

# EVACUATION PLANNING IN EARTHQUAKE DISASTERS, USING RS & GIS

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## ABSTRACT:

In this research a three-step method was adopted for evacuation planning. At the first step appropriate safe places for evacuation were identified and extracted using RS and image processing techniques. Then using by defining and implementing some constrains in GIS, suitable places were selected. At the second step, for each building block, optimum routes to its candidate safe areas should be determined. In this research, in order to simplify the modeling, the Euclidian distance was utilized. At the third step, by considering and optimizing different factors (such as distance from safe areas, the capacity of the safe areas, and the population of the building blocks) optimum distribution of people to the safe areas was determined. This paper outlines the results of the research.

## 1. INTRODUCTION

Disasters have always been with people during the history and the human generations have always had to tolerate disaster and its caused damages. According to [1] disaster is defined as:

“Serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.”

Due to negative impacts of disaster on society and sustainable making an appropriate management of disaster is a necessity.

With this in mind, disaster management is defined as a cycle of activities including mitigation, preparedness, response and

recovery. Mitigation efforts refer to those activities which reduce the vulnerability of society to the impacts of disasters. Preparedness efforts refer to those activities which make the government and disaster responders prepare for responding to a disaster, if it occurs. Response refers to the activities necessary to address the immediate and short-term effects of a disaster, which focus primarily on the actions necessary to save lives, to protect property and to meet basic human needs. Relief, rescue, search, firefighting, medical service, permit control, sheltering, evacuation, law enforcement and many others are samples of disaster response activities. Recovery efforts refer to those activities that bring communities back to normal (such as reconstruction) and they should be toward meeting mitigation and preparedness needs (Figure 1) [8].



Figure 1: Cycle of disaster management [2]

Depending on whether the event is predictable or unpredictable, the place of temporal sheltering in the cycle of disaster management will be different. If the disaster is predictable like the earthquake, sheltering the injureds is the major part after the

disaster, which is a part of the response phase. In this situation for temporal sheltering of the injured people, the safe areas around the city or the countryside should be recognized as well as the rescue operations. In the next process, the injured people

should be transferred to these safe areas by the optimum path. When the disaster is predictable like flood, sheltering the people will be explained in the preparation phase. In other word, people should be carried to safe areas by optimum path before the

disaster occurrences. In figure (2) the process of improving evacuation planning in general in GIS environment can be seen with the usage of remote sensing images. In next part of the article the process will be explained in details [7].

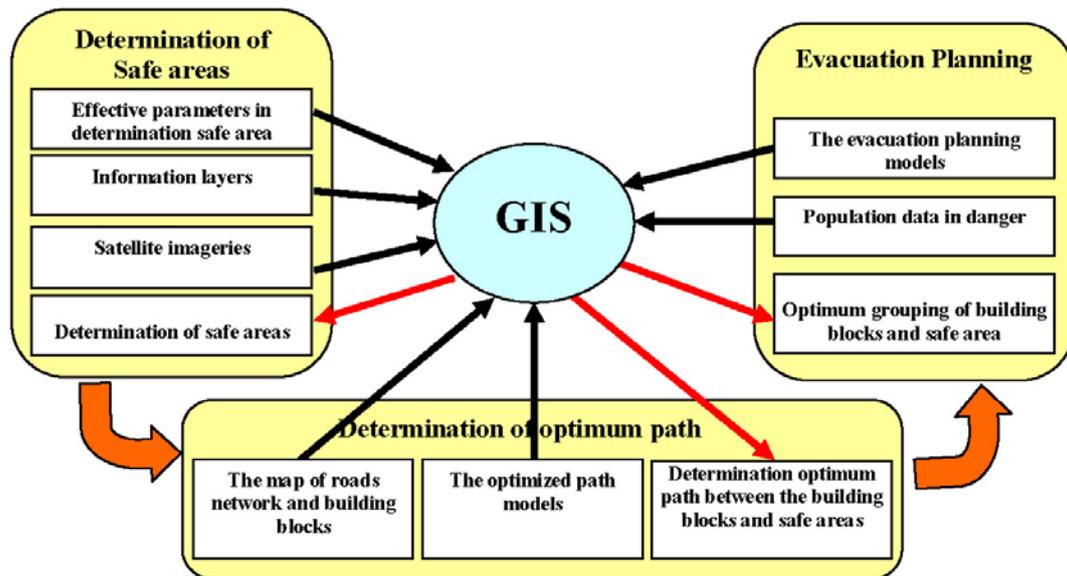


Figure 2: The process of evacuation planning

## 2. THE PROCESS OF EVACUATION PLANNING

Based on the figure (2) the process of evacuation planning is done in three steps. First, determination of safe areas, second, determination of optimum path between building blocks and safe areas, and finally grouping of building blocks relating to each safe area. Each of these processes will be explained next.

### 2.1. Determination of safe areas

Safe area must be safe for people transferred there from danger and should be available [3]. On the other hand, the capacity and distribution of these places should be in a way that not only it should support surrounding all building blocks but also the distance between building blocks and the safe area should not be more than a defined threshold (e.g. 1 km). For determining safe areas some parameters such as availability of facilities, area size, slope, the distance from danger, etc. should be brought into consideration.

Safe areas maybe open (e.g. parks) or closed (e.g. schools). Closed areas should be extracted from available maps. However, open areas can be extracted from satellite imageries. Open areas classified open areas with smooth texture and coarse texture.

In this research, for extracting open areas with smooth texture, texture analysis is used. At first the texture analysis is conducted by applying a window with suitable size to the image. Then by thresholding on the image entropy areas are extracted. Some post processing in GIS and image processing systems are also applied for extracting safe areas based on the mentioned parameters. That defines a safe area.

.For extracting areas with coarse texture, the NDVI index is also used since this index has higher sensitivity to chlorophyll from plants (figure 4). The other steps for extracting coarse texture are similar to smooth ones, as mentioned above.



Figure 3: The extract of areas by textures analysis



Figure 4: The extraction of green area by NDVI index

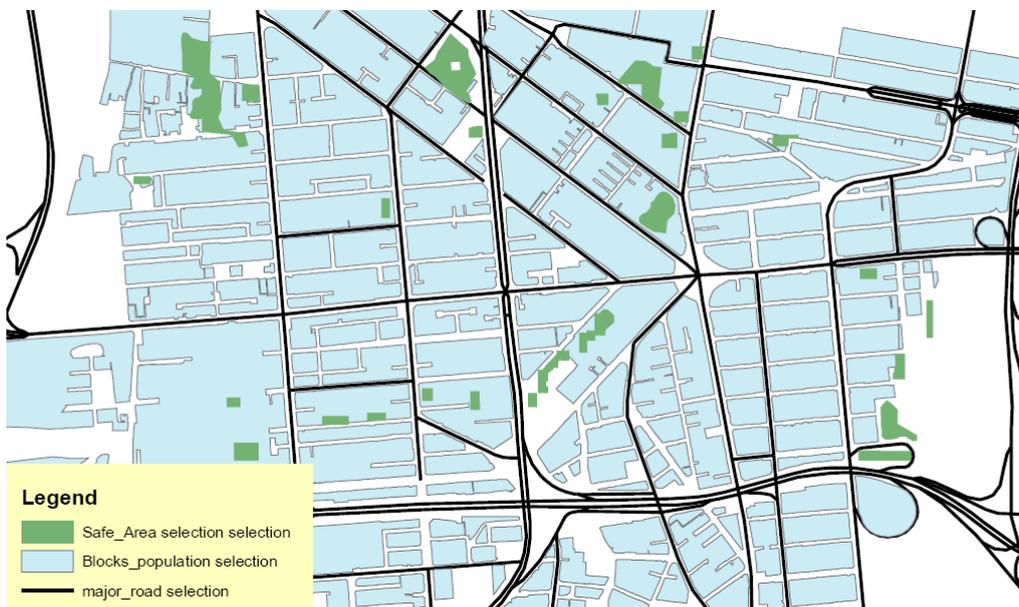


Figure 5: Safe areas extracted from satellite imageries

## 2.2. Determination of optimum path

After determination of safe areas for evacuation planning, determination of optimum path between the building blocks and safe areas is the second phase. In fact, for reducing the displacement time/distance of population in danger, the optimum path between each building blocks and the safe area located in a suitable distance, should be searched and determined by roads network.

For determination of optimum path between the building blocks and safe areas, we can consider three simple to complicated standard: (A): The shortest straight path between them. (B): The shortest path between them in roads network. (C): The shortest safe optimum path in roads network (by considering traffic data, safety of the road, etc.). In this research the first case is consider to continue procedure.

## 2.3. Evacuation Planning

Optimization evacuation planning means grouping building blocks for each safe area in such away: 1- Distribution of the population in the safe areas to be corresponding with its capacity. 2- The population movement from building blocks to

the safe areas should be minimized so that people can be sheltered rapidly. In order to have the least movement of people, the highly-populated building blocks should get closer to safe areas nearby. In other words, the multiplication of the population in danger means the number of people who are remained alive in the building blocks with high dangerousness.

Thus, the multiplication of the length of the optimum path in the population in danger equals to the cost of replacing the population of each block. The aim of optimization is to minimize the total of these costs for all building blocks (V objective function), In addition the population should also distribute to the safe areas with respect to their capacities (U objective function). Based on the equation (1), these two objective functions namely U and V should be simultaneously minimized [3].

$$V = \sum_j \sum_i P_{ij} d_{ij} \Rightarrow \min \quad U = \sum_j \left| \frac{\sum_i P_{ij}}{C_j} - 1 \right| \Rightarrow \min$$

Equation 1: objective Function (U & V) which should be minimized for solving the optimization problem

In this equation  $d_{ij}$  is the length of path and  $p^{ij}$  is the population in danger relating the  $i^{th}$  building blocks that are assigned to the  $j^{th}$  safe area with the  $C_j$  capacity.

For having an optimized grouping the above objective function should be optimized simultaneously. To minimize the Mentioned objective functions (U and V) simultaneously, multi-objective optimization problem was used[6]. There are three general ways for solving multi-objective optimization problems: 1. Weighted Averaging. 2. Making Constrains. 3. Pareto Front.

In this research the second method was used. V objective function is considered as the optimizing function and the U objective function is considered as additional constrain. The

concluded answer from the first objective function is refined in order to bring the second condition. For this work, safe areas that have overflow of population as a result of doing the first objective function are being solved by the optimized replacement of population to empty safe areas (Figure 6).

In the figure (6 & 7), the color of safe areas explains the amount of population overflow and the color of the line explains the amount of V costs.

The table(1) shows the amount of optimizing objective functions for each safe area and in its last line the total overflow of population (sum of positive amounts of U cost) and the total V cost.

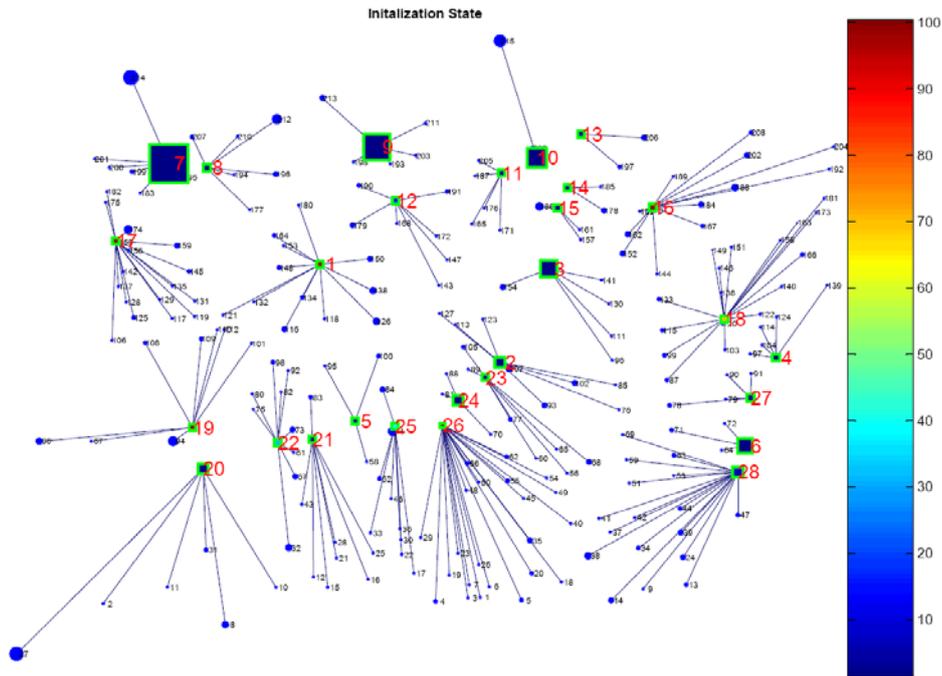


Figure 6: The optimum solution for V objective function

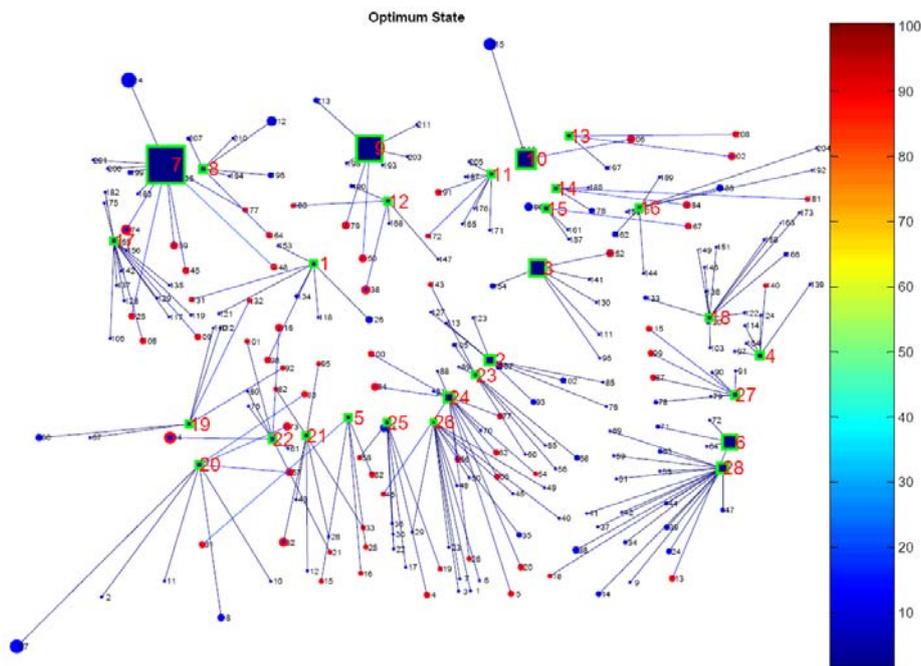


Figure 7: The global optimum solution for V and U objective functions

No.	initialization State			Optimum State		
	U Cost	V Cost	Number of Blocks	U Cost	V Cost	Number of Blocks
1	1.518	0.479	12	-0.026	0.256	7
2	-0.424	0.494	8	-0.424	0.494	8
3	-0.822	0.305	6	-0.763	0.441	7
4	-0.778	0.104	5	-0.688	0.188	6
5	-0.549	0.076	3	-0.221	0.310	5
6	-0.931	0.162	3	-0.868	0.547	4
7	-0.878	0.661	6	-0.778	1.384	12
8	-0.024	0.412	6	0.023	0.457	6
9	-0.949	0.142	5	-0.891	0.398	7
10	-0.824	0.503	2	-0.785	0.614	3
11	-0.705	0.039	5	-0.282	0.132	7
12	0.156	0.253	7	0.026	0.322	5
13	-0.357	0.081	2	-0.025	0.279	3
14	-0.590	0.046	2	-0.120	0.246	4
15	-0.502	0.062	3	-0.298	0.250	4
16	1.152	1.952	13	-0.040	0.936	8
17	1.269	0.773	17	-0.005	0.560	14
18	0.681	1.057	17	-0.049	0.541	12
19	1.425	1.032	8	0.027	0.800	6
20	-0.264	0.775	6	0.028	0.929	8
21	-0.183	0.560	8	-0.012	0.685	7
22	0.314	1.102	9	0.043	1.470	7
23	0.016	0.421	7	-0.092	0.430	7
24	-0.933	0.034	3	-0.089	1.452	14
25	0.398	0.411	9	0.017	0.438	8
26	2.232	1.426	22	-0.065	0.440	12
27	-0.744	0.165	4	-0.371	0.596	7
28	0.058	3.185	17	0.008	3.114	17
Sum	9.163	16.714	215	0.173	18.707	215

Table 1: Amount of optimizing objective functions for each safe area

Figure (8) explain the amount of changes for objective functions within the optimization.

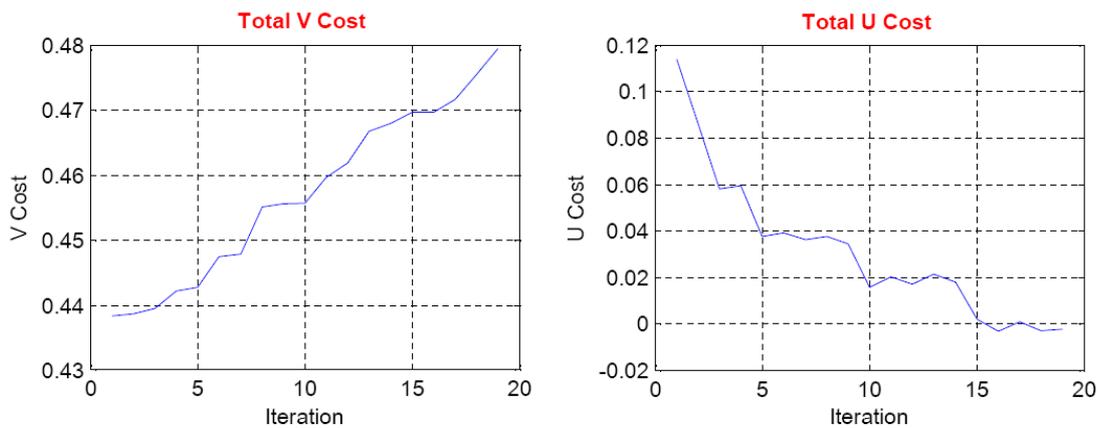


Figure 8: Amount of objective Functions (U & V) for all safe areas

### 3. CONCLUSION

In this research, evacuation planning in disaster management was modeled and explained. In this regard the details of three steps of determining safe areas, determining optimum path and

groupings of building blocks were explained and the result of the model was given.

For minimized objective function of U and V simultaneously, multi-objective optimization problem was used. In this research

the Making Constrains method was used. V objective function is considered as the optimizing function and the U objective function is considered as additional constrain. The concluded answer from the first objective function is refined in order to bring the second condition.

Finally, results of model were evaluated for sample data and real data.

#### REFERENCE

- [1] UN-ISDR, (2003).  
<http://www.adrc.or.jp/publications/terminology/top.htm>  
visited on Jan 2004.
- [2] Mansourian, A., Development of an sdi conceptual model and web based system to facilitate disaster management, PhD Thesis, K.N.Toosi University of Technology, Faculty of Geodesy & Geomatics Engineering, 2005.
- [3] Saadatseresht, M., and Mansourian, A., Preplanning for Temporal Settlement of Victims in Disasters, MapAsia 2006, Thailand, 2006.
- [4] Queiros, E. and Martins, V., Bibliography of papers on multiobjective optimal path problems, access through website: <http://www.mat.uc.pt/~eqvm/cientificos/biblio/mo.ps.Z>, Dec. 2006.
- [5] MATLAB, manual of optimization toolbox, Mathworks, 2006.
- [6] Coello Coello, C.A., An empirical study of evolutionary techniques for multiobjective optimization in engineering design. PhD thesis, Department of Computer Science, Tulane University, New Orleans, Louisiana, 1996.
- [7] Naghdi, K., Saadatseresht, M., Mansourian, A., and Valadan-zoej, M.J., Temporal settlement optimization in disaster management, GIS 85, Iran-Qeshm, 2006.
- [8] A. Mansourian, A. Rajabifard, M.J. Valadan Zoej, I. Williamson, Using SDI and web-based system to facilitate disaster management, Computers & Geosciences 32 (2006) 303–315.