

# Designing a Rescue System for Earthquake-Stricken Area with the Aim of Facilitation and Accelerating Accessibilities (Case Study: City of Tehran)

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**Abstract**—Natural disasters, including earthquake, kill many people around the world every year. Society rescue actions, which start after the earthquake and are called LAST in abbreviation, include locating, access, stabilization and transportation. In the present article, we have studied the process of local accessibility to the injured and transporting them to health care centers. With regard to the heavy traffic load due to earthquake, the destruction of connecting roads and bridges and the heavy debris in alleys and street, which put the lives of the injured and the people buried under the debris in danger, accelerating the rescue actions and facilitating the accessibilities are of great importance, obviously. Tehran, the capital of Iran, is among the crowded cities in the world and is the center of extensive economic, political, cultural and social activities. Tehran has a population of about 9.5 millions and because of the immigration of people from the surrounding cities. Furthermore, considering the fact that Tehran is located on two important and large faults, a 6 Richter magnitude earthquake in this city could lead to the greatest catastrophe during the entire human history. The present study is a kind of review and a major part of the required information for it, has been obtained from libraries all of the rescue vehicles around the world, including rescue helicopters, ambulances, fire fighting vehicles and rescue boats, and their applied technology, and also the robots specifically designed for the rescue system and the advantages and disadvantages of them, have been investigated. The studies show that there is a significant relationship between the rescue team's arrival time at the incident zone and the number of saved people; so that, if the duration of burial under debris 30 minutes, the probability of survival is %99.3, after a day is %81, after 2 days is %19 and after 5 days is %7.4. The existing transport systems all have some defects. If these defects are removed, more people could be saved each hour and the preparedness against natural disasters is increased. In this study, transport system has been designed for the rescue team and the injured; which could carry the rescue team to the incident zone and the injured to the health care centers. In addition, this system is able to fly in the air and move on the earth as well; so that the destruction of roads and the heavy traffic load could not prevent the rescue team from arriving early at the incident zone. The system also has the equipment required firebird for debris removing, optimum transport of the injured and first aid.

**Keywords**—earthquake-accelerating-accessibilities transportation-rescue system

## I. INTRODUCTION

ABOUT 110 fatal earthquakes have occurred in 75 countries around the world between the years 1900-1990 more than %80 of the death toll due to these earthquakes has been in 6 countries and Iran, with a death toll of 120000, is among these countries [1].

Studies show that, each week 2 earthquakes with less than 4 Richter magnitude, each year 3 earthquakes with 6 Richter magnitude and each 10 years one earthquake with more than 7 Richter magnitude occur in Iran. However, the important fact is the undesirable condition of Tehran and its high vulnerability to the earthquake. For example, a 6 Richter magnitude earthquake in Tehran would lead to the most unprecedented catastrophe in the entire history [2]. On the other hand, Tehran city has a great influence on the political and economic stability of country and with an area of more than 1200 square kilometers, is highly exposed to strong earthquakes in the region. The transport network of this metropolitan city, which has more than 2000 kilometers of pathways, is involved with several issues at normal conditions. It is obvious that in a state of happening an earthquake.

The situation becomes very abnormal and if suitable routes for rescue actions are not previously predicted, the activities of rescue team will face many obstacles and might be stopped [4]. The aim of present article is to find the most important items of the transport and rescue system for the injured and earthquake-stricken people in that area of Tehran with limited accessibility. Providing rapid rescue action for the injured after an earthquake and transporting them to the health care centers are among the most important rescue problems at critical condition. If supplying the earthquake-stricken people buried under the debris with rescue action takes less than 72 hours, their survival will be more probable. The question is, are we able to design a rescue system which could transport the injured to the hospital as early as possible, in spite of the high density of building in Tehran, the traffic load resulting from earthquake, destruction of roads and collapsing the debris?

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## II. RESEARCH HISTORY

According to the studies carried out by Dr. Ali Zangiabadi et.al, the growing and progressive trend of civilization and urban population is a factor for high damage in the time of occurring natural disaster. The expansion of communication networks and urban infrastructures on the one hand, and violation of the most basic safety rules in urban construction and the unprogrammed growth and development of cities on the other hand, provide a basis for high damage in earthquakes. Studies show that city of Tehran faces many fundamental problems with respect to the above discussion. Considering the indices obtained at the level of zones, it could be easily observed that 12<sup>th</sup> zone is the most vulnerable region of Tehran and will obviously be involved with innumerable issues in a state of happening an incident. the zones 11,16,14 and 20 take the next orders, respectively. On the other hand , 22nd zone is the most resistant region of the city on the basis of vulnerability index, and the zones 2,8,4,5 and 21 are placed in the next order respectively. These results have, of course, been calculated at normal condition and without taking into account the distance between each zone and the crisis center. According to the statistical data presented by Dr.Kianpour, the senior expert at the program of reducing the impacts of natural disasters in the ministry of health, treatment and medical education , more than 120000 people have been killed as a result of natural disaster in Iran in the past 90 years, and %75 (91000)of which has been due to earthquake.

## III. METHODS

In the present research which is a kind of cross-sectional descriptive study, earthquake has been considered as the independent variable and the rapidity of rescue action as the dependent variable, and the required information have been collected at libraries.

## IV. THE GEOGRAPHICAL SITUATION OF TEHRAN

City of Tehran is located on the southern slope of Alborz Mountains and the northern margin of the central desert of Iran, on a relatively flat plain with a north-south slope and a height of 1700 meters in the north, 1200 meters in the center and 1100 meters in the south from the level of open waters.

## V. THE WEATHER CONDITIONS OF TEHRAN

Tehran has a warm and dry climate and only the northern regions of this city, which are situated on the mountainous slope of Alborz, are a little temperate and humid. The maximum temperature recorded in Tehran is nearly 44c, the average annual temperature is 17c and the amount of annual rainfall is about 20-40mm [1].

## VI. THE MAIN FOULTS OF TEHRAN

The major faults of Tehran include, Masha, Fasham, and north of Tehran, Niavaran, Telo, Mahmoudieh, Shian and Kossar, north Rey, Kahrizak, Gamsar, Pishva and Parchin faults. There are of course, many minor faults all around the city; for example Narmak, Shadabad and Baghfeiz.

With regard to the very high number of faults in Tehran and the history of their activities in the past, we understand the point that a huge earthquake will happen in this city in the near future. Some big earthquakes, like a 1.7 Richter magnitude in Damavand in AD1830, a 2.7 Richter magnitude in AD 117, a 7.7 Richter magnitude in Taleghan in AD 958, a 1.7 Richter magnitude in Rey AD 855 and many other earthquakes with more than 7 Richter magnitude have been recorded in the history of Tehran. The return period for the earthquakes in Tehran is about 150-200 years and because the last strong earthquake in Tehran occurred 170 years ago, the risk of happening an earthquake in this city is very high[3].

## VII. THE SPECIAL STATUS OF TEHRAN

City of Tehran has a broad area of about 1200 square kilometers and more than two third of which has been constructed. Tehran has population of 9.5 millions [9].

With an average population of 110 people per one hectare; however, the density reaches near 350 people per a hectare in some urban region %46 of the buildings are old (in some regions up to %75) and the rest have not necessarily a good structural status. 3 and 6 meter-width alley include a high percent of the southern zones of Tehran.

Tehran possesses a transport network composed of 2356 kilometers of pathways; interurban highways and freeways include nearly 9 of this network is spread all around Tehran ; an area of about 780 square kilometers of the city has been constructed. Almost 1000 vehicle pass the input-output ports of Tehran, daily. There are 180 hospitals, 4 red crescent center, 55 fire station and about 109 police stations in Tehran and it is necessary to provide transport network access for these centers [4].

## VIII. THE KINDS OF DAMAGE TO TEHRAN AFTER EARTHQUAKE

*The list of possible damage to Tehran after earthquake is presented below:*

- Collapse of residential, commercial and office buildings
- Disconnection of water and gas pipelines
- Disconnection of electrical grid
- Destruction and blockage of roads and bridges

Most of the buildings in Tehran are old and do not have enough resistance to earthquake. Even most of the new building will not be stable against earthquake, as a result of profit seeking and illegal constructions. Many of the buildings that have been made according to the principles of civil engineering and stability against earthquake will not be resistant as well, because of some phenomena liquefaction due to the high water level in Tehran and the type of soil in some areas [5].

## IX. THE URBAN TEXTURE OF TEHRAN

*The urban texture of Tehran is divided into five groups:*

- 1) The old texture, which is run-down, very vulnerable and made of material such as adobe

brick, wood and mud.		
2) The middle texture, which is unstable and made of brick, iron and cement.	30 minutes	%99.3
3) The new texture, which has not been constructed based on the requirement related to earthquake and the standard instructions2800.	1 day	%81
4) The new texture with average stability, specifically most of the towers built in the past two decades.	2days	%53.7
5) The new texture with high strength.	3days	%36.7
	4days	%19
	5days	%7.4

*First group:* Mainly includes Gajar-area constructions, the village integrated into Tehran and the slums in the margin and the center of city; which will have the maximum damage, if an earthquake happens.

*Second group:* Includes the middle texture with an average age of about 30 years.

*Third group:* consists of the new buildings have been constructed by builders without following the requirements related to earthquake safety. These buildings have a decorated and illusive appearance and a high degree of vulnerability; so that they would collapse by a minimum shake. This group of buildings lack safety principles, from the aspect of type, composition and the strength of the materials, structural connections and the resistance of concrete and steel structures, and include almost %40 of the constructions of Tehran.

*Fourth group:* consists of the tower which have desirable Structural strength, but most of them do not have the required safety; so that the excessive loading on the bed has resulted in the deviation from the vertical axis which increase the probability of collapsing and thus threatens the lives of the residents seriously.

*Fifth group:* includes part of the new buildings (and some of the old buildings)in which the necessary safety principles against earthquake have been well followed and are not seriously in danger [4].

#### X. THE STEPS OF SEARCH AND RESCUE AFTER EARTHQUAKE

- 1) *Locate:* It means to determine the incident zone exactly and to find the fastest and shortest access way to the incident zone far the rescue personnel [8].
- 2) *Access:* After specifying the location of incident, the access procedure is performed through simple or wide spread actions, together with making the place as safe as possible.
- 3) *Stabilize:* The next step after getting access to the zone is to stabilize the injured physically.
- 4) *Transport:* The last step after releasing the injured, is to transport them from the incident zone to a secure place in order to do the treatment process [6].

TABLE I  
THE PROBABILITY OF SURVIVAL VERSUS THE DURATION OF STAYING UNDER THE DEBRIS [8]

The duration of staying Under debris	The probability Of survival
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#### XI. THE AVAILABLE RESCUE EMERGENCY FACILITIES

##### A. Helicopter

One of the fundamental parameters of providing rescue actions for the injured is time. Since the heavy traffic load following an earthquake prevents the rescue team from arriving at the incident zone in time, using non-terrestrial ways becomes very important. However, applying rescue helicopters has some restrictions, such as limited number of runways, limited capacity for carrying and transporting the injured and the impossibility of flying over the small-width alleys and streets.

##### B. Ambulances

Using Ambulances to reach the incident zone is always accompanied the problem of high traffic load due to the blockages on roads because of the collapsed debris and the cars have left in the middle of streets by their owners.

Further more, ambulances have limited capacity for carrying the injured to the health care centers.

##### C. Rescue Boats

Due to the absence of waterways in Tehran, boats could not be applied for rescue actions.

##### D. Rescue robots

The robots have created so far to perform rescue operations in earthquakes, are all specialized in discovering the living bodies buried under the debris and no robots have made to deal with the problem of high traffic load and to transport the injured to hospitals.

#### XII. CONCLUSION

A transport system for the injured with the following specifications is compatible with the conditions of Tehran:

- 1) Ability to reach the incident zone despite the high traffic load in Tehran, which is one of the main issues of this city and becomes even heavier in critical conditions and also in the earthquake and the destruction of bridges and roads, the disconnection of electrical grid and tuning off the traffic lights afterwards.
- 2) Capability of moving on the debris, especially in the narrow alleys of Tehran, the width of which is 3-6 meters in some areas.

- 3) Being able to carry the necessary medical and rescue equipment, such as stretcher, respiration capsule and the devices for immobilizing the body of the injured person.
- 4) Having enough speed to arrive at the incident zone as early as possible; because if the duration of staying under the debris is less than 30 minutes the chance of survival will rise to %99.3. The probability of survival decrease with increasing the delay time.
- 5) Ability to carry the injured person in a suitable position.

The recommend system could be in the form of a Segway. This is equipped with a folding stretcher and medical equipment at the back and is capable of moving in small-width pathways and on the debris. In addition, these devices could be fixed (modularly and with a number of 10-15) on a base, which is carried by a rescue helicopter. When the helicopter lands, they move the rescue team towards the incident location, after being separated from the base; then move the injured back to the helicopter and finally are again fixed on the base and are transported to the health care centers by the helicopter.

### XIII. DISCUSSION

With regard to the situation of Tehran, which is located 2 important and big faults (Masha in the north of Tehran and Rey in the south of Tehran) [3], the constructions with low strength against earthquake, small-width allays specially in south Tehran [4] and the heavy traffic in Tehran (the economic, political and cultural capital of Iran) [4], there is a need for a rescue system which could carry the injured in a minimum time to the health care centers in critical conditions; so that the heavy traffic, the collapsed debris and the narrow alleys could not be stop its functions.

According to the epidemiological studies on the accidents reported to the fire stations in Tehran, it has been demonstrated that the number of accidents has increased in 1379 compared to the previous decade. The average time of arrival at the incident zone has been 9 minutes and 7 seconds and the rescue obstacles have been first related to the heavy traffic and second to the absence of enough and suitable equipment and the narrow streets [10].

Based on the reports published by the Japanese International Cooperation Agency (JAICA) in 1999, if an earthquake happens in Tehran due to the activation of Rey fault, 480,000 buildings (%55 of the buildings) will collapsed. The majority of the damaged buildings will be in the 15<sup>th</sup> zone. The ratio of the damage buildings to the undamaged buildings will be about %80 in the 11<sup>th</sup>, 12<sup>th</sup>, 16<sup>th</sup>, and 20<sup>th</sup> regions. The reasons for this high ratio are the existence of many vulnerable buildings and a strong earthquake movement (with the intensity of 9) in these area. Dr. Bahram Akkasheh, the director of the faculty of science in Islamic Azad University, has interpreted the results obtained from "JAICA" research in an interview with the reporter of Mehr. He said that "the statistical data presented in the report are based upon the result of a

study which was carried out in 1999 and certainly, the number of buildings has risen since then, due to an increase in the population and the rate of contraction" [11].

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