Research Paper

On the GIS-Based Seismic Risk Maps of Jablah City, Syria

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ABSTRACT

Seismic risk assessment is a necessary study to mitigate future earthquake damage in urban area. Jablah city is an old coastal city in Syria; it had been affected by many historical earthquakes, and it has not been studied seismically yet. The seismic database in National Earthquake Center in Syria was used to calculate seismic hazard maps of the study area. These maps indicate that the values of the ground acceleration are increasing towards the north and southeast of the Jablah city. Field work on soil shows that dominant period values range from 0.34 to 2.5 seconds, and amplification factor values from 1.1 to 3.7. The period of free vibration of the buildings varied from 0.09 to 0.45 seconds for the selected buildings. To assess the current status of the buildings, an evaluation form of vulnerability has been prepared. As a result, the vulnerability coefficient of the studied buildings to seismic forces ranged from 0.3 to 0.6. To obtain seismic risk maps, GIS program was used to process multiple layers such as seismic hazard map, dominant period, amplification factor of soil, free vibration period of buildings and assessment of their current status. The results show that many crowded neighborhoods in Jablah city are located in high seismic risk areas where tall and important buildings are located. This confirms that the high potential of human and economic losses concentrated in the city center

Keywords:
Risk assessment; Seismic hazard; Vulnerability; Dominant period; Amplification factor

1. Introduction

The damage caused by strong earthquakes has led to increase the interest in studies that concerned with mitigating the effects of earthquakes on the population and infrastructure of cities. Jablah is a coastal city on Mediterranean Sea located in the northwestern Syria, 22 km south of Latakia city.

The city is situated in the northwestern Arabian plate and surrounded by many important tectonic structures such as: Al-Ghab, Latakia-Killis faults and Cyprus Arc. It had been affected by historical earthquakes, in the years 1408, and 1796 with intensity IX and VIII-IX, respectively (Plassard & Kogoj, 1981; Ambraseys & Barazangi, 1989) (Sbeinati et al., 2005). Geologically, the city is located on the fluvial and marine quaternary deposits (Ponikarov, 1966). Based on Syrian seismic code (The Syrian Arab code for the design and structure of reinforced concrete structures, 2015), the area of Jablah is exposed to a strong earthquake with a spectral acceleration equal to 1.5 g for natural period of 0.2 sec and 10% exceedance rate. Figure (1) shows the location of the study area

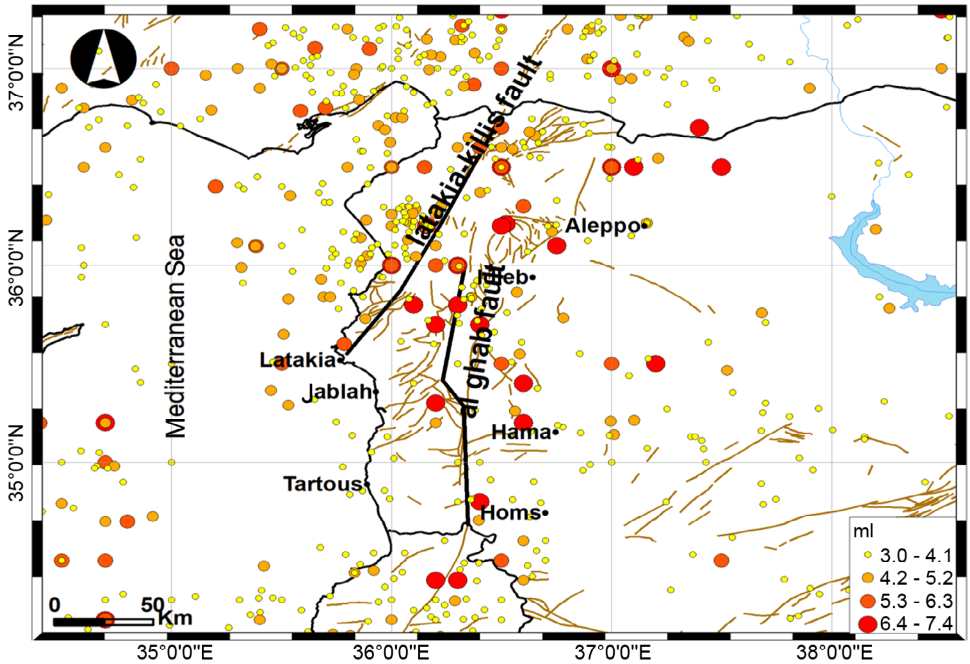


Figure 1. The location of linear seismic sources and Jablah city. In the background: circles represent earthquake epicenters, faults and major cities.

and the affected seismic sources.

Seismic risk is the knowledge of population and economic losses that caused by strong earthquake of a given magnitude in a particular city at a particular time. In other words, high seismic hazard does not imply high seismic risk, unless it is accompanied by high population density and building vulnerability (Wang, 2006). Much research has focused on seismic risk assessment around the world such as, Federal Emergency Management Agency (FEMA-NIBS, 1999) suggested a model which is called HAZUS methodology, and it is one of the most complete methodologies for seismic risk assessment. HAZUS relies on the GIS program to map natural hazards, assessing expected human losses and economic damage that could be associated with future earthquakes. It has improved knowledge of seismic risk and the building codes; however, this method is based on one type of soil.

Hajibabaee et al. (2013) presented a simple and comprehensive method to assess the relative seismic risk for urban areas instead of absolute seismic risk in Tehran, Iran. They used hazard factors and vulnerability indicators, then determined the important weight factors of each indicator and its parameters. The assessment of risk and response capacity was obtained by integrating indicators of vulnerability and hazard factors. According to their study, the proposed model showed the highest level of seismic risk in the southeastern part of Tehran. This method is important to evaluate seismic risk in a regional area, but without considering the effect of the site.

Badawy et al. (2016) simulated the Cairo earthquake on October 12, 1992 with magnitude mb(5.8) to update the seismic risk assessment and evaluate the social and economic losses. HAZUS-MH methodology was used to combine seismic hazard, earthquake catalog, building vulnerability and the population distribution to get the seismic risk assessment and social-economic losses of Cairo city. As a result, most urban areas in Cairo city would face high seismic risk due to their high density population and building types. In this research, no consideration is given to the effect of location.

Crowley et al. (2020) created the database of building in 45 countries in Europe. Rely on national agencies for information on residential and non-residential buildings and construction cost as well as population density. The information was combined with European seismic hazard model of PGA (of 0.1 g) for a return period of 475 years to build the European Model for seismic risk assessment. The problem is that European countries have more than one level of seismic hazard caused by a lot of seismic sources.

Zaalishvili et al. (2020) assessed the seismic risk of Vladikavkaz city based on HAZUS system. The method included seismic hazard maps, site effect, and building's type, density of population, life facilities and secondary effects of earthquake. In the end, physical and human losses were calculated but the resonance between structure and soil did not take into account.

Dolce et al. (2021) used seismic hazard model with six vulnerability models and one exposure data and the same class of soil (type A) to calculate the seismic risk for Italy. They obtained unconditional seismic risk maps and social-economic losses. The problem is that, authors based their study on one type of soil to get seismic risk maps.

In this study, we have used several indicators to assess seismic risk in Jablah city. These indicators are: 1) seismic hazard level in terms of peak ground acceleration, 2) the amplification factor of the soil, 3) the resonance probability between buildings and soil, 4) the vulnerability of buildings, 5) the density of the population distribution map, 6) the estimated cost of the buildings. These indicators were weighted into numeric values then they processed by Analytical Hierarchy Process (AHP) method (Saaty, 1980).

As well known that the seismic hazard is the first index to create seismic risk map for any city; seismic hazard is the probability of occurrence of certain level of ground shaking with an expected magnitude at a given time for a specific place. Many researchers around the world have used probabilistic seismic hazard approach for seismic hazard analysis (e.g. (Rahman & Bai, 2018; Sil, 2016; Rout et al., 2015; Gaspar-Escribano et al., 2010; Deif et al., 2009; Leydecker et al., 2008; Aliaj et al., 2004; Mantyniemi et al., 2003).

Based on seismic, geologic and tectonic settings of Syria, two linear seismic sources were determined. These sources are: Al-Ghab and Latakia-Killis faults. The probabilistic approach was used to create seismic hazard maps for Jablah city.

Al-Ghab fault is the Syrian segment of Dead Sea fault system; it is a pull-apart basin of 15 km wide and 90 km long, located near to the Coastal Mountains. According to Alchalbi et al. (2010), the slip rate of this fault is about 2 mm/year. Another active seismic source is the oblique sinisterly-thrust Latakia-Killis fault (Trifonov et al., 1991). It extends from Latakia city on the coastal line in Syria to Killis city in south of Turkey.

Seismic risk study is a process that contains several input indicators such as soil characteristics, soil building interaction, building dynamic properties, infrastructure vulnerability and socio-economic affects. In this work, we recorded seismic noise measurements in 48 locations in the city to devise the dominant period and amplification factor of soil. We used fast Fourier transform and spectral horizontal to vertical ratio. The results were mapped along the city design plan. Also we did a survey to measure the free vibration period of 42 residential and government buildings. The selected sample of buildings contains 2 to 9 floors with height from 6 to 27 m. The current status of these buildings was studied to assess the vulnerability of their response to seismic forces using several parameters that will be discussed later in the following sections.

Google earth satellite image was used for identifying houses, then counting population density and assessing construction cost. The main objective of this research paper is to evaluate seismic risk maps for Jablah city.

Analyzing the obtained results from seismic hazard maps shows that the values of the ground acceleration are increasing towards the north and southeast of Jablah city.

Soil properties estimated by seismic noise field work indicate that the dominant period of soil foundation range from 0.34 to 2.5 seconds. Its value increases from east to west of the city area. The spectral ratio amplification factor values vary in the range from 1.1 to 3.7.

Measuring the free vibration period of buildings indicates that the values belong to the range of 0.09 to 0.45 seconds. Using these measurements, empirical equation which correlate free vibration period of the longitudinal and transversal components with the number of floors is developed.

To assess the vulnerability of building in Jablah city, a set number of buildings were selected to represent all types. A set of criteria were used to estimate building vulnerability to seismic forces. The vulnerability coefficient of the studied buildings to seismic forces varies in the range from 0.3 to 0.6.

Finally, maps of socio-economic losses were estimated in terms of seismic risk maps showing that potential human and economic losses are concentrated in the center city.

This study shows the expected high damage locations and the buildings vulnerability. Both criteria are of great importance to mitigate potential economic and human losses. Therefore it is recommended to use the results of this study by relevant local government agencies that concerned with planning, design and management of natural future disasters.

In general, seismic risk assessment is difficult to calculate, especially when absolute data on buildings and population distribution are not available. The proposed method is the first of its kind as it took into accounts the site effect, the free vibration period of buildings and the resonance between soil and buildings. Seismic risk assessment was performed by processing these parameters with detailed maps of the ground acceleration and buildings and population distribution. Also, empirical equations were introduced to calculate the free vibration period of buildings in Syria.

2. Methodology

Most of the methods used to study seismic risk assessment have focused on ground acceleration, building's status and population density, and most researchers have based their study on one type of soil. In this method, to perform seismic risk assessment, we used seismic hazard level, the distribution of buildings and residents, the status of buildings, and also field work was carried out to obtain detailed information of the site effect and the free vibration period of buildings, then the resonance between soil and buildings was evaluated.

In order to perform Seismic risk assessment of Jablah city the following indicators are considered: 1) seismic hazard level in terms of ground acceleration, 2) the soil site effect in terms of amplification factor, 3) the interrelationship potential resonance between buildings and soil, 4) the vulnerability buildings, 5) the density of the population distribution in the city, 6) and the expected economic cost. The indicators were given weighted value then processed by Analytical hierarchy process (AHP) (Saaty, 1980).

3. Seismic Hazard Assessment

The Seismic database that prepared by Syrian National Earthquake Center staff is used to study two seismic linear sources. These sources are Al-Ghab and Latakia-Killis faults. We have derived the seismic parameters for the seismic linear sources. The Gutenberg-Richter parameters (a, b value, $\beta = b*\log(10)$, σb, $\sigma\beta$), the exceedance rate "λ_0" of threshold magnitude "M_0", maximum magnitude "M_{max}", lower limit for the maximum magnitude "M_1" and upper limit of the maximum magnitude "M_2" were estimated.

Processing probabilistic seismic hazard method, using Joyner and Boore (1993) attenuation relationship, the spectral acceleration map for Jablah city is prepared for 10% probability of exceedance rate, 0.2 sec structural period in 50 years of building economic age. To draw and manipulate acceleration data we used CRISIS (Ordaz et al., 2007) hazard software. Table (1) illustrates the derived parameters for the three seismic sources that used to calculate spectral acceleration map.

4. Soil Site-Class Effect

To know the soil-site seismic characteristics, we carried out filed work which includes 48 seismic noise measurements in Jablah city using a portable seismometer (Guralp CMG 40T-1), which records the weak ground motions in terms of velocity. Analysis of seismic noise measurements

Table 1. The linear seismic sources parameters that estimated based on earthquake catalog.

Seismic Source	Number	a	b	σb	β	σβ	M_0	M_{max}	M_1	M_2	R
Al Ghab	34	2.49	0.28	0.04	0.64	0.09	3.5	7.9	7.4	8.4	0.99
Latakia-Killis	42	3.82	0.49	0.07	1.13	0.16	4	7.8	7.3	8.3	0.99

using the fast Fourier transform method allows us to estimate spectral horizontal to vertical H/V ratio. Consequently, the soil dominant period and amplification factors were estimated for the selected 48 sites. Uniform maps of amplification and dominant period of soil for the city were created using ArcGIS program.

5. Vulnerability of Building

To achieve the goal of this work, the dynamic properties of structures were estimated for different selected types. A field survey of buildings was conducted to measure the free vibration period and study the current status of buildings by means of number of floors, type of occupation, type and age of building, and construction site. A specific form has been developed to include all the required parameters needed by the survey work.

5.1. Measuring Free Vibration Period of Building

After selecting different types of structures, the free vibration period was measured for 42 residential and government buildings with height ranging from 6-32 meters. The chosen buildings were classified based on their number of floors ranging between 2-9 floors. This survey was done using a portable broadband seismometer (Guralp CMG 40T-1). The seismometer was placed on the roof of buildings then turn on to measure the seismic noise for about 15 minutes. The records were analyzed to obtain the free vibration period of the horizontal components of each building by fast Fourier transform method; the results indicate that the values range 0.09-0.45 seconds. These values were used to derive empirical equations that relate the free vibration period of building for longitudinal and transversal components with the number of floors as Equation (1):

$$\begin{aligned} &T = 0.047 * N + 0.018 \\ &R = 0.94,\ SE = 0.33,\ SD = 0.1 \end{aligned} \tag{1}$$

where T is the free vibration period, N is the number of floors, R is the regression factor, SE is the standard error, SD is the standard deviation.

5.2. Building's Data Handling

In order to prepare various data layers regarding the factors that cause damages to buildings while resisting seismic forces, we must examine the current state of the building's resistance.

Reference studies indicated that there are a number of indirect factors that increase the damage to buildings. These factors are the structure type, type of occupancy, height, regularity, age, location, ground floor area, the current state and the presence of defects in the construction system. Figure (2) shows a flowchart of the factors that can effect on the seismic response of buildings.

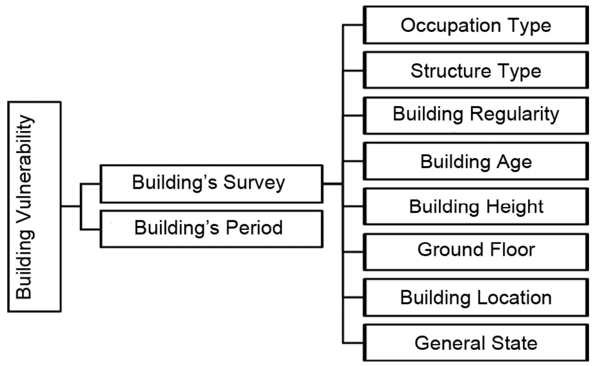


Figure 2. A flowchart of the factors that can effect on the seismic response of buildings.

After obtaining the data layers, Analytical hierarchy process (AHP) (Saaty, 1980) was used to predict the potential damage to the studied buildings according to the following proposed equation:

$$\begin{aligned} &BVFi = 0.15OTi + 0.5BHi + \\ &0.10BRi + 0.15STi + 0.15BAi + \\ &0.15GFAi + 0.15BLi + 0.20GSi \end{aligned} \tag{2}$$

where $BVFi$ is Building Vulnerability Factor, OTi is Occupation Type, BHi is Building Height, BRi is Building Regularity, STi is Structure Type, BAi is Building Age, $GFAi$ is Ground Floor Area, BLi is Building Location, GSi is General State.

The vulnerability coefficient value of the studied buildings to seismic forces ranged from 0.3 to 0.6.

6. Building and Population Statistics

To implement the seismic risk map, one must know the statistical information of the distribution of buildings and population per unit area. Also, knowing the cost of reconstruction of each damaged building per metric area is very important to estimate the massive losses which would occur. However, the expected area of damage from a future earthquake for the predicted scenario is related to several factors including the magnitude, distance to the main shock, building fragility and dynamic soil properties.

In this work, we used Landsat satellite image with 20 m resolution to map the distribution of buildings and population in Jablah city. This image was referenced using World Geodetic Reference WGS84 method. Using ArcGIS software the vector image was produced by digitizing the buildings and roads into the satellite image. Figure (3) shows the digitized layer of Jablah city. We found that the number of buildings in Jablah city is about 3600 building. Through field work we found that the floors of buildings range 1-9 floors, which are dominated by the reinforced concrete type, except for some stone buildings in the old neighborhoods. Field work showed that the population of the city is about 266000.

Figure 3. The digitized layer using Landsat satellite image of Jablah city.

According to the municipality of Jablah city, the cost per square meter for construction is about 80-100 thousands Syrian pounds (2018) depending on the type of occupation residential or government. The estimated cost of building was around 13 million Syrian pounds per 200 m^2 unit area. Consequently, the expected economic cost and the population density layers were prepared and then reclassified. These layers were integrated with the other layers to produce the necessary maps. Figure (4) shows a flowchart of the process used to map seismic risk assessment and calculate the expected human and physical losses in research.

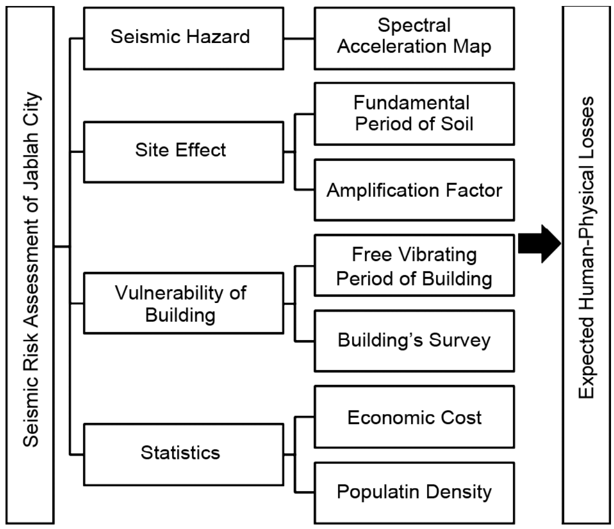


Figure 4. A flowchart of the process that used to calculate the expected human and physical losses in the research.

7. Seismic Risk Assessment

Layers that represent soil effect and vulnerability of buildings were compiled using developed weighting equations to produce the seismic risk map. In order to use Analytical hierarchy process (AHP) (Saaty, 1980) we have converted the layers from vector to raster 200*200 m images using ArcGIS software. These layers also reclassified into several classes using spatial analyst tools then were weighted using raster calculator. The following formula were developed and used in calculation.

$$IF_i = 0.40 * BVF_{ij} + 0.25 * TB_{ij} + 0.25 * A0_{ij} + 0.10 * SA_{ij} \tag{3}$$

where IF is influence factor, BVF_{ij} is building vulnerability factor, TB_{ij} is possibility of resonance, A0ij is amplification factor, SA_{ij} is spectral acceleration factor. The constant numbers in the above formula represent the weighting values of each layer.

Table (2) shows the main factors that affect seismic risk and the layers of criteria representing them, which are used in processing seismic risk map of Jablah city. The table also shows the degree of reclassified layers and their weighting values.

Four major affect factors were gathered to represent the possible influence factor of seismic risk assessment in Jablah city such as: the spectral acceleration, soil's amplification factor, the potential resonance between buildings and foundation, and the vulnerability of buildings. In this study, we try to discuss and emphasize the main reasons that may increase the damage of buildings due to seismic load as well as predict the amount of economical and human losses that may occur at the time of strong seismic load. Figure (5) shows the main factors layers that were processed and reclassified by ArcGIS program.

8. Human and Economic Losses

To predict the amount of human and economic losses, the following two equations that formed based on Analytical hierarchy process (AHP) (Saaty, 1980) have been applied:

$$PLF_i = 0.50 * IF_{ij} + 0.50 * PF_{ij} \tag{4}$$

$$ELF_i = 0.50 * IF_{ij} + 0.50 * EF_{ij} \tag{5}$$

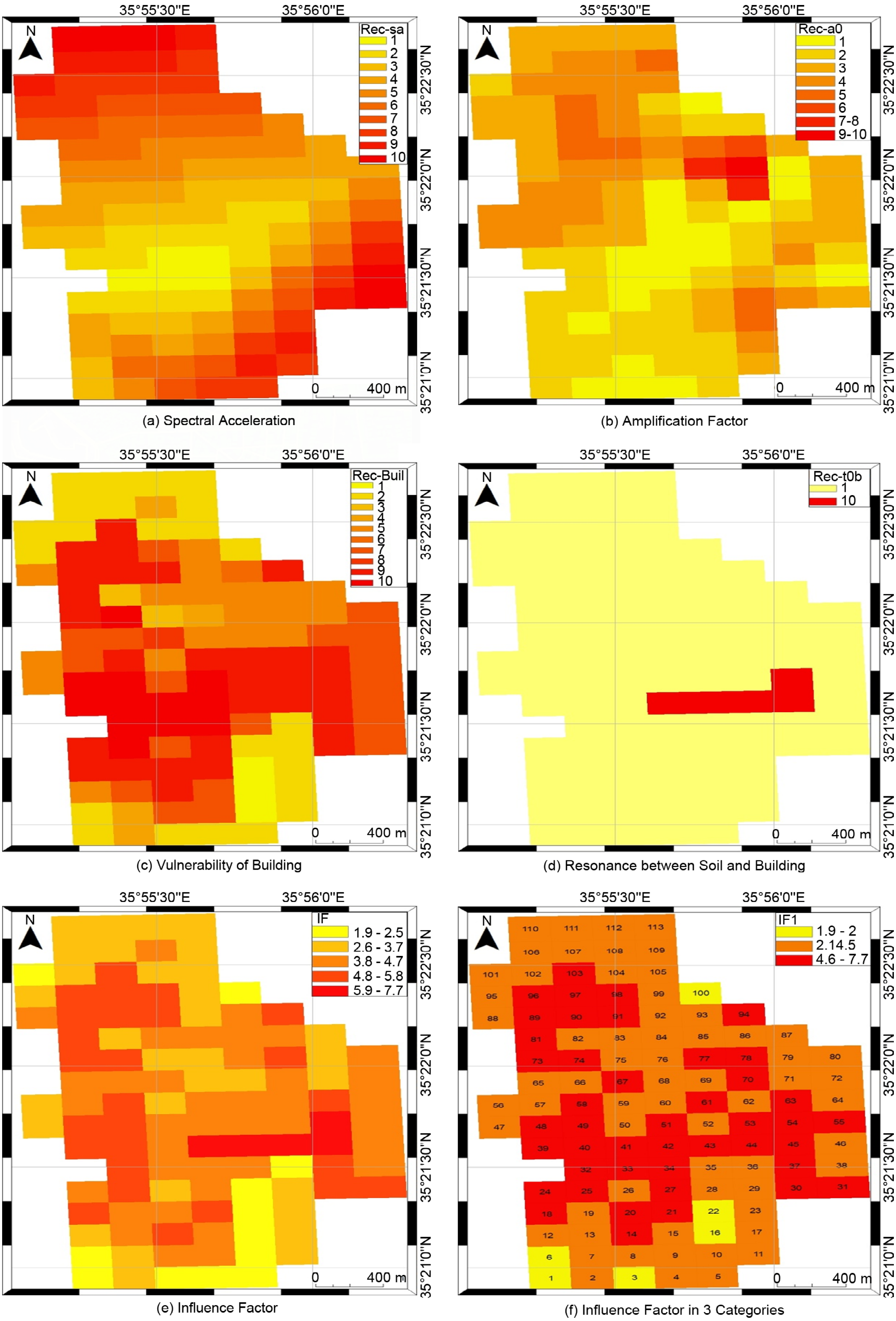
where PLF_i is human loss, PF_{ij} is population density distribution, ELF_i is economic loss, EF_{ij} is economic cost distribution, IF_{ij} is influence factor. The weighting value of each factor is W_{ij} =0.50. Figure (6) shows the estimated human and economic losses layers.

9. Results and Discussion

The resulting maps show that values of the

Table 2. The criteria layers, their weighted values and the reclassified degree Wij.

Criteria Rank Ri	Criteria Type	Range	Reclassified Degree Wij	Range	Reclassified Degree Wij
0.1	Spectral Acceleration SA (gal)	329.82-330.48	1	333.14-333.79	6
		330.49-331.14	2	333.80-334.45	7
		331.15-331.81	3	334.46-335.12	8
		332.48-333.13	4	335.13-335.78	9
		331.82-332.47	5	335.13-335.78	10
0.25	Amplification Factor A0	1.35-1.83	1	3.77-4.25	6
		1.84-2.32	2	4.26-4.73	7
		2.33-2.8	3	4.74-5.21	8
		2.81-3.28	4	5.22-5.7	9
		3.29-3.76	5	5.71-6.18	10
0.4	Vulnerability Building BVF	0-0.6	1	3.1-3.6	6
		0.7-1.2	2	3.7-4.2	7
		1.3-1.8	3	4.3-4.8	8
		1.9-2.4	4	4.9-5.4	9
		2.5-3	5	5.5-6	10
0.25	Resonance TB (sec)	0	1	_	_
		0.27	10	_	_
0.5	Population Density Person/200 m^2	0-240	1	2031-2570	6
		241-540	2	2571-3840	7
		541-1130	3	3841-5160	8
		1131-1680	4	5161-6400	9
		1681-2030	5	6401-8700	10
0.5	Economic Cost EF Million Syrian Pound	0-182	1	2433-3011	6
		183-476	2	3012-3513	7
		477-886	3	3514-4516	8
		887-1713	4	4517-5580	9
		1714-2432	5	5581-7171	10



(a) Spectral Acceleration

(b) Amplification Factor

(c) Vulnerability of Building

(d) Resonance between Soil and Building

(e) Influence Factor

(f) Influence Factor in 3 Categories

Figure 5. The main factors layers that were processed and reclassified by ArcGIS program to estimate the influence factor of seismic risk assessment in Jablah city.

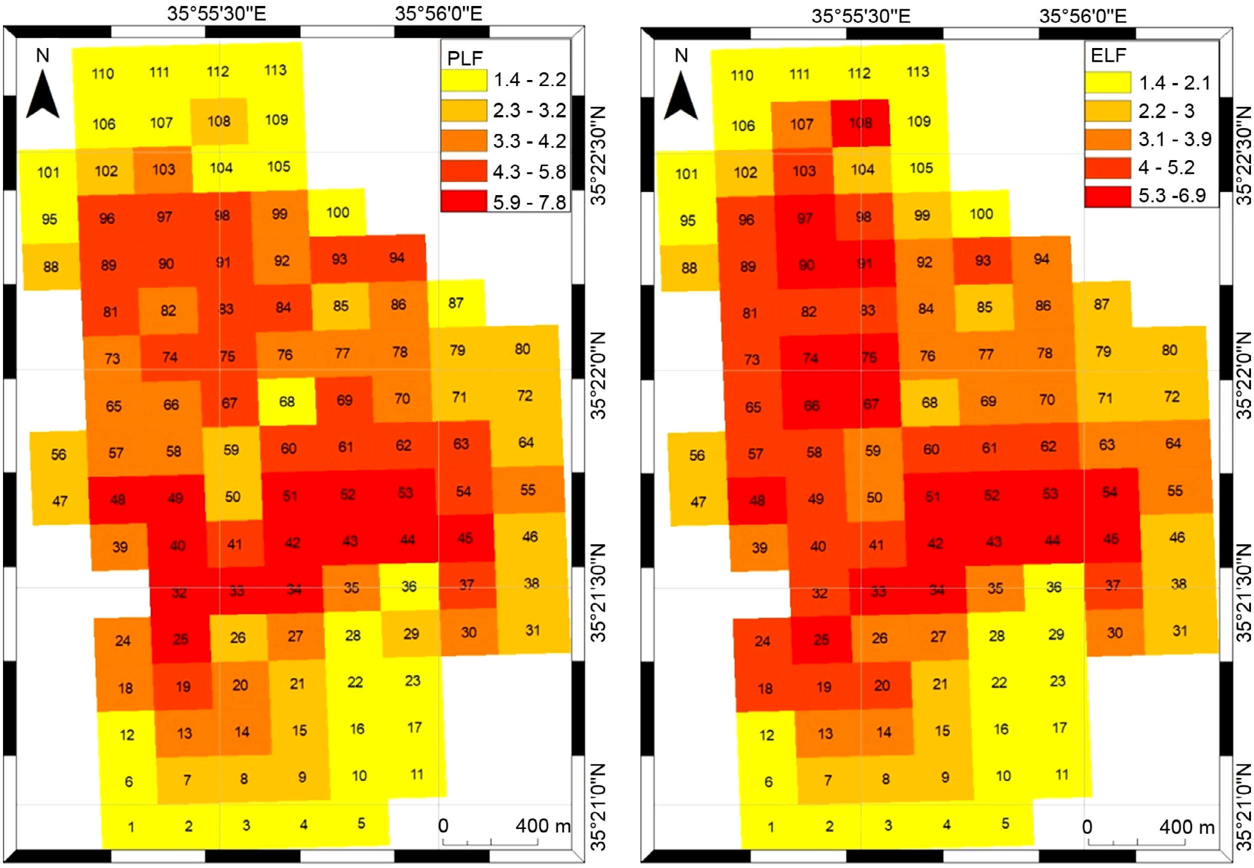


Figure 6. The estimated human and economic loss layers in Jablah city.

influence factor "IF" of the seismic risk vary in the range between 19-77% as a percentage of expected damage. These values were divided according to the classification (FEMA, 2016) (ATC, 1985) into three categories: slight, moderate and extensive. The expected building damage in terms of influence factor were grouped into 3 categories and shown in Table (3) along with the percentage of damage and building number. Figure (7) shows these categories with the buildings count in each section of the city. The letter (s) represents buildings count in the first category, (m) buildings count in the second category and (e) buildings count in the third category.

The probabilistic seismic hazard method was used to obtain seismic hazard maps in terms of

Table 3. The classified categories of damage factor "IF" and buildings count according to FEMA, 2016 and ATC, 1985.

Damage Factor: Influence Factor (IF)	Percentage	Buildings Count
Slight (s)	<20 %	48
Moderate (m)	20-45 %	1164
Extensive €	45-80 %	2295

return period, structural period and spectral acceleration. The output data maps have been reclassified and introduced into the methodology of seismic risk evaluation. One of the major inputs which may increase the human and economic losses is the soil effect. This factor has been studied in details in Jablah city. Firstly, we carried out seismic noise measurements; the dominant period of soil was estimated using horizontal to vertical spectral Fourier transform methods. We examined the vulnerability of buildings by doing field work on some buildings to verify their ability to withstand future earthquake forces. The free vibration period of buildings were estimated, and other characteristics of buildings as structural type, age, height, were reported in details. Also, the probability of resonance between soil and buildings was predicted.

All the input layers were prepared, reclassified, and then weighted using proper equations. The general influence layer was estimated using major affected factors. This layer has been processed with population density and economic coast

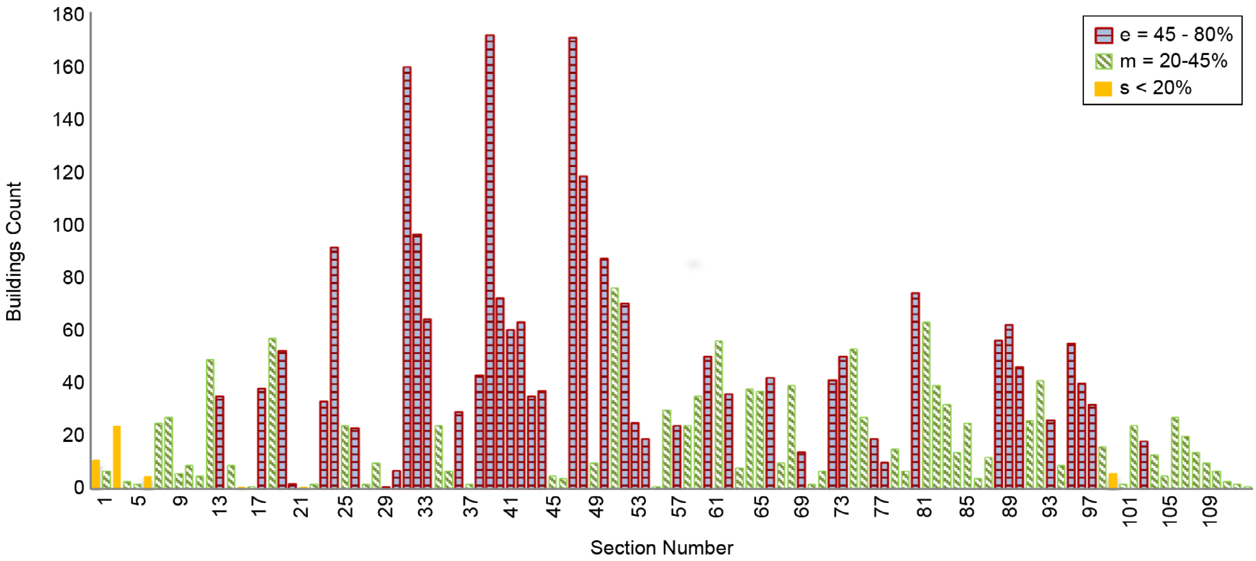


Figure 7. Buildings count in each section of the city; the letter (s) represents buildings count in first category, (m) buildings count in second category and (e) buildings count in third category.

layers to produce seismic risk maps. The value of influence factor *IF* varies in the range of 19-77%, *IF* has been divided into three categories of expected damage: slight (s) contains 48 buildings, moderate (m) contains 1146 buildings and extensive (e) contains 2295 buildings.

The results of the seismic risk assessment show that the potential human losses are concentrated in the neighborhoods of al-'Izzi, al-Drayba, al-Tadamon and al-Adiyat Avenue in Jablah city.

In case of occurring of an earthquake on Al Ghab fault (ml = 7.9) and Latkia-Killis fault (ml = 7.8), the potential human losses will range between 59-78% in these neighborhoods, which means that the losses may reach 63000 people.

Potentially high economic losses are concentrated in the Naqaa neighborhood, and the center of the city where governmental departments and schools, markets, Al-Amara and al-Azi district.

The potential economic losses will range between 53-69%, which means that the losses could be around 60 billion Syrian pounds as a result of the two scenarios mentioned above.

10. Conclusions

In this paper, the multiple criteria method was used to compile multiple layers to evaluate seismic risk of Jablah city. Several layers representing spectral acceleration, dominant period and amplification factor of soil, dynamic properties of buildings and their current anti-seismic status have been processed and reclassified in the ArcGIS program. The layers were weighted then processed to obtain the main influence factor *IF* of the seismic risk.

In order to estimate the potential human losses, the influence map and the population density distribution layers were weighted and manipulated. Also, the influence layer was used again with the economic cost layer to evaluate the economic losses.

Consequently, the proposed methodology used in this study has been revealed the following results:

- Seismic hazard maps indicate that the ground acceleration values are increasing towards the north and southeast of the city.
- The results of the field work on the soil show that the dominant period values ranged from 0.34 to 2.5 s as it increased from east to west. The amplification factor values ranged from 1.1 to 3.7.
- Values of free vibration period of buildings ranged from 0.09 to 0.45 s for the selected buildings.
- The results of field measurements were used to devise empirical equations relating the free vibration period on the longitudinal and transversal components of the building with the

number of floors.

- To assess the current status of the buildings, an evaluation form of vulnerability building has been prepared. As a result, the vulnerability coefficient of the studied buildings to seismic forces ranged from 0.3 to 0.6.
- Potential human losses are concentrated in densely populated neighborhoods such as al-'Izzi, al-Drayba, al-Tadamon and al-Adiyat Avenue from Jablah city. Potential human losses are in the range of 59-78% for these areas.
- Potential economic losses are concentrated in the Naqaa neighborhood, the center of the city, the main market, and Al-Amara and al-Azi district where the high-rise and important buildings are located. High values of potential economic losses ranged between 53 - 69% for these areas.

What distinguishes this method is its use of the site effect, the free vibration period of building and the resonance between soil and building, as well as the status of building and approximate number of people and buildings to assess seismic risk and calculate percentage values of human and economic losses. The method is very useful, especially in the absence of real statistical data, and the inability to measure the free vibration period of all buildings.

Although the proposed method considers the factors that should be used for seismic risk assessment, it has three limitations: initially, there are no attenuation relationships specific to the study area; therefore, it was necessary to use a general attenuation relationship. Secondly, it was not possible to measure the free vibration period of all buildings in the city because there are more than 3600 buildings as shown in the satellite image and the work team is not enough to make such measurements. Thirdly, there is no real statistical data on the population density and the number of buildings in the city, so the study needs to be based on a satellite image.

The study has been shown the locations of expected damage and the status of the existing buildings to withstand the seismic forces in the future, which are of great importance to mitigate economic and human losses. Therefore, it is necessary to take advantage of them by government agencies interested in planning, design and management of natural disasters.

In general, it is difficult to comply with building codes in developing countries due to the high cost and lack of awareness of the importance of earthquake-resistant construction. Monitoring the seismic activity in Syria has increased awareness of the earthquake potential in areas such as Jablah city, so the Syrian engineering syndicate is collaborating with other agencies to improve earthquake-resistant building codes, and they can use the results of site effect, the ground acceleration maps and the empirical equation to improve Syrian seismic code.

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