



## **Full Length Article**

# **A optimal model for emergency evacuations in an urban areas (case: Kerman)**

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### **ABSTRACT**

*In urban areas, the occurrence of disasters can cause extensive damage to human society. For this reason, evacuation, regarded as a critical course of action to relocate people and property, helps to alleviate loss of life and property to a great extent. A scientific and effective emergency evacuation plan plays an important role in improving the event reaction ability of the urban traffic system, as well as, saves rescue time and reduces property losses. Evacuation route construction and network distribution in each network junction are vital for evacuation planning problems. An optimal objective based on the shortest emergency time is established and the optimal solution is acquired using the Pontryagin minimum principle. The evacuation route construction algorithm in each junction are employed to deliver the traffic flow in the evacuation area to a safe region rapidly and safely. The idea of feedback is introduced in the execution using real-time information to adjust and update the evacuation plan. In this study Dayjstra Algorithm is used to route for emergency evacuation in Kerman. The suggested method based on the Dayjstra Algorithm searches the routes rapidly and finds the shortest path between the damage spot and the safe place finally the most suitable route for evacuation is selected. The results of the study show that the suggested method considering the population density and the passages width finds the shortest path for reaching.*

**Keywords :** Emergency evacuation, Routing, Evacuation route, Dayjstra algorithms.

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### **INTRODUCTION**

Factors such as global warming, environmental degradation and increasing urbanization expose a greater number of people to the threat of natural disasters. In the last three decades, the rate of disasters has risen from 50 to 400 per year [21], and it is still expected to increase five times more on the next 50 years (Thomas et al, 2007) In 2010, 207 million people suffered from disasters, which caused 296,800 deaths and losses of 109 billion dollars (Sapir, 2011). These natural disasters require the immediate mobilization and action of multiple stakeholders due to the unexpected nature and amplitude of the event, the diversity and quantity of supplies and services needed by the victims [9]. The focus of these disaster relief operations is to "design the transportation of first aid material, food, equipment, and rescue personnel from supply points to a large number of destination nodes geographically scattered over the disaster region and the evacuation and transfer of people affected by the disaster to the healthcare centers and shelters safely and rapidly [5]. In this context, logistics for emergency relief operations is known as humanitarian logistics. Transporting the critical supplies and personnel from source to affected areas, evacuation of all types of individuals to shelters and medical facilities wherever necessary play major roles in humanitarian logistics [4]. Whether they are predictable or not, man-made and natural disasters could both result in severe life loss and property damage. Emergency evacuation, which drives a mass movement of people and their properties from disaster-impacted areas to safe areas, has been studied and practiced as a major means of countermeasure to mitigate these calamitous consequences. Houston had first formulated a dissipation rate model for estimating evacuation time in which a statistical aggregate method was considered [1]. Several aspects of evacuation route planning make it a complicated problem for towns to solve [23], a number of

researchers have analyzed the effects of different behavioral and managerial factors on evacuation [13], [14], [26]. First, for security purposes, evacuation zones should be established before a disaster happens. Second, shelters and safe places should be established and evacuees notified of their location in advance to reduce evacuation related risks and costs. Third, evacuation routes need to be established, as many studies have been proposed. Several sets of dependency scenarios have been identified and proposed for disaster recovery [22], [19]. Evacuation can be mandatory, recommended, or voluntary, besides it may differ by scale, objects of relocation (people vs. property), and by level of control by authorities [31]. Depending on the disaster type, pre-warning of sudden-onset disasters can leave enough time for evacuations prior to the event [20]. Another influential factor in the case of natural disasters is the probability of their occurrence and effects. Seasonal disasters, even if sudden, pose lesser problems than non-seasonal disasters, even though evacuation plans can be in place for either situation [4]. Emergency evacuation plans assign evacuees to fixed routes or destinations even before the disasters. An evacuation plan defines optimal evacuation policies for the population from areas under risk and uncertainty [31]. A lesson learned due to the evacuation fiasco after Hurricane Katrina in the United States is the need for evacuation planning [4], even though real-time design or re-evaluation of these plans may be required after the disaster strikes [2].

Techniques and models have been developed to emergency the evacuation of people living near the affected area, with the main objective of identifying the problems that can happen in the moment of evacuation. These problems can be vehicular congestion and accidents that contribute to increasing the time of evacuation and the number of injuries. However, conventional methods and heuristics for defining evacuation routes generally are based mainly on geographic proximity and seek for the shortest travelling time [16].

Such techniques do not guarantee that the capacity of the routes will satisfy the intense demand for transportation during evacuation, and neither that the resulting routes will not present coincident intersection points, which could be eventual bottlenecks susceptible to potential accidents. Therefore, this paper presents a method for defining two independent paths from the disaster area (origin) to each destination points (shelters) for vehicle flow allocation in evacuation planning, considering both travelling time and capacity of the transportation network as parameters for analysis. This type of routes has no intersection points (they are called disjoint paths). Besides, routes to different destinations points (shelters) cannot have intersection points as well, so their use minimizes the problem of accidents and permits a continuous traffic flow. The application of this method allows the identification of the best possible independent evacuation routes from a potential disaster area to different shelters, previously defined. The method is applied iteratively, allowing the removal of intersection points among the different routes. However, in cases which a set of routes without intersection points is unfeasible, the method provides previous knowledge of this intersection point, indicating the need for interventions at this point in order to avoid potential accidents caused by conflicting movements.

Several researchers have studied numerous aspects of the vulnerability of urban habitation area to natural disaster. Urban earthquakes inflict serious damage to regions experiencing rapid rates of population growth and to developing countries undergoing urbanization. In designing evacuation methods for urban areas post-earthquake, it is useful to consider multiple scenarios of fire spread [25]. As for evacuation from buildings, numerous studies have considered evacuation behavior in panics. Some researchers have focused on the evacuation time of the World Trade Center on September 11, 2001. Such studies have significant potential to inform us about preparedness, response policies, and procedures for disasters in residential areas. Historic preservation areas, however, are among the most vulnerable to disaster, particularly in a city subject to earthquakes like Kerman. Necessary solutions for disaster prevention for people in a historic preservation area, at the same time maintaining the width of the narrow paths.

### **Aim of study**

Planning routes and solving comprehensive problems in order to emergency evacuation routes are neither clear nor easy. Though it is necessary to make a comprehensive system for planning emergency evacuation routes in a historic preservation area, the differences in various areas make it difficult to do so. Thus, this study aims to discover the fundamental problems in establishing a method for analyzing a urban area in order to establish emergency evacuation routes as a case demonstration. In addition to considering the shortest path for reaching the safe place we also consider the population density and the passage width because only finding the shortest path is not always the best choice. Hence in the passages with different widths the population density may be in a way that it is not possible to pass them in a short time. Two aims are investigated in this study.

First some of the shortest paths are found using Dayjsra Algorithm (the number of the paths is specified by the user according to the size of the web) and then the population density present in the passage on

the route are found with respect to the passage with and finally the optimal route is specified based on the following function

$$1) \min (\sum_{i=1}^n L_i + \sum_{j=1}^n W_j T_j)$$

in which  $n$  is the amount of the passages which has been obtained in an optimal route.  $L_i$  the length of the passage with  $i$  tag.  $T_j$  and  $w_j$  show population density in the passage with  $j$  tag and passage with  $j$  tag respectively. Of course the user can put a weight for each of the optimal route factors (shorter) and density in using this formula for selecting the best route and with respect to their importance change the optimal function as the following

$$2) \min (k_1 \sum_{i=1}^n L_i + k_2 \sum_{j=1}^n W_j T_j)$$

In which  $k_1$  and  $k_2$  show the degree of importance and their total is one it means we have

$$3) \sum (k_1 + k_2) = 1$$

Since the considered parameters in the problems are not of the same kind, for combining them in the formulas first they should be normalized and a same unit should be specified for their weighing combination. So all the parameters are divided to their own normalized amount and then are combined.

### Evacuation planning

Evacuation is a complex process consisting of several consecutive phases. After the detection of an incident, decision makers evaluate the potential threat for specific areas and then issue an evacuation order for these areas if the risk is significant and there are no shelters to provide adequate in-place protection [31]. The type of disaster will dictate total or partial evacuation to distant or near-by relief location and if it is long term or temporary process [4]. Evacuation alert is communicated to the population, who makes a decision to evacuate or not depending on their perception of danger and then the population is transferred through a transportation network to designated safe areas [31]. Condition of the infrastructure will force which mode of transport to use but the evacuation also depends on the available fleet of vehicles, their capacity and on circumstances surrounding the evacuee [4]. Finally, evacuees arrive to areas outside of danger and a verification that they have made it safely must be carried out [31].

The evacuation time may range from hours to weeks or even months (Church et al, 2002, [31]). Depending on the scale of the operations is that evacuation-zone exit routes are often limited in number and insufficient in capacity to handle the traffic surge during a large-scale emergency evacuation. Stepanov et al [31] reinforces that capacity of transportation networks generally cannot satisfy the intense demand for transportation during an evacuation, and that even on small neighbourhood scale evacuations, transportation networks can impede the fast clearing of the population from an affected area. In order to manage such emergencies more effectively, decision makers may benefit from having in-place evacuation plans for scenarios which are most likely to happen, even though real-time design or re-evaluation of evacuation plans may be required after the disaster strikes [2]. Therefore, studies have focused on methods to improve the planning and operational aspects of the evacuation process to maximize the utility of the existing transportation network [16]. Apte [4] presents a summary of some of the research in evacuation. Stepanov et al [31] also reviewed a series of evacuation models and proposed that modeling techniques can be grouped by computation techniques into analytical and simulation techniques. From a review of the evacuation models, Stepanov and Smith [31] conclude that two approaches are evident: (i) the first approach defines a set of optimal routes and evaluates performance measures simultaneously; and (ii) a second approach uses an analytical optimization technique to offer a routing policy, and then this policy is evaluated with traffic simulation model. According to Stepanov and Smith [31], the first approach is prevalent in practice. In this context, this paper presents a heuristic algorithm that can be applied for defining independent routes for developing in-place evacuation plans. According to Stepanov and Smith's [31] classification, the algorithm proposed applies analytical techniques to define a set of optimal routes and evaluate measures simultaneously. The characteristics of the method are presented in the following section.

**Characteristics of the Method** According to Graph theory (Boaventura, 1996; [8]), there is a limited number ( $k$ ) of independent paths (called disjoint paths) between a pair of nodes in a network; however it is possible to exist several sets (of  $k$  elements) of these paths in the same network.

### METHODOLOGY

Routing process includes the selection of the optimal route in the passages web. In small web routing is simple but in larger webs it is more complicated and finding the optimal route turns out to be hard before explaining the suggested method first the primary concepts of the graph are stated.

#### Graph theory

In mathematics and computer science, graph theory is the study of graphs, which are mathematical structures used to model pairwise relations between objects. In the most common sense of the term [6], a graph is an ordered pair  $G = (V, E)$  comprising a set  $V$  of vertices or nodes together with a set  $E$  of edges or lines, which are 2-element subsets of  $V$  (i.e. an edge is related with two vertices, and the relation is represented as an unordered pair of the vertices with respect to the particular edge). To avoid ambiguity, this type of graph may be described precisely as undirected and simple.

Other senses of *graph* stem from different conceptions of the edge set. In one more generalized notion,  $E$  is a set together with a relation of incidence that associates with each edge two vertices. In another generalized notion,  $E$  is a multi set of unordered pairs of (not necessarily distinct) vertices. Many authors call this type of object a multi graph or pseudo graph.

All of these variants and others are described more fully below.

The vertices belonging to an edge are called the ends, endpoints, or end vertices of the edge. A vertex may exist in a graph and not belong to an edge.

$V$  and  $E$  are usually taken to be finite, and many of the well-known results are not true (or are rather different) for infinite graphs because many of the arguments fail in the infinite case. The order of a graph is  $|V|$  (the number of vertices). A graph's size is  $|E|$ , the number of edges. The degree of a vertex is the number of edges that connect to it, where an edge that connects to the vertex at both ends (a loop) is counted twice. For an edge  $\{u, v\}$ , graph theorists usually use the somewhat shorter notation [3].

### Dayjstra algorithm

In graph theory, the shortest path problem is the problem of finding a path between two vertices (or nodes) in a graph such that the sum of the weights of its constituent edges is minimized.

Dijkstra's algorithm, conceived by computer scientist Edsger Dayjstra in 1956 and published in 1959 [11, 12].

is a graph search algorithm that solves the single-source shortest path problem for a graph with non-negative edge path costs, producing a shortest path tree. This algorithm is often used in routing and as a subroutine in other graph algorithms.

For a given source vertex (node) in the graph, the algorithm finds the path with lowest cost (i.e. the shortest path) between that vertex and every other vertex. It can also be used for finding costs of shortest paths from a single vertex to a single destination vertex by stopping the algorithm once the shortest path to the destination vertex has been determined. For example, if the vertices of the graph represent cities and edge path costs represent driving distances between pairs of cities connected by a direct road, Dijkstra's algorithm can be used to find the shortest route between one city and all other cities.

Let the node at which we are starting be called the initial node. Let the distance of node  $Y$  be the distance from the initial node to  $Y$ . Dijkstra's algorithm will assign some initial distance values and will try to improve them step by step.

1. Assign to every node a tentative distance value: set it to zero for our initial node and to infinity for all other nodes.
2. Mark all nodes unvisited. Set the initial node as current. Create a set of the unvisited nodes called the unvisited set consisting of all the nodes.
3. For the current node, consider all of its unvisited neighbors and calculate their tentative distances. Compare the newly calculated tentative distance to the current assigned value and assign the smaller one. For example, if the current node  $A$  is marked with a distance of 6, and the edge connecting it with a neighbor  $B$  has length 2, then the distance to  $B$  (through  $A$ ) will be  $6 + 2 = 8$ . If  $B$  was previously marked with a distance greater than 8 then change it to 8. Otherwise, keep the current value.
4. When we are done considering all of the neighbors of the current node, mark the current node as visited and remove it from the unvisited set. A visited node will never be checked again.
5. If the destination node has been marked visited (when planning a route between two specific nodes) or if the smallest tentative distance among the nodes in the unvisited set is infinity (when planning a complete traversal; occurs when there is no connection between the initial node and remaining unvisited nodes), then stop. The algorithm has finished.
6. Select the unvisited node that is marked with the smallest tentative distance, and set it as the new "current node" then go back to step 3(fig:1)

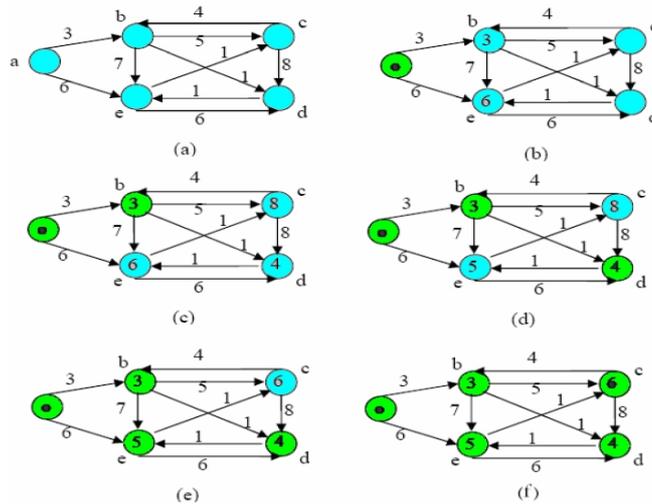


Fig 1. Dayjstra algorithm [34]

**DISCUSSION**

In order to investigate the efficiency of the method first a hypothetical web with 15 nodes has been considered in which the source and the destination have been specified for finding the optimal route all the nodes are searched and z routes are specified with the lowest costs.

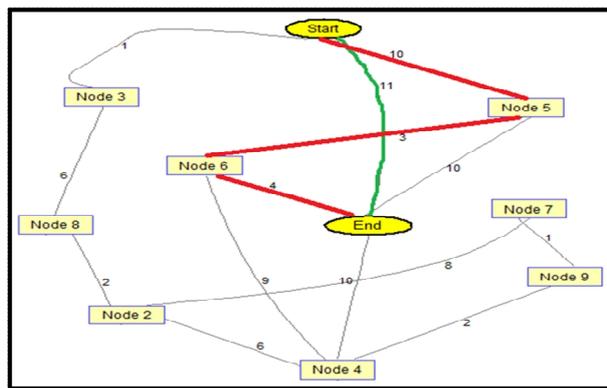


Fig 2 .hypothetical web with the best route

for implementation of the suggested method in real web.Kerman is area 3has been considered for preparing the data first information large related to the urban passages and blocks and also suitable spaces for emergency evacuation population information of urban blocks and urban passage with have been gathered from.

Kerman s GIS data base . Then for using them local information of the blocks and crossing of the streets and also local information of safe places center are considered the considered are a includes building nodes , safe place node and urban passage or nodes of the graph.



fig 3. kerman area 3

In Routing test in real web a damaged spot has been specified as the start and a secure adjacent spot as the end.

Then using genetic Algorithm, 3 best routes have been determined in which the route which is clear by color red is the best route between the damaged spot and safe place and considering the passage width and population density is low.



**Fig 4. Optimal Routing in real web**

## CONCLUSIONS

In urban areas, the occurrence of disasters can cause extensive damage to human society. For this reason, evacuation, regarded as a critical course of action to relocate people and property, helps to alleviate loss of life and property to a great extent. In this study Dijkstra Algorithm is used to route for emergency evacuation in Kerman. The suggested method based on the Dijkstra Algorithm searches the routes rapidly and finds the shortest path between the damage spot and the safe place finally the most suitable route for evacuation is selected. In order to investigate the efficiency of the method first a hypothetical web with 15 nodes has been considered in which the source and the destination have been specified. For finding the optimal route all the nodes are searched and 3 routes are specified with the lowest costs. The results of the study show that the suggested method considering the population density and the passages width finds the shortest path for reaching.

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