

## **Zoning Earthquake Vulnerability Using Fuzzy Logic in GIS (Case Study: Savadkoh City)**

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### **Abstract**

**Introduction:** Earthquake hazard is the sudden movements and vibrations of the earth's surface, caused by the breaking of the rocks of the earth's crust and the release of the energy stored in them, which in case of high intensity, causes a lot of damages and losses in human centers. The origin of the earthquake is tectonic and probably a failure is necessary. This phenomenon, on the one hand, causes breaking and shifting between the rocky masses of the earth's crust, and on the other hand, this shifting and breaking leads to the creation of waves and propagation inside the earth. Usually, more than 95% of the causes of earthquakes are related to tectonic movements. But other factors such as volcanoes, collapse of underground caves and landslides can play a role in causing earthquakes.

**Material and methods:** In order to carry out this research, basic maps of the studied area, including: geological maps, fault lines, topography, etc., were collected from various sources and a database was formed in the GIS environment. The layer of fault lines and geology with a scale of 1:50000 of the studied area was prepared and entered into the database. The height and slope maps were obtained from the digital elevation model (DEM) of the area (12.5 meters). Road maps of the region, urban and rural settlements and drainage network were also extracted from topographic maps. The lithology map and existing landslides were also received from the General Directorate of Natural Resources of the province. Six standard maps include: maps of the distance from the fault (main and sub-fault), distance from the existing landslides, geology, slope and type of land or soil are considered as criteria for evaluating the vulnerability caused by earthquakes. At the same time, it is mentioned that the factors related to building engineering and the quality of buildings (building life, quality and composition of materials...) are also involved in the level of vulnerability of settlements against earthquakes, which should be taken into account for the micro-area. It is necessary to determine and estimate the amount of possible damages, and of course, it requires a detailed and separate work.

The method of conducting this research is descriptive-analytical. In the stage of collecting information and primary data, library studies were used as well as field studies and observations, interviews with experts and distribution of questionnaires among experts related to the subject under study. In choosing the criteria, we were careful enough to have a comprehensive and systematic view of the subject. In this study, the triangular model and their fuzzification in the environment of geographic information system was chosen as the criteria evaluation model, which will be discussed in detail about the calculation steps in the next sections. In the next stage, the mentioned and fuzzy criteria were overlapped by

combining the data using the analysis functions of the geographic information system software, the result of which is the extraction of the final map that shows different areas in terms of sensitivity to earthquake.

**Results and Discussion:** Introduction of factors and criteria Fuzzy logical model was used in the area under investigation for the zoning of vulnerable areas from earthquakes. To implement this model, 6 effective variables in vulnerability zoning were used. Then, for each of the research criteria, the corresponding fuzzy function was designed and fuzzy maps were drawn for each criterion. Fuzzy maps were finally combined in the geographic information system by adding, multiplying and Fuzzy gamma operators. These indicators or criteria are:

The criteria are:

1. Geology (C1)
2. Distance from the main fault (C2)
3. Distance from the minor fault (C3)
4. Slope (C4)
5. Existing landslide (C5)
6. Soil type (C6)

The geological factor is considered as one of the main parameters in causing damage caused by earthquakes. Since the major part of the city is located on gray shale formation and sandstone, it can be said that it increases the risk of earthquake. Therefore, the most points are given to them. The type of function for its fuzzification is incremental linear.

The presence of faults is considered as an important factor in the occurrence of earthquakes in the region. The presence of many faults in the region plays a major role in the occurrence of earthquakes. Due to the existence of many main and sub faults in the area of Swadkoh, the closer we get to the boundaries of the faults, the risk of earthquake is higher and therefore the highest score has been given. The type of function for its fuzzification is incremental linear. Due to the existence of numerous faults in the Swadekoh area, the level of damage caused by an earthquake is very high.

The location of the buildings has an important effect on the amount of destruction caused by the movement of the earth and earthquakes. Basically, lands with a slope of less than 5% are considered as suitable lands for the establishment of human settlements, and slopes above 15% are unsuitable lands for this purpose. The type of function for fuzzy. Its construction is linear. All the devastation and casualties caused by earthquakes are not directly "and exclusively" related to the earthquake itself, but an important part of these damages are indirectly, with the intervention of the phenomenon. Geomorphological changes take place. Due to the existence of numerous landslides in the Swadekoh region, the closer we get to the landslide sanctuary, the greater the risk of earthquakes, and therefore the highest score has been given. The type of function for fuzzification of this criterion is linear.

Considering the type of soil is very effective for preparing a vulnerability map. Since the major part of the city is located on alfusols soil, the effect of the earthquake will be intensified. The type of function for fuzzification of this criterion is linear.

**Conclusion:** The growing and increasing trend of urbanization and urban population is a factor for large losses when natural disasters occur. The expansion of communication networks and urban infrastructures on the one hand and the non-observance of the most basic safety points in urban construction and the lack of a plan for the growth and development of the city on the other hand, provide the basis for causing great damage during an earthquake. The purpose of this research is to zone the vulnerability potential due to earthquake risk using effective criteria and fuzzy logic algorithm, for this purpose, six criteria including slope,

geology, soil type, distance from the main fault, distance from the secondary fault and The distance from the existing landslides has been selected as the study criteria and by applying fuzzy logic and its membership functions and by using geographic information system (GIS), weighted layers have been produced from the mentioned criteria. The results show that the use of fuzzy sets in quantifying and increasing accuracy is very effective and more suitable than other qualitative and hierarchical methods. To adjust the very high sensitivity of the fuzzy multiplication operator and the very low sensitivity of the fuzzy addition, all the fuzzy operators were used to achieve a better result. Due to the complications and factors caused by geomorphology, the presence of major and seismic faults in the region, which is a sign of their tectonic activity in the region. These faults are stretched from east to west in the study area, and their most scattered is in the north and center of the study area, and its evidence can be seen in Swadkoh city itself. Also, due to the nature of the earth's layers in the region and the expansion of the city on thin formations (barracks, alluvial cones) and the protrusions of older alluviums on newer alluviums, the presence of faults main and seismic and alluvial networks and rivers that are located in this area, it can be said that these processes and geomorphological risks of earthquakes limit the development of security in the city and can increase the risk of earthquakes. By identifying these processes and geomorphological hazards of earthquakes and zoning earthquake risk areas and applying special measures, it is possible to reduce the amount of life and financial losses caused by earthquakes and help the welfare, comfort and safety of citizens more and better. The results of the investigations have led to the production of a zoning map of vulnerability caused by earthquakes, which according to the zoning map of the whole country by the Seismological Organization of the country, the SUM operator is closer to this map and accordingly in this research has used this operator to produce the final earthquake risk zoning map of Swadkoh city. According to the final map, most of the area of Swadkoh city is more vulnerable to earthquakes, which includes areas with a high risk of about 64% of the area, and according to the map, these high-risk areas have settlements. There are many villages and cities that are at risk of earthquakes, which include low and low slope areas in the northern part of Swadkoh city. The high risk zone also covers more than 35% of the entire city.

**Keywords: future research, spatial planning, sustainable development, Khadafarin city**

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