are used for other purposes such as education and business. These buildings are classified as the non-residential and due to the correlation removed from the input layers, because the people inside these areas are those citizens who live in another residential building. Figure 4 shows a part of dataset after preparation step.

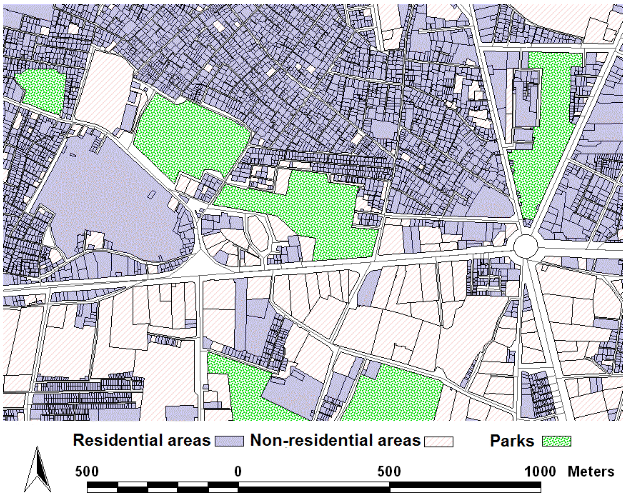

Figure4. A part of case study area after preparation step

3.2 Implementation and Evaluation

After the preparation of dataset, they were entered to the prepared program. The outputs of the system are in two formats of graphical presentation on maps and tabular reports. Part of the output for input dataset is illustrated in Figure 5. There are four classes presented by colours.
Allocated buildings to a park are shown by the same colour as the parks are labelled. The non-residential and non-allocated areas are presented with white colour and diagonal gray pattern, respectively.

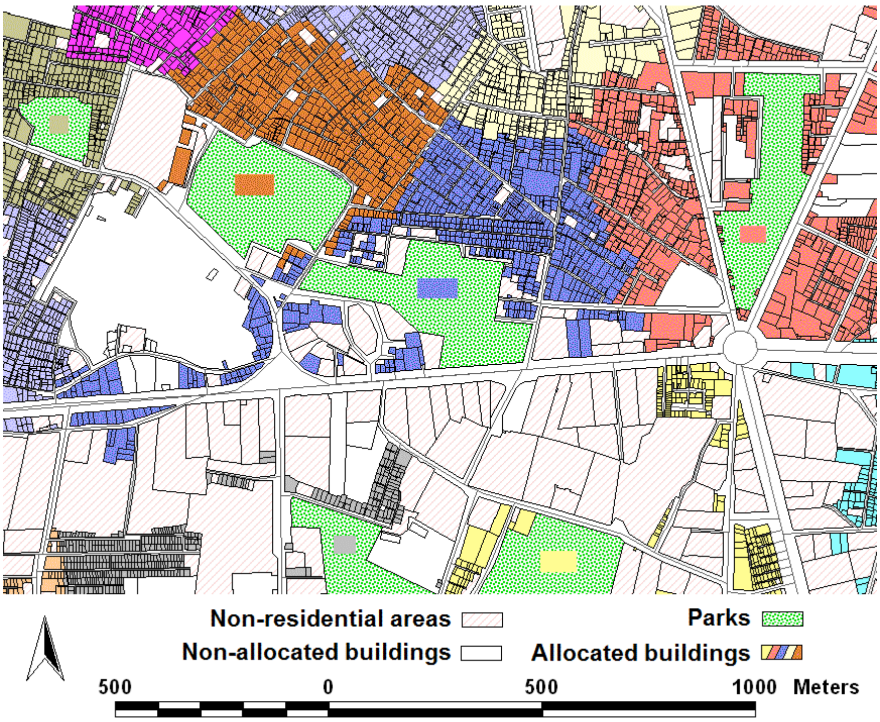

Figure5. The result of proposed method applied on sample dataset.

As the Figure 5 shows, the capacity of the parks plays the dominant role rather than the temporal distance in allocation.

The evidence to this reasoning is the blue buildings. Although some buildings are far from the park labelled by blue, but during allocation, they are assigned to this park.

The other important point of this evaluation is the non-allocated buildings, which are illustrated by white colours. This happened due to the high ratio of demand to supply. In these cases, since the capacities of accommodations are low with respect to the population of buildings, especially those that are farther, they lost the opportunity to be allocated. Because in the urban are, the pattern of population is hardly changeable, the numbers of supply centres, i.e. temporary safer places, should be increased to solve this problem.

4. CONCLUSION

This paper addresses the allocation of safe dwelling places to the citizens according to the defined parameters for the supply and demand model. The main criteria for this optimization problem are capacity of parks, population of buildings, and transportation network. The problem is modelled and developed in ESRI ArcGIS software, and evaluated on a test data set of part of Tehran. The results show the safe place where the residents of each assigned building should go after the earthquake. Having this information before the disaster facilitates the management in post-disaster phases especially in the evacuation. The results are also useful during pre-disaster phases. As the results present the non-allocated residential areas, they may be use to create further safer places in needed places. The results of evaluation show the workability of proposed method.

Since the pattern of populations changes during time, it is necessary to develop an on-line and up to date system to improve the efficiency of disaster management. Such a system offers the newest assigned safer places to citizens.

5. ACKNOWLEDGEMENTS

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