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VULNERABILITY ZONING OF URBAN AREAS AGAINST EARTHQUAKE (CASE STUDY: URMIA CITY)

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Abstract. The danger of earthquake always overshadows human societies and causes irreparable damage to these societies; therefore, preparedness to deal with this crisis by identifying vulnerability points and removing them is effective in reducing the damages caused by earthquake. Due to the location of Iran on one of the two world's earthquake belts and the existence of many faults, the occurrence of earthquakes on the plateau of Iran is a natural phenomenon. Iran is one of the ten earthquake-prone countries in the world. Consequently, the city of Urmia is no exception to this rule due to its location in the hillsides of the Zagros Mountains and witnesses a large number of earthquakes with different intensities every year. Therefore, to deal with the above problem, we need more detailed studies in the fields of construction and safety. In this study, in order to evaluate the severity of earthquake vulnerability, effective parameters were identified and weighted using fuzzy hierarchical analysis process. Vulnerability maps were prepared by index overlap method and fuzzy logic, for statistical blocks of Urmia city and were presented visually in spatial information system. The results showed that about 50% of the city is vulnerable to earthquakes; to be more precise, about 151574 square meters, i.e. 0.005% has a very high degree of vulnerability and 11538359 square meters, with a percentage of 0.40%, has a high degree of vulnerability to earthquakes.

Keywords: zoning, risk assessment, earthquake, fuzzy logic, Urmia city.

Introduction

Natural hazards are the realities of our world today that significantly affect people's living conditions. Because they are not preventable, basic precautions must be taken to protect people before they occur.

It is at this point that preparedness for any threat is really important, which reduces the devastating effects of disasters on communities and shortens recovery interventions. In terms of preparedness to identify vulnerable people in the community plays an important role in better planning in natural disaster management (Haki, 2003). Urban planning in most Third World cities is routinely faced with unpreparedness to deal with future events, and therefore, natural disasters occur before taking appropriate measures (Smith, 2003). Today, the current civilization has become more urban and urban growth has had adverse consequences on the body of cities. The dimensions of urban settlements are becoming more complex day by day and as a result, security instability is becoming more apparent in urban areas. In this way, urban society, especially in its modern forms, is constantly and extensively exposed to various types of hazards (Amini Varaki et al., 2014). On the other hand, this rapid development of cities and the increasing urban population in recent decades, has made planning, management and control of cities more and more difficult. This problem becomes much more complicated during natural disasters, especially when they are accompanied by social anomalies (Habibi et al., 2012). Among the natural hazards and crises, earthquakes are one of the most important hazards that affect many countries throughout the year and always are a factor whose impact on human societies has been remarkable, both in terms of casualties and economic aspects, during History (Ziari, 2006; Mahdavi & Hazarian, 2017). Earthquake, both psychologically and financially, due to the speed and occurrence of the volume of destruction, has had devastating effects and are at the forefront of natural disasters (Shamsipoor & Sheikhi, 2010). The intensity of this impact is a function of various

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factors that cause vulnerability and crisis (Zangiabadi & Tabrizi, 2009, p. 116). Urban vulnerability analysis is the assessment and prediction of the possibility of human, material and moral damage to the city and its residents against possible hazards (Musavand, 2011). There are various vulnerable factors (natural, physical, social, economic, fundamental, laws and regulations, etc.) that constantly affect each other; not individually but in a comprehensive system. On the other hand, crisis vulnerable groups are also associated with demographic factors such as age, religion, minority, poverty and literacy (Paton & Johnston, 2001). According to statistics released by the United Nations, more than 3 million people have died from natural disasters in the last 20 years, and the lives of more than one billion people have been affected by these disasters (United Nations, 1991). Due to its geographical location and geology, Iran is one of the ten most catastrophic countries in the world and has always suffered significant human and financial losses due to disasters such as floods, droughts, hurricanes, etc. (Hashemi et al., 2010, p. 306). The city of Urmia is also one of the most important cities in Iran, which despite its special conditions has a high seismic potential. The plateau, in which the city of Urmia is located and includes Lake Urmia, is an area with an altitude of 1300 to 3000 meters above sea level. This area is a mountainous area that decreases in height from west to east. This range of mountains and their peaks are mostly located on the border of Iran and Turkey. Existence of young and border mountains and large number of faults around Urmia city has increased the possibility of seismicity in the city. Therefore, in order to prevent the increase of vulnerability, it is necessary to know the resilience of the local community and measure the ability of the community to withstand and recover from risks in the event of a crisis. With this backdrop, in this study, we have made an attempt to identify the earthquake-vulnerable areas in different areas of Urmia accurately.

1. Theoretical foundations of research

Environmental hazards: Burton and Kit define natural hazards as hazards posed by forces outside society. (Ghafouri Zarandi et al, 2009, p. 2). For example, floods are now less prevalent due to climate induced natural fluctuations and are more related to human activities such as drainage, canalization and deforestation (Burton et al., 1999). Natural hazards have the ability to turn into horrible accidents in the absence of hazard reduction systems (Karami & Amirian, 2018, p. 111). Vulnerability of societies: The concept of vulnerability of physical and human capital during crises in rural areas are most important issues that is taken into consideration today in many fields of study such as sociology, general humanities, and general humanities. In general, the concept of vulnerability provides a very suitable framework for understanding the nature of the crisis, critical events, effects and consequences of the crisis, as well as response to the crisis at different levels. Extent of potential damage due to natural disasters to communities, buildings and geographical areas is also used. According to the UNESCO definition, the sensitivity of the environment to the occurrence and severity of a natural disaster determines the vulnerability of that environment. According to the UN Strategic Plan for Disaster Reduction, all hazards have two sources, natural hazards and hazards from activities and technology that result from human intervention (Moe & Pathranakul, 2006, p. 396). In general, we mean vulnerability is an internal condition that increases exposure and sensitivity, vulnerability to other dangers or other shocks and pressures (United Nations Office for Disaster Risk Reduction, 2004, p. 207). In other words, vulnerability to damage caused by potential or actual critical elements and phenomena to manpower, equipment and facilities in the range of zero to one hundred (Wihtol de Wenden, 2006, p. 49) are very different vulnerability factors, which include natural, physical, social, economic, fundamental factors, laws and regulations, etc. These factors affect each other, not individually, but as a system of society (Paton & Fohnston, 2001, p. 270). Today, the vulnerability of rural settlements, defenseless spaces, insecure neighborhoods, villages with wrong architecture, all are security threats (Bayat, 2008, p. 86) that can cause major disruptions in any residential area and disrupt the other functions of organizations (Reynal-Querol & Montalvo, 2005, p. 8). On the other hand, the issue of protection of human lives, their belongings against natural and human hazards is so important that it is considered as one of the main goals of planners (Gibson, 1997, p. 8). Therefore, finding useful solutions to reduce vulnerability is always a priority for governments and their communities.

Vulnerability: Vulnerability is defined as a continuous measure of the comfort of combining environmental, economic, and political elements exposed to a range of potentially harmful disturbances. According to the definition of the United Nations (1991), vulnerability is: the degree of loss of a certain element or group of elements at risk, as a result of the occurrence of a natural phenomenon of a certain magnitude and expressed on a scale from zero (without vulnerability) to one (complete vulnerability), (Kamelifar, 2012, p. 431). On the other hand, vulnerability is defined in terms of different principles such as the degree of loss and damage caused by a potentially harmful phenomenon, socio-economic status and a feature of a human-environmental system (Maleki et al., 2017, p. 10).

Urban vulnerability: is a measure of the capacity difference of urban communities to deal with the effects of natural hazards based on their position in the material world (spatial structure of the city) and the social characteristics of those communities (social structure) (Ahadnejad Roshani, 2009, p. 43). Urban Vulnerability Theory: Based on the theory of urban vulnerability and its conceptual features in any given urban space, there is a certain amount of risk, but the levels and scope of vulnerability and safety are not evenly distributed in the city; Because spaces with the title of polluted, defenseless, vulnerable are the place where all kinds of violence, crimes and even environmental hazards occur (Mohammadi Deh Cheshmeh, 2013, p. 47).

2. Research background

Vulnerability of settlements to natural events such as earthquakes is a function of the behavior of human units, which indicates the degree of vulnerability or ability to withstand socio-economic and damage assets. One of the principles of risk management is the need to carefully locate the elements of the environment and intelligently use design facilities to reduce the damage caused by this event and hazards (Burton et al., 1999). Nagae et al. (2012) provide a framework for finding ways to strengthen the anti-seismic, for transportation facilities and urban road network. To test the computational efficiency and rationality of the method, they used its scenario in Kobe, Japan and its suburbs. Lantada et al. (2009) performed modeling of the vulnerability of the city of Barcelona using the Risk_UE model, to assess the human and economic damage in the city of Barcelona. Cutter et al. (2003) assessed and analyzed social disaster vulnerability in the United States. Haki (2003) has evaluated Social Vulnerability Assessment to earthquake using Geographical Information System in Pendik district of Istanbul. Khakpour et al. (2011) determined physical vulnerability in the 9th district of Mashhad from the perspective of seismicity and concluded that the city of Mashhad lies in a moderate risk area. Further they prepared vulnerability zoning maps which were helpful to adopt necessary solutions in the field of urban management. Habibi et al. (2013) have assessed physical-spatial indicators for predicting the instability of ancient urban textures against earthquakes with inverted hierarchical logic and GIS affecting the vulnerability of cities.

Isalou et al. (2016) employed IHWP Method in GIS using 5 Indicators (Land Use, Building Quality, Building Life, Access to Relief Centers and population density) to assess physical vulnerability of earthquake in Tehran. Faraji Sabkbar et al. (2016) performed vulnerability assessment using field data and satellite images and concluded that the aged buildings lying in the central, southern and especially southeastern parts in Tehran are more vulnerable to earthquakes.

Darban Astaneh et al. (2018) employed AHP FUZZY method to determine the vulnerability of residential fabric to earthquake risk in District 6 of Tehran and showed that the neighborhoods of Amirabad, Nosrat, Ghezel Ghaleh, University of Tehran and Laleh Park have low vulnerability and Shariati, Argentina-Saei, Behjatabad and Gandhi neighborhoods have moderate vulnerability. Vulnerability analysis has also been conducted by several other researchers namely Allen and Bryant (2011), Normandin et al. (2011), Ainuddin and Routray (2012), Mokhtari et al. (2018), Poorahmad et al. (2018).

3. Materials and methods

3.1. Study area

Urmia city is one of the fourteen cities of West Azerbaijan province, which is located in the middle part of the province. Urmia city is limited to Salmas city from the north, Naqadeh and Mahabad cities from the south, Urmia Lake from the east and Iran-Turkey border from the west. The city of Urmia is the center of the city and also the capital of the province of West Azerbaijan, which is located 18 km from Lake Urmia, at 45 degrees and 4 minutes east longitude from the Greenwich meridian and 37 degrees and 33 minutes north latitude from the origin of the equator inside a 70-meter-long plain Km and is located 30 km wide (Design and Planning Consulting Engineers, 2013, p. 24). According to the latest census provided by the Statistics Center of Iran, this city has a population of 680,000 people, which in total have been spread in the area of the city (Figure 1).

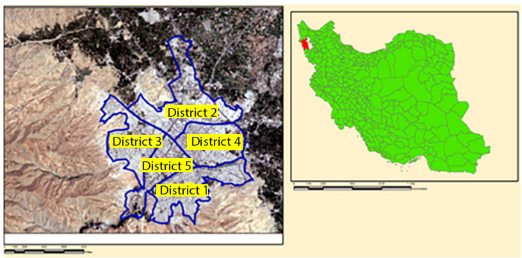

Figure 1. Location of Study Area in IRAN

3.2. Research method

The present study is applied in terms of goal setting and "descriptive-analytical" in terms of data collection method. In order to achieve the final goal of the research, first the production and formation of physical data and natural factors affecting the vulnerability caused by earthquakes were discussed. The steps of this research are described in Figure 2.

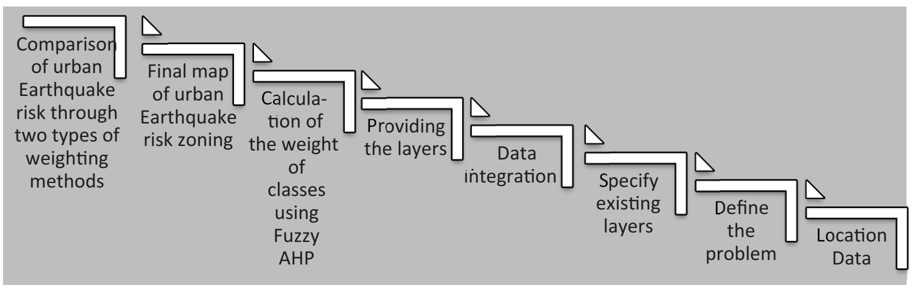

Figure 2. Overview of research steps

In this research, first the data related to the physical part and buildings were extracted from the comprehensive plan of Urmia city and then using Arc GIS software it was converted into vector layers and then through the fuzzy hierarchical model weights were assigned to the produced layers.

In the next step, the weights and ranking values were assigned to the layers and classes of each layer. The process of assigning weights and ranked values was executed using the Fuzzy AHP method. FAHP is a multi-criteria decision-making approach that uses the pairwise comparison procedure to achieve the desired goals among multiple options and selects the desired locations with different performance. Therefore, in the following, an explanation about these two decision-making methods is provided.

3.3. FAHP hierarchical analysis model

This model was first proposed in 1983 by two Dutch researchers named Larhorn and Pedriks, which is based on the logarithmic least squares method, but was not accepted due to the complexity of the computational and methodological steps, until in 1996 a Chinese researcher named Chang. He presented a method called developmental analysis method based on fuzzy hierarchical analysis in which triangular fuzzy numbers were used (Ataiee, 2010, p. 64). Fuzzy numbers used in this model and specifically in the present study as Fuzzy numbers are triangular 2 which will be M = (m, α, β) (Momeni, 2013, p. 87). The geometric space of such a set in a fuzzy environment is given in Figure 3.

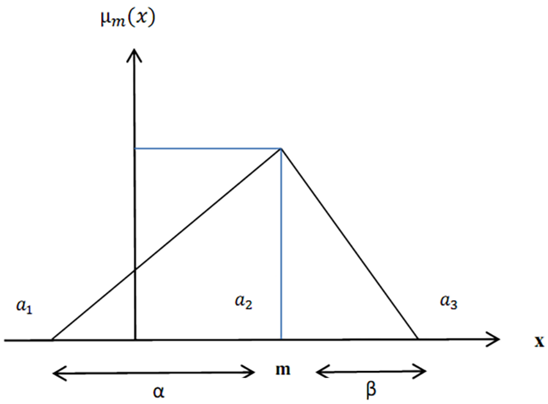

Figure 3. The membership function of triangular numbers in a fuzzy environment

The mathematical structure of the membership of triangular fuzzy numbers will also be as follows.

$$\left\{\begin{matrix} 1-\dfrac{m-x}{\alpha} m-\alpha \le x \le m \\ 1-\dfrac{x-m}{\beta} m \le x \le m+\beta \\ If \ne 0 \end{matrix}\right\}.$$

Therefore, according to Chang method, the fuzzy hierarchical analysis model has the following steps:

Step 1: In this step, a hierarchical diagram is drawn.

Step 2: In the second step, fuzzy numbers are defined for pairwise comparisons. Based on the studies that have been done in this regard and also the recommendation that Chang offers, the fuzzy spectrum used in this research is presented in the form of Figure 4.

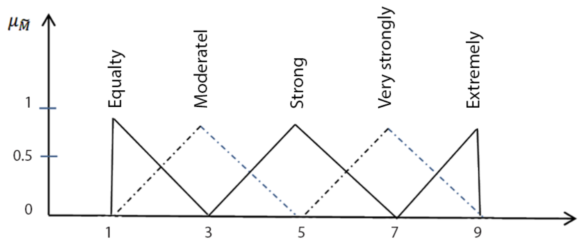

Figure 4. Linguistic variables used in the research

Step 3: The formation of the matrix will be a pairwise comparison that has been done using triangular fuzzy numbers in the present study.

$$\tilde{A} = \begin{bmatrix} \tilde{x}_{11}\tilde{x}_{12}\dots\tilde{x}_{1n} \\ \tilde{x}_{21}\tilde{x}_{22}\dots\tilde{x}_{2n} \\ \dots\dots\dots\dots \\ \tilde{x}_{m1}\tilde{x}_{m2}\dots\tilde{x}_{mn} \end{bmatrix}.$$

Step 4: Calculate the value through the following equations:

$$S_i = \sum_{i=1}^{m} M_{gi}^{i} \otimes \left[\sum_{i=1}^{n}\sum_{i=1}^{m} M_{gi}^{i} \right]^{-1};$$

$$\sum_{i=1}^{n}\sum_{i=1}^{m} M_{gi}^{i} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right);$$

$$\left[\sum_{i=1}^{n}\sum_{i=1}^{m} M_{gi}^{i} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} l_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} u_i} \right).$$

In this relation, *i* and *j* are the row number and the column number, respectively.

Step 5: The calculation the degrees of magnitude for all indicators will be in which the magnitude of two fuzzy numbers of and is defined as follows:

$$\left\{\begin{matrix} 1 \ if\ m_1 \ge m_2 \\ 0 \ if\ u_2 \ge l_1 \\ \dfrac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} \ otherwise \end{matrix}\right\}.$$

Step 6: In this model, calculating the weight of the indicators in the matrix will be a pairwise comparison. The following relationship has been used for this purpose:

$$d'(A_i) = MinV(S_i \leq S_k),\ k = 1, 2, \ldots n.$$

Therefore, the non-normalized weight vector for the research indicators will be as

$$W'(d'(A_1)\, d(A_2) \ldots d(A_n))^T.$$

Final step: In this model, the calculation of the final weight vector will be:

$$W = (d(A_1)\, d(A_2) \ldots d(A_n)).$$

4. Results and discussion

In the stage of data analysis and research information, it is necessary to draw 13 urban earthquake risk variables in study area (distance from fault, slope, land type, type of land cover, distance from medical centers, urban facilities, green space, urban gas station, quality fire, number of floors, area of buildings and the status of access to buildings). Therefore, to do this, we first prepared a base map of the study area and formed a database and mapped the layers related to each of the 13 variables in the form of Arc GIS software, Figures 5–14.

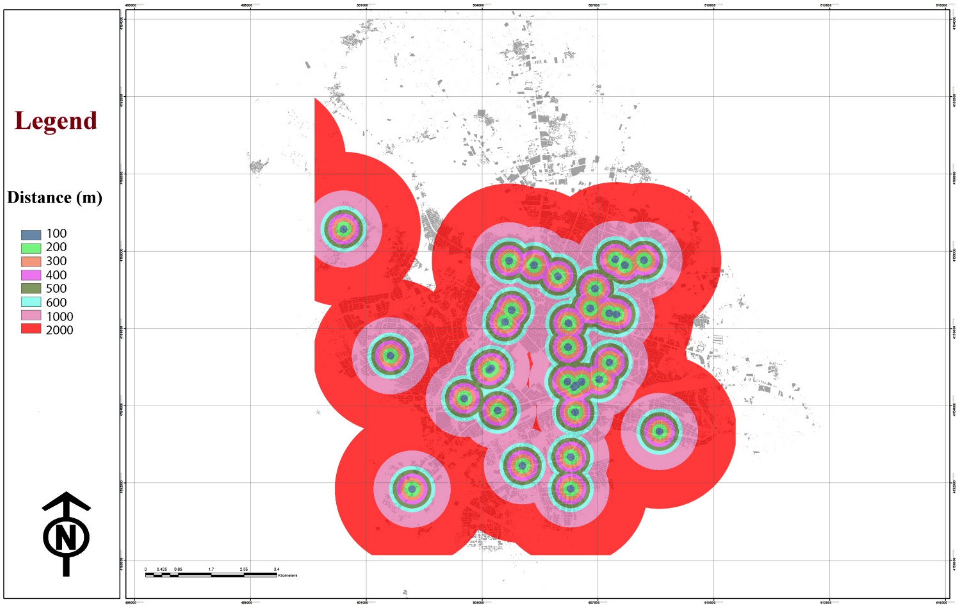

Figure 5. Distance health centers area

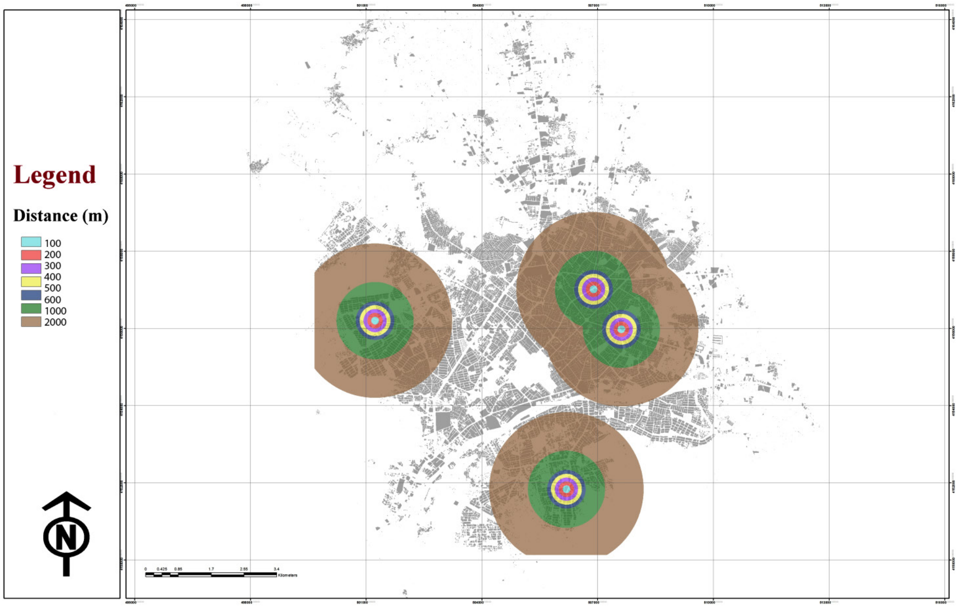

Figure 6. Distance fire stations area

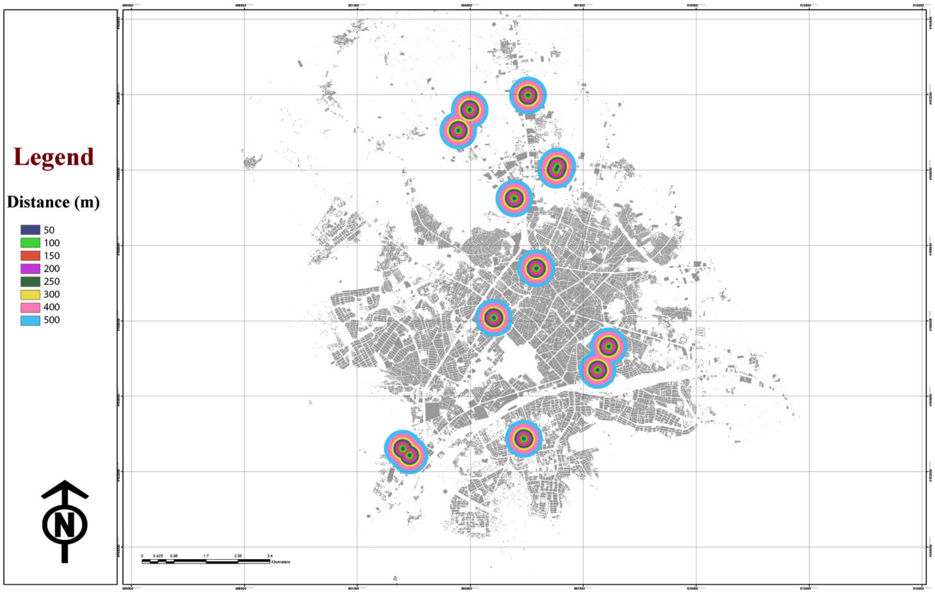

Figure 7. Distance urban gas stations

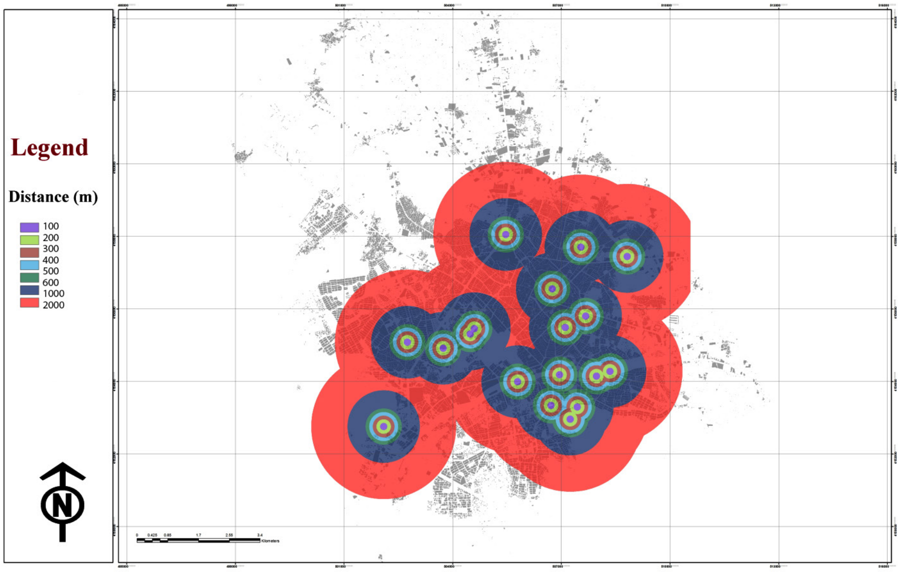

Figure 8. Distance green spaces and park

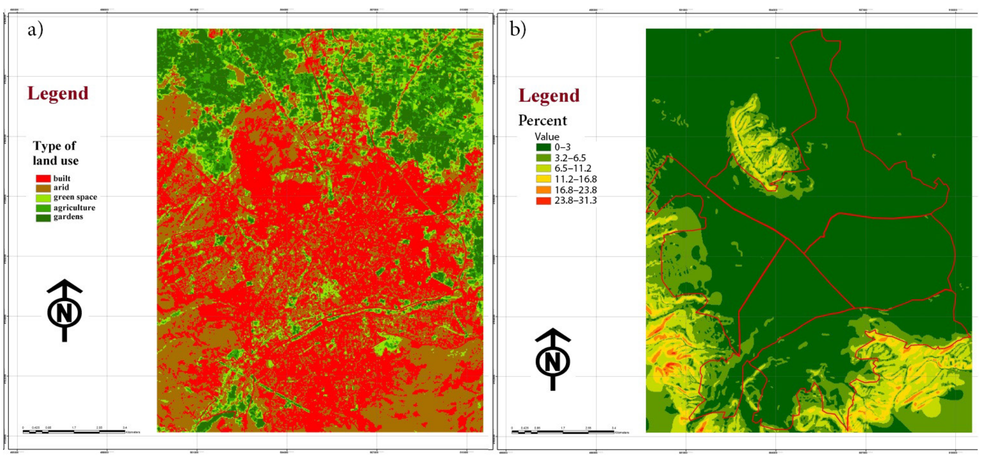

Figure 9. Maps of a) type of land use, and b) slope classes

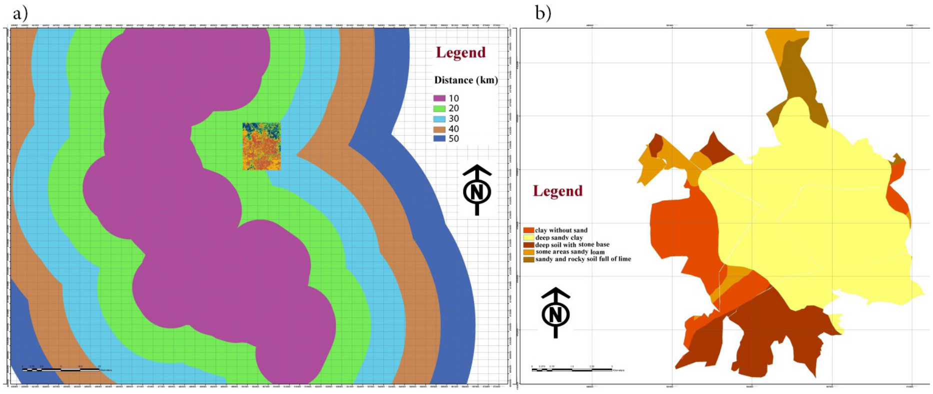

Figure 10. Maps of a) city distance from faults, and b) land type

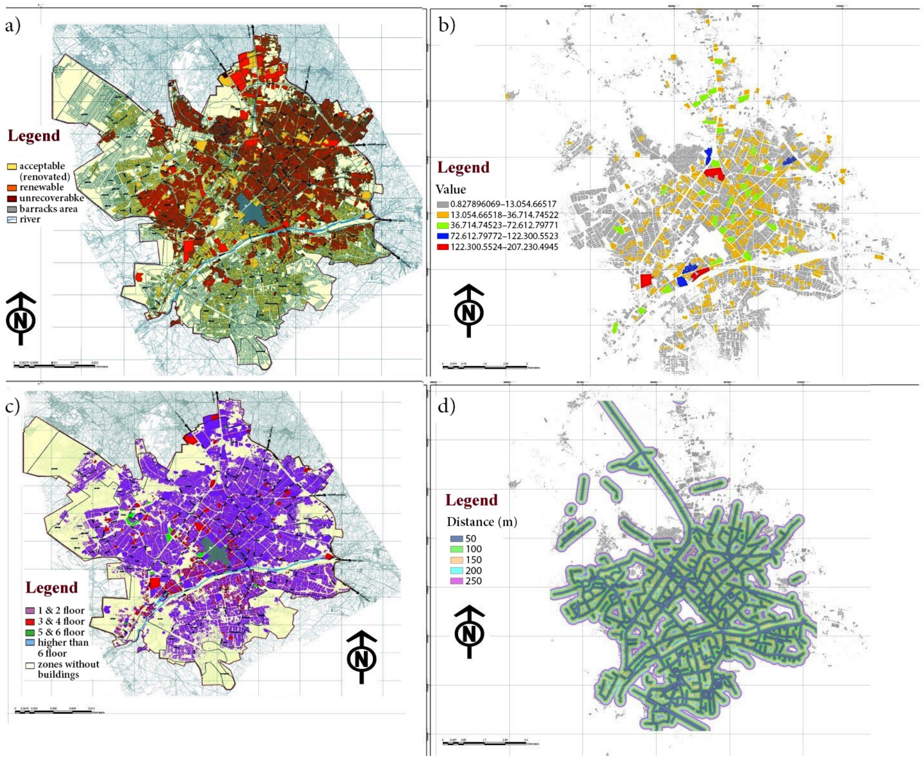

Figure 11. Maps of a) quality of buildings, b) block area, c) buildings floors number, and d) access to buildings

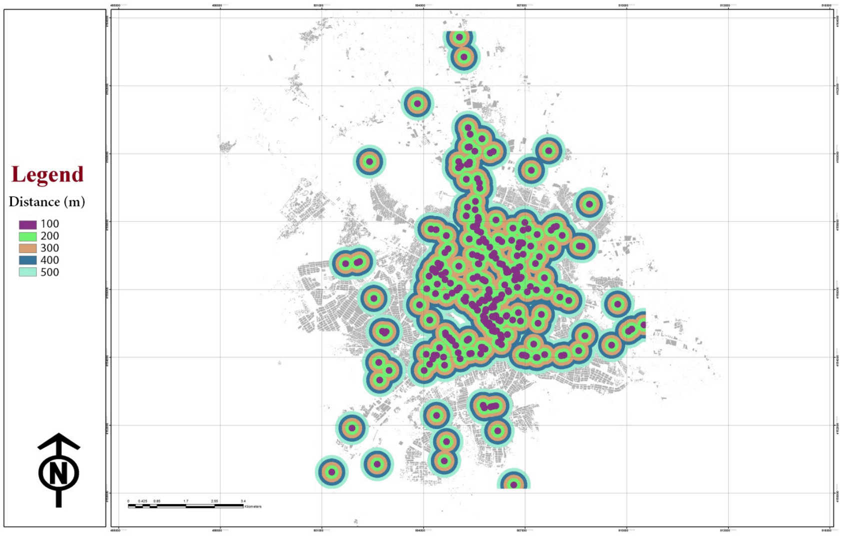

Figure 12. Distance from important urban facilities and equipment affecting vulnerability

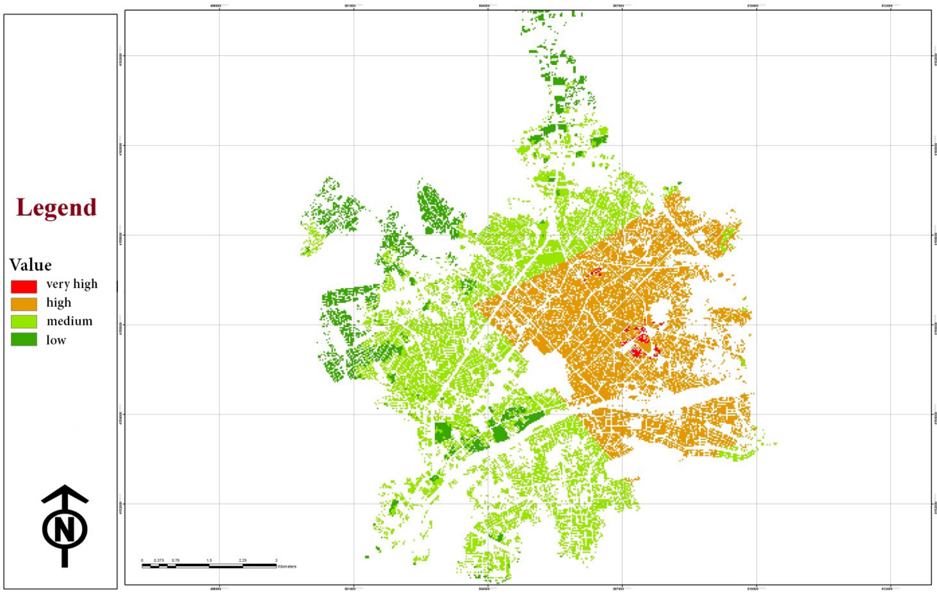

Figure 13. Final map of earthquake vulnerable areas in the city of Urmia using the Fuzzy AHP model

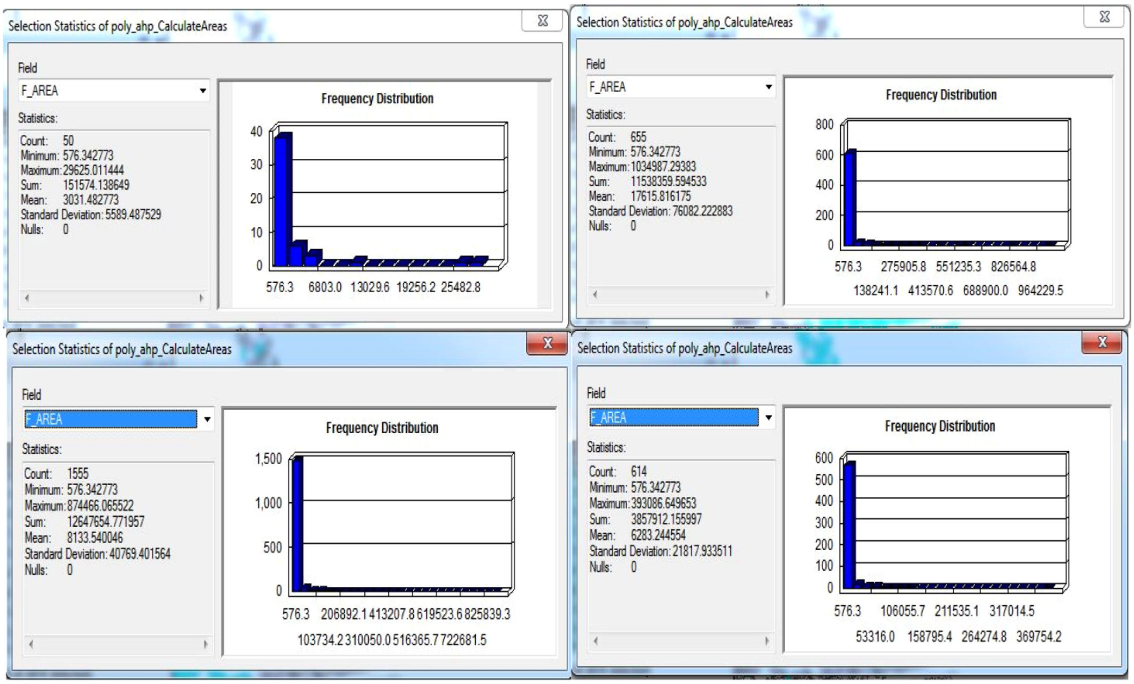

Figure 14. Area of vulnerable zones in grades 1 to 4 (from left to right)

Then, after preparing the maps, a fuzzy hierarchical model was used to achieve the desired result. In this model, after weighting the research variables in the form of trigonometric fuzzy numbers, the variables with different weights from minimum weight to maximum weight were identified, which are shown in the Table 1.

According to Figure 15, the east of Urmia is very vulnerable to earthquakes. To be more precise, about 42% of Urmia is highly vulnerable to earthquakes. These areas often include District 2 of Urmia Municipality. These areas are less safe due to the type of texture and materials used in its construction. These areas cover an area of 11 689 933 square meters, which includes the city center to the east and southeast of the city (Figure 13). However, about 58% of the city is in the grade of medium and low vulnerability, which is an area of 16 505 566 square meters, which is located in the west and north of the city. This area has new houses and buildings in terms of construction and often includes a small number of floors and high quality.

Table 1. Final weight of layers for zoning of vulnerable areas

Options	Abnormal weight	Normalized weight
Distance from fault	0.64	0.141
Slope	0.38	0.084
Land type	0.27	0.060
Land use	0.24	0.053
Distance from health centers	0.17	0.038
Distance from green areas	0.21	0.046
Distance from fire stations	0.14	0.031
Distance from urban gas station	0.18	0.040
Distance from urban facilities	0.19	0.042
Buildings floors number	0.45	0.099
Buildings area	0.34	0.075
Quality of buildings	1	0.221
Access to buildings	0.32	0.071

Conclusions

Vulnerability is a function of the degree to which a system is exposed and sensitive to the degree to which places and individuals are harmed. In recent years, much attention has been drawn to the issue of vulnerability and its management among planners, governments and nations. The catastrophes that have occurred in recent years indicate that communities and individuals are becoming increasingly vulnerable and the risks have increased. However, risk reduction and vulnerability are often overlooked until after an accident. The characteristics and conditions of urban spaces and the density of investments and environmental loads have made it necessary to pay attention to the necessary planning regarding the immunity of cities against various types of hazards. With the development of societies and the complexity of internal processes in cities (physical, structural, social and economic), the effects of natural disasters have become very complex and it is much more difficult to reduce and control vulnerabilities. Therefore, the study of the effects of natural disasters on human settlements, especially cities, is one of the most important issues for urban planners. It is clear that so far the lack of attention to the principles of crisis management has caused a lot of damage from numerous earthquakes to residential communities. Studies on the topic of prevention have shown that the study of physical vulnerability in the texture of cities and attention to the principles and standards of urban planning in it and the improvement and renovation of the texture that needs action, can greatly reduce the effects of earthquakes. The possible occurrence of an earthquake in the city of Urmia and related concerns has made it necessary to assess physical vulnerability. In this study, according to the special conditions of Urmia, 13 different indicators such as: distance from fault, land type, number of building floors, quality of buildings, access status, etc. were used to express the vulnerability of

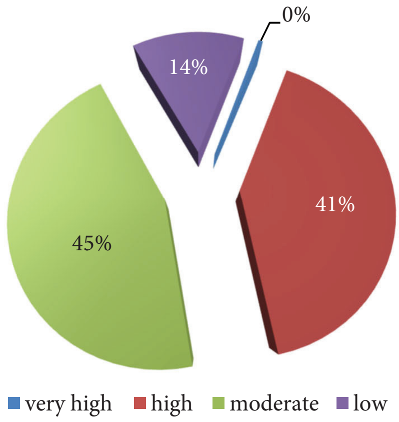

Figure 15. Graph of the percentage of earthquake-vulnerable areas in the city of Urmia Using the Fuzzy AHP model

the region to earthquakes. The results showed that according to the type of materials used in housing construction, the number of floors and the quality of buildings and the weights assigned to it, about 42% of the area of Urmia, which is 11689933 square meters, has a high potential for damage. The northern and western regions of Urmia have less potential against earthquakes due to their renovation and better access to the main arteries and green space. Therefore, according to the evaluation of the study area, District 2 of Urmia should be renovated or improved in terms of construction and the quality of access to buildings in this area should be improved.

References

Ahadnejad Roshani, M. (2009). *Modeling the vulnerability of cities to earthquakes, a case study; Zanjan* [PhD Thesis]. Faculty of Geography, University of Tehran, Iran.

Allen, P., & Bryant, M. (2011). Resilience as a framework for urbanism and recovery. *Journal on Landscape Architecture*, *6*(2), 34–45. https://doi.org/10.1080/18626033.2011.9723453

Amini Varki, S., Modiri, M., Shamsaii, F., & Ghanbari Nasab, A. (2014). Developing and presenting a model for assessing threats, vulnerabilities and risk analysis of critical infrastructures with emphasis on passive defense. *Iranian Journal of Crisis Management, 4*, 69–85.

Ainuddin, S., & Routray, J. K. (2012). Community resilience framework for an earthquake prone area in Baluchistan. *International Journal of Disaster Risk Reduction*, *2*, 25–36. https://doi.org/10.1016/j.ijdrr.2012.07.003

Ataiee, M. (2010). *Fuzzy multi-criteria decision making* (2 ed.). Shahroud University of Technology Press.

Bayat, B. (2008). *Sociological explanation of the feeling of security of Tehran citizens* [PhD Thesis]. Faculty of Sociology, University of Isfahan, Iran.

Burton, I., Kates, R., & White, G. F. (1999). *The environment as hazard.* Oxford University Press.

Cutter, S., Boruff, B., & Shirley, W. (2003). Social vulnerability to environment hazards. *Social Science Quarterly*, *84*(2), 242–261. https://doi.org/10.1111/1540-6237.8402002

Darban Astaneh, A., Sheikhzadeh, M., & Bazigar, S. (2018). Strategies to reduce the vulnerability of residential fabric to earthquake risk Case Study: District 6 of Tehran. *Iranian Journal of Geography and Urban Planning*, *6*(2), 288–265.

Design and Planning Consulting Engineers. (2013). *Master plan of Urmia city.*

Faraji Sabkbar, H. A., Ghaderi, B., & Rezaei Narimisa, M. (2016). Factors affecting vulnerability in district 6 of Tehran and vulnerability zoning in the face of natural crises. *Urban Management Studies*, *8*(28), 1–11.

Ghafouri Zarandi, A., Qamian, G. H., & Amini Hosseini, K. (2009). Earthquake; sustainable rural development and risk management. In *The First National Conference on Sustainable Rural Development* (pp. 1–3). Razi University, Kermanshah.

Gibson, G. (1997). *An introduction to seismology, disaster prevention and management.* MCB University Press, Emerald Group limited.

Haki, G. Z. (2003). *Assessment of social vulnerability using geographic information systems: Pendik, Istanbul case study* [Msc Thesis]. Middle East Technical University, Turkey.

Habibi, K., Sarkargar Ardakani, A., Yousefi, Z., & Safdarnejad, M. (2012). Implementation of fuzzy hierarchical algorithms to determine the multi-factor vulnerability of the core of cities Case study; Region 6 of Tehran. *Iranian Journal of Crisis Management*, (2), 67–76.

Habibi, K., Behzadfar, M., Meshkini, A., & Nazari, S. (2013). Preparation of a model for the stability of ancient urban textures against earthquakes with inverted hierarchical logic and GIS. *Iranian Journal of Earth Sciences*, *22*(87), 83–92.

Hashemi, M., Al-Sheikh, A. A., & Malek, M. R. (2010). GIS earthquake vulnerability zoning: A case study: Tehran. *Environmental Science and Technology*, *16*(93).

Isalou, S., Latifi, G., & Goodarzy, V. (2016). Assesment of physical vulnerability of the texture in District One of Tehran against earthquakes using IHWP method and GIS system. *Sepehr Geographical Information Quarterly*, *25*(100), 73–87.

Kamelifar, M. J. (2012). *Assessing the vulnerability of the urban road network to earthquakes with a crisis management approach case study; Region 1 of Tabriz* [Master Thesis]. Faculty of Humanities, Zanjan University, Iran.

Karami, M. R., & Amirian, S. (2018). *Zoning of urban vulnerability due to earthquake using Fuzzy-AHP model case study: Tabriz. Iranian Journal of Physical Development Planning*, *3*(6), 110–124.

Khakpour, B. A., Zomorrodian, M., Sadeghi, S., & Moghaddami, A. (2011). The analysis of physical–structural vulnerability of the Ninth District of Mashhad from a seismological perspective. *Journal of Geography and Regional Development*, *9*(1). https://doi.org/10.22067/geography.v9i16.11025

Lantada, N., Pujades, L., & Barbat, A. (2009). Vulnerability index and capacity spectrum based methods for urban seismic risk evaluation. A comparison. *Natural Hazards*, *51,* 501. https://doi.org/10.1007/s11069-007-9212-4

Mokhtari, L., Shekari Badi, A., Beshkani Z., (2018). Evaluation of the vulnerability of urban areas of Kashan against earthquake risk using IHPW model. *Iranian Journal of Natural Environment Hazards, 7*(16), 105–126.

Mahdavi, D., & Hezarian, E. (2017). Assessment and analysis of anatomical vulnerability of rural settlements to earthquakes case study: Yazd villages. *Iranian Journal of Physical Development Planning*, *2*(4), 27–45.

Maleki, S., Amanpour, S., Safaei Pourf, M., Pour Mousavi, S. N., & Movadat, E. (2017). Evaluation of the physical resilience spectrum of cities against earthquakes using case planning models: Ilam city. *Iranian Journal of Physical Development Planning*, *2*(1).

Moe, T. L., & Pathranakul, P. (2006). An integrated approach to natural disaster prevention and management: Public project management and its critical success factors. *Disaster Prevention and Management, 15*(3), 396–411. https://doi.org/10.1108/09653560610669882

Mohammadi Deh Cheshmeh, M. (2013). *Passive urban safety and defense.* Shahid Chamran University of Ahvaz Publications.

Momeni, M. (2013). *New Topics in Operations Research,* University of Tehran Press, First Edition.

Musavand, J. (2011). *Determining the optimal use in order to reduce the natural risk of earthquakes Case study: Region 1 of Tehran* [Master Thesis]. University of Geographical Sciences, Kharazmi University of Tehran.

Nagae, T., Fujihara, T., & Asakura, Y. (2012). Anti-seismic reinforcement strategy for an urban road network. *Transportation Research Part A*, (46), 813–827. https://doi.org/10.1016/j.tra.2012.02.005

Normandin, J. M., Therrien, M. C., & Tanguay, G. A. (2011). City strength in times of turbulence: strategic resilience indicators. In *Urban Affairs Association 41st Conference, New Orleans*. P2.

Paton, D., & Johnston, D. (2001). Disaster and communities: Vulnerability, resilience and preparedness. *Disaster Prevention and Management*, *10*(4), 270–277. https://doi.org/10.1108/EUM0000000005930

Poorahmad, A., Ziari, K., & Sadeghi, A., (2018). Spatial analysis of the components of physical resilience of worn-out urban tissues against earthquakes case study: District 10 of Tehran municipality. *Iranian Journal of Spatial Planning (Geography)*, *1*, 111–130.

Reynal-Querol, M., & Montalvo, J. G. (2005). Ethnic polarization, potential conflict, and civil wars. *American Economic Review*, *95*(3), 796–816. https://doi.org/10.1257/0002828054201468

Shamsipoor, A. A., & Sheikhi, M. (2010). Zoning of sensitive logic and environmental vulnerability in west fars region, using fuzzy classification method and hierarchical analysis process. *Iranian Journal of Natural Geography Research*, (73), 53–68.

Smith, K. (2003). *Environmental hazards book* (E. Moghimi & S. Goodarzi, Trans.). Samat Publications. https://doi.org/10.4324/9780203595015

United Nations. (1991). *Mitigating natural disasters. Phenomena effect and options.*

United Nations Office for Disaster Risk Reduction. (2004). *Living with risk: A global review of disaster reduction initiatives.* United Nations international strategy for disaster reduction.

Wihtol de Wenden, C. (2006). Urban riots in France. *SAIS Review of International Affairs*, *26*(2), 47–53. https://doi.org/10.1353/sais.2006.0032

Zangiabadi, A., & Tabrizi, N. (2009). Tehran earthquake and spatial assessment of vulnerability in urban areas. *Iranian Journal of Geographical Research*, (55), 115–130.

Ziari, K. (2006). *Principles and methods of regional planning* (1 ed.). Yazd University Press.