Journal of Civil Engineering and Materials Application
Journal home page: https://jcema.com

Received: 12 January 2018 • Accepted: 22 May 2018

Research

doi: 10.22034/JCEMA.2018.92048

Emergency evacuation routing, at critical condition (earthquake), using Analytical Hierarchy Process Technique, and based on the actual weight of the sub-criteria related to the alternative

Amin Basirat, Seyed Mahdi Sajjadi*, Seyed Amir Hossein Beheshty

Department of Civil Engineering, Islamic Azad University, Zanjan Branch, Zanjan, Iran

*Correspondence should be addressed to Seyed Mahdi Sajjadi, Department of Civil Engineering, Islamic Azad University, Zanjan Branch, Zanjan, Iran; Tel: +989132773024; Fax: +989132773024; Email: s.mehdi.sajjadi@gmail.com.

ABSTRACT

In recent years, research on emergency traffic evacuation has increased intensively. Detection of the optimal discharge route is one of the most important parts of crisis management due to the large number of effective measures. In this research, we have used the Analytical Hierarchy Process, taking into account three criteria, road capacity, population density, and structural parameters, and several sub-criteria, and taking into account the actual weight of the criteria for traffic emergency evacuation routing . The method presented in this research is not limited to these three criteria, and can be done with other criteria, based on the conditions of the case study area. The study area in this research is the region of Sabzemeydan, a region in Zanjan city (capital of Zanjan province, northwest of Iran), which has been studied based on the above criteria. The proposed route for emergency traffic evacuation in the studied area, using the proposed method in this research, has all the effective parameters in traffic evacuation, in times of crisis, and is the most optimal route for simultaneous examination based on their real impact.

Key words: Emergency evacuation, Critical conditions, Analytical Hierarchy Process.

Journal of Civil Engineering and Materials Application is published by *Raika Pajuhesh Pars*; Journal p-ISSN xxxx-xxxx; Journal e-ISSN 2588-2880.

1. INTRODUCTION

More than 50 percent of the world's population lives in large cities, which is less than 3 percent of the total land area. The over-population density, assets, infrastructure, and production and service resources in metropolitan areas have caused the large number of urban residents to be vulnerable to accidents. Natural disasters (especially earthquakes), which are unrelenting threat all cities in the world with the potential for injury. Natural disasters kill more than 150,000 people annually, causing more than $ 140 billion in financial losses, especially in developing countries. In addition to natural, human and technological factors, factors also increase the risk of accidents, and the destruction of various urban tissues, where people are the most important of them. The severity of this in the cities of Iran, due to the particular geographic location of Iran, and its earthquake is more than in other parts of the world. So, two of the five natural disasters that occurred in 1985 to 2003 had the highest number of casualties in the world, in Iran (1). In recent years, many studies have been done on determining the optimal route for traffic emergency evacuation around the world. These studies, by taking into account the various types of parameters affecting discharge, try to answer the question of how the importance of different routes, in certain areas, for emergency evacuation of traffic, in times of crisis such as earthquakes, so that , We can identify the most important route, and strengthen it for emergency evacuation in times of crisis. Wen-mei Gai et al (2017) had a research for optimising multi objective evacuation routing for toxic clouds (2). Their paper develops a model for assessing the risks of chemical accidents. The objectives of the evacuation routing model in their study are to minimize travel time and individual evacuation risk along a path respectively. Two heuristic algorithms are proposed in their paper to solve the multi-objective evacuation routing model. Simulation results show the effectiveness and feasibility of the model and algorithms presented in their paper (2). Mojahid Saeed Osman and Bala Ram (2017) had a paper about Routing and scheduling on evacuation path networks using centralized hybrid approach (3). They propose a centralized hybrid approach for time-dependent point-to-point evacuation routing and scheduling, which is a novel spatio-temporal algorithm with discrete optimization models as sub problems. This algorithm does account for node and arc capacities and objects in transit over dynamic networks for routing and scheduling in a deterministic setting. The key results they found reveal the effectiveness of the proposed centralized hybrid approach for solving evacuation routing and scheduling problems (3). Kaveh Shahabi had a research on Scalable evacuation routing in a dynamic environment (4). In their article major works in evacuation routing have been studied and a new algorithm is developed that is faster and can generate better evacuation routes. Additionally, it can quickly adjust the routes if changes in the road network are detected (4). Annunziata Esposito Amideo and Maria Paola Scaparra 2017 worked on A Scenario Planning Approach for Shelter Location and Evacuation Routing (5). Their model considers both supported-evacuation and self-evacuation. Their objective is to minimize the duration of the supported-evacuation while guaranteeing that the routes of self-evacuees do not exceed a given traveling time threshold. Both shelter location and routing decisions are optimized so as to identify solutions which perform well across different disruption scenarios (5). Tan Zhao et al (2018) had a research on Route Planning for Military Ground Vehicles in Road Networks (6). A kth shortest- path method was introduced to find intact routes from the origin to the destination for each vehicle. A binary integer programming was presented to formulate the problem. As the combination of the uncertainties results in a huge number of scenarios, they employed the sample average approximation method to obtain a robust solution for the problem. The solution approach is illustrated and tested through three road networks with different scales. The computational results show that, for networks of small scale, their method can provide a good solution with a sample of small size, while, for the large network, with sample of small size, this method usually leads to a suboptimal solution (6). Halit Uster et al (2018) had a research on Strategic Evacuation Network Design (SEND) under cost and time considerations (7). They pose and analyze an evacuation network design problem to provide a planning tool to help with high-level design decisions involved in strategic preparedness for large scale evacuations. They propose a mathematical model for Strategic Evacuation Network Design (SEND) that prescribes shelter regions and capacities, intermediate locations that support/supply for en route evacuees as well as road segments and their capacities under evacuation time constraints. To solve the model, they devise an efficient Benders Decomposition based approach enhanced with surrogate constraints, strengthened Benders cuts, heuristics, and the use of multi-cuts. They apply methodology to solve test instances developed based on real data from Central Texas (7). Rahul Swamy et al (2017) studied about Hurricane evacuation planning using public transportation (8). Their paper provides a mass- evacuation strategy using public transportation before the strike of a hurricane. At the first stage is the planning framework, where pickup locations are determined and assigned to shelters, and an initial set of routes is generated along these locations. This is done by weighing each location based on the accumulated demand, and favoring multiple routes to pass through a location with higher demand. In the next stage, each route is assigned a trip number such that 1) routes with higher demand require more trips, and 2) two successive trips to a route are spaced evenly. A simulation tool has been developed to model the dispatching of the given number of buses, stochastic arrival of evacuees, queueing effects at the pickup locations, and the transportation of evacuees to the safety regions (8). Fuyu Hu et al (2017) had a research on Integrated optimization for shelter service area demarcation and evacuation route planning (9). Their study aims to optimize shelter service area demarcation and post-disaster evacuation route planning simultaneously in order to improve the efficiency of current shelter operation and further reduce disaster risk, which is seldom addressed before. They proposed an integrated optimization model for jointly solving shelter service area demarcation and evacuation route planning problems, which keeps contiguity of service areas, ensures an evacuation route within the same service district, shortens the evacuation route, satisfies capacity constraints and maintains integrity. To solve the problem, a ripple-spreading algorithm is adopted with combining contiguity and capacity operators. A real-world case study was conducted in the Chaoyang district of Beijing, China (9). Asif-Nawaz Qazi et al (2017) had a research on Demand variations and evacuation route flexibility in short-notice bus-based evacuation planning (10). In their study, two important factors, variation in demand and evacuation route flexibility, are discussed with respect to their effects on the optimality of bus-based evacuation planning. The model of short-notice bus-based evacuation under dynamic demand conditions (SBED model) was used to highlight the importance of these factors in evacuation planning through a case study of Kawajma Town. The model was run to simulate different evacuee demand and bus route scenarios, and the results were analyzed. In terms of the number of evacuees, better results were observed in the fixed-demand case than in the continuous-demand case (10). Corbiniano Silva et al. (2017) had a research to find the key elements to the decision-making process in the emergency planning of a nuclear power complex in Brazil (11). Their study confirmed the region's main geoenvironmental aspects as winds and rainfall, landslides and population density were evaluated as important elements in the local emergency process. Their integrated analysis supported scenario identification and critical regional points and highlighted population evacuation escape routes (11). Xue Han et al. (2016) had a research about traffic evacuation plan of Dongli square at Harbin city (12). They collect data for Dongli roundabout by analyzing traffic situation and putting ideas and strategies to improve the optimization of intersection. They find that using signals will improve the intersections during evacuation (12). Yaqin He and Shengpin Du (2016) classified urban emergency based on Fuzzy Analytical Hierarchy Process (13). In their paper a quantitative model of grading of emergency during the accident was proposed. They suggest a method to weight factors and sub-factors, and finally they applied their method in real fire (13). Xiang Chen and Qiang Li1(2017) modeled road network vulnerability for evacuees and first responders in no-notice evacuation (14). Their paper develops a network-based model to evaluate vulnerability during a no-notice evacuation and applies it to a case study in Dublin, OH, USA. Their model is suited to assessing network vulnerability in response to events with uncertainty and coordinating traffic control strategies in a no-notice evacuation (14). Jooyoung Kim et al. (2017) had a research on an evacuation route choice model based on multi-agent simulation in order to prepare Tsunami disasters (15). An evacuation network is designed to develop an evacuation plan based on a hierarchical network design problem used in communication networks, public transport, and social organization network designs. Experimental analyses have been carried out in order to find effective evacuation plans at Haeundae Beach, Busan, Korea, using multi-agent transportation simulation. In order to design an effective hierarchical evacuation network, a hierarchical evacuation network design was developed using the concepts of hub location, clustering, and network design. As a result of running each scenario using simulation, a criterion for establishing the corridor line was evaluated. An optimal evacuation route was find to minimize overcrowded queues of evacuees, when the total evacuation time from the area of the tsunami was approximately 3 hours and 30 minutes (15). A research team conducted an investigation in 13 Aban District of Tehran and attempted to determine the criteria and optimal route for emergency discharge after the earthquake; it was concluded that routes that do not have high population densities are in the priority for evacuation, as well as the routes that they have, bridge and tunnel are dangerous, and should be avoided. Huizhao et al. determined the Emergency Discharge Plan of Almere City, simulating driver behavior during discharge, and concluded that rapid and rapid acceleration does not have much effect on reducing the discharge time, and what is effective in reducing is headway time (16). Adam J Pel et al. conducted a research on the models of emergency evacuation travel behavior in 2012, and concluded that control the derivers' involuntary actions during an emergency evacuation is a very important factor in this matter (17). Parr et al. conducted a study on the effect of traffic lights on emergency evacuation routes, and concluded that the use of lights and guidance signs has no effect on the discharge process (18). Given the importance of the subject in this research, we have tried to determine the optimal emergency exit route during accidents, focusing on three criteria, road capacity, population density, and structural texture, and using the proposed method in the present study, which has calculated, directly, the weight of each subcategory of the options, in the hierarchical technique.

2. RESEARCH METHOD

In the present research, we have tried to provide a method for determining the optimal route for traffic emergency evacuation in the case study, using an Analytical Hierarchy Process technique. In this method, the weight of each of the following criteria can be calculated in real and field, for each of the options (routes available), so that at the end of the hierarchical analysis process, the optimal route proposed by this method is a route obtained based on the actual situation in the area, and can check all the criteria and sub-criteria existing at the same time, and consider the most optimal mode. The steps in the proposed method are presented in Figure 1, in flowchart.

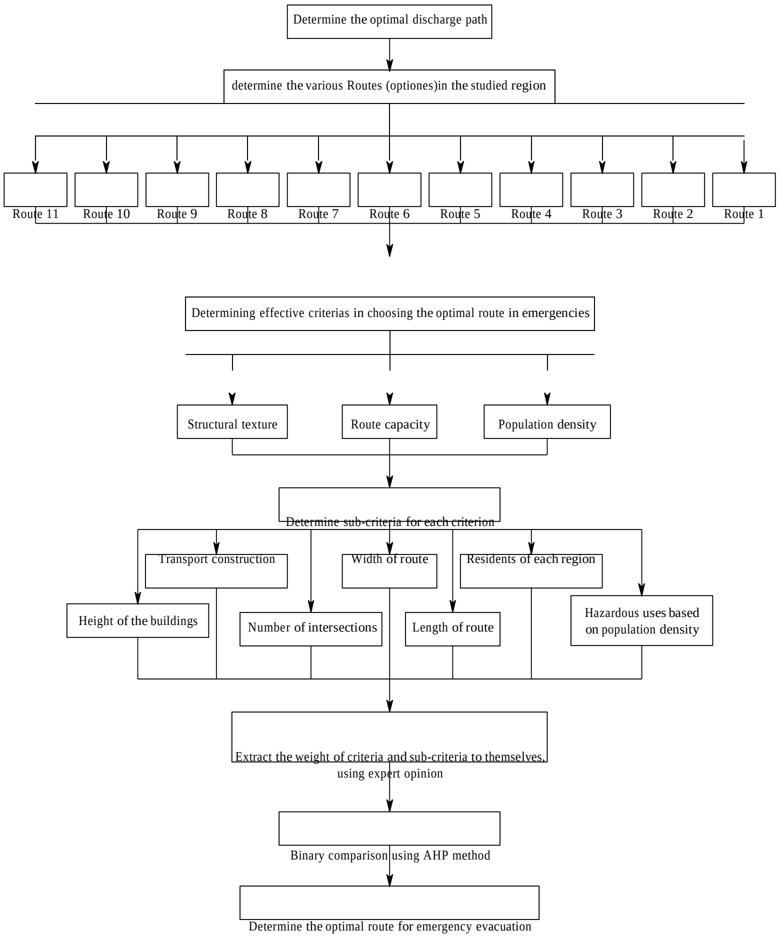

Figure 1. Flowchart Steps to determine the optimal emergency path

Flowchart of the steps for determining the optimal route, based on three main criteria, population density, road capacity, and structural texture, and also the following criteria of them, which are respectively: hazardous uses, and the number of inhabitants of region, for population density , And the width and length of the route, and the number of intersections for the capacity of the routes, and the infrastructure facilities for transport, and the height of the buildings, for structural texture, are given in Figure 1. After collecting data for each of the options, Weighting is done in both direct and reverse way, and finally the optimal route is determined by the AHP method. The following two methods are described below.

2.1. Inverse method I

As shown in Figure 2, this method is for the following criteria, such as length, so that if their values are less than their priority is the optimal path. Therefore, we consider them, in the process of inverse hierarchical analysis.

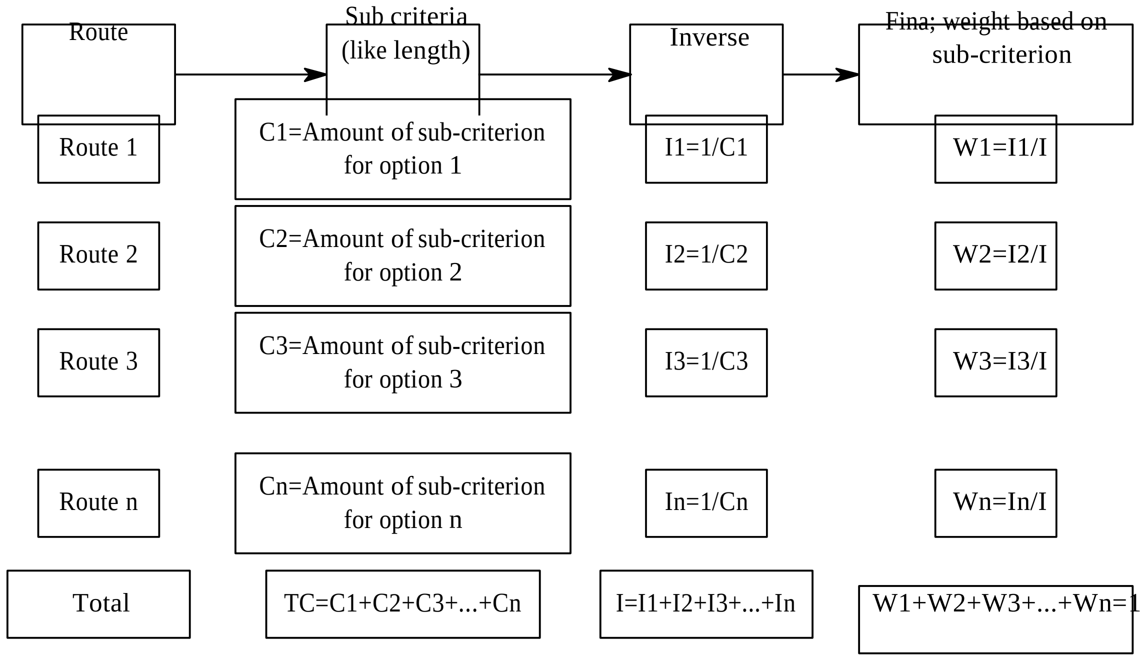

Figure 2. The method of inverse weighting of sub-criteria, relative to alternatives

2.2. Direct method D

As shown in Figure 3, this method is for further sub-criteria such as the width of the routes, which, if their values are greater, then their priority as the traffic drainage route is greater. In this method, the values derived from each sub-criterion are considered to be direct, and there is no need to inverse that.

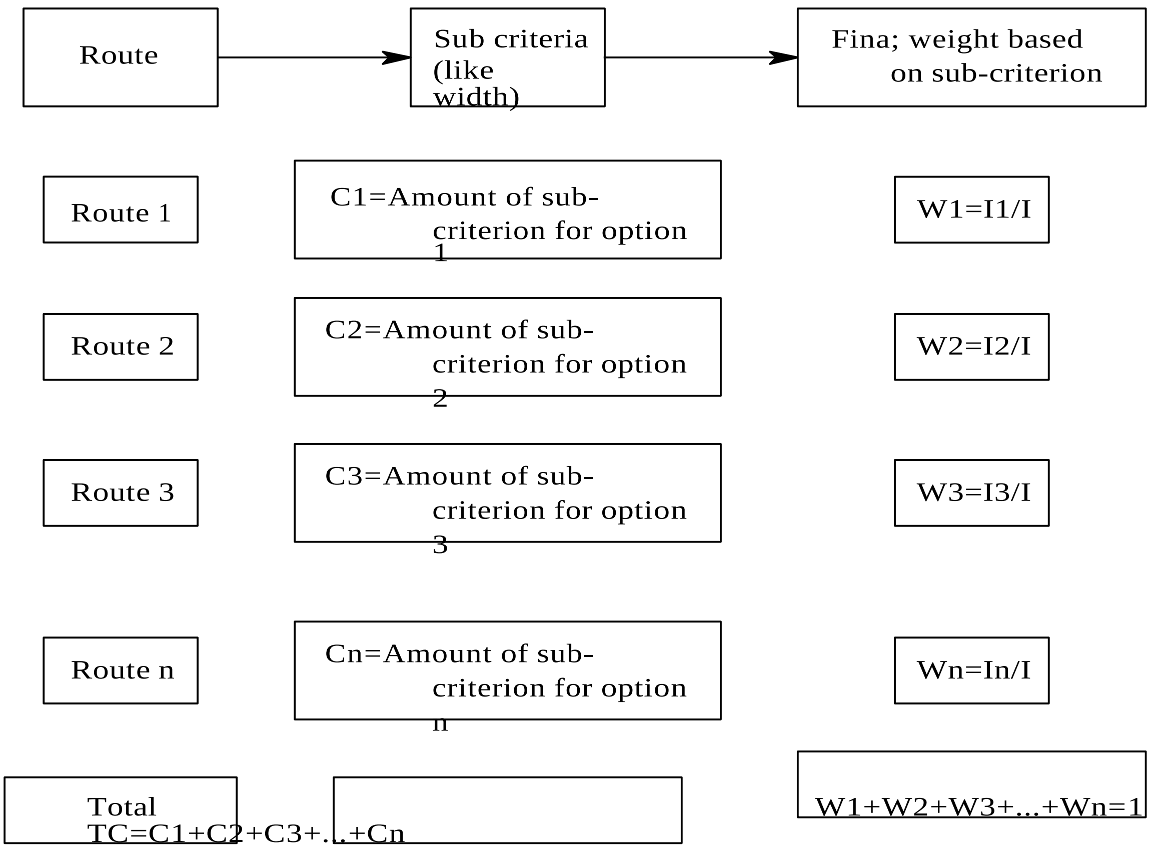

Figure 3. The method of directly weighing the sub-criteria relative to the alternatives

3. REGION OF STUDY

In the present research, the scope of Sabzemeidan of Zanjan is considered to evaluate the proposed method. The danger of earthquakes in Zanjan, due to the geographical and tangible situation, the numerous historical occurrences of earthquakes, and other tectonic and geological evidence, is very high. A look at the history of earthquakes in Iran shows that Zanjan has been damaged several times due to large earthquakes. The Sabzemeidan of Zanjan region, which has a significant structural and socioeconomic diversity, is one of the few tourist and pilgrimage areas in

Zanjan, and a large number of Zanjan citizens, who work for various jobs there. There are old buildings like the bazaar, Imam Zadeh, Hosseiniyeh, etc., in Zanjan city. The road network in the Sabzemeidan region has a variety of passages, and is connected to the arteries outside of Zanjan. Therefore, according to the specific characteristics of the Sabzemeidan region, it can be an appropriate example for assessing the network of roadways and technical criteria, to determine the optimal emergency discharge route. The data related to the following criteria are derived from the options with field studies and library studies. The study area and available routes are shown in Figure 4. We should point out that the basis for taking any route, the departure from the danger zone, and reaching the first safe point, and hence the length each of them is different depending on which area they are heading.

Figure 4. Map of the study area from Google map

4. ANALYTICAL HIERARCHY PROCESS TECHNIQUE

AHP stands for the Analytical Hierarchy process. Decision-making in complex processes, with multiple criteria and sub-criteria, is possible, with the help of the hierarchical analysis process. Based on existing conditions, and library studies, and the research of the study area, the main criteria for presenting the method in this research are population density, road capacity, and structural texture, each of which These criteria have the following criteria, in terms of hazardous uses, and the number of inhabitants for population density, the length and width of the route, and the number of intersections for the capacity of the passageways, and the structures of transportation, and the height of the buildings for the structural texture criterion, which we can Check them out to determine their optimal route. The hierarchy created for the analysis process is presented in Figure 5:

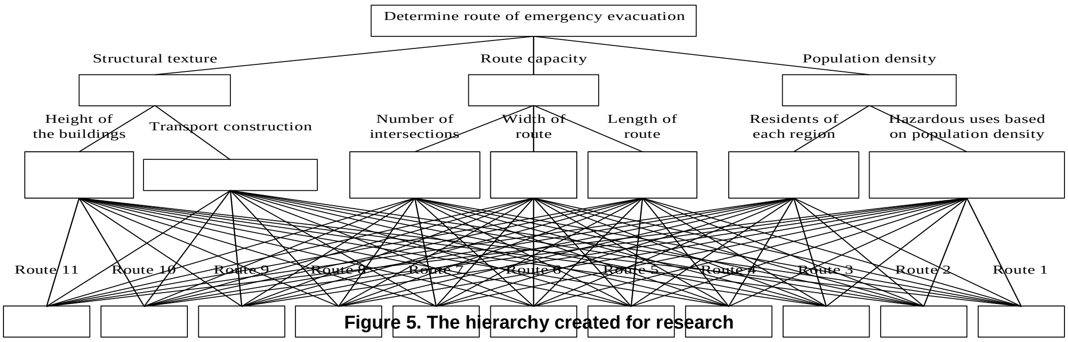

Figure 5. The hierarchy created for research

4.1. Route Capacity

This criterion follows the other three sub-criteria. The length of the route, the width, and the number of intersections per path, are effective under the criteria. The actual values of each sub-criterion are measured in relation to the studied area, and then weighed directly or reverse the method presented in Figure 2, Figure 3.

4.1.1. Route length

Table 1 shows the length of routes available on the network. Planned routes continue to be the first safe point, with the possibility of creating and delivering facilities and their length to these locations.

Table 1. The length of the 11 routes

11	10	9	8	7	6	5	4	3	2	1	Route number
1394	942	1378	783	773	738	843	2100	1400	1264	942	Length (m)

We have used the values obtained field-by-side to compare them together. In this case, shorter routes have more priority, so that, whatever routes have a shorter length, there will be more weight, as calculated in Table 2, in accordance with the flowchart shown in Figure 2.

Table 2. Weight of routes by length

11	10	9	8	7	6	5	4	3	2	1	Route
0.0673	0.09959	0.06812	0.1199	0.12108	0.1272	0.1113	0.04468	0.0670	0.7425	0.0995 9	Weight

4.1.2. Route width

The width of the hypothetical routes is given in Table 3. For calculations, there are fewer routes that have a width, width, width. The direct weight method of each track is calculated to determine the weight of the eleven routes, in other words, the more the route's width is, the more it is in priority.

Table 3. The width of 11 routes

11	10	9	8	7	6	5	4	3	2	1	Route
11	15	15	15	10	17	15	12	15	15	15	Route width (m)

The calculated weights are shown using the flowchart of Figure 3 for the 11 routes in Table 4.

Table 4. The weight of the routes is based on the width

11	10	9	8	7	6	5	4	3	2	1	Route
0.070968	0.09677	0.09677	0.09677	0.06451	0.109677	0.9677	0.07742	0.9677	0.09677	0.09677	Weight

4.1.3. Number of intersections

The number of intersections in the routes of study is very important, as the number of intersections on the route is more, the route cannot be a priority as the optimal route, then the inverse method is used to determine the weight of each path, relative to the number of intersections the Table 5 shows the number of intersections of the 11 routes. The weight of each route in terms of the number of intersections is shown in Figure 2 in Table 6.

Table 5. the number of intersections of each route

11	10	9	8	7	6	5	4	3	2	1	Route
4	3	3	3	3	2	2	3	2	1	2	Intersection number

Table 6. Weight of each route based on the number of intersections

11	10	9	8	7	6	5	4	3	2	1	Route
0.0508	0.677	0.0677	0.0677	0.0677	0.1017	0.1017	0.0677	0.1017	0.2034	0.1017	Weight

4.2. Population density

The population density criterion, and planning for it, are important issues in design. The purpose is to have emergency evacuation of the plan, and to protect the lives of people from incidents. We examine population density, with two sub-criteria of the number of inhabitants in each area, and the dangerous uses that people use.

4.2.1. Number of inhabitants

Any route we consider to be evacuated will be directly an option for the neighboring people to evacuate. Therefore, in emergency evacuation, not only the population density that leads to the routes is controlled there, but also one of the predictable crowd densities that come to the exit route should also be taken into account. For this purpose, the average population density of the inhabitants of the routes that passes through the various neighborhoods is considered. For this, data on the number of residents of each neighborhood, received from the Center of Statistics of Iran, and the average of the population of neighborhoods in the route, were calculated. The average population density is obtained through formula 1, based on people per hectare:

$$PDm = \sum_{1}^{n} PD / \sum_{1}^{n} n \quad (1)$$

Where:

PDm is the average population density, based on neighborhoods

PD is The population density of each neighborhood, in terms of number per hectare.

n is the number of controlled neighborhoods in each path.

By studying previous studies, as well as the statistics published by the Iranian Statistics Center from the previous years, the population density of Sabzemeidan region in each neighborhood is as follows (Table 7).

Table 7. Population density of neighborhoods around Sabzemeidan, Zanjan

Density (People / hectare)	Area (m2)	Population	Neighborhood name
98.557	318800	3142	Meidan-e paeen
154.82	326500	5055	KadiLar Bazari Hoseinieh
50.800	237202	1205	Gheisarieh-Bazarmahalleh
97.66	313100	3058	Zeinabieh
119.36	216000	2309	Saadi Vasat
109.58	147112	1612	
135.91	249500	3391	
107.72	167400	1648	Ghirbashi
118.067	150000	1771	
112.80	229800	1879	Yeri-Debaghlar mosque
106.29	230400	2449	
156.89	195800	3072	

The map of the neighborhoods adjacent to each route is given approximately as in Figure 6.

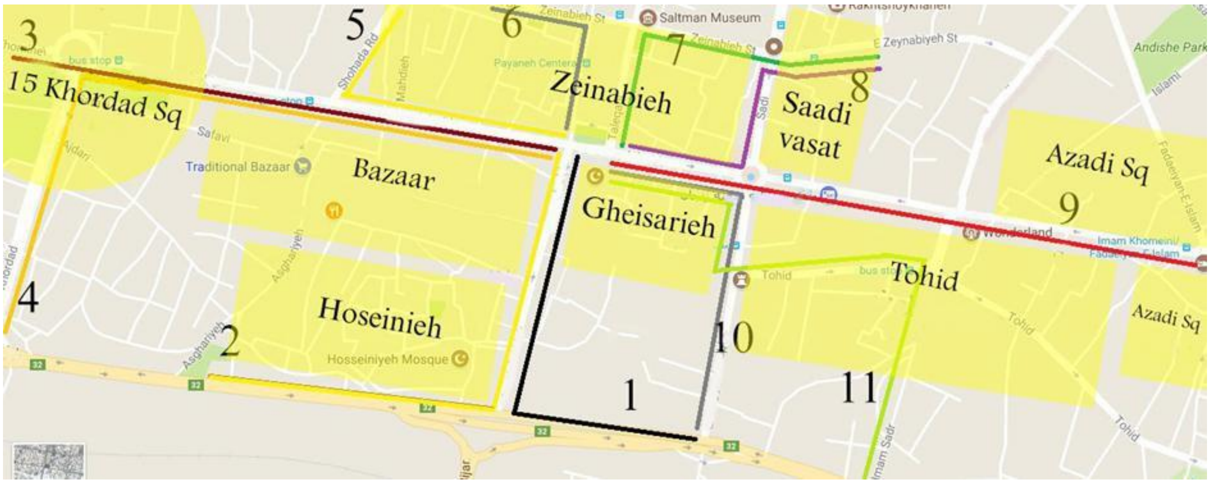

Figure 6. Map of adjacent neighborhoods of hypothetical routes

The averages obtained from Formula 1 are given in Table 8.

Table 8. Adjacent demographic density of each path

11	10	9	8	7	6	5	4	3	2	1	Route number
156	103	172	108	108	187	187	96.66	96.66	154.82	154.82	Density (P / he)

Given that, the smaller the density of the population in the range of a path, the route is the priority for evacuation in emergencies, therefore, using the flowchart of Figure 2 (reverse method), the weight of each route will be obtained based on the density Population below criterion in accordance with Table 9.

Table 9. Weight of each route based on population density

11	10	9	8	7	6	5	4	3	2	1	Route
0.076	0.114	0.0686	0.109	0.109	0.063	0.063	0.121	0.121	0.08459	0.076	Weight

4.2.2. Dangerous use

In this research, we examine the use of hazardous demographics, and these applications are examined by counting the number of traffic. To do this, one hour's traffic is counted at the peak hours of each user. The map of hazardous areas of the area is shown in Figure 7. Bazaar, Imam Zadeh, and Noor shopping centers, which are travel attraction sites in the case study area, are reviewed in this section. The rate of travel absorbing of each of these uses at peak hours is given in Table 10. Given that, if one user has the most recruiting rate at peak time, the routes leading to that user cannot be prioritized, so we can calculate the weight of each route, based on the sub criteria of hazardous applications, according to Table 11, using flowchart Figure 2.

Figure 7. The hazardous area map of the area

Table 10. Hourly traffic in hazardous applications

Adjacent routes of user	Number of traffic	Type of Usage
1,2,10,11	2424 people	Market (Bazar) - peak hours (5 to 6 pm)
9	1260 people	Noor Passage - peak hours (6 to 7 pm)
9	360 people	Emam Zadeh Ebrahim - Hours of Peace (Noon and Maghreb Prayer)
3,4,5,6,7,8	1	No dangerous user

Table 11. Weight of each route based on hazardous usage

11	10	9	8	7	6	5	4	3	2	1	Route
0.0000 68	0.0000 68	0.0001 02	0.166	0.166	0.166	0.166	0.166	0.166	0.0000 68	0.0000 68	Weight

4.3. Structural texture

Structural texture is examined, with two sub-criteria, transport infrastructure, and elevation of buildings. Transport infrastructures include bridges, tunnels, overpasses, etc., and the height of the buildings is also checked by measuring the highest building available on each track.

Transport structures include bridges, tunnels, etc., which will have a significant role in determining the optimal emergency discharge path, and it is clear that the absence of a bridge and tunnel in the optimum route can minimize potential hazards. Therefore, according to the experts' opinions in this section, the points in Table 12 are intended, for routes without structures and with structures.

4.3.1. Transportation structures

Table 12. Scoring based on transport structures

9	Directions without transport structures
1	Directions with transport structures

Considering the conditions of the case study region, in terms of bridges, tunnels, overpasses, etc., there are transport structures. Only Bijar three routes, and other parts of the case study area, and hypothetical routes, do not have these structures. Therefore, according to Table 12, we can compare the route privileges, based on this parameter, in Table 13. Then, the weight of each route is calculated according to Table 14, using flowchart Figure 3 (direct method).

Table 13. Score of transport structures for each route

11	10	9	8	7	6	5	4	3	2	1	Route
9	9	9	9	9	9	9	9	9	1	1	Score

Table 14. Weighing based on the sub-standard of transportation structures

11	10	9	8	7	6	5	4	3	2	1	Route
0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.1017	0.0119	0.0119	Weight

4.3.2. Height of buildings

The presence of high-rise buildings increases the risk of risk. Trails that are the lowest are high-rise buildings in the priority of traffic jams. This sub-criterion is calculated in terms of the width of the route, and applied in such a way that the route width is divided by the height of the tallest building on the path. The less this ratio, the less will be the priority of that route.

2) W / h= ratio of the width of the route to the tallest building [1]

Where:
h is the height of the tallest building on the path
W width of route

Table 15 shows the ratio of the width of the route to the height of the tallest building on the route. According to the results of column 4 of the table, and the method of determining the weight, shown in the flow chart in Figure 3, the weight of each route is calculated based on this sub-criterion, according to Table 16..

Table 15. Width to Building Height

W/h	Width (m)	Height of the tallest building (m)	Route number
1.428	15	10.5	Route 1
1.428	15	10.5	Route 2
1.07	15	14	Route 3
0.857	12	14	Route 4
0.66	15	21	Route 5
1.14	17	17.5	Route 6
0.612	10	24.5	Route 7
0.571	15	24.5	Route 8
0.428	15	35	Route 9
1.07	15	14	Route 10
1.04	11	10.5	Route 11

The weight of each route, according to the sub-criterion of the height-to-width ratio, is shown in Table 16.

Table 16. Weighting based on the height of the buildings

11	10	9	8	7	6	5	4	3	2	1	Route
0.1009	0.103	0.0415	0.055	0.059	0.110	0.064	0.0831	0.103	0.1385	0.1385	Weight

5. WEIGHT OF THE MAIN CRITERIA

In the present research, we have used the questionnaire method, and the question of experts to determine the weight of the main criteria and sub criteria. In the case study, for Sabzemeidan region of Zanjan, by considering expert opinions, the weight of each criterion is considered 0.33, which we can use from different values based on the conditions of each region. Also, the weight of the following criteria is considered, in accordance with Table 17.

Table 17. Weigh the following criteria of each major criterion

Population Density		Route Capacity			Structural texture		Main Criteria
Number of inhabitants	Dangerous uses	Route length	Route width	Intersection	Transport Structures	The height of the buildings	Sub criteria
0.5	0.5	0.33	0.33	0.33	0.5	0.5	Sub-standard weight

6. FINAL ANALYSES OF WEIGHTS

The general purpose of this example is to evaluate the proposed method, which was carried out with the case study of Sabzemean region of Zanjan. The criteria were determined, after the library and field studies, and according to the conditions in Zanjan, and especially the area in question, and the following criteria were determined according to the general criteria. The method presented in this study uses measured values of each sub-criterion. The final weight of the options, based on their scores, is given in the following section, using different criteria, which are calculated in the previous section.

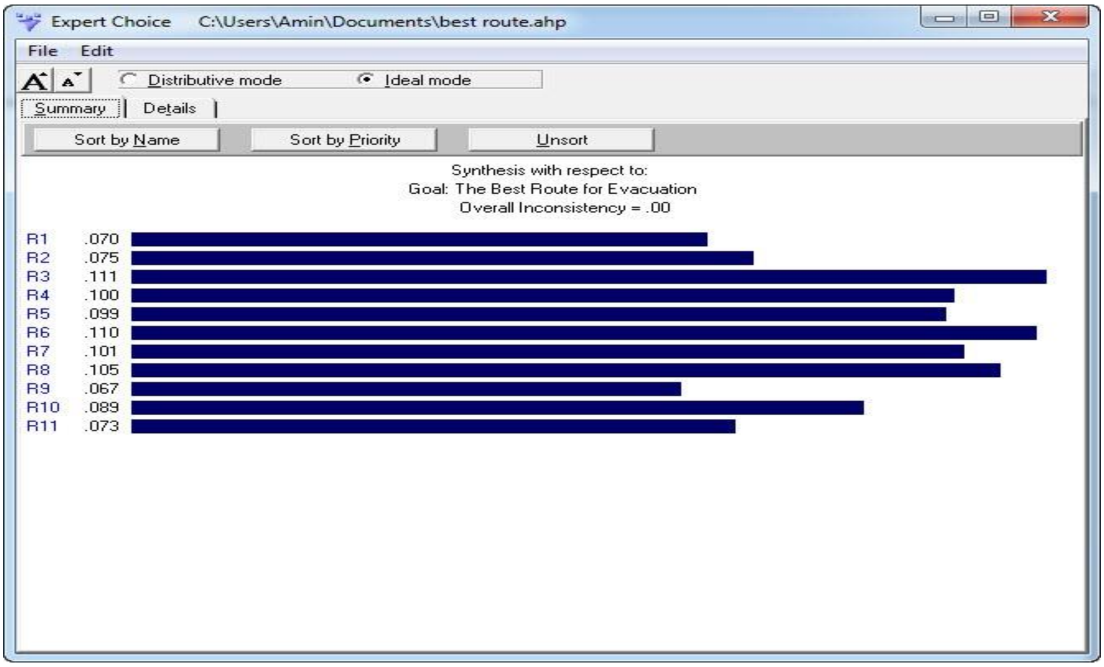

Figure 8. The results of weighting the total traffic evacuation routes

It is clear from Figure 8 that, both routes No. 3 and 6, with a difference of 0.01, are the best possible alternative to evacuate earthquake traffic in the Sabzemeidan region. These routes have the lowest high rise buildings, and without much conflict with market density and the appropriate width along the entire length of the route, and other parameters that are introduced as the most suitable option for evacuation. There is a park at the end of route 3, and close to Panzdeh-e Khordad, which is the best place for temporary accommodation and quick relief to the people we can equip it for this. According to the statistics of Iran, from the latest censuses, the average population density in Zanjan is 250 people per hectare, and the area of the case study region is about 405,000 square meters, we can predict that the facilities needed should be provided for more than 15,000 people. As it is clear in Figure 8, the incompatibility coefficient in judgments is zero, which should be less than 0.1, based on the assessment of the compatibility of judgments, in the hierarchical process analysis method, so this is a suitable number for judgments. Route No. 3 is compared with other available routes in terms of the sub-criteria examined in Table 18:

Table 18. Numerical values of each route based on sub-criteria

Route 11	Route 10	Route 9	Route 8	Route 7	Route 6	Route 5	Route 4	Route 3	Route 2	Route 1	Options	
156	103	172	108	108	187	187	96.66	96.66	154.82	154.82	Average person per hectare	population density
2424	2424	1620	1	1	1	1	1	1	2424	2424	User rating in dangerous	
1394	942	1378	783	773	738	843	2100	1400	1264	942	Length (m)	Route Capacity
11	15	15	15	10	17	15	12	15	15	15	Width (m)	
4	3	3	3	3	2	2	3	2	1	2	Intersection number	
9	9	9	9	9	9	9	9	9	1	1	The rating of the structures	Structural texture
1.04	1.07	0.428	0.571	0.612	1.14	0.66	0.857	1.07	1.428	1.428	Width Height	

7. CONCLUSION

In this research, we have attempted to use a hierarchical analysis method to determine the optimal route of traffic evacuation during critical conditions such as earthquakes. To ensure that the optimal route specified by this method is close to the real situation of the area and the routes, the weight of the existing routes is calculated based on the sub-criteria specified on the basis of actual data. Sabzizean region of Zanjan, which is the exception of the worn-out tissues of Zanjan city, with high population density and diverse uses, and travel attraction, has been investigated as the case study area for the proposed method. Out of 11 outlet hypothetical routes in the region, routes 3 and 6 were determined as the optimal route using the proposed method. In the comparison of proposed routes, with other available routes, it was confirmed that, although all of the sub criteria of the aforementioned route are not optimal, the proposed method has been able to determine the best route, using simultaneous optimization of all sub-criteria, based on Real conditions of the studied area. This method can be used as reference method, for other areas, using a variety of other criteria and sub-criteria.

FUNDING/SUPPORT

Not mentioned any Funding/Support by authors.

ACKNOWLEDGMENT

Not mentioned any acknowledgment by authors.

AUTHORS CONTRIBUTION

This work was carried out in collaboration among all authors.

CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

REFERENCES

1. 2017 -hwaoiaO.
2. Gai W-m, Deng Y-f, Jiang Z-a, Li J, Du Y. Multi-objective evacuation routing optimization for toxic cloud releases. Reliability Engineering & System Safety. 2017;159:58-68.
3. Osman MS, Ram B. Routing and scheduling on evacuation path networks using centralized hybrid approach. Computers & Operations Research. 2017;88:332-9.
4. Shahabi K, Wilson JP. Scalable evacuation routing in a dynamic environment. Computers, Environment and Urban Systems. 2018;67:29-40.
5. Amideo AE, Scaparra MP, editors. A Scenario Planning Approach for Shelter Location and Evacuation Routing. International Conference on Optimization and Decision Science; 2017: Springer.
6. Zhao T, Huang J, Shi J, Chen C. Route Planning for Military Ground Vehicles in Road Networks under Uncertain Battlefield Environment. Journal of Advanced Transportation. 2018;2018.
7. Üster H, Wang X, Yates JT. Strategic Evacuation Network Design (SEND) under cost and time considerations. Transportation Research Part B: Methodological. 2018;107:124-45.
8. Swamy R, Kang JE, Batta R, Chung Y. Hurricane evacuation planning using public transportation. Socio-Economic Planning Sciences. 2017;59:43-55.
9. Hu F, Yang S, Hu X, Wang W. Integrated optimization for shelter service area demarcation and evacuation route planning by a ripple-spreading algorithm. International journal of disaster risk reduction. 2017;24:539-48.
10. Qazi A-N, Nara Y, Okubo K, Kubota H. Demand variations and evacuation route flexibility in short-notice bus-based evacuation planning. IATSS research. 2017;41(4):147-52.
11. Silva C, Pimentel LCG, Landau L, Heilbron Filho PFL, Gobbo FGR, de Sousa PdJ. Supportive elements to the decision-making process in the emergency planning of the Angra dos Reis Nuclear Power Complex, Brazil. Environmental Earth Sciences. 2017;76(3):133.
12. Han X, Zhang X, He Y, editors. Traffic Evacuation Plan Research of Dongli Square. Proceedings of the 2015 International Conference on Electrical and Information Technologies for Rail Transportation; 2016: Springer.
13. He Y, Du S. Classification of urban emergency based on fuzzy analytic hierarchy process. Procedia engineering. 2016;137:630-8.
14. Chen X, Li Q. Modeling road network vulnerability for evacuees and first responders in no-notice evacuation. Journal of advanced transportation. 2017;2017.
15. Kim J, Lee S, Lee S. An evacuation route choice model based on multi-agent simulation in order to prepare Tsunami disasters. Transportmetrica B: transport dynamics. 2017;5(4):385-401.
16. Tu H, Tamminga G, Drolenga H, de Wit J, van der Berg W. Evacuation plan of the city of almere: simulating the impact of driving behavior on evacuation clearance time. Procedia Engineering. 2010;3:67-75.
17. Pel AJ, Bliemer MC, Hoogendoorn SP. A review on travel behaviour modelling in dynamic traffic simulation models for evacuations. Transportation. 2012;39(1):97-123.
18. Parr SA, Kaisar EI, Stevanovic A. Examining the level of service consequence of transit signal priority during urban evacuation. Procedia- Social and Behavioral Sciences. 2011;16:588-99.