



## **GIS Application Analysis Earthquake Data to Evaluate Risk Assessments of Seismic Hazard in Kurdistan of Iraq Using Probabilities.**

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### **Abstract**

Earthquakes in Kurdistan of Iraq are unorganized natural disaster, that happens without any schedule or any knowledge of when and where they may occur. However, it is important to know where and when they may happen or at least identify the risk locations, strength of the danger, numbers of occurrence per area (density) and predict the future earthquakes if possible, which are the key issues of this paper. The answer to these issues can be achieved through earthquake data evaluation. Hence it is important to look into the earthquake data from the past, and evaluates them through the power of GIS (Geographical Information System) application; this will build a method that will develop the access to the answers to the key issues through a spatial analytical procedure, as the answer helps future planning and risk assessments. GIS can evaluate seismic hazard and risk analysis, as it demonstrates an environment with many features that uses to carryout statistical and spatial analysis efficiently. The application first looks at the data in details, afterwards it allocates the information to each administrative area in the province of Kurdistan accordingly and maps the data vividly to produce graphical results to the issues and their answers, that are easier to illustrate the results. Eventually, the data needs to be examined for any available patterns that help for the future earthquake prediction, if there are any data. problem and your proposed technique to address it.

### **Introduction**

Using GIS in analyzing earthquake data aims to provide information on potentially risk areas to consent suitable response to the natural disaster in advance and allowing people to reduce loss of life and homes (1), it also helps simplifies the procedure of data pattern's discovery to identify the chance of prediction using the patterns if there is any. Human behavior plays significant responsibility to strength the vulnerabilities from natural hazard to certain level. In the last two decades, urban vulnerabilities distinguish between the vital concepts in earthquake hazards and growth of justification strategies on local, national, and international levels (2). Scientists and researchers estimate earthquake probabilities in two ways: by revise the history of great earthquakes in an explicit region, by studding the data to find patterns and the rate at which damage

accrues (1). Perhaps, GIS tools offer supreme platforms to carry out inclusive local and international earthquake hazards and risk assessments through data analysis and evaluation. It also can accumulate, manipulate, analyses, and display the large amount of required spatial and tabular data depend on the advancements of technology to help GIS moves forward and becomes more accurate and faster. This powerful tool can link to external computational programs, high level database management systems, and knowledge-based expert systems for more comparison and superior evaluation (3). In the study area, there is little information on earthquake's awareness and future planning. Perhaps, this study tries to provide more information on the quires by analyses the issues to illustrate the answers and trying to evaluate data to predict seismic hazard and plan for risk assessment. This study also helps other sciences to relate their sciences to earthquakes, such as: seismology, structural engineering, geo-technical engineering and so on, because it is important to understand the behavior of constructions in the events of earthquakes and to pay attention of formational design in the certain seismic area. Ultimately, the collaboration between human and nature decisively engrained at the heart of demonstrating earthquake hazards as dynamic phenomena that involve people not only as victims but also as contributors and modifiers (4). However, to answer all the queries, GIS is a significant tool for decision making of urban vulnerability analysis, as it helps to take the advantage of incorporation of technology, which intended to support spatial decision making into a field with a strong need to address numerous critical spatial decisions (5).

### Study Area:

The study area comprises of Kurdistan region of Iraq and some disputed territories, which are the close areas within the region, and they have Kurdish population, but there has been disputation between central government of Iraq and Kurdistan Region government (Nawzad Mahmoud 2014). Kurdistan of Iraq located in the north-eastern tips of Iraq with bordered to Iran from the east and Turkey from the north. This area has a Population around 5.2 million (KRG 2014) people.



Figure No. 1: Study Area (Kurdistan Province of Iraq including the disputed areas)

This region is situated in the geographical site between the longitude and latitude of 38 North, 33 south, 47 East and 40 West. Figure (1) showing forty-seven years of earthquakes in the region and surrounding areas, while figure (2) only showing the location of study area.

### Tectonic Setting of Kurdistan:

Kurdistan of Iraq is located in the North Eastern part of Arabian tectonic plate that is mostly continental plate. This plate converged with the Eurasian tectonic plates in the north and east across the study area (6), subsequently the study area becomes the border of convergence between the two plates. The current tectonics of the region is controlled by the collision and continuing convergence of the Arabian and Eurasian plates (7) and (8). Figure 2 showing the location of world tectonic plates in black lines; also it identifies the location of convergence with the red lines that is clearly shown that Kurdistan of Iraq is on and close to the convergence boarder.



Figure No. 2: world tectonic plates and location of convergence

There are two smaller tectonic plates that are the sub tectonic plate of Eurasian; they are recognized as Anatolian in the north and Iranian in the eastern part within the study area (9).

### Analyzing Risk Areas using GIS:

#### A. Data evaluation technique through classification data.

One of the excellent common techniques to evaluate earthquake risks or seismic hazard is to evaluate the earthquake data and perform probability analysis for the study area, through power of GIS application. Since it can examine earthquakes based on available data and their attributes for a limited period. However, Risk assessments can also merge to infrastructure's vulnerability, future planning, decision making, local government standards and emergency rescue (10). In order to evaluate the seismic hazard, it is significant to investigate the earthquake data and creates a seismic-hazard source model (SHSM), which is a description of the magnitude, location, and timing of all earthquakes, and then analysing SHSM through GIS application to affluence the study and illustrates the methods in an enhanced and easier way. Figure No. 2, 3 and 4 are different SHSM of the available earthquakes data.

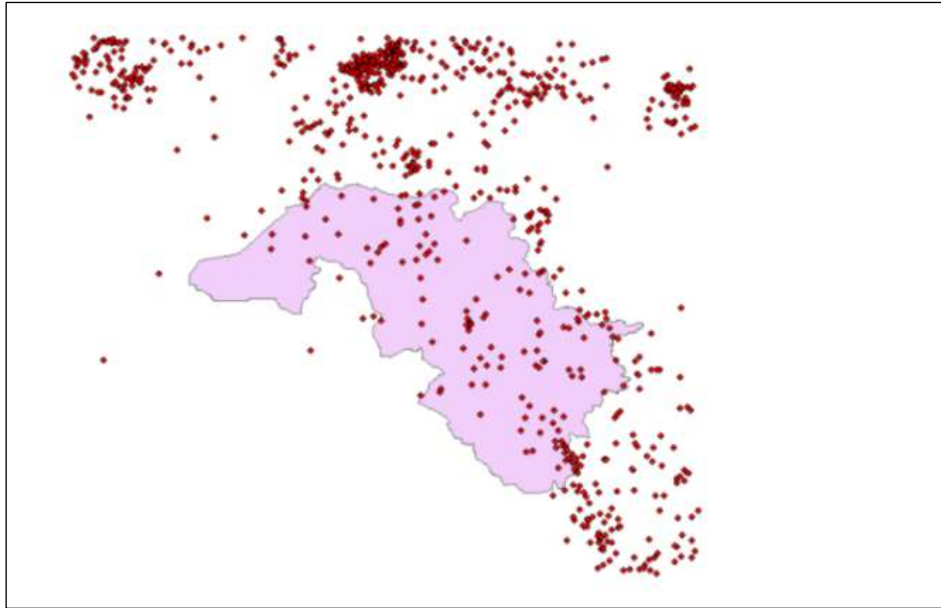


Figure No. 2: 47 years of earthquake data in Kurdistan of Iraq and surrounding areas.

GIS builds graphic maps from the data, which integrated to the real-life position on the map. However, the complete figures of the graphical data provided a clear idea about the hazard locations, and it completes the total map of hazard's or the SHSM; therefore, figure (3) showing the available data, that are 108 earthquakes during the forty-seven years.

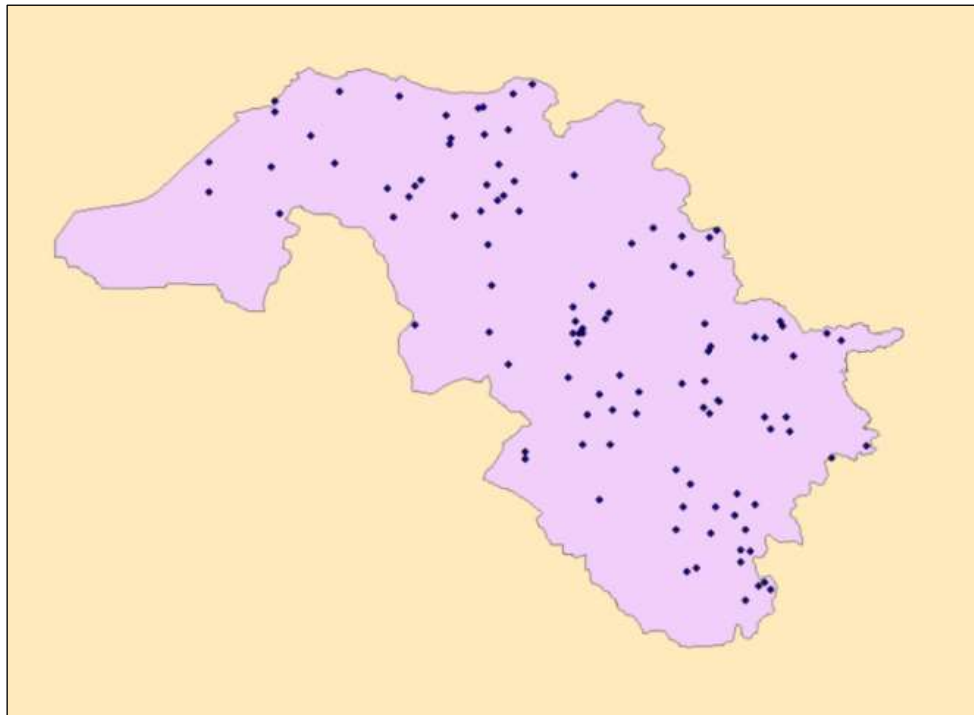


Figure No. 3: 47 years of earthquake data in Kurdistan of Iraq (Study Area)

Nevertheless, hazard level depends upon the strength and duration of earthquakes. Subsequently, the result of data analysis needs to be compare to international database and approve the certainty of the risks, through comparability with the outcomes to the surrounding area's results and then determine the hazard of study area.

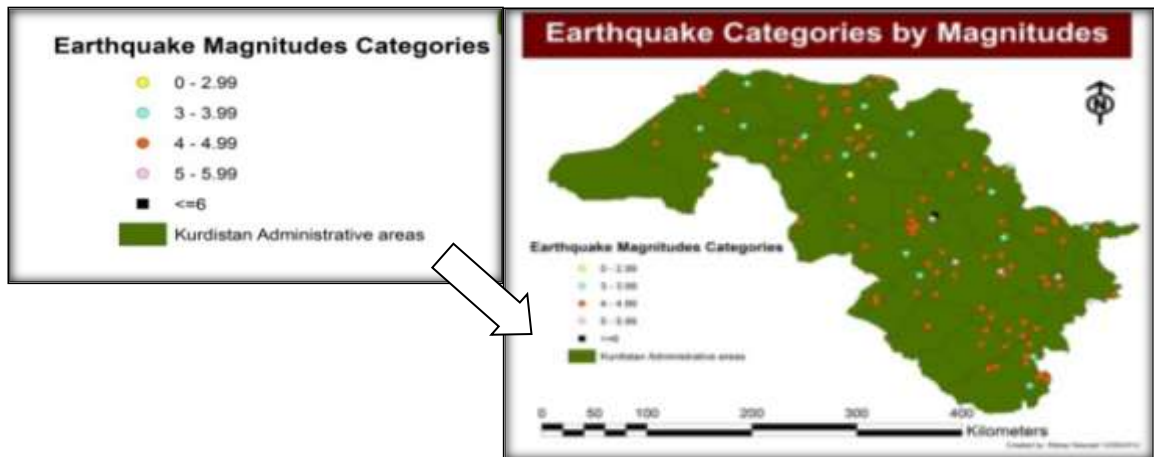


Figure No. 4: Earthquake categories by magnitudes

The data has been classification and analyzed in the following ways:

Figure 2 shows the data from the study area and its surrounding borders, and then they refined to cover the study area data in figure 3. Figure 4 showing the administrative areas within the study areas, while each area has its data allocated to it giving their magnitudes and numbers of earthquakes, hence figures (4) represent the SHSM via magnitudes and location through five classifications. This step confirms that most of the earthquakes occurred within the study area were between 4-4.99 magnitudes, this information also showing in table 1 in a different format. Study area as well encountered earthquakes between 6 - 7 during the period, although this has occurred only once, but it is important to be considered during the risk assessments.

Earthquake Data								
Earthquake Categories by Magnitudes								
Earthquakes in Kurdistan of Iraq	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	<=6	Numbers of earthquakes
Akre	1	0	0	1	5	0	0	7
Al Hamdaniyah	0	0	0	0	1	0	0	1
Al Shikhan	0	0	0	1	3	0	0	4
Amedi	0	0	0	0	7	0	0	7
Arbil	1	0	0	0	1	0	0	2
Chamchamal	0	0	0	0	4	1	0	5
Choman	0	0	0	0	0	0	0	0
Dahuk	0	0	0	1	0	0	0	1
Daquq	0	0	0	1	4	0	0	5
Darbandokeh	0	0	0	0	2	1	0	3
Dibis	0	0	0	0	1	0	0	1
Dukan	0	0	0	0	1	0	0	1
Halabja	0	0	0	0	1	1	0	2
Kalar	0	0	0	0	5	0	0	5
Khanaqin	0	0	0	2	9	0	0	11
Kifri	0	0	0	0	2	0	0	2
Kirkuk	0	0	0	1	8	0	0	9
Koisanjaq	0	0	0	0	3	1	1	5
Makhmur	0	0	0	0	1	0	0	1
Mergasur	0	0	0	2	2	0	0	4
Penjwin	0	0	0	1	1	0	0	2
Pshdar	0	0	0	2	4	0	0	6
Rania	0	0	0	0	1	0	0	1
Shaqlaw	0	0	0	0	0	1	0	1
Sharbazher	0	0	0	0	5	0	0	5
Shekhan	0	0	0	0	0	0	0	0
Simele	0	0	0	0	1	0	0	1
Sinjar	0	0	0	0	0	0	0	0
Soran	0	0	0	0	0	0	0	0
Sulaymaniya	0	0	0	1	6	1	0	8
Talafar	0	0	0	1	3	0	0	4
Tilkef	0	0	0	0	0	0	0	0
Touz Hourmato	0	0	0	0	1	0	0	1
Zakho	0	0	0	1	2	0	0	3
<b>Total Numbers</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>15</b>	<b>84</b>	<b>6</b>	<b>1</b>	<b>108</b>

Table 1: Administrative areas with their number of Incidents and their magnitudes

Analyzing SHSM through integration of GIS presents categorized data as well, which is important to answer several other questions to evaluate risk and hazard areas; therefore, such integrations answer questions like risk locations in the study area in comparison to the world risky areas?

The question can be answered in several ways;

perhaps it is easier at first to compare the study area to Global Seismic Hazard Assessment Program (GSHAP) to understand the variation and similarities, which is according to figure 4 and table 1, 77.8% of all the earthquakes in the study area were between 4-4.99 magnitudes, this is also comparable to the GSHAP map in 1999, which indexes the study area among moderate to high risk areas (11).

Dividing earthquakes by the administrative areas provides more precise analysis to individual areas, as it divides the incidents by the thirty four governmental areas. Table 2 is showing the selected areas that procured with five times and more earthquakes. This is the indication that of these areas has the possibility to face earthquakes more than the other areas, based on the numbers of incidents occurred in the areas. However, GIS presents these areas in graphical maps in figure 5, which is covering the numbers of the earthquake incident in colored legend.

Earthquake Data								
Earthquake Categories by Magnitudes								
Earthquakes in Kurdistan of Iraq	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	<=6	Numbers of earthquakes
Chamchamal	0	0	0	0	4	1	0	5
Daquq	0	0	0	1	4	0	0	5
Kalar	0	0	0	0	5	0	0	5
Koishjaq	0	0	0	0	3	1	1	5
Sharbazher	0	0	0	0	5	0	0	5
Pshdar	0	0	0	2	4	0	0	6
Akre	1	0	0	1	5	0	0	7
Amedi	0	0	0	0	7	0	0	7
Sulaymaniya	0	0	0	1	6	1	0	8
Kirkuk	0	0	0	1	8	0	0	9
Khanaqin	0	0	0	2	9	0	0	11
<b>Total Numbers</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>8</b>	<b>60</b>	<b>3</b>	<b>1</b>	<b>73</b>

Table 2: areas with 5 times and more earthquakes

In facts during the forty-seven years of study area, the range of earthquake took place in individual administrative areas were between 0-11 times in each area. However, the areas with five times and more need consideration, especially those earthquakes were above 3 degrees of magnitudes and further, as it had shown in table (2).

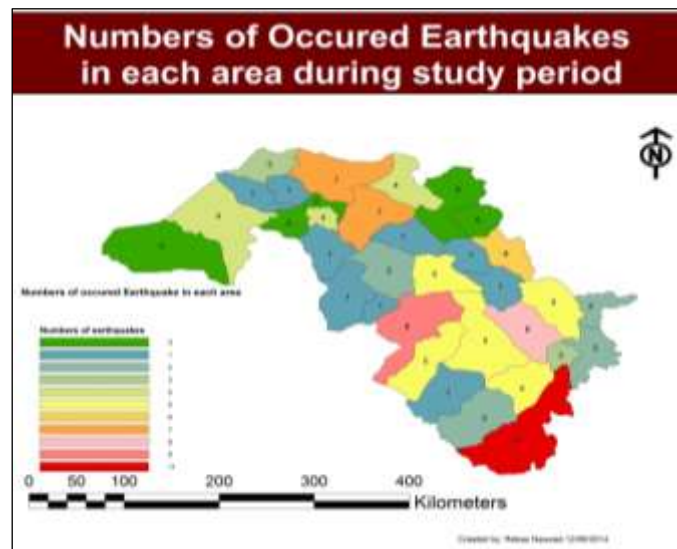


Figure 5: Numbers of Earthquake occurrence in each administrative area

Figure 6 is similar to figure 5, it focuses on the areas that got five-time earthquakes and more, which were eleven areas. In fact, these eleven areas got the total incidents of 73 earthquakes out of the 108; it makes the 67.6% of all the earthquakes that deserves the attention. These eleven areas seen various ranges of magnitudes, while the strongest earthquakes occurred in these areas were 6.1 magnitudes. Perhaps if the data evaluates for the numbers of occurrence like the graphical SHSM in figure 5, and calculates the 67.6%, hence the results indicate that the areas are more dangerous than the others. Although all the part of Iraq is on the same

tectonic plates, but Kurdistan faced more earthquakes than the other part of Iraq, because it is located in a relatively active seismic zone at the North Eastern boundaries of the Arabian Plate. The corresponding Zagros (ñTauros) Belts manifest the sub-duction of the Arabian plate into the Iranian and Anatolian Plates. Seismic history reveals annual activity of different strength. The north and North Eastern zones depicted the highest seismic activity with strong diminution in the south and south-western parts throughout the country (12).

**B. Density and Seismic Hazard Evaluation:**

GIS can analyze earthquake data to deliver the density of earthquakes, although density not the only factor to identify the risk area, but it is one of the important factors and techniques to identify the risk locations based on the numbers of incidence at the particular strength.

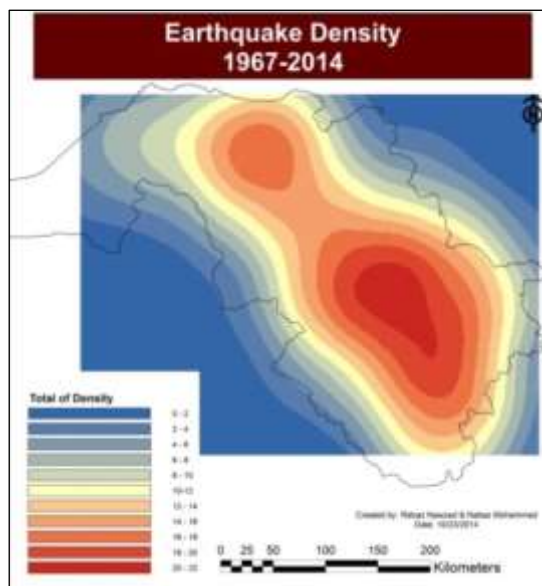


Figure 6: Density of Earthquakes in Study area

Density needs to be formed correctly through analyzing a larger region data rather than limiting itself to the study area. Nevertheless, the density maps have been created for distinctive sort of data analysis in order to compare then and provide the best results to the reader. Figure 6 showing the density of earthquakes in Kurdistan, using various representations.

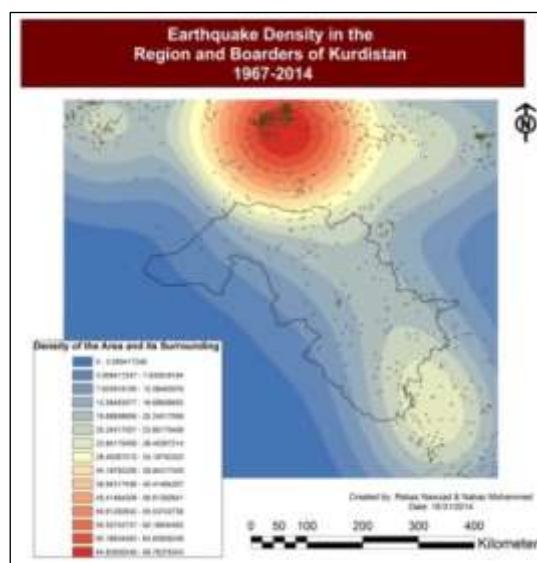


Figure 7: Density of Earthquakes in the study area and surrounding region.

Although this may not provide precise representation in comparison to GSHAP, because to understand the density, it is important to analyse greater area of data and then decide the risk location. However, according to figure 8 study area falls between 2.4-4.8-magnitude locations, which are moderate risk area.

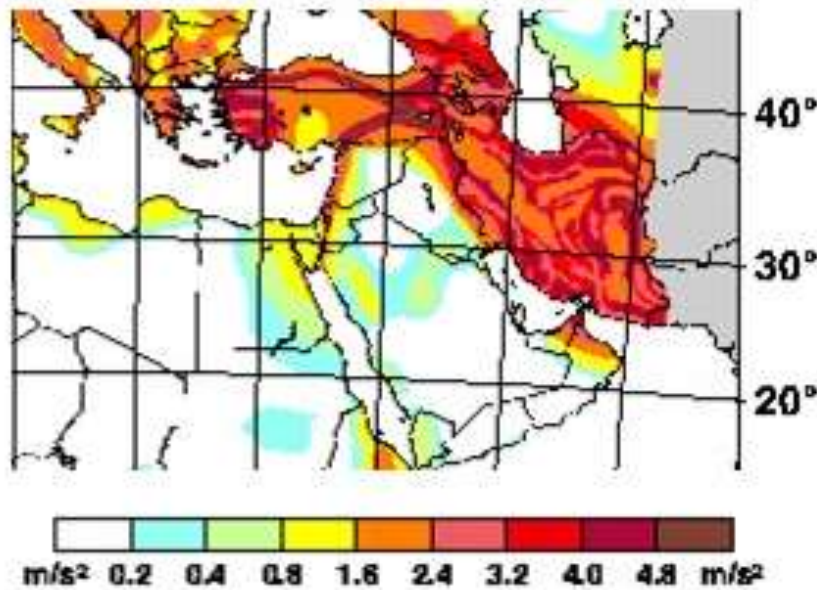


Figure 8: Global Seismic Hazard Assessment Program, 1999

This is dissimilar to figure 6, as it only analyzed data within the study. In order to achieve more accurate results, it requires to analyze data from the larger region, as it has shown in figure 7 that the study area, and its surrounding regions have been analyzed to draw a better and more exact map, which is closer to the (GSHAP) with more details and up-to-date information. Figure 9 is another map of density for the same area using a one-mile radius, hence it is providing more details and precision on the map for the hazard areas. Consequently, Kurdistan is less vulnerable in comparison to Turkey and Iran, even though they are neighboring countries, but they are on different tectonic plates, and this study confirmed this truth.

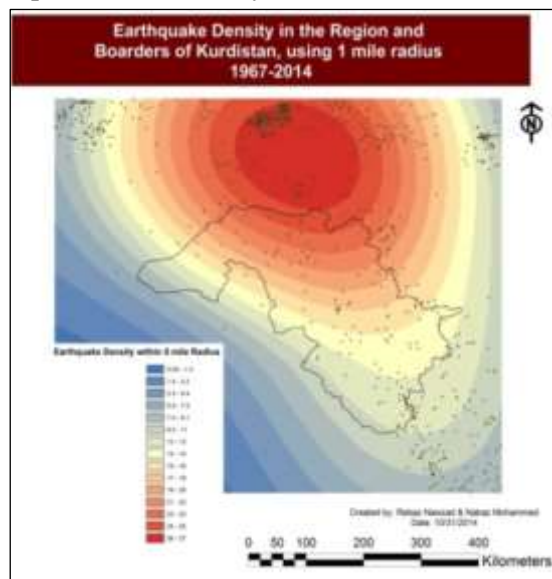


Figure 9: Density of Earthquakes in the study area and surrounding region using a one-mile radius analysis.

**C. Probabilistic Seismic Hazard Analysis (PSHA):**

In everyday activity, people are used to decide based on probabilities. This is from the flip of a coin (50% probability of heads) to weather forecasts (such as a 30% chance of rain) to the annual chance of being killed by lightning (about 0.0003%). In comparison, the probability of a magnitude 7.5 or greater earthquake striking somewhere in California is about 2% per annum (13). There are various events cannot be predicted with full certainty, thus, it is the best to say how likely they are to happen to use the idea of probability. Probabilistic seismic hazard analysis (PSHA) participate over-all possible earthquake ground motions at a location to grow complex demonstration of the hazards for the particular place (14). The analysis has a strong basis in evaluating data, comparing their pattern and similarities in order to allow for decisions on seismic hazard. This facility made in the context of the earthquake magnitudes, locations, time and ground motions. This examination studied magnitude and location to allocate the hazards. Looking into figure 7 and 8, Kurdistan of Iraq is located near the position that has a low risk of earthquakes, along with most of the magnitude ranges were between 4-4.99, which is a sign of moderate risk area, but there are several areas that have seen earthquakes with the magnitude of 5 and above, which consider to be the high-risk areas, while figure 4 showing their locations. The average strength of earthquakes occurred in the study area, concluded using the following formula:

$$\text{Average strength of earthquakes in Kurdistan of Iraq} = \frac{\text{Total strength of magnitudes}}{\text{Numbers of occurred earthquakes}} = 4.32037037 \text{ Avg. Magnitude}$$

The average of earthquake is 4.32037037 in the region. It is confirming the area is located in moderate risk area, also having 108 earthquakes during forty-seven years tells this area has  $108/47 = 2.3$ -time occurrences annually since 1967, while two times is not a lot of earthquakes in comparison to some areas like Japan and California, which get more than fifty times and more per-annum, which are the high-risk areas. Predicting earthquakes is not an easy task neither is certain, most of the previous researches assuring that forecasts are impossible, as there is not any mathematical algorithm to foresee exact time, location nor magnitude of an earthquake (15). Evaluating data in different ways to find patterns in the data may allow for prediction up to some level, but it cannot give an accurate prediction, while it is only a statistical estimation using the data series of the past to present earthquakes, table 3 showing the numbers of each earthquake in the administrative areas, and their time of occurrences. This table is merging table between the GIS data and the earthquake information table to form a new data that makes the analysis easier and more precise. In order to study prediction, some administrations need to select and review their patterns if there are any, also to determine the similarities and magnitudes of the occurred earthquakes during the forty-seven years of study. This requires detailed evaluations and has to be done individually for each selected area. However, the areas and data from table 2 are used, as it presenting the areas that have five-time earthquakes and more.

Earthquakes in Kurdistan of Iraq by magnitude	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5-5.99	≥6	Numbers of earthquakes	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Akre	1	0	0	1	5	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al Hamdaniyah	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Al Shikhan	0	0	0	1	3	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amedi	0	0	0	0	7	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arbil	1	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chamchamal	0	0	0	0	4	1	0	5	0	0	0	0	0	0	0	0	5.1	0	0	0	0	0	0	0	0	0
Choman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dahuk	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Darzi	0	0	0	1	4	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.6
Darbandokeh	0	0	0	0	2	1	0	3	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Dibis	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.3	0	0
Dukan	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halabja	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.1	0	0	0
Kalar	0	0	0	0	5	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Khanaqin	0	0	0	2	9	0	0	11	0	0	0	0	0	0	0	0	4.3	0	0	0	0	0	0	0	0	4.7
Kfiri	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kirkuk	0	0	0	1	8	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.8	4.9	4.6	4.5
Kosinjiq	0	0	0	0	3	1	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	6.1	4.4	0	0
Mahmur	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mergasur	0	0	0	2	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perjiwin	0	0	0	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paikdar	0	0	0	2	4	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.8
Rania	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.6
Sharqlawa	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sharbazher	0	0	0	0	5	0	0	5	0	0	0	0	0	0	0	0	4.2	0	0	0	0	0	0	0	0	0
Shekhan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Simele	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Singar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soran	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sulaymaniya	0	0	0	1	6	1	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Talafar	0	0	0	1	3	0	0	4	0	0	0	0	0	0	0	3.9	0	0	0	0	0	0	0	0	0	0
Tilkef	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Touz Hourmato	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zakho	0	0	0	1	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	total magnitude	avarage
	0	0	3.7	0	0	0	0	4.7	0.1	0	0	0	0	0	0	0	0	0	0	27.2	3.885714286
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.2	0	0	0	4.2	4.2
	0	0	0	3.8	0	0	0	0	0	0	0	0	0	0	0	4.2	0	4.9	4.3	17.2	4.3
	0	0	0	0	0	4.3	4.2	4.5	0	0	0	4	0	0	0	4.6	4.3	4.5	0	30.4	4.342857143
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	4.5	2.25
	0	0	0	0	0	0	4.2	0	0	0	0	0	0	0	0	0	0	0	0	22.3	4.46
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	3.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.9	3.9
	0	0	0	0	4.5	3.8	0	0	0	0	4.5	0	0	0	0	0	0	0	0	21.7	4.34
	0	0	0	0	4.3	0	0	0	0	4.5	0	0	0	0	0	0	0	0	0	13.8	4.6
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.3	4.3
	0	0	0	0	0	0	0	0	0	0	0	4.3	0	0	0	0	0	0	0	4.3	4.3
	0	0	0	0	0	0	0	0	4.5	0	0	0	0	0	0	0	0	0	0	9.6	4.8
	4.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.3	0	4	0	21.4	4.28
	0	0	0	4.4	3.7	0	0	0	3.8	0	0	0	0	0	4.1	4.2	4.2	4	46.5	4.227272727	
	0	0	0	0	0	0	0	0	0	4.5	0	0	0	0	0	0	0	0	0	8.8	4.4
	0	0	0	0	0	0	4.1	0	0	0	4	0	0	0	0	0	4.6	4.4	0	39.8	4.422222222
	0	0	0	4.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24.8	4.96
	0	0	0	4.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.1	4.1
	0	0	0	3.6	0	0	4.7	0	3.9	0	0	0	0	0	0	0	0	0	0	16.3	4.075
	0	0	0	0	0	3.4	0	0	0	0	0	0	0	0	0	0	0	0	0	8	4
	0	0	0	0	0	0	0	0	3.7	0	0	4.4	0	0	0	0	0	0	0	25.5	4.25
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.6	4.6
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.5	5.5
	0	0	0	4.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.6	4.52
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	4.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.7	4.7
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	4.7	5.1	4.3	4.6	4.3	0	0	0	0	0	0	0	0	0	0	3.8	35.8	4.475
	0	0	0	0	4.2	0	0	0	4.4	0	0	0	0	0</							

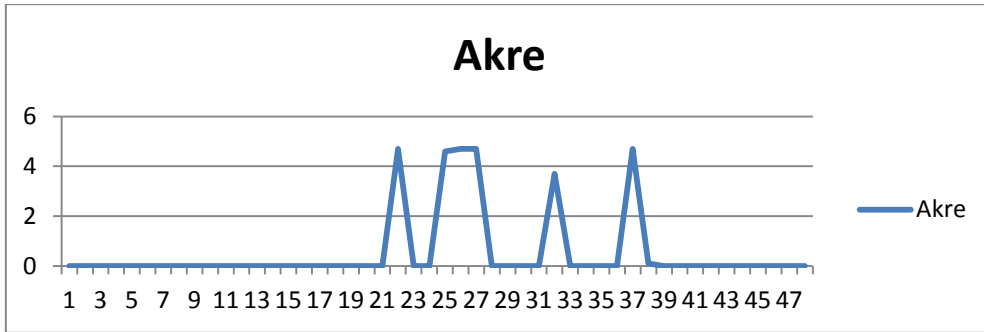


Table 4: Akre earthquakes charts of occurrence and magnitudes.

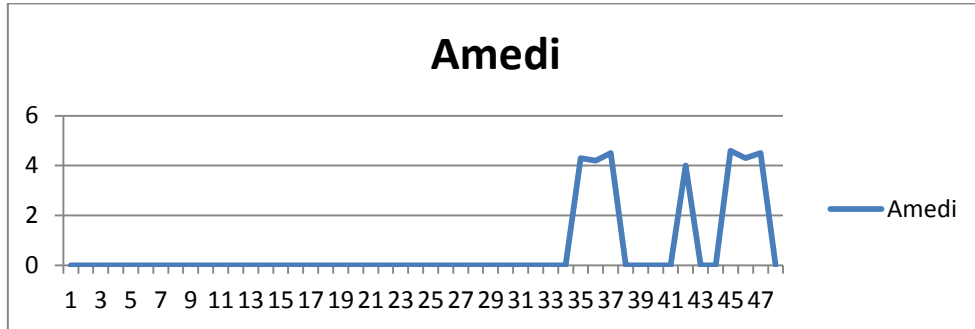


Table 5: Amedi earthquakes charts of occurrence and magnitudes.

The second administrative area is “Amedi,” it also got hits seven times during the same period, while all the earthquakes were between 4-5 magnitudes. Strength predictions through data evaluating are very likely. It is possible to predict that the future earthquakes will happen between the rate of 4-5 magnitudes by 90%, as all the previous incidents were between the identical range, but predicting earthquake incidences in this region is only 30%, as the earthquakes in the area may occur every 2-4 year, and it will continue three years in the row, as there are some similarities in the data patterns.

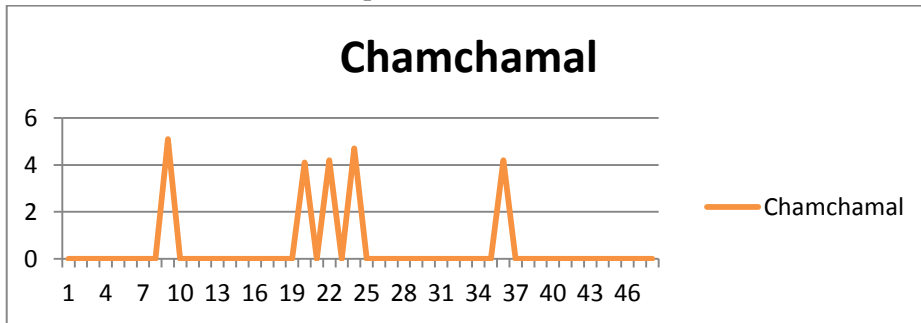


Table 6: Chamchamal earthquakes charts of occurrence and magnitudes.

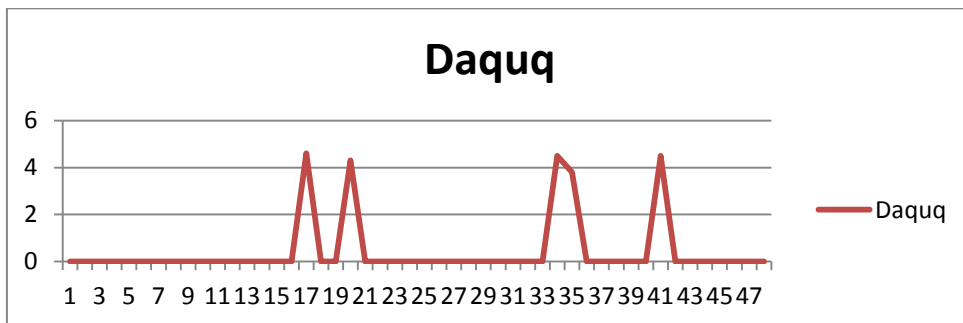


Table 7: Daquq earthquakes charts of occurrence and magnitudes.

The above two tables 6 & 7 are the charts for two different areas, according to this each of these areas got more than five-time earthquakes, and none of these earthquakes were less than four magnitudes. This is the key fact of predicting future earthquakes to be between 4-5 magnitudes is 90%, but to predict when the earthquakes happen; it is important to evaluate the data from the chart and according to this “Chamchamal” has a tiny similarity in the pattern, but in “Daquq” is more or less were random. Chamchamal is more likely to get hits by series of earthquakes every 10-12 years, although this is only probability, but the chance of future earthquakes is 40%.

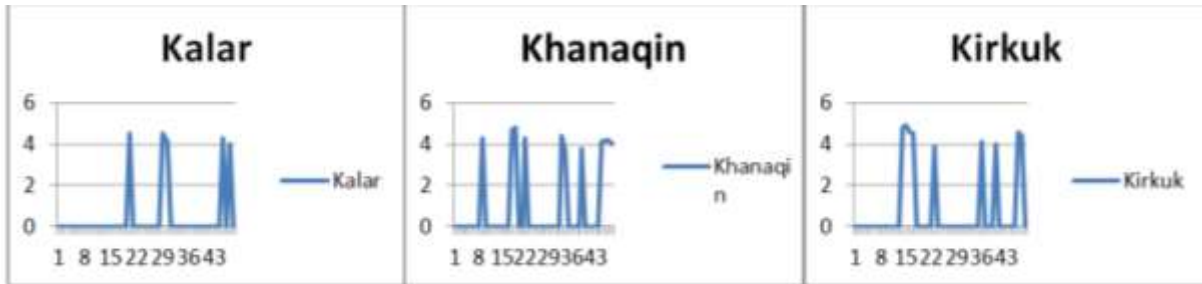


Table 8, 9 & 10: Kalar, Khanaqin and Kirkuk earthquakes charts of occurrence and magnitudes.

According to the above tables 8, 9 & 10, most of the earthquakes occurred in these areas were between 4-5 magnitudes. Although twenty five earthquakes occurred in these areas, which are 23% of all the area’s earthquakes, but twenty-three of them were between the magnitudes of 4-5. However, predicting future earthquake’s strength is 92% at 4-5 magnitudes. This is according to the available data, but, to predict when they occur, this depends upon the similarity of patterns within the data, which is not any related pattern available. Looking into the tables again showing that only table 10 & 11 has various similarities, perhaps the data on the table 8 is random and prediction is very unlikely, but predicting the occurrence for “Khanaqin” with a series of earthquakes between every 8-10 years is correct by 18%, while the similar prediction for “Kirkuk” table 10 is 33%, this is to occur once every 4-5 years, but the prediction for “Kirkuk” is more likely to be accurate than all the other tables. The following tables are the data tables for another four areas. These areas are among the areas that got the strongest earthquakes 6.1 in “Koisnjaq.”

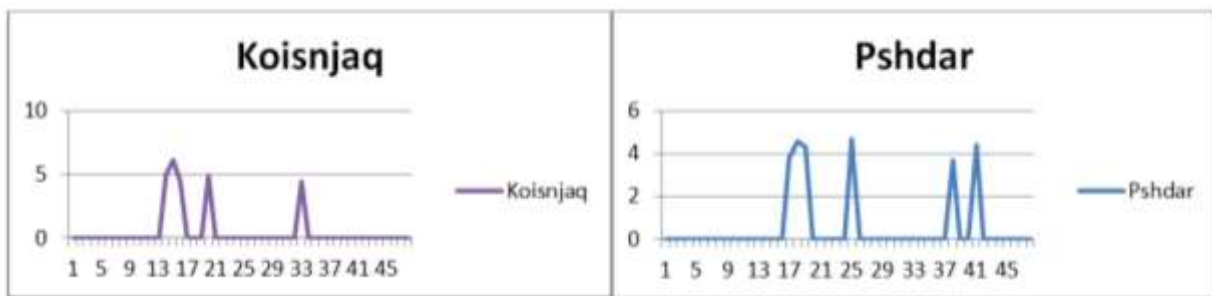


Table 11 and table 12: Koisanjaq and Pshdar earthquakes charts of occurrence and magnitudes.

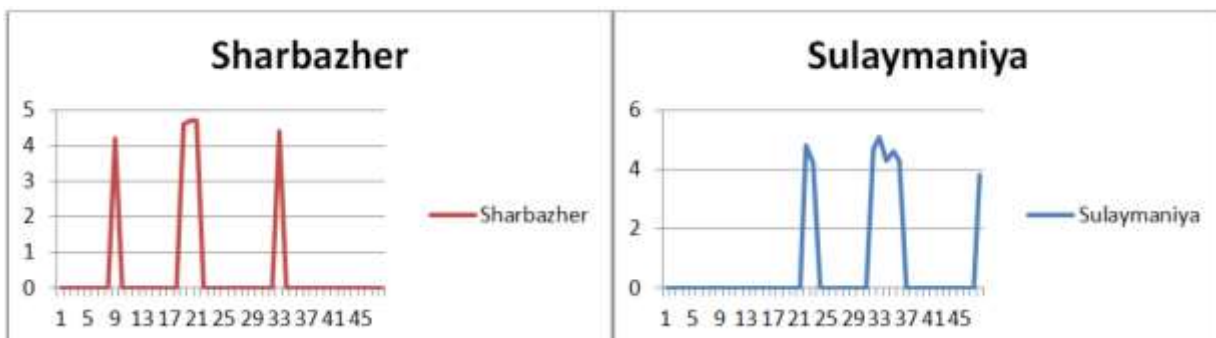


Table 13 & 14: Sharbazher and Sulaymaniya earthquakes charts of occurrence and magnitudes.

Earthquake magnitude's prediction relies on data evaluation. However, table 11 "Koishnaja" area has seen five earthquakes, and all of them were stronger than four magnitudes. Hence, it is 90% likely that future earthquakes happen at four magnitudes or more, but six magnitudes and more only may occur 15-20%. Although these predictions are not details, it just forecasts the strength between the ranges of magnitudes. Predicting incident times according to the available patterns is 40% for each series of earthquakes that occur every 14-16 years, and the series are 3-4 years once in each year. Table 12 is "Pshdar" area. The chance of earthquake occurrences at the magnitude of 3-4 is 33%, but the chance of earthquake occurrences at the magnitude of 4-5 is 66%, but their occurrence's time cannot predict, as the available data for this area is showing random earthquakes and there is not any pattern in the data, hence is very unlikely to predict the earthquakes in the area.

Looking into the table 12 & 13, showing that during two areas, there have been thirteen earthquakes occurred, while the incidences of table 13 were at the strength of four magnitudes and more, therefore, the prediction is likely to be at the same strength by 90%. Most of the earthquake incidents were occurred within the area of "Sulaymaniya," at the strength of 4-4.99 magnitudes, although some earthquakes occurred between 3-4 magnitudes, hence to predict the forthcoming earthquakes in this area is 12.5% may occur between 3-3.99, but 80% will assure the future earthquakes to be at the rate of 4-4.99 magnitudes.

### **Related Works:**

There are several attempts has been done locally and internationally in order to predict earthquakes. (Scholz et al 1973) tried to predict earthquake using a physical basis, and it wasn't successful. In 1981, Kanamori and Hiroo tried to predict the large earthquakes using the nature of seismic patterns before great earthquakes, it didn't succeed. These attempts carrying on until nowadays, while Azad Yazdani & Milad Kowsari in 2013 also tried distinctive equations to predict earthquakes (16), while they didn't provide a good resolution, hence these studies will continue to find a best solution, eventually this study used different techniques to reach near or trying the best of attempts to provide a solution to the issue of prediction, and prediction was one of them, and it was more successful in finding answers for other issues such as locating the risk areas...

### **Conclusion:**

In probabilistic seismic hazard analysis, diverse techniques should be selected with different considering influences to progress reliable results, although the data got analyzed properly, but the results were negative about predicting the time of prospective earthquakes. However, the chance of predicting the magnitude of future earthquakes is easier and would be more accurate than the time prediction using the methods of probabilistic analysis.

Although most of the previous studies were not successful to predict earthquakes, but this paper looked into different techniques of data analysis in this case to find any similar pattern in the data and provides the solution for this issue, even though the predictions were not successful, but GIS were a great application to find the risky location depending upon the area's locations through use of SHSM. Density is another technique that applied to find the correct locations or the areas of thickness earthquakes. The SHSM compared to the Global Seismic Hazard Assessment Program to decide the level of risk and hazard in the study area, which concluded the area to be between the low to moderate risk area.

Kurdistan of Iraq is subject to frequent and occasionally critical earthquakes. Accurate evaluation helps people to be prepared for these unpredictable events, at least they can relate seismic to their structure structures and figure more robust and stronger building. Studying earthquake data concluded that science, and seismology cannot yet make predictions of the date, time, and place of future earthquakes until nowadays. Even so, most of the earthquakes in Kurdistan 77.78% of them were between 4-4.99 magnitudes, whereas the lighter earthquakes may not be felt or cause any damage. Although the comparisons seemed to

be reliable with the several recorded data from different administrative area, but it is not predictable that the standard deviations of the calculations presented for most of the areas.

Eventually, the study has reached several worthy answers, such as density, maximum-minimum numbers of earthquakes, magnitudes, hazard areas and etc.... This evaluation is important to reduce the risk of earthquakes in the future of urban planning. Nevertheless, all the techniques for earthquake prediction were not successful in allowing future prediction, because the earthquake data were random, and it was very hard to find any patterns, perhaps there was nothing certain.

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