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Recommendation For Earthquake Preparedness In Tehran

An Interactive Qualifying Project Report
submitted to the faculty
of the
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by

Babak E. Kashef

Ashkan Nowtash

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Approved by:

Professor Tahar El-Korchi
Project Advisor

Abstract

By doing research, solutions were found and recommendations were made that could be used in Tehran to prepare the people and the city in case of an earthquake. Hiring inspectors from the city's engineers, establishing a new flooding control system, and educating people were some of the solutions that would be useful in Tehran. Knowledge and experience of different earthquakes in other countries were used and summarized throughout the course of this IQP.

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Chapter 1 Introduction

1.1 Objective

The objective of this project is to prepare the city of Tehran and its residents for the expected earthquake. The project begins with the background of Tehran, its history of earthquakes, types of earthquakes, and expected earthquakes. Then the project evaluates and makes recommendations for the city of Tehran in the event of a major earthquake in order to improve vital structures and enforcement of building codes. Finally, it summarizes what was learned and experienced throughout this research in order to educate people and spread awareness to different organizations; such organizations include hospitals and emergency response groups.

1.2 Background of Tehran

Iran, also known as Persia, is located in western Asia, and it has borders with Armenia, Azerbaijan, and Turkmenistan to the north as well as Caspian sea, and Turkey and Iraq to the west, and Pakistan and Afghanistan to the east, and Persian and Oman golf is on south of Iran.[1]

Figure 1 - Iran's map, www.pnm.my/mtcp/images/maps/Iran-map.jpg

Different Persian Empires have had different capitals, and Tehran is the current capital of Iran (Persia) since 1795. The Existence of Tehran dates back to 6000 BC and there have been human settlement since 5000 years ago and Tehran was a well known village in 9th century, at that time Ray City a well known city in Iran and South of Tehran Village was improving and was being Constructed day by day. During the 13th century after Mongolians Attack to Iran and destructing the Ray City as well as destroying most of the villages and cities in Iran, Tehran survived and many of inhabitants of Ray city came to Tehran. Tehran grew slowly in the following centuries. During the Empire of the Safavid Shah (1524-1576) a wall and four watchtowers were built around the city in 17th century Tehran became the residence of Safavid rulers and at that time Tehran had only 3000 houses. In 1788 Agha Mohammad Khan, founder of the Qajar

dynasty, made Tehran his capital and it was the beginning of the modern history of Tehran. At this time Tehran's population was estimated to be 15,000. Under the Qajar dynasty (1786-1925), Tehran grew in population and size, and new administrative buildings, palaces, mosques, and garrisons were constructed. [1]

1.3 Information about Tehran

Tehran the capital of Iran has a population of 15 Million and area of 2465 km². It is the most economical and industrial city of Iran. Tehran is Located on the slopes of the Mount Damavand. Tehran has 13 townships and 1358 villages, 84 percent of the population is concentrated in big cities and 16 percent of the pollution is in the villages. Although Tehran is a modern city, but there are still a lot of houses in south and suburb area that don’t meet the requirement of a standard building.

Chapter 2 Overview of Earthquakes

2.1 What is an earthquake?

The goal of this chapter is to give general information about earthquakes, different types of earthquakes and types of earthquakes happening in Tehran. “An earthquake is a sudden, rapid shaking of the Earth caused by the breaking and shifting of rock beneath the Earth’s surface”. The large scale movements of the earth crust are known as plate tectonics. The forces of plate tectonics have shaped the earth’s surface to move slowly over, under, and past each other. Sometimes the movement is gradual, and other times the plates are locked together, and unable to release the accumulating energy. When the accumulated energy increases more, the plates go free and it causes the earth to shake. Most of the earthquakes occur at the boundaries where the plates meet; however, some others occur in the middle of plates, Tehran is located on Eurasian plate close to where Arabian and Eurasian plate meet. [2]

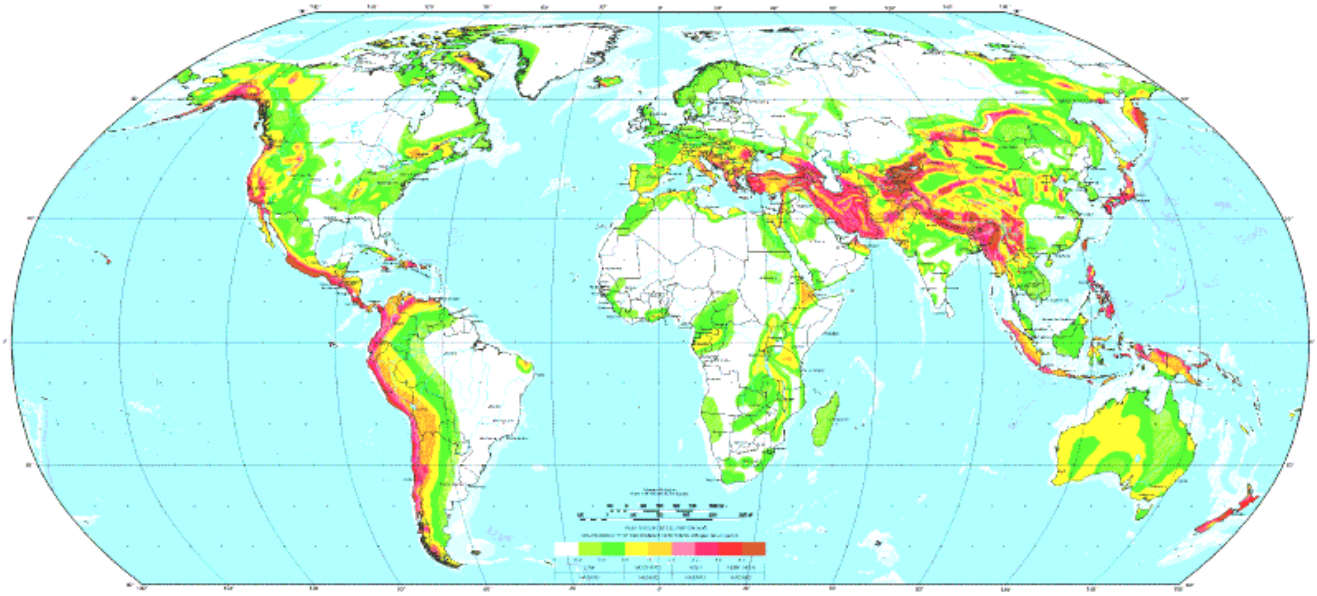


Figure 2- Global Seismic Hazard Map, Giardini, D.; Grünthal, G.; Shedlock, K.M.; Zhang, P., (1999) The GSHAP Global Seismic Hazard Map.
Annali di Geofisica, Vol. 42, No.6, p. 1225 - 1230

As it is shown in figure 10, Iran is in located where many earthquake fault line are situated. In this map the red zones are the ones where seismic activity is most likely to occur and the white zones shown are areas where seismic activity is least likely (but still possible). [2]

2.2 Types of Earthquakes

Naturally occurring earthquakes

Most naturally occurring earthquakes are called tectonic earthquakes and are related to the tectonic nature of the Earth. The fault plane is the boundary of tectonic plates along which failure occurs. The elastic strain energy is released and elastic waves are radiated, thus causing an earthquake when a failure at the fault plane occurs in a displacement of the Earth's crust. It is estimated that less than 10 percent of an earthquake's total energy is ultimately radiated as seismic energy, while most of the earthquake's energy is used to power the earthquake fracture growth and is eventually converted into heat. The majority of tectonic earthquakes originate at depths of tens of kilometers. Earthquakes occurring at these boundaries are called interplate earthquakes. Where the crust is thicker and colder, earthquakes occur at depths of hundreds of kilometers. These types of earthquakes are called deep focus earthquakes. Earthquakes may also occur in volcanic regions and are caused by the movement of magma in volcanoes. Such quakes can be an early warning of volcanic eruptions. Some earthquakes may occur in a sort of earthquake storm, where one earthquake will trigger a

series of earthquakes each triggered by the previous one, similar to aftershocks, but occurring years later, and with some of the later earthquakes as damaging as the early ones. Such a pattern was observed in the sequence of about a dozen earthquakes that struck the Anatolian Fault in Turkey, the half dozen large earthquakes in New Madrid in 1811-1812. [2]

-Induced earthquakes

Seismic events caused by human activities are referred to by the term induced seism city or induced earthquake. Such human activities are extraction of minerals and fossil fuel from the Earth's crust, the removal or injection of fluids into the crust, massive explosions, and collapse of large buildings. Few earthquakes have been causes by the build-up of large masses of water behind dams, such as the Kariba Dam in Zambia, Africa. For instance in the northern Netherlands earthquakes have happened by the removal of natural gas from subsurface deposits. The detonation of powerful explosives, such as nuclear explosions, can also cause low-magnitude ground shaking. In Tehran earthquakes are natural accruing type because there are no mines or gas field or any human interference that can cause an induced earthquake. [2]

Chapter 3 Earthquake in Tehran

3.1 History of earthquakes in Tehran

Tehran state is widely seen as one of the most earthquake-prone places in the world as it is shown in figure 13. Although Tehran is located on a lot of strong fault lines, it hasn't had any strong earthquake yet. The history of the region indicates strong earthquakes of magnitude 7.0 and higher, with a return period of 175 year. This is also shown in table 3. Based on research, it is found that the occurrence of a strong earthquake with Magnitude greater than 7 in Richter scale is around 70 per cent. [3]

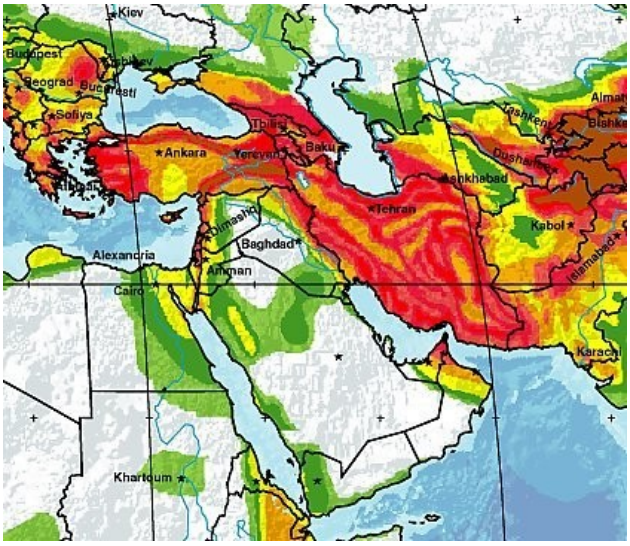


Figure 2 - Middle East Seismic Hazard Map, http://geology.about.com/library/bl/maps/blmiddleeast.htm

Table 3.1 - Earthquakes in Tehran, http://emeraldinsight.com/

Year	County	Fault	Ms	MMI
300 BC	Ray	Parchin, Ray	7.6	X
743	Caspian Gate	Garmasar	7.2	VIII+
855	Ray	Kahrizak	7.1	VIII+
958	Teleghan	Mosha	7.7	X
1117	Karaj	Tehran	7.2	VIII+
1665	Damavand	Mosha	6.5	VIII+
1815	Damavand	Mosha	N/A	V+
1830	Damavand	Mosha	7.1	VIII+

Notes: N/A = not available

This table shows the history of earthquakes for different counties in Tehran. MS stands for Magnitude of the earthquakes, and MMI is known as the Modified Mercalli Intensity scale. MMI defines the severity of shaking. For more details look at the chart below:

Table 3.2-MMI description, http://www.abag.ca.gov/bayarea/eqmaps

MMI Value	Description of Shaking Severity	Summary Damage Description Used on 1995 Maps	Full Description
I.			Not felt. Marginal and long period effects of large earthquakes.
II.			Felt by persons at rest, on upper floors, or favorably placed.
III.			Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
IV.			Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frame creak.
V.	**Light**	**Pictures Move**	Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI.	**Moderate**	**Objects Fall**	Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle).
VII.	**Strong**	**Nonstructural Damage**	Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII.	**Very Strong**	**Moderate Damage**	Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
IX.	**Violent**	**Heavy Damage**	General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations.) Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluvial areas sand and mud ejected, earthquake fountains, sand craters.
X.	**Very Violent**	**Extreme Damage**	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI.			Rails bent greatly. Underground pipelines completely out of service.
XII.			Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

3.2 The Risk of Faults in Tehran

How dangerous are the Fault lines in Tehran:

Based on studies of earthquakes and fault lines during different earthquakes in Iran and other countries, it is shown that the degree of damage, magnitude and the length of movement has approximate relationship with the length of the fault lines. [4]

The fault lines that have a length around 10 kilometers, have a 0.5 meters movement, and for the fault lines with 100 kilometers length, it is not uncommon to see a movement up to 4 meters. [4] Based on research and activities on earthquakes in Tehran, it is shown that in the 20th century the number of earthquakes was less than the number of earthquakes in previous centuries. It has been long times that Tehran has not have an earthquake even of small magnitudes, so this can be an alert to the city of Tehran because fault lines around Tehran are sliding and gathering energy therefore the likelihood of an earthquake striking is increasing. [4]

3.3 Faults in the vicinity of Tehran

In Tehran, there are many active fault lines. Some of their information is listed below: [4]

Main Faults:

These fault lines are greater than 10 kilometers which makes them very severe. The following is a list of main Fault lines which may affect earthquake activity in Tehran:

Mosha Pressure Faults:

This fault passes through Fasham and Mosha Village, and its path is from south east to North West for 400 kilometers and 10 meters wide along Alborz Mountain. [4]

Northern Tehran Fault:

This Fault is actually a branch of Mosha Fault and it has a length of 75 Kilometers in direction of north east to south west. It starts from the east of Lashkarak Valley which is north east of Tehran and ends at Karaj city west of Tehran. This fault passes through Kazem Abad Village and the Tehran-Karaj Highway. It is known as the closest fault to Tehran. [4]

Niyavaran Fault:

This fault line is 13 kilometers in direction of north east to south west, and it has 1 kilometer distance from the Northern Tehran Fault. This fault passes through Sadat Abad, Niyavaran and Aghdasiye which are the rich neighborhoods of Tehran. [4]

Telopayin Fault:

This fault line is 13 Kilometers long and has a direction of north west to south east. It passes 1/5 kilometers south of Telopayin Village. [4]

Mahmoodiye Fault:

This fault line is about 11 kilometers with direction of west east. It is located north east of Vanak, and it goes up to Chamran Highway. This fault line is a pressure kind, and the plates are able to move 10 to 15 meters. [4]

Shiyan and Kosar Fault:

This fault line is located north of Tehranpars, Shiyan and Kosar. It is about 3 kilometers long, and it has a direction of west to east. This Fault line includes the Majidiye Area; it has a curvy figure with the length of 13 kilometers. [4]

Northern Ray Fault:

This fault line is about 16.5 kilometers long, and it is around the Azim Abad Area (Southern part of Ray-Behesht Zahra Highway). It is 10 kilometers south of Tehran. [4]

Southern Ray Fault:

This fault line is about 18.5 Kilometers long, and it is located around the area of Ghalehno Village, and it is 14 kilometers south of Tehran. [4]

Kahrizak Fault:

This fault line is about 40 kilometers long and the direction of west to east in south of Ray city and 20 kilometer south of Tehran. This fault starts from Soltan Abad in west and continues to Kahrizak in east side. [4]

Garmsar Fault:

This fault line is about 70 kilometers long, and it has the direction of east to west and starts from north of Garmsar, and it goes until south east of Varamin. [4]

Pishva Fault:

This fault line is about 34 kilometers long, and it is located south east of Pishva, and parts of the residential houses of Pishva are located on this fault. This fault is pressure kind. [4]

Parchin Fault:

This fault line is pressure kind, and it is in south of Parchin, and it has the direction of northwest to southeast. [4]

Medium Fault Lines (Length of 2 to 10 kilometers):

These Fault lines do not shake by themselves, but because of the shaking of other faults, they have the possibility of shaking. There is a list of Medium Fault lines in Tehran:

1- Shah Abad Fault line
2- Narmak Fault line
3- Davudiye Fault line
4- Ayuby Fault line
5- Abbas Abad Fault line
6- Shahrdad Fault line
7- Feyz Garden Fault line
8- Firooze Castle Fault line

Secondary Fault Lines:

These Fault lines have the length of less than 2 kilometerss. There are 46 secondary fault lines in Tehran. They do not shake by themselves but shake by the movement of neighbor fault lines. The base for construction on those areas is very weak so they should avoid building on them. [4]

Some of the fault lines' direction and their location are shown in figure 3.3.

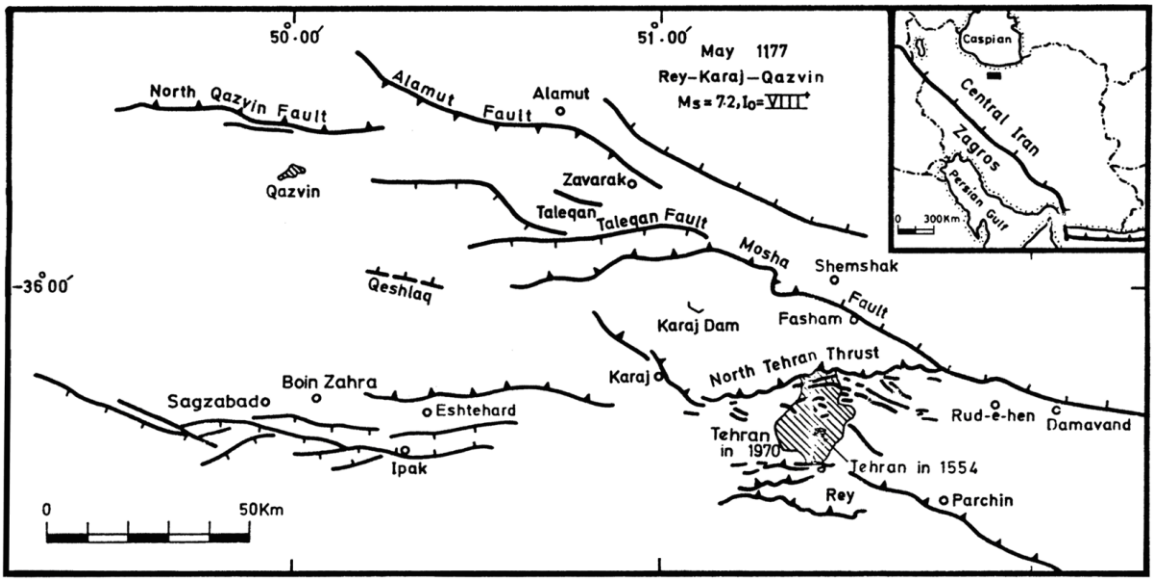


Figure 3.3 - Tehran Fault Lines, Berberian et al (1983)

This table below shows a list of the fault lines and their length. As it is shown Mosha Pressure Fault is the most critical fault line, because of its longer length.

Table 3.3, Fault's length

Category	Name of the fault line	Length
Main Faults	Mosha Pressure Faults Northern Tehran Fault Garmsar Fault Kahrizak Fault Pishva Fault Southern Ray Fault Northern Ray Fault Telopayin Fault Niyavaran Fault Shiyan and Kosar Fault Mahmoodiye Fault	400 kilometers 75 kilometers 70 kilometers 40 kilometers 34 kilometers 18.5 Kilometers 16.5 kilometers 13 Kilometers 13 kilometers 13 kilometers 11 kilometers
Medium Fault Lines	Shah Abad Fault line Narmak Fault line Davudiye Fault line Ayuby Fault line Abbas Abad Fault line Shahrdad Fault line Feyz Garden Fault line Firooze Castle Fault line	2-10 Kilometers 2-10 Kilometers 2-10 Kilometers 2-10 Kilometers 2-10 Kilometers 2-10 Kilometers 2-10 Kilometers 2-10 Kilometers
Secondary Fault Lines	46 Fault lines	Less than 2 Kilometers

3.4 Expected Earthquake in Tehran

It's been a long time since there was any earthquake in Tehran. The history of earthquake shows that when an earthquake does not happen too often in a city that is located on multiple strong fault lines, there is a very high chance of a highly destructive earthquake occurring after a long period of time. Tehran is in a similar situation and lots of experts and organizations are warning about the expected earthquake and its possible damages to the city. A member of the scientific Board of International Earthquake Engineering Research Center Mrs. Shadi Azizi said that Iran is among the most earthquake-prone countries in the world and she said many earthquakes have inflicted huge damage to the country over years. Speaking at a seminar on building construction in Tehran, she highlighted the need for constructing strong and earthquake resistance buildings in the capital. [5]

Another expert, Farid Mahdian the Head of Tehran Earthquake Research Center, said that "Iran is situated on a seismic fault line and several seismologists predict a major earthquake may strike Tehran. Activation of the fault line will cause one of the strongest earthquakes in the world. In Tehran district we will witness a big loss of human life". Mahdin talked about the southern area of Tehran and its Vulnerability to an earthquake and said:
"The activation of Ray fault line will lead to the destruction of over 90 percent of southern Tehran suburb because, southern part of Tehran is vulnerable to earthquake due to the existence of a soft ground, high buildings and population density, and narrow and congested streets".[6] He further warned of extended

losses in the event of a major earthquake due to lack of adequate safety precautions in buildings. According to Mohsen Ghafouri Ashtiyani the head of the International Seismographic Research Center affiliated to the Ministry of Science, Research and Technology, specialized studies shows that the fault lines around Tehran are sliding and gathering energy and there is a strong likelihood of an earthquake striking the Iranian capital. [5]

On the basis of the studies, the probability of a quake above seven degrees on the Richter scale in the next 10 years currently stands at 65 percent and this is expected to increase with the passing of time, Ashtiyani said. And he referred to the fact that buildings in Tehran are incapable of withstanding a strong earthquake.[5]

Chapter 4 Tehran's vulnerability to earthquake

4.1 Introduction

Tehran with a population of 15 Million has a big risk of earthquake, but it does not seem that the people of Tehran are much worried about the earthquake and its consequences. Few of the reasons that they are not worried are that they have many more problems to deal with, such as, economical, unemployment, health. On the other hand some of the religious people think that the earthquake will be God's will and there is nothing that they can do to change their fate. [7]

4.2 Casualty and Destruction due to Earthquake

Buildings:

Since 1925- 1979, by the order of Pahlavi regime, Tehran was modernized and the shape and organization of the whole city was modified from the old look to a new look with stronger buildings. In 1964 in Iran, the first building codes for earthquake were written by the Ministry of Building and Urban Development. These codes were written after the Buyin-Zahra earthquake (7.2 Richter and 12000 people dead) which happened in south of Qazvin city which is in west of Tehran. These buildings codes have been modified since then.[8]

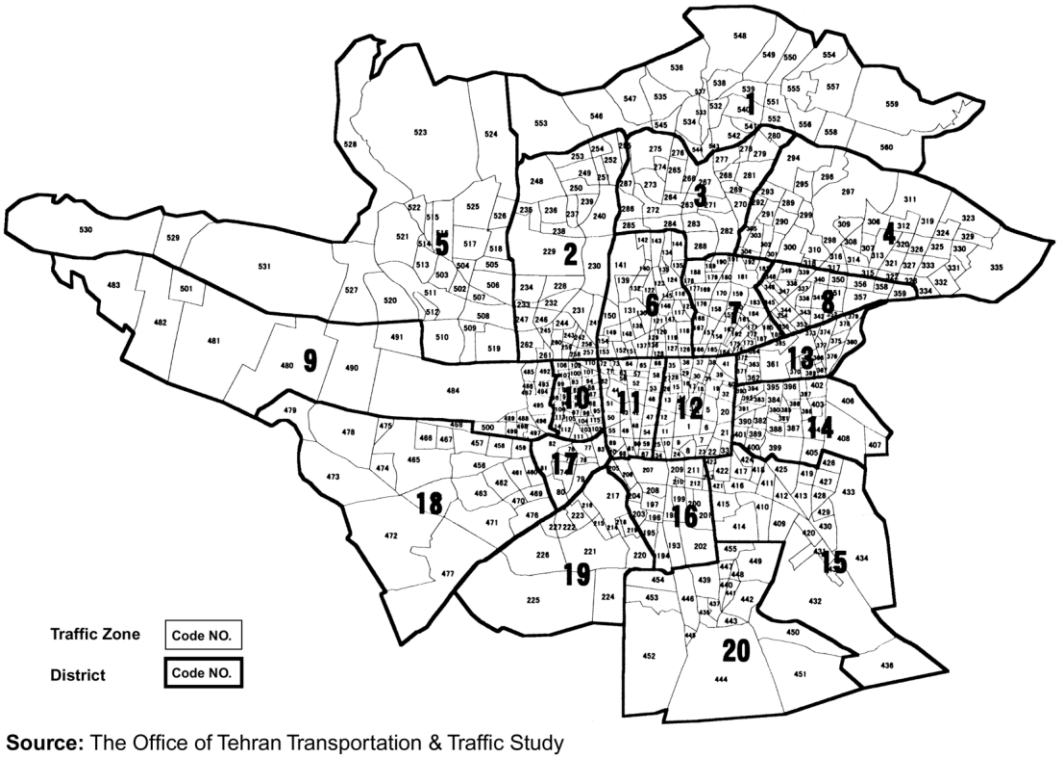
After the revolution in 1979 and during the Iran-Iraq war (1980-1988), there was not that much development in Tehran especially because of Tehran's bombing by Iraq. After the war there has been a lot of development, especially in northern part of the city. As a result, the houses in northern part are newer and more expensive. In the eastern part there has not been much development,

particularly in the southern part of Tehran. The buildings in those areas are old and more vulnerable against earthquake and the people are poorer in those regions. Tehran is mostly known for tall buildings; typically apartments build in narrow streets and close to each other.

Building Vulnerability

Most of the buildings in Tehran or in any part of the country do not go through detail vulnerability analysis. However, based on the trial studies at various part of Tehran and other cities as well as performance of the similar buildings in the past earthquakes (Table 3.1), analytical and experimental studies, type and age of buildings, and expert judgment; overall high quality vulnerability evaluation have been done. [6]

Tehran is composed of 20 regions as it can be seen in the picture below.



Source: The Office of Tehran Transportation & Traffic Study

Figure 4.1, Map of Tehran regions

Also, overall risk of various regions in Tehran, based on the seismic hazard level, geotechnical hazard, building concentration and occupancy, medical services, roads, etc. have been evaluated. For more details please refer to Figure 19.[6]

The picture below shows the structural types and the number of building in all different regions in Tehran.

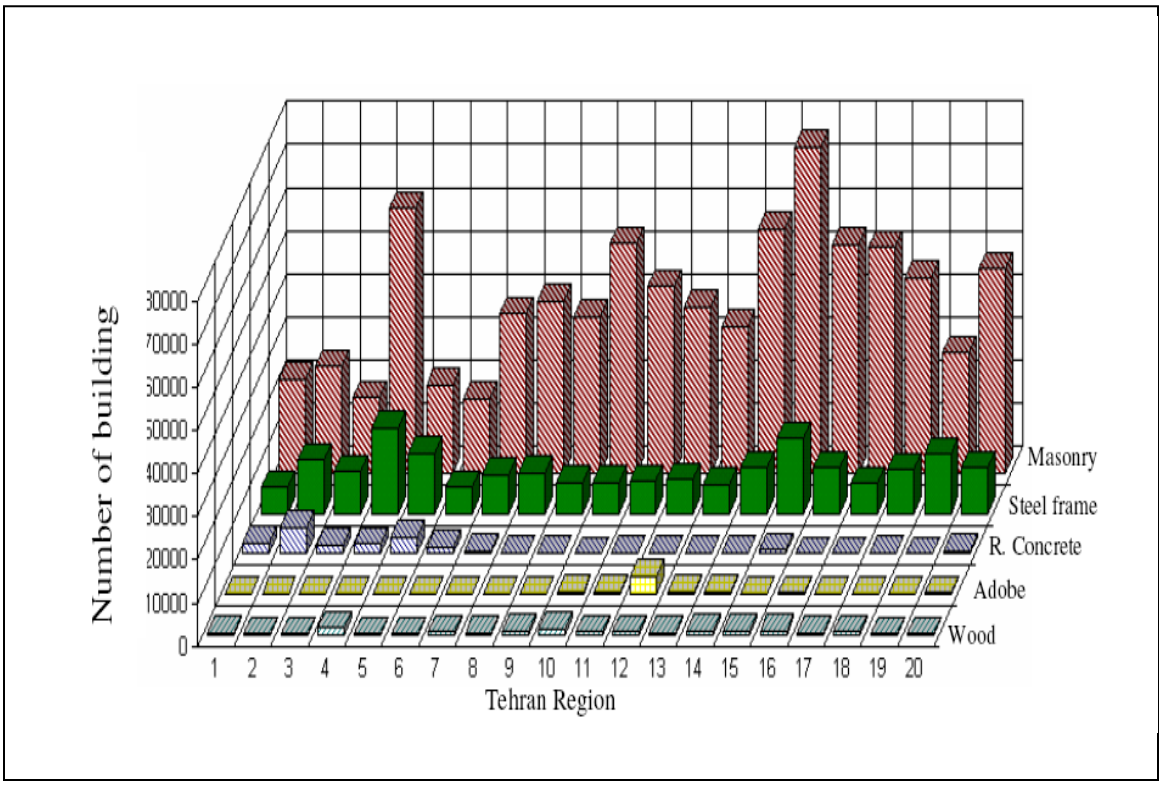
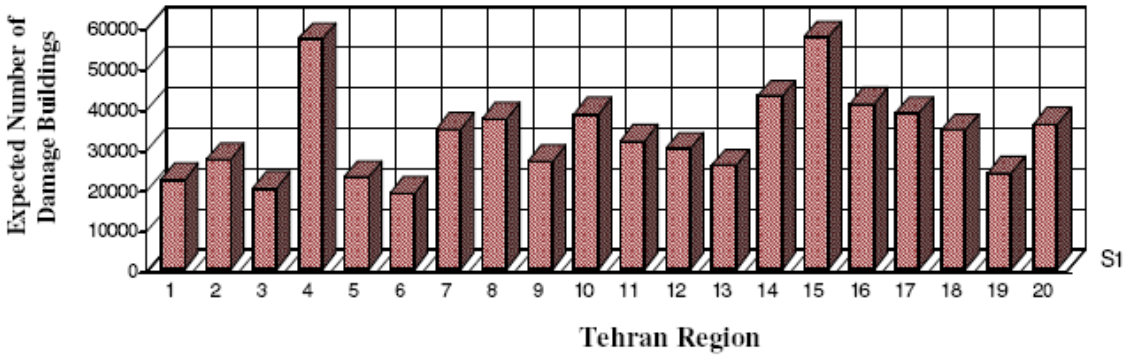


Figure 4.2, number of buildings in Tehran,
http://www.gadr.giees.uncc.edu/DOCS/

The picture below shows the expected number of damage buildings in case of an earthquake in different regions of Tehran.



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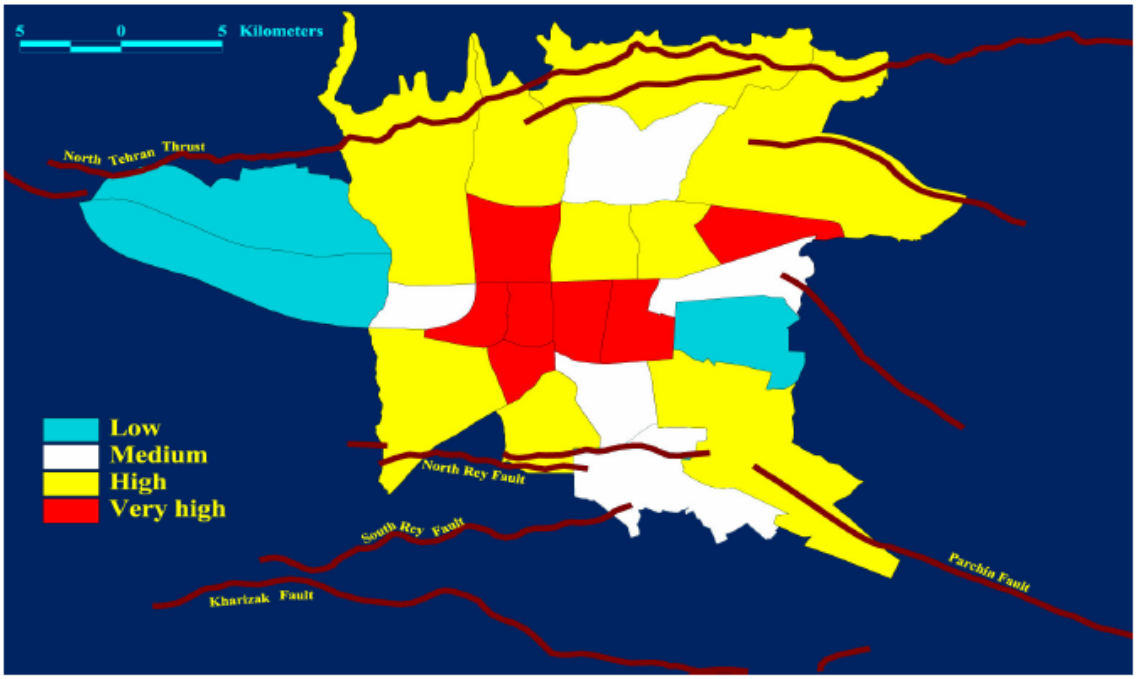

Figure 4.4, risk of Earthquake in regions of Tehran, http://www.gadr.giees.uncc.edu/DOCS/

The table below (Table 4.1) was build based on Figure 4.3 and data was also taken from Figure 4.2. The number of buildings in each region was determined approximately from Figure 4.2, while the number of buildings damaged was taken from Figure 4.3. Also, a conclusion can be drawn by looking at Table 4.1. For example, in region 8 there are nearly 48,000 buildings, out of which approximately 37,000 will be destroyed in case an earthquake hits this region. The same analysis can be done for all the other regions of Tehran and conclusions can be drawn. In the end, region 8 has the largest percentage of damaged buildings, nearly 77%, in case of an earthquake and region 19 has the smallest percentage of damaged buildings, nearly 55%.

Nr. of region	Nr. of building	# of Buldings destroyed	% of damaged buildings
8	48,000	37,000	77%
7	45,000	34,000	76%
1	30,000	22,000	73%
6	25,000	18,000	72%
3	28,000	20,000	71%
10	56,000	38,000	68%
17	56,000	38,000	68%
20	52,000	35,000	67%
2	38,000	25,000	66%
13	38,000	25,000	66%
4	85,000	55,000	65%
12	45,000	29,000	64%
11	47,000	30,000	64%
18	52,000	33,000	63%
16	65,000	40,000	62%
14	68,000	41,000	60%
9	43,000	25,000	58%
15	98,000	55,000	56%
5	40,000	22,000	55%
19	40,000	22,000	55%
Total	999,000	644,000	64%

Table 4.1, % of damaged buildings

Also, a chart was drawn to give the reader a better understanding of the results. Please refer to the figure below.

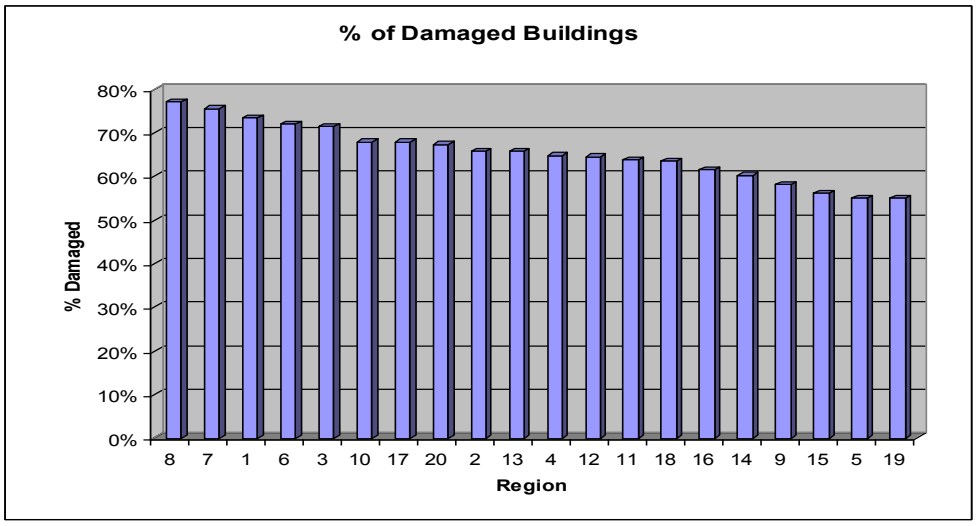

Figure 4.5, % of Damaged Buildings.

Based on this analysis it is found that 64% (Table 4.1) of the buildings in Tehran are in danger of getting destroyed in case of an earthquake.

Uncertified Materials and Contractors:

In Iran the government sells cement to any company that makes concrete. This is a problem because most of the companies are not certified and to make more profit they use less cement and more water. The average life of a concrete building is 100 years if standard concrete is used. If standard concrete is not used, the building life would be less; plus it would be weaker against earthquake. Steel is another material that is not standard but it is very important in construction. In Iran a big portion of steel is imported from Russia and Ukraine. The imported steel does not match the standard of Iran because it has less

strength and it's lighter than the one produced in Iran. Usually on big projects, they test the steel for its tension and capability before using it. For small and private projects the owner does not want to pay for testing. They prefer to use the imported steel since it's cheaper than the domestic one. [8]

In Iran, 90% of the buildings are built by unprofessional people who don't have any license in construction. These people don't really take in consideration safety issues and earthquake's resistance. They only look at their budget and try to use cheap and non standard material to make a higher profit. Also, in Iran the final inspection is not official. A lot of the buildings do not undergo inspection and if they do, the contractor bribes the inspector or the inspector might be the contractor's friend. [8]

4.3 Infrastructure

Tehran Dams

Tehran dams are Karaj dam, Amir Kabir Dam, Latian dam, And Lar dam. Dr. Hassani, the head of Natural Disaster Organization, warned about the danger of the Latian dam. He also said the first priority of Tehran is to protect the dams. These dams are very important for Tehran because their water is used to provide the city with drinking water, electricity and other purposes. Due to this importance, if there be any serious damage to the dams, the city would have a lot of problems, like electricity and drinking water shortage. [9]

Tehran Hospitals:

Tehran has 110 hospitals and 70 percent of them are older than 25 years

old and are not equipped for times of natural disasters especially earthquakes. The earthquake safety procedures and standards for health care facilities are not implemented either. [8]

Tehran fire stations:

Comparing the number of the fire stations in Tehran to San Francisco, one of the most earthquake prone cities in the world, it is seen that Tehran does not have enough fire stations. San Francisco with a population of 750,000 people has 48 fire stations but Tehran with a population of 8 million people has only 32 fire stations and 2 rescue centers with few employees. Also, the fire stations buildings are not earthquake resistant.[12]

Chapter 5 Solutions and Earthquakes in Other Countries

5.1 Solutions for problems due to Earthquake

From the previous conducted analysis, the conclusion can be drawn that Tehran is not ready for an earthquake. Different organizations in Tehran have to think about solutions for this matter to make people and the city ready to prevent more casualties and damages.

Municipality:

- Tehran's engineers should make sure that all of the structures in Tehran be based on earthquake codes, and structural engineers in engineering firms should consider earthquake loads in their structural calculations.
- All contractors need to check with the city engineer in order to build a property, so only professional contractors could build buildings.
- Tehran needs to have organizations for inspection of the structures during and after the building process.
- Consider an open space with enough capacity for people of an area to go there during the earthquake.
- Organizing the help units and organizations so they would be ready during the occurrence of the earthquake.
- Having cleaning units so after the earthquake they would clear the streets and make them ready for emergency responses.

-Recovery of damage due to the earthquake.

-Dividing the buildings in different categories in the view of safety, like: safe, half safe or unsafe in order to be used by people.

-In case of the old neighborhoods, they need to make the streets wider gradually.

Safety of Dams:

The existing dams of Tehran (Karaj, Latyan and Lar) are not safe against big earthquakes (Mr.Mohajer Ashjai), and in case of a big earthquake they would get destroyed and flooding would occur. This problem was also experienced in the 29th of January 1925 in Santa Barbara; State of California which the earthquake had a magnitude of 6.3 Richter and it destroyed the Sheffield dam. A useful solution in this case is a flood control system for all of the dams in Tehran, so they could keep it away from the city. [4]

The Canal and water pipes of Tehran:

The water pipes that lead the water to the city of Tehran from Karaj, Latyan and Lar dams pass either on the North fault line or close to it (especially the Karaj-Terhan Pipes). Due to an earthquake, these pipe lines will be cut and there will be no drinking water or any water that fire fighters could use. It has been predicted that during the earthquake there would not be any ability to prevent the pipe lines from getting damaged or to repair them after the earthquake.

In San Francisco earthquake, Santa Barbara Earthquake, Long Beach Earthquake and Earthquake of San Fernando, all of which were above 6.3

Richter. The main water pipe lines were passing from the different fault lines and wet lands, the water pipe lines broke.

In December 23, 1972, the Managua Earthquake with 6.2 Richter destroyed the fire department of the city so the city was on fire, and because of the destruction of the pipe lines they had to pump the water from the lake. But this is not possible in Tehran, because there is no lake close to the city. One of the possible things that they could do in Tehran is that they could use the under ground water by digging vales in different parts of the city.

High pressure Power Cables:

There are a few units of High pressure power Cables and towers in north of Tehran that are located on the north fault line. If an earthquake happens, these cables would fall on the houses or roads which will cause problems like fatalities and destruction of houses, interrupting the transportation and disconnecting the electricity.In Managua earthquake in 1972, the radio and communication stations were disconnected and because of this they were not able to call up other cities. In this case they need to put supports for such big cables and towers.

Liquefaction:

During the big or medium size earthquakes the liquefaction of earth would happen. Liquefaction is when there is a wet land where the level of water under the ground is high and it will even raise more due to the earthquake. This

problem is expected in south of Tehran in Ray city and also along with the Karaj, Kan, Jajrood and other rivers.

In January 16 of 1968, in Niigata Earthquake of Japan with the magnitude of 7.5 Richter caused the buildings to curve from the foundation and because of that a lot of the buildings fell. [7]

Landslide and rock fall:

This disaster would usually happen in the mountain area, and it causes a lot of casualties and damages. It would mostly happen in the winter time.
In 1970 the Peru earthquake, with the magnitude of 7.75, caused an avalanche of 50 Million cubic feet that was all rock, ice and snow that had a speed of 320 kilometer per hour and moved for 15 kilometer and destroyed 2 cities.
Also in 26 of March 1983, earthquake of Baijan killed thousands of travelers that is another example of this disaster. [7]

Fire Station

- There should be more fire stations around the city with earthquake resistant buildings.
- Research of how fires happen after earthquakes.
- Because of damage to water pipelines during earthquake, they must have pipelines that can stand strong earthquakes.
- Education and drills how to deal with fires that are caused by earthquake and how to prevent fire from expanding to other places. [4]

Red Crescent

National disaster response committee of Iran and Red Crescent Society of Iran are two societies responsible for rescue and relief. Red Crescent Society of Iran currently has 6,929 paid staff and 2,200,000 volunteers as well as members of the society's youth organization, mainly high school and university students

- Red Crescent must store tents, foods and other necessary equipment in earthquake resistant buildings in different parts of the city. [4]

Ministry of health

- Ministry of health has to make sure that all personnel are ready when earthquake happens.
- Improving or building hospitals that are earthquake resistant.
- Ready personnel and ambulances in earthquake resistant parking lots to take people to earthquake resistant buildings. [4]

Ministry of water

- Providing drinkable water to people that don’t have running water after earthquake.
- Emergency water to use for fires that happen after earthquake.
- Research how to improve pipelines and how to fix them quickly after earthquakes happen.

- Improving or build few earthquake resistant vales in each part of the city with complete filtering system to be used for emergency situations.
- To improve or move the pipelines that are built over fault lines. [4]

Ministry of electricity

- Providing electricity in emergency situation for phone services, radio, water departments, lighting, hospitals and other necessary services.
- Finding quick ways of fixing electric lines after earthquake.
- Finding ways to decrease the possibility of fire because of faulty electric lines.
- Power plants and electric lines must be improved so to stand earthquake.
- To improve or move the main electric lines that are built over fault lines.
- Use of automatic switches that cut electricity in emergency situations.

Oil and Gas companies

- Using automatic switches to stop flow of oil and gas in the pipelines to prevent fire during and after earthquake.
- To improve or move the oil and gas pipe lines that are built over fault lines.
- Be ready to fix Oil and Gas pipe lines quickly and prevent the pipe lines from leaking.

Air force

- Improving the runways and control towers so they can stand strong

earthquakes.

- Having power generator for electricity for emergency situations.
- Protecting the fuel tankers.
- Helping and transporting the casualties after earthquake.
- Using the entire helicopter fleet during and after earthquake. [4]

Ministry of Nuclear Energy

- Controlling radioactive material during and after earthquake and making sure that it does not leak out.

Police

- Keeping order in the city.
- Preventing theft.
- Helping people and rescue people.[7,12]

Readiness:

Some of procedure that Japans Officials recommend to their people during earthquake:

- Every household should keep a survival kit consisting of water and food for a few days, a flashlight, a radio and a first aid kit.
- Avoid placing heavy objects into places where they could easily fall during an earthquake and cause injury or block exits.
- Have a fire extinguisher.

- Familiarize yourself with the designated evacuation area in your neighborhood.
- Falling objects, toppling furniture and panic present the greatest dangers during an earthquake.
- Try to protect yourself under a table or doorway.
- Do not run outside, and try to remain as calm as possible.
- If you are in the streets, try to find protection from glass and other objects that may fall from surrounding buildings.
- After a strong earthquake, turn off ovens, stoves and the main gas valve. Then, listen to the radio or television for news.
- In mountainous areas beware of possible land slides triggered by the earthquake. [4, 7]

Education and advertisement:

One of the ways to inform people about the danger of earthquake and the basic things that they should do, is education about earthquake. There are different ways to educate the people:

It can be done through school by teaching the students what that they need to do before the earthquake, during the earthquake, and after the earthquake, and there should be earthquake drills during the school once in a while.

Education can also be done through Television shows and advertisement about earthquake. It can also be done by distributing brochures and poster to the people.

For an example in this project, a brochure is included about what to do and what not to do during an earthquake. [4, 7]

Making of brochure:

First the appropriate brochure format was downloaded from the Microsoft website that was given by Microsoft Words. For this brochure, colorful animation format was chosen so it would be interesting for all the age groups. This brochure is divided to six equal sections. The first section included the title and a picture related to the title. The second section talks about the things that should be done in case of an earthquake. In this section a picture of two children is shown. They are staying under the table in order to protect themselves from the destruction of the place. This is one of the things that they should do in case of an earthquake. The third section gives information about the things that should not be done. In this section a picture of a red sign is included. This picture is chosen, because a red sign is a common known sign for avoiding or stopping. The fourth section lists the emergency supplies that are helpful to have in case of an earthquake. A picture that includes some of these supplies is shown in this section. The fifth section lists the important emergency contact numbers that every one should know, as well as some of the personal contact numbers. The last section includes contact information about the sponsor of this brochure.

5.2 Different Earthquakes:

Kobe earthquake

In Japan during Kobe earthquake most of wooden houses collapsed but houses built by reinforced concrete had suffered less structural damage. The number of wood versus masonry buildings that collapsed in Kobe surprised most observers, as wood-frame structures are usually thought to be much better at resisting shear forces. Possibly the concrete houses were better-designed and stronger even for their greater weight. Heavier tile roofs on wooden houses also might have been a factor. So we see even wooden houses would not help from destruction of houses in Tehran but in case of destruction of wooden houses and concrete houses there is more chance of some one surviving in a wooden house. The destruction of lifelines and utilities made it impossible for firefighters to reach fires started by broken gas lines. Large sections of the city burned, greatly contributing to the loss of life. And there is same situation in Tehran so we have to found out what they did after Kobe earthquake to prepare for next earthquakes.[13]

San Francisco earthquake

Most of the destruction of San Francisco from the 1906 earthquake was also due to fire. The city installed an entirely independent water system for firefighting, with its own reservoirs. The 1989 earthquake broke a firefighting

water main near the Mission Street Post Office, draining the entire system in less than 15 minutes. Fortunately most damage and fires were confined to low-lying districts of the city near the Bay, and fireboats were available to pump bay water as much as one mile inland. Only a few blocks were lost.

But in Tehran there is not lake or sea nearby so they have to secure the water sources as much as possible.

Izmit Earthquake

The Izmit bay area is the heart of Turkey's industry. In august 17, 1999, An earthquake of magnitude 6.7 Richter occurred on North Anatolian Fault Zone with an epicenter near the Gölcük town in the western part of Turkey. Within two hours of the first earthquake there were 10 strong aftershocks that caused more damage and loss of life. These after shocks had a magnitude around 4 Richter. In the Izmit bay area most of the buildings that were collapsed or damaged were 4 to 8 story buildings with structure of reinforced concrete. It is indicated that about 800 buildings were heavily damaged and the Government estimated that financial cost of the earthquakes was $ 10 billion.

The following are the technical cause of building damages or collapses:

-Poor concrete quality.

-Poor detailing of the reinforcement (lack of concrete confinement in the columns and at the beam-column joints, inadequate splice length).

-Weak/soft story (Open space at the first floors) .

-Structural alterations (added floor) .

-Long cantilevers with heavy load .

-Improper construction site.

The collapse of buildings was widespread, but not uniform because of different soil conditions and inconsistent building codes.

The first building codes in Turkey, mostly taken from the building codes in other countries, were written in 1942. After that there were some revisions that were made, until 1997 which was the latest update of it. Since then numerous revisions have been made, the last one in 1997. The Turkish code is acknowledged to be modern and includes strict regulations for earthquake resistant design (EERI Special Report, 1999).[15]

Izmit earthquake killed over 17,000, and the total affected population was between 150,000 and 180,000. Local hospitals have been unable to cope with the flood of injured people and a lot of the hospitals were damaged. There were a lot of industrial facilities in the area that stopped their production due to power shortages and some had suffered major damage. [16]

Industrial facilities:

Tupras (Turkish Petroleum Refineries Co.) is the biggest industrial facility in Turkey and the seventh in Europa. This company has the second valuable shares in Istanbul Stock Exchange Market. This company has 4 refineries that one of them is located in Izmit which is shown in the picture below was built in 1961. Due to the earthquake, one of the crude oil towers collapsed and then it caught fire. The fire could not be controlled by local authorities for several days.[16]

Emergency Response in Turkey

- The Ministry of Public Works and Settlements deployed 550 experts to the affected area for damage assessment purposes. The ministry also had 233 various construction machines in the area.
- The Department of Rural Affairs had sent 1,931 construction machines and 3,295 personnel to the affected area.
- There were 7 tent cities for the homeless population and a number of public facilities, with a bed capacity of 42,366, had been dedicated to the homeless. A guardianship capacity of 34,520 had been assigned for children who had lost their parents, or whose families were unable to take care of the children. [17]
- Wireless communication systems were set up in tent cities to keep the residents informed of developments.
- All transportation routes remain fully operational and international aircraft that were carrying relief supplies were provided the necessary landing and handling services. [17]
- There were a lot of engineers and technicians assigned to solve the electrical and water problems.
- The Turkish Red Crescent had provided 29,725 tents, 79,200 blankets, 2,000 sleeping bags, 25,224 kg of food, 26 mobile kitchens, and 4 mobile

hospitals that two of them had a capacity of 200 beds, one 100 beds and the other one 50 beds. [17]

- 12,000 rescue workers came to the area and the total number of people pulled from collapsed buildings was estimated to be 300.
- Field facilities surrounding the hospital buildings were set up immediately after the quake, with volunteer doctors and nurses coming from nearby towns to treat the injured. [17]

Chapter 6 Conclusion

6.1 Introduction

The purpose of our research was to evaluate, propose solutions and make recommendations in order to prepare the city and its people for major earthquakes. For evaluation, the project examined the geographical situation and background of Tehran and looked at Tehran fault lines--where they pass, how dangerous they are, and if the city of Tehran is ready for a strong earthquake. Based on research it was discovered that the city of Tehran is not ready for an earthquake, so different organizations should think about solutions for this matter and prepare the people and the city. By research and comparisons of earthquakes in cities with similar situations, different solutions and recommendations were found that would be useful in Tehran. Some of these recommendations should be applied by the government and organizations and the others should be applied by the people and private companies.

6.2 Preparedness

- The city engineer should have inspectors in order to make sure that all the buildings are designed based on earthquake codes, and are built by professional contractors with proper building material.
- In order to prevent flooding in the city already devastated by earthquake, there should be a flood control system built for the dams of Tehran to change the path of water to somewhere outside of the city.
- In Tehran there are a lot of underground gas and oil pipe lines that might catch on fire during an earthquake. Beside dams and water pipe lines that might be destroyed during an earthquake, we need other sources of water

to prevent the fire in the city and also to produce drinking water. Vales are the best sources of water in Tehran, so they need to build many earthquake resistance vales around the city.

- The best way to prepare the people for an earthquake is to educate them. This can bed done by educating the students, advertisements, articles and brochure, and television shows.

6.3 After the Earthquake

- Red Crescent should be able to setup tents in open spaces of the city, and they have enough first aid supplies for the people.
- The hospitals should setup tents close to the hospital for fast medical services.
- Iran has one of the largest helicopter fleet in the world. After the earthquake because of destruction of roads and highways, helicopters would be the best way of transportation and rescuing.
- After the earthquake The Ministry of Public Works should deploy rescuers and construction machines to affected areas to rescue and clean up the destruction.

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POLICE: 110

EMERGENCY RESPONSE: 125

AMBULANCE: 330

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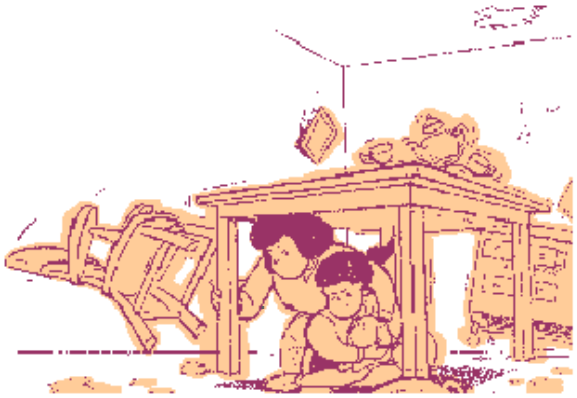

WHAT TO DO

- If you're inside your home, stay there. Get out of the kitchen... safer places are inside halls, in corners, in archways. Take cover under a heavy table, desk or any solid furniture that you can get under and hold onto. Protect your head and face. Doors may slam on your fingers if you're in a doorway. Avoid areas near windows.
- If you're in a yard outside your home, stay there and get clear of buildings and wires that could fall on you.
- If you're in a vehicle, pull over to the side (leave the road clear), away from bridges, overpasses and buildings. Stay in your vehicle.
- If you're in a crowded public place, take cover and watch that you don't get trampled. In shopping centers, take cover in the nearest store and keep away from windows, skylights and display shelves of heavy objects.
- Try to remain calm and help others.

WHAT NOT TO DO

- Don't go outside where you may be hit by falling debris... sidewalks next to tall buildings are particularly dangerous.
- Avoid elevators... if you're in an elevator when an earthquake happens, hit all floor buttons and get out when you can. High rise residents will hear fire alarms go off and electricity may fail.
- Don't run out of gas. Run on the top half of the tank, not the bottom half.
- Don’t go near downed power lines.
- Don’t stop under underpasses or on bridges.

Your emergency supplies:

Water, First Aid Supplies

Prescriptions, Pre-Paid Phone Card

Food, Personal Care/Hygiene Items

Cash, Light Source/Flashlight

Walking Shoes, Comfortable Clothes

Jacket Hat, Pencil, Tablet Radio

Whistle Emergency Blanket

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اضطراری: 125

آمبولانس: 330

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زمین لرزه

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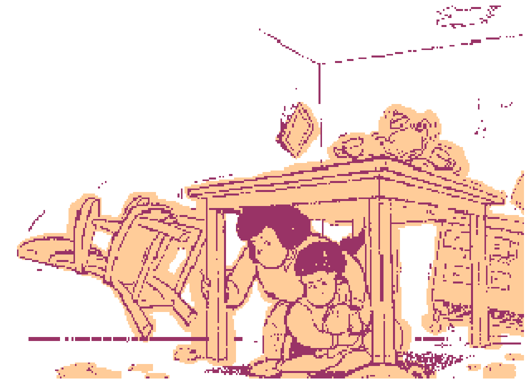
آماده زمین لرزه



ده‌چه چ یزی از جام می

اگ ر شمادرون ازخانه ،ماند ن آن جاهسد ت ید

ازآ شد پزخانه خارج ب شوید د

مکانهاایمن ت ردرون از سال نها،درگ و شه ها،درگ ذرگ اه سرپ و شد یده هاهسد ت ند

پ و شش زیر ریک م یز سد نگ ین یمکحمه ی ذ اثاو ب ابسااي ريرحد ت زيم، ب گ يريد دکه شمامی ت واند يد

ب گ يريد دوروی ن گه ب داريد د

د مرک زیر تان رامحاف ظت ک ن يدومواجه ب شوی

دربهامم کن ا ست روی ان گ شد تهاي تان محکم ب سد ته ب شوندداگ ر شمادری ک درهسد ت يد

وي ندوزمنط قه هان زدي ک اج ت ناب ب نماي يد

اگ ر شمادری ک و سد يله ن ق ل يه ،ک شش ب رروی ب ه طرف خارج ازپ لها،پ ل هوای ی هلو ساخ تمانها

هسد ت يد

درو سد يله ن ق ل يه ت ان ب ماند يد

اگ ر شماهسد ت يددری ک م کان عمومی پ رجمع يت يمن‌هد شد دگلامش‌ه ک دريگب تعاسو شد شوپ، گ يري د

درمرک زهای خريد د،پ و شش درنزدي ک ت ري ن ف رو شد گاه می گ يردوخارج ازوي ندوز،نورگ ير سد ق فها

ن گهداری ک ن يدونماي ش ازهفد های سد ن گ ين سرازير رمی ب ا شد

ب ماندودي گران ک مک سعی ب نماي يدکه آرام ب اق ی ک ن يد

چه زه از جام می دهد

درنزدي ک ساخ تمانهای ب لندمخ‌صو صاخطرن اک هسد ت ند

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روی ن يم ب الامخزن ،نه ن يم آخراجراک ن يد

خطاد ت قال ن يروهاد روي د ن زدي ک

رگ ذرايا وی درپ لهاد وق ف ن ک ن يد زي رز

•

و ضع ا ضطراری شمات هـ یه می ک ند

آب ،ت هـ يه های

ت ل فن

غذا،مراق بت

م ن بع ن ور،

ويدار ، يرارطضا،