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Estimating Damages Caused by Earthquake Using RADIUS and GIS Model (Study Area: Tabriz Region 8)

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Abstract

Natural disasters are phenomena that have always exposed human life in all ages and centuries and had harmful effects. Today's cities in different parts of the world are always exposed to risks caused by natural disasters such as earthquakes due to many reasons such as the type of location, inappropriate physical development, non-compliance with necessary standards and lack of proper management. Assessing the vulnerability of cities against these hazards from different aspects and as one of the factors that determine the level of risk, can lead to the reduction of physical, economic and social damages caused by the occurrence of such incidents. In this research, the 8th region of Tabriz municipality was chosen as the historical and cultural region due to its dilapidated texture, heavy traffic and high and vulnerable population density. The method of research and analysis of the collected information is carried out according to the methods based on the information base and using the Radius program, and three scenarios, according to the fault in the north of Tabriz (scenarios 5, 6 and 7 on the Richter scale) to estimate the damages caused by a possible earthquake in the study area was considered.
The results indicate that the results of the damages and casualties caused by the earthquake based on the considered scenarios indicate that, in the 5 Richter scenario, 20-26% of the buildings will be destroyed, in the 6 Richter scenario, 35-45% of the buildings will be destroyed, and in the 7 Richter scenario, 55-60% Buildings will be destroyed.

***Keywords**:* Radius Model, Earthquake, Damage, Tabriz Region 8, Scenario

1. Introduction

Natural hazards such as earthquakes, floods, and droughts are some of the things that all humans on

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the planet are at risk of. Earthquake is a natural phenomenon that neglecting it will lead to irreparable damages. The occurrence of severe earthquakes has prompted mankind to think of developing an infrastructure plan to reduce the risks and damages caused by it. The characteristics of the country's land structure have raised earthquakes as one of the most destructive factors in the destruction of human life. Historical studies show that large areas of our country suffered from this natural disaster . Iran ranked first among countries in the world in the number of earthquakes with an intensity greater than 5.5 on the Richter scale and one of the highest ranks in terms of vulnerability to earthquakes and the number of people killed. as a result of this accident. According to the same report, in Iran, earthquakes have the dominant aspect among natural disasters (UNDP, 2004).

What turns an earthquake into an accident is the lack of human awareness and the inability to face and deal with it. This problem is generally aggravated by the most extensive human interventions in the natural environment, such as illegal constructions in the vicinity of faults, lack of or disregard for construction rules and standards. Experience has shown that in the countries that are involved with this phenomenon, they have reduced the destruction caused by earthquakes to a great extent and built their cities based on the correct principles of engineering and have no fear of earthquakes (Mahdian, 2008). A clear example of these countries is Japan, where several earthquakes with a magnitude of more than seven occur in different parts of the country every year, and as a result of these earthquakes, the number of structures and people who suffer vulnerability is very small and small. Proper urban infrastructures do not cause crises and disruptions in urban systems. Its occurrence will create many crises in human societies. Therefore, it is necessary to properly manage accidents in order to reduce as much as possible the negative effects of these cases on the society. Based on this, only paying attention to structural indicators is not enough to reduce seismic vulnerability, but by creating a two-way relationship between urban planning and earthquake risk management, it is possible to evaluate seismic vulnerability. and made a more complete and accurate risk assessment and compiled strategies and plans to deal with earthquakes. Because the city is a social, human, cultural, economic and physical phenomenon. The physical aspect is only one of the aspects of the city and the buildings are considered to be only a part of the physical elements, for this reason, the protection of the city against earthquakes cannot be sought only in the strengthening and construction of earthquake-resistant buildings.

According to Iran's earthquake risk zoning map, the city of Tabriz is located in a high risk zone, as a result, assessing its vulnerability using effective and appropriate models is essential for urban crisis management. Due to the fact that the 8th area of Tabriz is a historical and cultural area, the presence of dilapidated fabric, heavy traffic and high population density is vulnerable, it was chosen as the study area. So, according to the stated content, this necessity is seriously felt that by creating a suitable model and using all types of spatial and non-spatial data and performing related analyzes in geographic information systems and also by using The existing world experiences in this field can help to evaluate and analyze the vulnerability of Iranian cities, for example, the city of Tabriz against earthquakes, and in addition to obtaining the necessary preparations against this natural hazard, in a systematic process to crisis management. payment due to natural disasters. It should be stated that the research that has been done in relation to earthquakes and its risk assessment has mostly examined earthquakes in the city with spatial data and based on multi-criteria decision models and about buildings, but in this research using the damage radius model The adaptability of urban buildings has been investigated and at the same time the number of dead and injured as well as the condition of vital organs in different scenarios of earthquake intensity has been investigated, which is not observed in other researches.

So far, many analyzes and evaluations have been carried out in connection with damage estimation and earthquake vulnerability assessment in the form of various researches, each of which has used multiple models and methods according to goals and assumptions.

One of the most important measures to determine the physical vulnerability of buildings in Iran was carried out by Tavakoli (1993), whose results led to the estimation of failure curves for three different types of buildings based on the Rudbar and Manjil earthquakes. has been They studied the damage caused to the villages near the epicenter of the 1990 Manjil Iran earthquake and extracted the relationship between the maximum ground acceleration and the damage to the buildings.

Another case related to vulnerability estimation is JICA's project for Tehran. In this project, the vulnerability of the city of Tehran in various physical and human aspects as well as for specific places has been investigated based on the failure curves prepared by Tavakoli (Japan International Cooperation Agency, 2010).

Zangi-Abadi et al. (2007) in research that was survey, analytical and based on quantitative and qualitative characteristics, analyzed the vulnerability indices of the houses of Isfahan city against earthquakes, which their study showed the vulnerability of the houses in Isfahan city to the risk of earthquake is high, and the access to rescue centers in critical situations such as earthquakes is in an unfavorable situation.

Azizi and Akbari (2007) have investigated the city's vulnerability to a possible earthquake by applying urban planning criteria and using AHP and GIS, and the results of their research showed that by increasing the number of variables such as land slope, population density, building density, life of buildings and distance from open spaces increase vulnerability. On the other hand, increasing the value of variables such as distance from the fault, access based on the width of the road and the compatibility of uses in terms of neighborhood reduces vulnerability.

Hataminejad (2008), using the analytical method of seismic vulnerability assessment and using AHP and GIS, investigated the vulnerability of the 10th district of Tehran city and for this work, the indicators: type of materials, life It has used structure, population density and communication network.

Ahdanjad (2008) modeled the vulnerability of Zanjan city against earthquakes by using RISK_UE and AHP models, and finally by presenting earthquake scenarios in different intensities and by using existing models in the field of damage estimation, to evaluate the human, economic and social losses of Zanjan city have been paid.

Amini (2010) in research using RISK_UE and TOPSIS Fuzzy and GIS models and spatial and non-spatial criteria and according to experts' opinions, investigated and analyzed the vulnerability of houses in the 9th district of Tehran Municipality against earthquakes and the damage He examined the acceptability of this area in different intensities of earthquakes and came to the conclusion that this area is vulnerable to possible earthquakes.

Amini (2013) has evaluated the RADIUS model and examined the advantages and disadvantages of this model and estimated the damage caused by an earthquake in a municipality.

Gionazi (2006) in research first examined different vulnerability models including the RISK_UK model and different damage scenarios, and then using the RISK_UK model, evaluated the vulnerability of the Liguria region in Italy and carried out the damage scenarios. It has been concluded that the studied area is vulnerable and needs planning to prevent the crisis.

Gulati (2006) in research, while comparing the RADUIS and TELES models for assessing the city's vulnerability to earthquakes, evaluated the risk of buildings in the city of Dehradun, India, against earthquakes, using the Hazus model, and came to the conclusion that the Hazus model Due to the abundance and variety of data and variables used, it can be used as a suitable model to evaluate and reduce the vulnerability of cities against earthquakes.

In a research, Rashid et al. (2007) investigated the role of geographic information system and remote sensing in modeling and predicting the vulnerability of California city against earthquakes and by using analytical functions and geographic information system, the vulnerability They have modeled the city.

In research, Martinelli et al. (2008) evaluated the vulnerability of buildings and different damage scenarios in the city of Selano, Italy, and to do their work, they divided the buildings into two categories, concrete and masonry, and evaluated their vulnerability using the RISK_UE model in They have investigated different intensities of earthquakes and estimated and modeled damages caused by possible earthquakes in different intensities of earthquakes.

Lantada et al. (2009) in research while modeling the vulnerability of the city of Barcelona using the RISK_UE model, have evaluated the human and economic losses in the city of Barcelona by using the existing models in the field of damage estimation.

In a research, Tang and Wen (2009) used artificial intelligence system to assess earthquake risk in

Diang City, China based on the development of GIS and artificial network. This system is used to detect the seismic weakness of structures in pre-earthquake conditions, to quickly assess earthquake damage, and to provide immediate, intelligent conditions for public and government response during and after an earthquake.

In the research conducted, most of the earthquakes in the city have been investigated with spatial data and based on multi-criteria decision-making models and about buildings, but in this research, using the radius model, the vulnerability of urban buildings has been investigated, and at the same time, the number of dead and The injured as well as the condition of the vitals in different earthquake intensity scenarios were investigated and the amount of damage was estimated, which is not observed in the conducted research.

2. Methods and Materials

Tabriz city with an approximate area of 2167.19 square kilometers is located at 45 degrees 50 minutes to 45 degrees 36 minutes east and 37 degrees 42 minutes to 38 degrees 29 minutes north latitude. This city is located in a wide plain and is limited from all directions except the west and northwest by the steep slopes of the surrounding mountains. Figure (1) shows the location of the studied area.

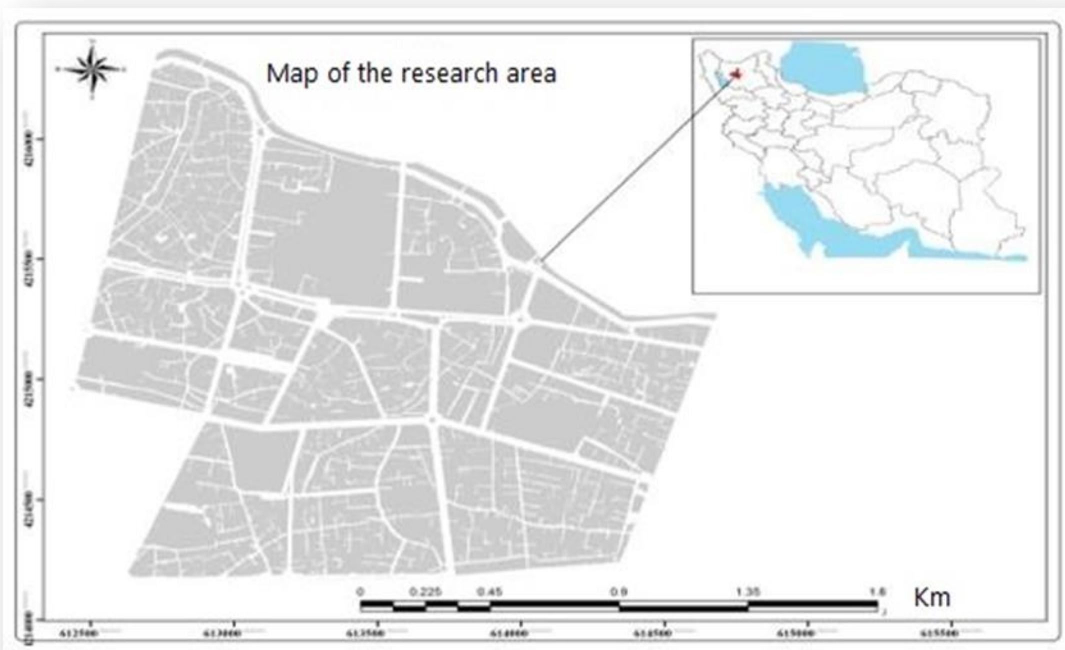

Figure 1. Location of the studied area (case study of Tabriz region 8)

To carry out the research, the city of Tabriz region 8 was selected, the analysis of the collected information is done according to the methods based on the information base and using the used models and software based on the geographic information system approach. Accept the type of developmental-applied research and its investigation method is descriptive-analytical.

Based on the research model (Risk Assessment Tool for Diagnosis of Urban Areas, RADIUS model), the data used in this research includes the number of buildings in the study area according to the type of structure and their use, the number of building floors, the total population of the area and the vital arteries of the area (road network, water reservoirs, post office) electricity and telecommunications, water and sewage lines, gas stations), ArcGIS and RADIUS software are also used.

3. RADIUS Model

The RADIUS approach was used in 1996 with the aim of preparing an earthquake scenario and developing an action plan for cities at risk of earthquakes in developing countries. The main goal of the RADIUS project, which was started with the support of the United Nations, is to raise awareness and create a scientific and practical tool to reduce the risk of earthquakes in urban areas. This approach, with the modifications made, was used as a software for estimating damage and preparing and compiling an earthquake scenario. This program is used in information and awareness programs for all stakeholders in the city. The goals of the RADIUS program are (Carlos and Cynthia, 1999):

1- Designing a tool for seismic risk management that can respond to earthquake-prone cities.
2- Conducting comparative studies to understand seismic vulnerability in urban areas of the world
3- Exchange of information in order to reduce the effects of seismic vulnerability in urban areas
4- Preparing a plan to upgrade the existing urban structure, such as strengthening vulnerable buildings and infrastructures, securing open spaces and emergency roads.
5- Providing rescue facilities, firefighting and emergency transportation

RADIUS is a program that works in the Excel environment and the user must enter the following information in this software:

1- The size and boundary of the study area through grid
2- The total population of the study area
3- The total number of buildings and the type of structure of the buildings
4- Soil type of the study area
5- Information of the vital arteries of the study area
6- Selecting the earthquake scenario and its parameters

Then the program checks the validity of the input data and performs the analysis. The outputs of this program are:

1- Seismic intensity in the form of PGA and MMI intensity
2- Damage to buildings
3- Damage to vital arteries
4- Casualties, including the number of dead and wounded
5- Tables and maps that display the results thematically.

One of the main goals of this project was to develop an experimental tool for city risk management. The RADIUS method for destroying buildings can be determined in 10 steps, determining the earthquake scenario, calculating the damping using the function, calculating the strengthening caused by the local soil conditions using the soil map, converting PGA to the modified death intensity, using the function Vulnerability for building types, using vulnerability function for infrastructure types, using vulnerability function for losses, using building cost information and combination with vulnerability to calculate damages for different return periods, combination Destroy information for different return periods and risk calculation by adding destructions from these periods, combining information and summarizing to be separated (Carlos and Cynthia, 1999).

The general process of damage estimation in this program is shown in Figure (2).

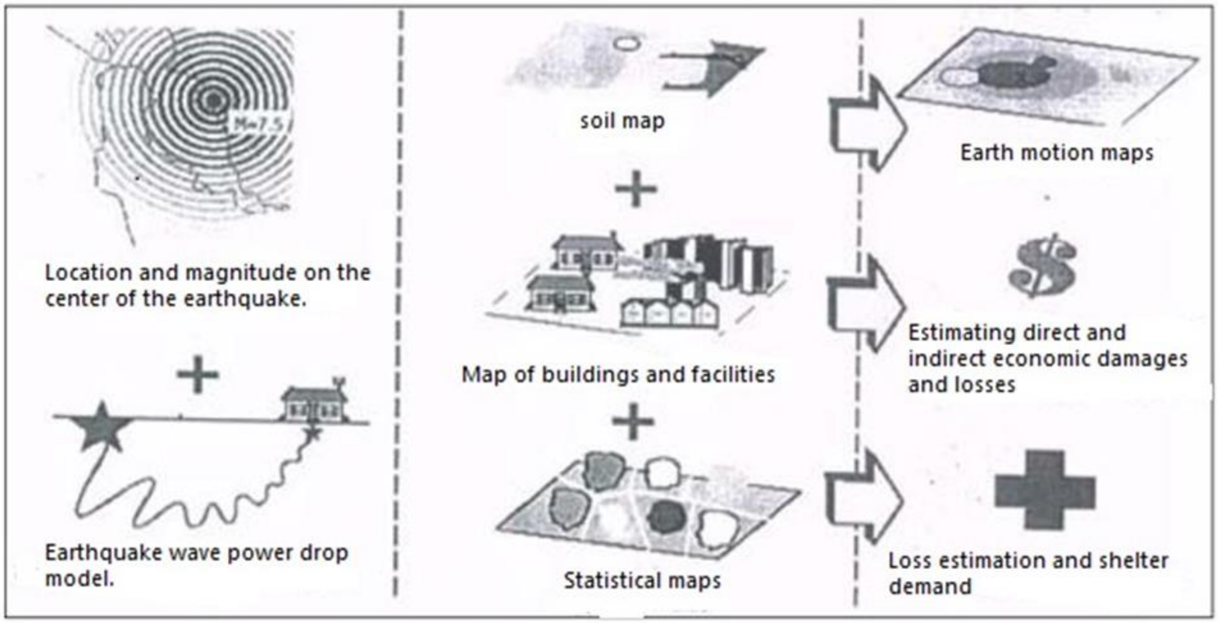

Figure 2. Damage estimation process in the RADIUS program (Cynthia, 2002)

4. Estimation of Earthquake Damage using RADIUS Software

The method of doing work for damage estimation using the RADIUS program can be seen in Figure (3). Earthquake scenario, ground condition, statistical data and vulnerability performance of buildings are the most important input data for earthquake damage estimation. In order to prepare and develop an earthquake damage scenario, the target area should be determined and according to the geology and location of the faults, the magnitude, center of the earthquake and the wave power loss model should be determined. The damage estimate will be estimated according to the danger and existing structures and the number and type of structures and vital arteries. The damage map will show the relationship between the seismic intensity and the degree of damage to the structures. Casualties such as death and injury are estimated when an earthquake occurs at night or during the day. Therefore, the whole process of damage estimation leads to the knowledge of the total damage and how they are distributed in the event of an earthquake. Of course, it should be noted that when an earthquake occurs, its effects and results will definitely have many differences with the results of the scenario. The scenario is only a hypothesis to know that the effects of the earthquake are worse or similar to what the scenario has calculated.

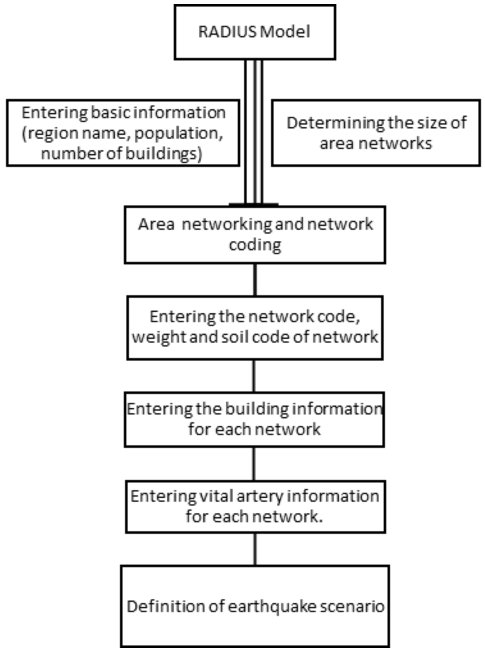

Figure 3. General process of damage estimation using the RADIUS program (Amini, 2019)

In the whole process of estimating damage caused by earthquake in Radius software, it can be implemented in the following steps (Amini, 2019):

1- Area Networking: Considering that in urban areas, each part of the area has different characteristics such as the condition of the land, different types and uses of buildings, as well as different statistical information, to estimate and estimate the damage, the studied area is connected to the network. The squares of the division and the information required by the program are entered into the software separately for each network.

2- Determining the condition of the soil in the area: the condition of the soil in the area is effective in the amount of damages caused by the earthquake, because the condition of the ground directly aggravates the shaking of the ground and seismic effects. Radius software offers a simple classification for the soil type, in which the soil type is divided into four categories: hard rock, soft rock, medium soil, and soft soil, and the earthquake intensity factors are also calculated according to the software.

3- Classification of buildings: the vulnerability of buildings is one of the key issues in seismic risk, the destruction of buildings is the main cause of killing victims. Damage caused to buildings due to an earthquake is directly influenced by two factors, the type and type of buildings. The first step in determining the damage of buildings is their grouping (Table 2). Radius software classifies buildings according to the type of materials used in construction, use and number of floors.

4- The condition of vital arteries in the region: If vital arteries such as water supply networks, electricity networks or other communication networks are damaged due to an earthquake, while they have been damaged in an earthquake, the damages and injuries The next ones follow, for example, we can refer to the road network, which as one of the important urban elements, becomes especially important immediately after the earthquake, because the need to evacuate the injured as soon as possible. turns This evacuation is done through inter-city roads, inner-city streets and secondary roads, and if one of the main roads or even secondary roads is closed, the damages and injuries caused by the earthquake are multiplied and this It is possible that it will take days or even months to get back to normal. The Radius program uses the general statistics and total number of vital arteries in the entire region and its relationship with the seismic intensity to estimate the damage of the vital arteries, which means that as the intensity of the earthquake increases, the amount of damage to the vital arteries, for each One of the facilities, in the form of an increase curve finds the grouping of vital arteries according to the radius model is shown in table (3).

5- Earthquake scenario: predicting possible events and their effects is called scenario preparation. Scenario preparation is often done in order to prepare a plan and create preparedness in disaster-prone communities and helps to better understand the possible future. The meaning of scenario earthquake is to determine the magnitude, intensity and other parameters of an earthquake, which the software considers as a possible earthquake in the region. The input parameters to the system to determine the earthquake scenario are: the location of the earthquake, the depth of the earthquake, the magnitude of the earthquake and the time of the earthquake, because the amount of casualties and damages depends on whether the earthquake occurs at night or during the day and what damages are caused to public buildings, schools and departments, it is completely different. Of course, it should be noted that when an earthquake occurs, its effects and results will definitely have many differences with the results of the scenario. The scenario is only a hypothesis to know that the effects of the earthquake are worse or similar to what the scenario has calculated.

1- Area networking

Considering that in urban areas, each part of the area has different characteristics, such as the condition of the land, different types and uses of buildings, as well as different statistical information, for estimating the damage, Tabriz area 8 is divided into 20 equal grids, 500 meters in 500 meters, the division and information required by the program were entered into the software separately for each network. that the network of the area has been done in ArcGIS software and according to the boundaries of the area and the distribution of existing users in it, which Figure (4) shows the network of the area in the RADIUS model.

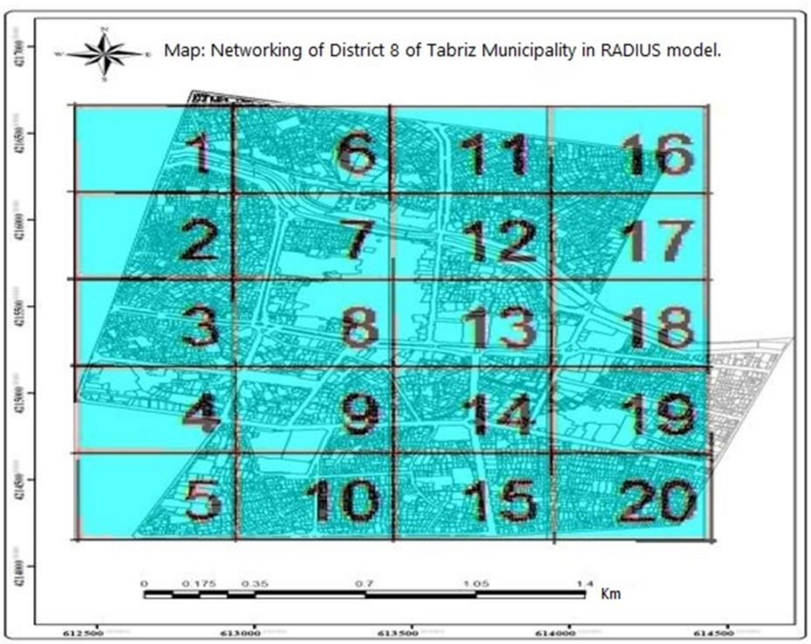

Figure 4. General process of damage estimation using the RADIUS program (Amini, 2019).

2- Determining the condition of the soil in the area

The condition of the soil in the region is effective in the amount of damages caused by the earthquake, because the condition of the ground directly aggravates the shaking of the ground and seismic effects. RADIUS software offers a simple classification for the soil type, in which the soil type is classified into 4 categories, hard rock, soft rock, medium soil and soft soil, and the earthquake intensity factors are also according to them. Applied by software, it is divided. The soil grouping of the region is according to Table (1) and Figure (5).

Table 1. Soil grouping of the region based on the RADIUS program

Soil type	**Its description and type**
Hard rock	**---------------**
Soft rock	**----------------**
Medium soil	**Red sandstone and marl**
Soft soil	**Young alluviums and current age alluviums**

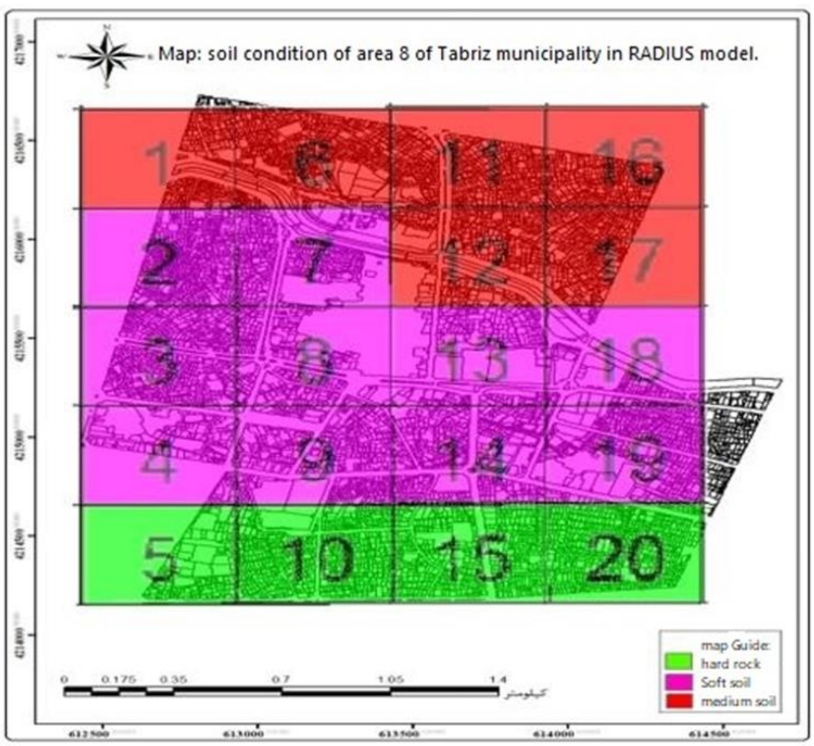

Figure 5. Soil grouping of the region based on the RADIUS program

3- Classification of buildings in the studied area

Vulnerability of buildings is one of the key issues in seismic risk, the destruction of buildings is the main cause of death. Damage caused to buildings due to an earthquake is directly influenced by two factors, the type and type of buildings. The first step in determining the damage of buildings is to group them. The grouping of buildings in the 8th district of Tabriz municipality was done according to the RADIUS program, and the number of buildings in each group and their percentage can be seen in Table (2)

Table 2. Grouping of buildings according to the RADIUS program

Building	Specifications	percentages	number
residential	Type 1: Buildings with building materials that are not resistant to possible earthquakes, made of bricks, straw and roofs and walls without siding.	**34.56**	**3371**
residential	Type 2: mixed structures, non-standard structures that do not comply with building regulations, up to three floors high.	**42.42**	**4138**
residential	Type 3: Buildings with a metal or concrete frame, not in accordance with building regulations, 4 to 6 floors high.	**10.52**	**1026**
residential	Type 4: Buildings with metal frame or reinforced concrete, engineered, newly built and multi-storey.	**9.74**	**950**
educational	Type 1: School buildings up to 2 floors	**0.51**	**49**
educational	Type 2: School buildings higher than 2 floors	**0.38**	**37**
treatment	Type 1: Small and medium hospitals	**0**	**0**
treatment	Type 2: large hospitals	**0.02**	**2**
commercial	shopping center	**0.03**	**3**
industrial	Industrial buildings and facilities	**1.82**	**178**

4- Determining damage to vital arteries

If vital arteries such as water supply networks, electricity networks or other communication networks are damaged as a result of an earthquake, in addition to the damage caused to them in the earthquake, subsequent losses and damages also follow, for an example, we can point to the road network, which as one of the important urban elements, becomes especially important immediately after an earthquake, because the need to evacuate the injured as soon as possible is raised. This evacuation is done through inter-city roads, inner-city streets and secondary roads, and if one of the main roads or even secondary roads is closed, the damages and injuries caused by the earthquake are multiplied and this It is possible that it will take days or even months to get back to normal. The RADIUS program uses general statistics and the total number of vital arteries in the entire region to estimate the damage of vital arteries and its relationship with the level of seismic intensity, which means that as the intensity of the earthquake increases, the amount of damage to vital arteries increases for each One of the facilities increases in the form of a curve. Table (3) shows the condition of the vital arteries of the 8th region of Tabriz Municipality.

Table 3. The condition of the arteries in the 8th area of Tabriz

Vital arteries	Description	Unit	Level
First type road	**Local roads to surrounding areas**	**KM**	**14**
Second type road	**Highways and highways**	**KM**	**0**
Bridge	**-**	**Number**	**3**
Tunnel	**-**	**Number**	**0**
Electricity 1	**The number of electricity and telecommunications masts**	**Number**	**0**
Electricity 2	**The number of electricity and telecommunications stations**	**Number**	**5**
Water 1	**Length of water and sewage lines**	**KM**	**17**
Water 2	**Number of water pumping stations**	**Number**	**0**
Water 3	**The number of industrial water and sewage stations**	**Number**	**0**
Water tank 1	**The number of reservoirs and dams**	**Number**	**0**
Water tank 2	**High number of tanks**	**Number**	**0**
Gasoline and diesel fuels	**The number of gas stations, etc**	**Number**	**2**

5- Determining the earthquake scenario

Predicting possible events and their effects is called scenario preparation. Scenario preparation is often done in order to prepare a plan and create preparedness in disaster-prone communities and helps to better understand the possible future. Of course, it should be noted that when an earthquake occurs, its effects and results will definitely have differences with the results of the scenario. The scenario is only a hypothesis to know that the effects of the earthquake are worse or similar to what the scenario has calculated. Being prepared based on the obtained earthquake scenario helps us to prepare to face a real earthquake in that area and take the necessary measures to reduce the damage and losses caused by a possible earthquake in that area.

Among the many faults in the region, the most likely dangerous fault, the North Tabriz fault, which is located in the northeast of the region, was selected. By studying the historical earthquakes of Barzagi region, the earthquake was selected in three scenarios of 5, 6 and 7 Richter and also the depth of the earthquake was 5 km.

As a result, the following three models for scenario earthquakes were considered in the RADIUS program, whose specifications can be seen in Table (4), and the time of the earthquake is considered to be 1 am.

- North Tabriz fault model with 5 Richter scenario
- North Tabriz fault model with 6 Richter scenario
- North Tabriz fault model with 7 Richter scenario

Table 4. Characteristics of earthquake scenario models

Specifications	North Tabriz fault model	North Tabriz fault model	North Tabriz fault model
Location relative to the area	northeast	northeast	**northeast**
Magnitude of the earthquake	7	6	**5**
Earthquake depth	15 km	15 km	**15 km**
Distance from reference network (8)	4.2 km	4.2 km	**4.2 km**

In the continuation of the results, the amount of destruction of buildings and damages caused by these scenarios will be explained in detail.

5. Results and Discussion

The results of estimating damages caused by earthquake in Tabriz city using RADIUS approach.

Based on the stated contents, the results of damages and casualties caused by the earthquake are based on the scenarios considered in the study area according to table (5). The statistics and figures in the table indicate that, based on the 5 Richter scenario, 1093 buildings will be destroyed, 55 people will be killed and 650 people will be injured. According to the 6 Richter scenario, 2526 buildings will be destroyed, 252 people will be killed and 2270 people will be injured, and also according to the 7th scenario, 4345 buildings will be destroyed, 680 people will be killed and 4340 people will be injured. Also, the results of the table show that the central parts of the studied area (zones 2, 3, 6, 7, 8, 9, 13, 14, 18 and 19) will have the highest level of vulnerability based on the desired scenarios. In order to have a spatial perspective regarding the amount of casualties in relation to the studied area and the statistics and figures stated in the table can also be specified in terms of location, the percentage of destruction of buildings based on the considered scenarios is shown in figures (5, 6, and 7). According to these figures, in the most damaged zones, 20-26% of the buildings will be destroyed in the 5th Richter scenario, 35-45% of the buildings will be destroyed in the 6th Richter scenario, and 55-60% of the buildings will be destroyed in the 7th Richter scenario. It should be noted that the number of dead and injured is affected by the level of destruction of buildings, that's why only the map of the destruction of buildings is mentioned. The results of damage to vital arteries based on the considered scenarios are shown in table (6), the statistics of the table show that according to the Richter 5 model, 2.3 percent of the road network, 0.8 percent of water and sewage lines and 2 9.9% of the fuel stations in the study area will be destroyed, according to the Richter 6 model, 5.2% of the road network, 1.9% of the water and sewage lines and 18.9% of the fuel stations will be destroyed. Also, according to the Richter 7 model, 11.4% of road network, 4.4% of water and sewage lines and 28.8% of fuel stations will be destroyed in the study area.

Table 5. Amount of damages and casualties in the 8th area of Tabriz in different scenarios

The injured	The dead	Building	Earthquake scenario
650	55	1093	**Richter 5 scenario**
2270	252	2526	**Richter 6 scenario**
4340	680	4345	**Richter 7 scenario**

Table 6. Percentage of damage to the vital arteries of the region in different scenarios

Earthquake scenario	Road type 1	Road type 2	Water and sewer lines	gas stations
Richter 5 scenario	2.3	0	0.8	**9.2**
Richter 6 scenario	5.2	0	1.9	**18.9**
Richter 7 scenario	11.4	0	4.4	**28.8**

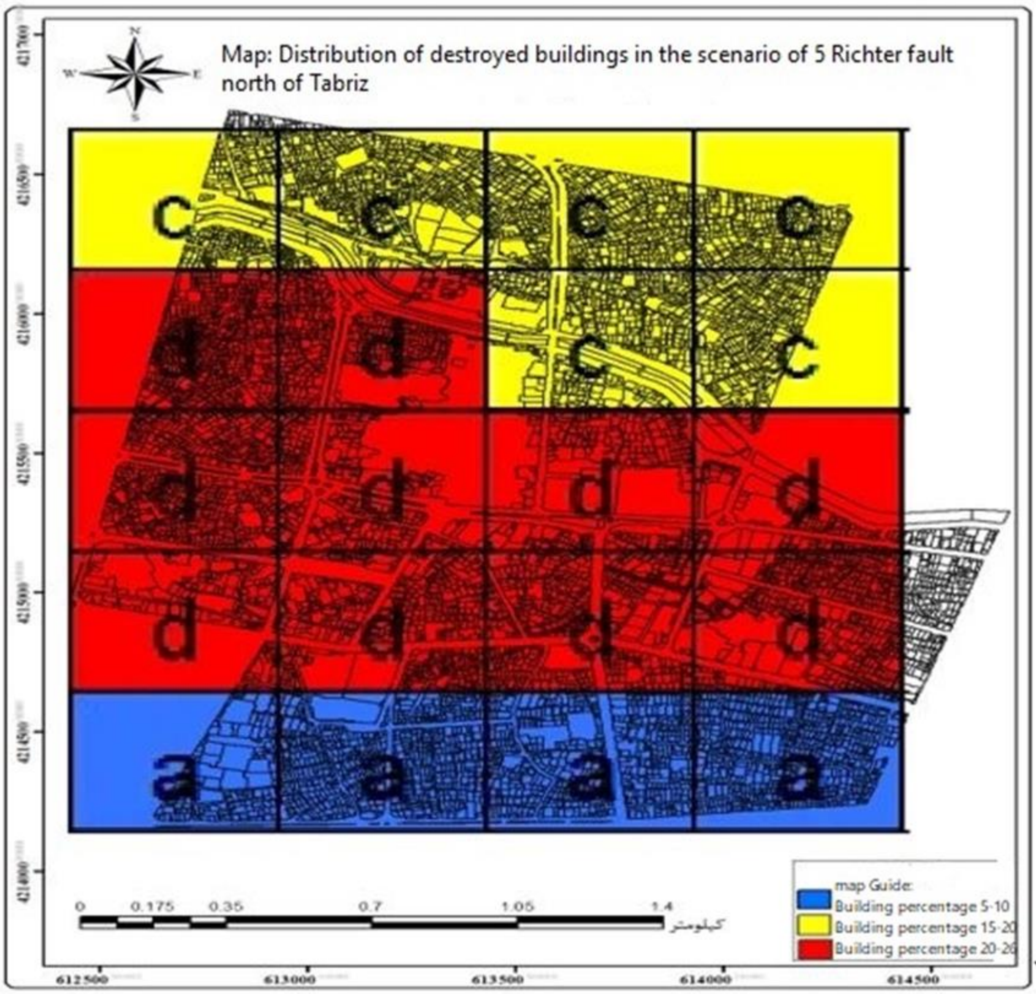

Figure 5. Building destruction map based on the 5 Richter scenario

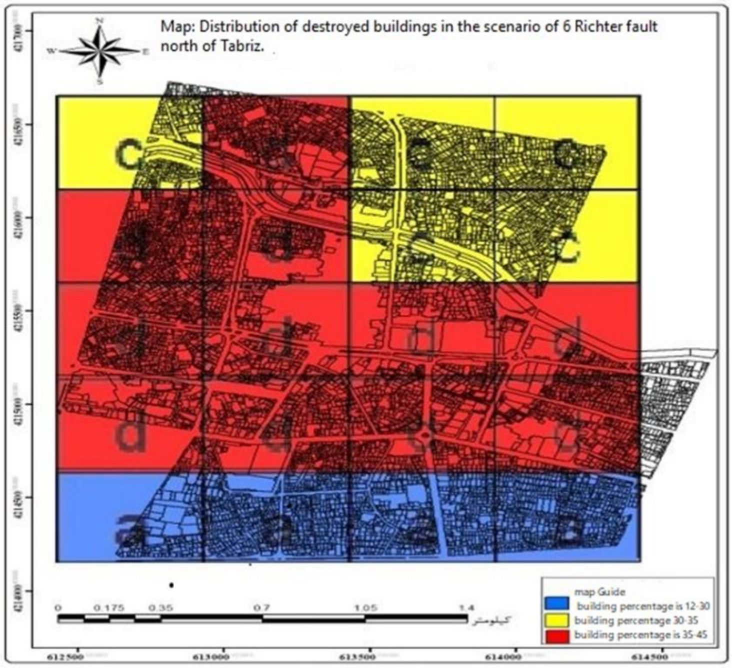

Figure 6. Map of the percentage of buildings based on the 6 Richter scenario

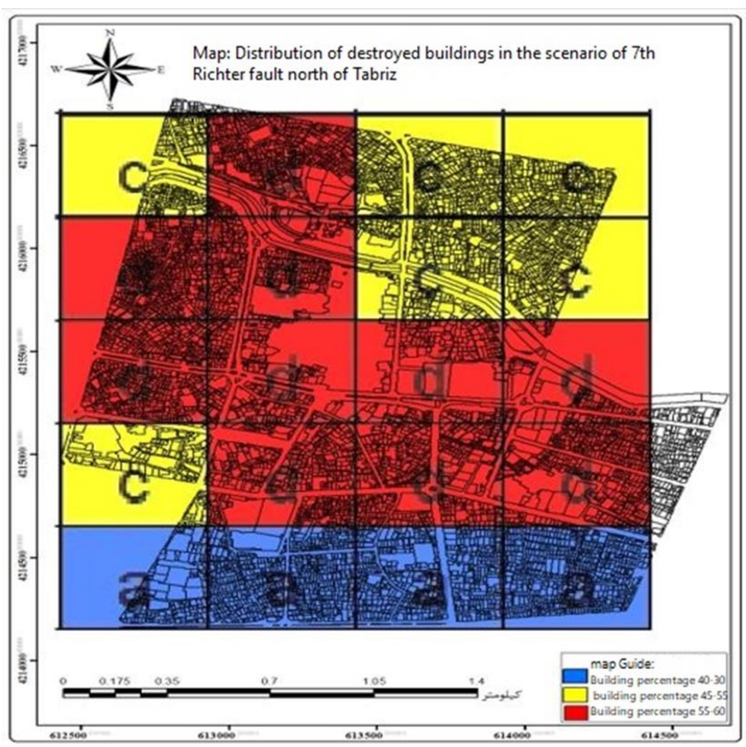

Figure 7. Map of the percentage of buildings based on the 7 Richter scenario

6. Conclusion

Examining the results of the earthquake damage estimation in the study area based on the three developed scenarios, indicates that the 7th scenario will cause the most damage to the area. One of the most important advantages of the RADIUS model is that all the relationships and functions used in the program are clearly shown and available, and if needed, it is possible to change and localize them based on the functions available in the country. By using this approach to formulate an earthquake scenario and estimate possible damages, we can have a better understanding of the earthquake and the amount of risk we are facing, as well as the extent and range of damage and vulnerable areas in the city will be determined. Radius model has a simple structure and its use does not require complex expertise, so local experts can easily use it.

Many models have been presented to analyze and evaluate the vulnerability of cities against earthquakes, and various researches have been conducted both inside and outside the country. In the works that have been done inside the country, the damage has been checked.

Small areas have not been done, for example, we can refer to the JICA project (2008) which has investigated vulnerability in the form of statistical areas. Undoubtedly, the vulnerability of any region is not unrelated to the human characteristics of that region and it is a reflection of human behavior and the human management method of that region, because the construction and implementation of engineering principles in the building depends on the opinions and thoughts and the human management method. Yes, as Alexander states that vulnerability varies from place to place and from time to time (Smith, 2002), which indicates the difference in the social, cultural and geographical characteristics of one region compared to another region. Therefore, in any research, the models used should be compatible with the conditions of the studied area, which was not considered in the research conducted by JICA for Tehran city, and they are based on the failure curves that were developed by Tavakli. 1993) was prepared for Rudbar and Manjil, they used it for the city of Tehran and used it as the basis of their work. In this regard, it can be useful to use different opinions of experts who are related to the city, building and earthquake and can be effective in determining the criteria and weighting them and make the results more reliable, which in the works and research done are not seen. Another topic is the investigation of vulnerability in different intensities of earthquakes, which is usually less observed in the research conducted in the country. Therefore, depending on the influencing factors, including the intensity of the earthquake, the location of the fault (far and near), the geology of the area (soil type) in each scenario will have a direct relationship with the intensity of destruction.

In this research, many of the mentioned cases have been taken into consideration, the area's vulnerability has been examined partially and in the form of small areas according to the model used, and the degree of damage has been obtained and examined in three scenarios.

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