Copyright © 2014 Scienceline Publication

Journal of Civil Engineering and Urbanism

Volume 4, Issue 2: 169-178 (2014) ISSN-2252-0430

Assessment less Developed Neighborhoods to Earthquake Risk (A Case Study of Qaradiyan Neighborhood of Sanandaj City)

Kyoumars Habibi[1], Roohallah Tavallaei[1]*, Mohammad Azami[2]

[1]*Department of Urban Planning, University of Kurdistan, Sanandaj, Iran*
[2]*Department of Urban Planning, University of Mazandaran, Babolsar, Iran*

*Corresponding author's Email: tavallaei.1986@gmail.com

ABSTRACT: Earthquakes are known as a recurrent phenomenon during history. In most cases, they have destructive effects on human settlements and put considerable damage on the citizens. Whereas, The old and erosion texture of the city are the most vulnerable parts to natural disasters. Not paying enough attention to consolidation these textures has led to their increasing vulnerability in a way that there is the most damage in these parts in the smallest natural disasters. This paper, which is based on a quantity-analytic approach, is seeking to investigate and analyze the vulnerability of the Qaradiyan neighborhood as an old texture in Sanandaj city by decadence and intervention indexes using the Fuzzy model to provide strategies that reduce the vulnerability of these textures to earthquake dangers and achieving to urban sustainability. Results of this paper show that high population density, high level of household rate, low level of building ownership, high occupancy rate, small size blocks, narrow and impasse pathway, unavailability to open and suitable spaces, durable buildings and their low resistance of structure to earthquakes are some of the features of this district.

ORIGINAL ARTICLE
Received 15 Jun. 2013
Accepted 03 Oct. 2013

Keywords: Urban Sustainability, Vulnerability, Crisis Management, Fuzzy model

INTRODUCTION

Earthquakes are one of contemporary era's main unkind natural phenomena that create great calamities during its short length of happening. Sustainability and safety from natural disasters have always occupied human's mind. What raises earthquakes as a threat is, in fact, human's unpreparedness for encountering. Earthquakes have been and will be repeatable phenomena during history. In most cases, they have destructive effects on human settlements and put considerable damage on the citizens. Although, scientific progresses, in the past recent decades, have realized the scientific how of their creation and have studied their occurrence and outcomes, but they still are not able to prevent their occurrence and to resist them and they have not the knowledge to predict their exact and scientific power and occurrence time.

About %50 of the world's large cities are located near to active earthquake faults or flood zones. It is estimated that %95 of natural disaster victims are from developing countries and the damage produced in such countries is 20 times more than that of developed countries (Kreimer et al., 2003). Considering natural disasters is such an important issue that the United Nation's General Assembly in the December of 1987 announced the decade between 1990 and 2000 as the international decade of reducing natural disaster's effects (Azizi and Akbari, 2008). The importance of paying attention to crisis and event management forced us to study and analyze the vulnerability of Qaradiyan district as an old and erosion texture of Sanandaj city using erosion and intervention indicators to provide methods to reduce the vulnerability of such areas to earthquake dangers.

Theoretical bases

About half of the 6 billion population of the world live in the cities today and it has been predicted that during the next 30 years, 2.1 billion people of the 2.2 billion population that is going to be added to the current world's population will inhabit the cities and it is expected that 2 billion people of this population will be born in the developing countries (USAID, 1998).

Thousands of people are killed in each earthquake and the number of the victims is even several times more in Iran because of being unprepared to face it. Official statistics show that 6 percent of human casualties in Iran in the last 25 years have been due to earthquakes (Ranjbar et al., 2006). Recent earthquakes show the vulnerability level of the cities in Iran. Each one of Boueen Zahra earthquake (1962), Roudbar earthquake (1990) and Bam earthquake (2003) caused thousands of people killed. Bam earthquake, for example, caused more than 30 thousand killed, more than 10 thousand injured, and more than 100 thousand homeless and more than 80 percent of city was ruined and destroyed all the city infrastructures and cost more than 800 million dollars (NCNDR, 2005). Whereas, a similar earthquake to that of Bam occurred in San Rubles state of the United States just 4 days later and only 2 people were killed (UNISDR, 2005).

Iran's wide geographical range is a disaster prone region that experiences natural disasters such as earthquakes, landslides, flood, hurricanes, drought, volcanoes and desertification. In the United Nation's Department of Planning 2003 report, Iran had the first rank in the number of earthquakes with the intensity of higher than 5.5 Richter in a year. It also had a high rank in the vulnerability to earthquake and the number of the people killed. The report also showed that earthquakes constitute the majority of natural disasters (UNDP, 2003).

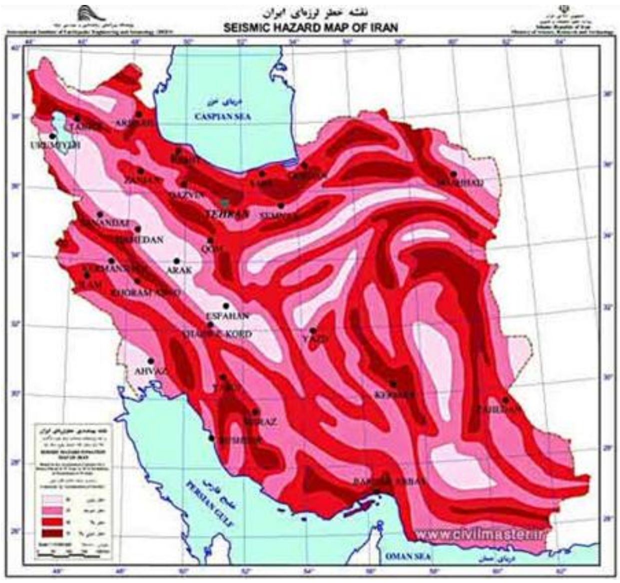

Figure 1. Earthquake hazard zoning map of Iran (www.ngdir.ir)

Having special geological features and being located on the Alp-Himalaya earthquake belt, Iran is in danger of earthquakes in many places. Few places can be found in Iran that is safe from earthquakes. So no place is completely safe from earthquakes. According to the official statistics 6 percent of Iran's casualties have been due to earthquakes in the last 25 years and on average there is a 6 Richter-strong earthquake in each year and a 7 Richter-strong one in each ten years, the last one being the 6.8 Richter-strong Bam earthquake in December of 2003 (Ranjbar et al., 2006). In the literature of earthquake discussion, vulnerability is defined as the resistance level, stability or being safe from a natural disaster in long-term or short-term (Mileti, 1999). It seems that it is necessary to have a special planning in order to make city spaces safer. The knowledge of urbanization can reduce the effect of such disasters to a great extent using geographical data and its own principles and concepts and city managers can apply management principles to reduce the vulnerability of the cities to these disasters (Abdollahi, 2004).

Therefore, the reduction of earthquake effects, i.e. the reduction of vulnerability of human societies to earthquake, is achieved when the safety of the city is considered in all levels of management. It seems that the mid-level, i.e. urbanization, is of the most efficient levels of management to reduce the vulnerability of the cities to earthquakes (Ardalan et al., 2006). The statistics of the year 1375 show that 274 cities of the total 614 cities of the country are in the danger range of rather high, high and very high. This means that about the half the urban population in that year were in the danger range of rather high, high and very high Figure 1. This is a warning for the city management principals of the country that they should pay more attention to crisis management in the urban spaces (www.ngdir.ir).

According the vulnerability of Iran's cities is high and inappropriate location allocation of new town in regions in danger of natural disasters and the number of the cities is increasing, evaluating vulnerability and crisis management in the cities of the country is necessary. According to the census report of the year 2011, 53 million people (nearly %70) out of 75 million people population of the country were living in the cities whereas it was 6 million people (%31.4 of the population) in the year 1976. The number of the cities has risen from the year 1976 to the year 2011 and this shows the necessity of crisis management more than ever (www.sci.org.ir).

Using modern technologies such as GIS is widespread in developed countries and much study has been done (Zipf and Leiner, 2004) that can help much to predict vulnerable areas and to help the injured people and organize post-occurrence activities.

Research history

The vulnerability of the city to the natural disasters like earthquake is a function of human behavior that indicates the impressibility level or the resistance ability of the economic and social units and physical possessions of the city to natural disasters (Rashed & Weeks, 2003). Several models have been proposed to calculate the vulnerability level of the texture in the last two decades to direct societies to a way to reduce the effects of natural disasters.

Rashed used GIS in the modeling of the vulnerability to earthquake in 2003

Figure 2. He has a Fuzzy approach to the world around in his model and accordingly proposes a model based on analytic hierarchy process (AHP) to predict the danger level. Factors that he counts in his model include: the minimum function of bridges, emergency services, hospitals, power transferring lines, highways, and the maximum cost of rebuilding the buildings, shelter need, debris amount and the percentage of the destroyed areas by fire.

To cite this paper: Habibi K, Tavallaei R, Azami M. 2014. Assessment less Developed Neighborhoods to Earthquake Risk (A Case Study of Qaradiyan Neighborhood of Sanandaj City). *J. Civil Eng. Urban.* 4 (2): 169-178.
Journal homepage: http://www.ojceu.ir/main/

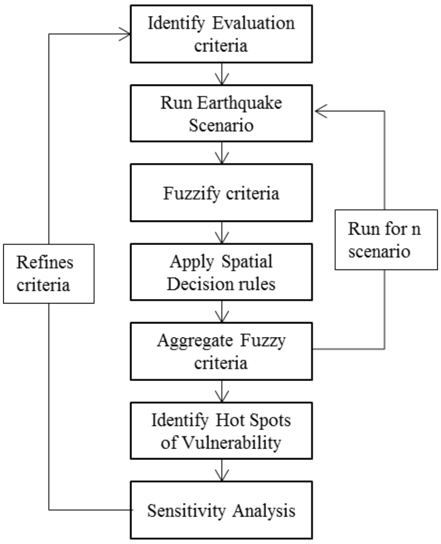

Figure 2. Framework for the study (Rashed and Weeks, 2003)

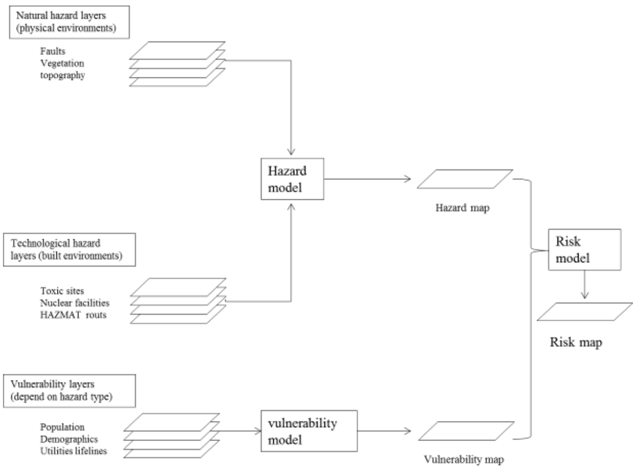

Figure 3. One approach to modeling the concepts of hazard, vulnerability, and risk in a GIS context (Cova, 1999)

The process he uses to analyze vulnerability is composed of seven stages. The first stage is selection of the evaluating criteria and indicators that determine the analysis border. Possible ground movements due to earthquakes are evaluated in the second stage using statistical calculation and therefore the damage of a supposed earthquake can be measured. The possible damage from the implemented scenario is made Fuzzy in the third stage. The Fuzzify criterion are compared and ranked two by two using AHP technique to produce some Fuzzy weights in the fourth stage. In the fifth stage, the criteria are merged together to form a one-dimensional array of the laws based on a set of weighted Fuzzify methods. After that, these laws are used to measure the membership level of each Fuzzify set that indicate the damage level (low risk, average risk, high risk). Levels 3 to 5 are repeated for all scenarios and in the sixth stage, the Fuzzy layers that have a high risk and are obtained from implemented scenarios are used to locate important vulnerable places. In the final stage, in a part called sensitivity analysis, the effects of used factors or layers are simulated and the effect of each are determined in the final outcome (Rashed and Weeks, 2003).

Cova has used geographical information system to prepare a vulnerability map and has used information like topography and the location of the district's faults, the location of the infrastructure installations such as nuclear facilities and HAZMAT routs in his model and finally used population demography to vulnerability modeling (Cova, 1999).

Davis and Aysan, who are theorists and experts in disasters, emphasize that using experiences from studying natural disasters can reduce the damage and produce different models (Aysan and Davis, 1992).

Vulnerability and determining city vulnerability level

Thousands of people are killed annually due to natural disasters. The map of the high-risk earthquake places show places that experience the most damage in an earthquake. The map is called the map of the risk probability level when probabilities are used to show the danger level. To draw such a map we should estimate the probability of P(x) in which x is the vulnerability factors in earthquakes. Natural disasters are complicated systems that are under the effect of many different factors. Available data to estimate P(x) are usually incomplete and even if they be complete, it is impossible to use them all in one model. Therefore estimating P(x) exactly seems to be impossible and no one can guarantee that they have estimated P(x) exactly. Using Fuzzy probability functions are one of the best and most proper ways. Fuzzy logic, for the first time, was proposed by Lotfi Zadeh professor, the Berkeley university professor. This theory can give a mathematical form to the concepts, variables and systems that are imprecise and vague and pave the way to reasoning control and decide in a situation of uncertainty. It should be mentioned that estimating vulnerability potential is surrounded by ambiguities and uncertainties because the factors used to determine the vulnerability level are not precise and exact and the reason to use Fuzzy model is that, unlike a Bolin model, it lets the vulnerability factors to be a member as a continuous spectrum. In this research, the erosion and intervention maps have been drawn in three steps. In the first step, the main maps that are effective in the destruction caused by earthquakes are ranked and rated from the view point of importance. In the second step, they are turned into Fuzzy models using Fuzzy functions. Fuzzy maps are merged in the third step based on each map's rate.

Study area

Sanandaj city have always been in the danger of natural disasters such as earthquakes and floods. For instance it is located on the big Sanandaj-Sirjan earthquake fault with the average risk of danger. It has experienced rather dangerous earthquakes during history. In this paper Qaradiyan neighborhood, having an area about 201684 square meters that was previously a country near Sanandaj and has now become a part of the city, is studied in this research Figure 4. The quantitative and qualitative condition of the housings, the poor status of the positioning of the physical elements, inappropriate land uses, inefficient city network, compressed city

To cite this paper: Habibi K, Tavallaei R, Azami M. 2014. Assessment less Developed Neighborhoods to Earthquake Risk (A Case Study of Qaradiyan Neighborhood of Sanandaj City). *J. Civil Eng. Urban.* 4 (2): 169-178.
Journal homepage: http://www.ojceu.ir/main/

contexture, the poor status of the positioning of the infrastructure installations, the lack and inappropriate distribution of the city's open spaces, etc. are the factors that increase the vulnerability level of this district to unexpected events.

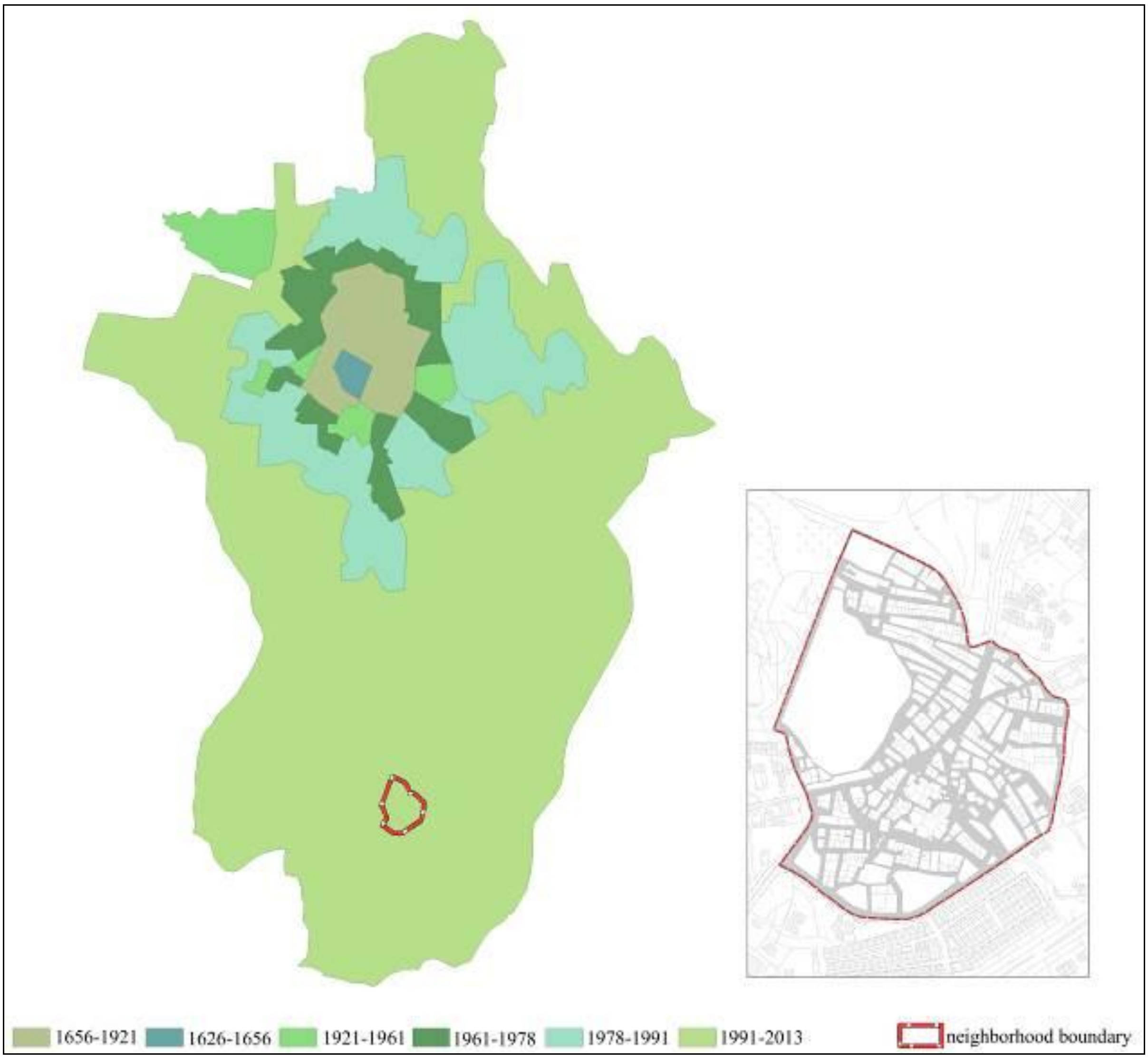

Figure 4. Location of Qaradiyan neighborhood in Sanandaj city

The first stage: determining data matrixes

The data matrix for this research is made up of 19 variables that they themselves are a combination of 38 indexes. It is evident that these variables sometimes have linear and sometimes have lateral relations. This matrix has been categorizes in two different classes: socio-economical and physical. The selected 19 factors are examined from the viewpoint of erosion and intervention (picture 5).

The results from questionnaires expert show the level difference and data importance compared to each other. Therefore, it is necessary to use the average achieved ranks in erosion and intervention. The below table show the average and achieved rank of each variable Table 1.

After pointing out the being studied layers based on each factor's importance in place vulnerability, selected indexes are ranked based on Entropy index. Then the reverse of each layer's rank is considered as its weight. Based on the experts' viewpoint in Delphi model, 11 indexes in different classes are classified based on their importance level in the physical section. Accordingly, the most important variable to dangers takes the number 11 and the least important one takes the number 1.

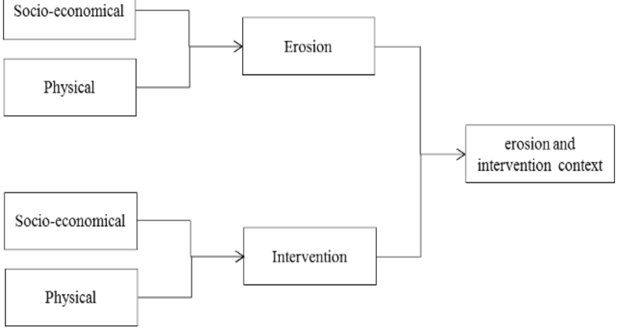

Figure 5. approach to modeling the concepts of erosion and intervention context

Table 1. Classification of indicators and variables to determine erosion and intervention areas with using fuzzy models

Indicators	Variable	Average and rate of erosion		Average and rate of intervention		Reverse rate	
		Average	Rate	Average	Rate	Erosion	Intervention
Socio-economic indicators	Building Ownership	1.25	1.00	1.25	1.00	8.00	8.00
	Employment rates	2.25	2.00	2.50	4.00	7.00	5.00
	Population density	3.50	3.00	3.00	5.00	6.00	4.00
	Percentage of vulnerable groups	4.00	4.00	2.50	2.00	5.00	7.00
	Rate of immigrants	5.00	5.00	2.50	3.00	4.00	6.00
	Literacy	5.25	6.00	5.00	6.00	3.00	3.00
	Household rate	6.00	7.00	5.25	7.00	2.00	2.00
	Sex ratio	6.00	8.00	5.25	8.00	1.00	1.00
Physical indicators	Quality of construction	1.25	1.00	1.25	1.00	11.00	11.00
	Skeleton buildings	4.25	2.00	5.75	3.00	10.00	9.00
	Lane width	4.75	3.00	3.75	2.00	9.00	10.00
	Dates back Buildings	6.25	4.00	6.75	5.00	8.00	7.00
	Number of access to parcel	8.00	5.00	7.25	6.00	7.00	6.00
	Land use	8.25	6.00	5.75	4.00	6.00	8.00
	Building Density	10.75	7.00	8.50	7.00	5.00	5.00
	Parcel size	11.25	8.00	8.50	8.00	4.00	4.00
	Number of Floors	11.25	9.00	11.00	9.00	3.00	3.00
	Occupancy rate	12.25	10.00	12.00	10.00	2.00	2.00
	Building frontage	13.25	11.00	14.50	11.00	1.00	1.00

According to the experts' comments, some assumptions are made for all being studied indexes in all sections. In this part of the research, some assumptions are deduced for the 19 indexes of the research as follows.

In the physical section and the occupancy rate indicators, the main assumption is that intervention in the buildings with low occupancy rate is easier and in the buildings with the minimum open space is harder, because compression and the high ground usage is the necessary foundation of renovation. Therefore, we classify the map of the building's occupancy rate into 3 groups. Buildings with the lowest occupancy rate get the most score and vice versa. Data weighting is different from the erosion perspective. According to the 0 to 100 standard for most of buildings with different uses, buildings with the occupancy level of 0% or 100% are considered more erosion and data weighting is also based this principle.

In the social section and inhabitancy duration indicator, the main assumption is that the intervention in buildings is easier with the inhabitants' lower residence, because the feeling of living for a long period is less. Such a condition can also be seen in the building erosion, because living for a long time in a place makes problems for its ownership. So, the residence duration has a direct coefficient with the intervention and erosion weight. As mentioned before, such equations are assumable for other skeletal, social and economic indicators (Habibi, 2006).

The second stage: Fuzzify the effective factors in the amount of earthquake danger

Making data Fuzzy is done in several ways based on the type of input data.

A- Nominal data: in these data, numbers and signs are used merely for categorization, such as the quality and skeleton of the building that describe only the building. To Fuzzify these data, they should first be turned into Interval scales and then made Fuzzy.

B- Ordinal data: this type of data, in addition to input data categorization, makes their priority order clear, such as Dates back Buildings. To Fuzzify these data, they should first be turned into spatial scale and then made Fuzzy.

C- Interval data: these data are stronger than ordinal data and they can be used to determine the distance and space. However, no data of this type exist in the factors being used in this research. But nominal and ordinal data should be turned into spatial scale so that they can be used in Fuzzy functions.

D- Ratio data: it is the strongest form and its zero value is real zero. These data have two subcategories themselves: continual and discrete.

Examples for the discrete type include: the ratio of the height to the width of the neighboring pathway, the number of the floors, and the width of the opposite pathway. Since the input data are discrete, the output of the Fuzzy functions will be discrete, too.

Examples for the continual type include: area, occupancy rate, distance from fire stations, distance from clinics, and distance from brown lands. Since the input data are continual, the output of the Fuzzy functions will be continual, too.

The Fuzzy function used in this research is a linear one that turns the data from the classic mode into the Fuzzy mode linearly and with the same gradient.

$$f(x)=\begin{cases} 0 & x<a \\ \dfrac{x-x_{\min}}{\Delta x} & a<x<b \\ 1 & b<x \end{cases}$$

In this formula we have:

$f(x)$ = Fuzzy function

x = vulnerability factor

a and b = the minimum and maximum acceptable level for vulnerability

Δx = the difference between x_{min} and x_{max}

To cite this paper: Habibi K, Tavallaei R, Azami M. 2014. Assessment less Developed Neighborhoods to Earthquake Risk (A Case Study of Qaradiyan Neighborhood of Sanandaj City). *J. Civil Eng. Urban.* 4 (2): 169-178.
Journal homepage: http://www.ojceu.ir/main/

Table 2. Fuzzify effective factors in vulnerability due to earthquake (physical indicators)

Rate	Effective factors in vulnerability	Layers points	Full fuzzy	Fuzzify data	No fuzzy
1	Quality of construction	11	Ruined place	Under construction, renewal, acceptable, repair, no stability	
2	Skeleton buildings	10	Brick and wood	Concrete, metallic, brick and iron	
3	Lane width	9	Less than 4 meters	Between 4 to 24 meters	More than 24 meters
4	Dates back Buildings	8	More than 50 years	Between 0 to 50 years	
5	Number of access to parcel	7	0 and 1	Between 1 to 4 access	
6	Land use	6	Brown field	Religious, cultural, commercial, residential and complex, educational, administrative, health	
7	Building Density	5	%240 up	Between %0 to %240	
8	Parcel size	4	Less than 100 meters	Between 100 to 3850 meters	More than 3850 m
9	Number of Floors	3	4	Between 1 to 4 floors	No building
10	Occupancy rate	2	%100 occupancy rate	Occupancy rate between %0 to %100	%0
11	Building frontage	1	Thatch	Stone, brick, cement, glass	No building

Table 3. Fuzzify effective factors in vulnerability due to earthquake (socio-economic indicators)

Rate	Effective factors in vulnerability	Layers points	Full fuzzy	Fuzzify data	No fuzzy
1	Building Ownership	8	Private	Governmental, public, appropriative	
2	Employment rates	7	Less than %60	Between %60 to %70	%70 up
3	Population density	6	More than 500	Between 0 to 500	
4	Percentage of vulnerable groups	5	More than %15	Between %0 to %15	%0
5	Rate of immigrants	4	More than %30	Between %0 to %30	%0
6	Literacy	3	Less than %70	Between %70 to %90	More than %90
7	Household rate	2	More than 5	Between 1 to 5	Less than 1
8	Sex ratio	1	More than 110	Between 90 to 110	Between 0 to 90

The third stage: merging the map

In this step, using Raster Calculator tool and map-merging functions like UNION, the columns of scores of the layers (vectors and raster's) are summed. Therefore, the sum of the columns of data layers of each section show the score of each parcel's from the perspective of intervention or erosion.

For instance, layers like building ownership, employment rate, population density, and the percent of vulnerable groups, migration rate, literacy level, household rate and sex ratio are evaluated after being weighted in the form of socio-economic erosion and socio-economical intervention.

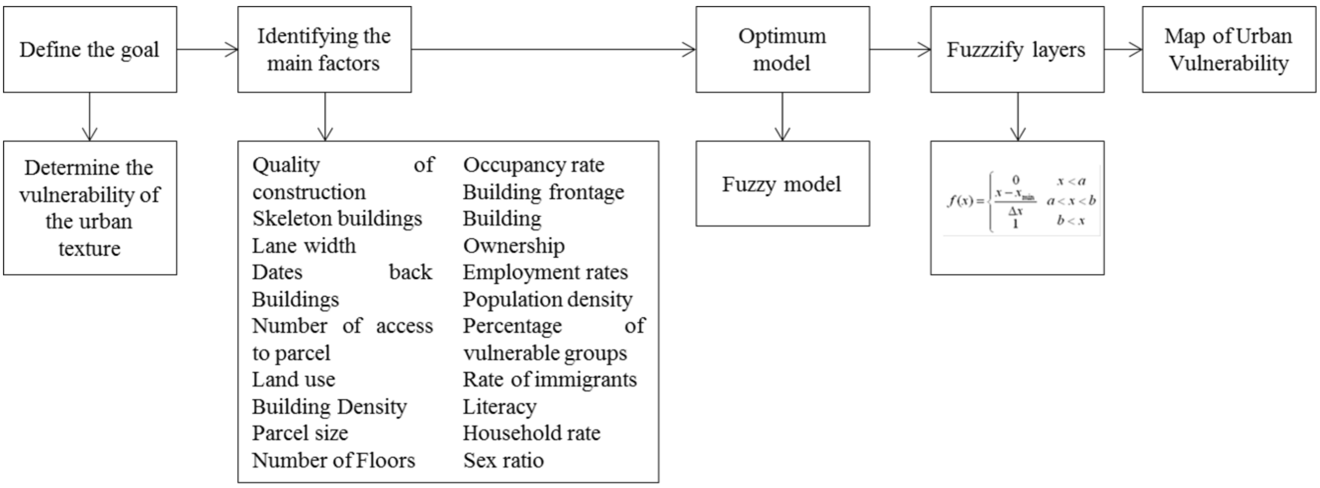

Figure 6. The production process of urban vulnerability map

To cite this paper: Habibi K, Tavallaei R, Azami M. 2014. Assessment less Developed Neighborhoods to Earthquake Risk (A Case Study of Qaradiyan Neighborhood of Sanandaj City). *J. Civil Eng. Urban.* 4 (2): 169-178.
Journal homepage http://www.ojceu.ir/main/

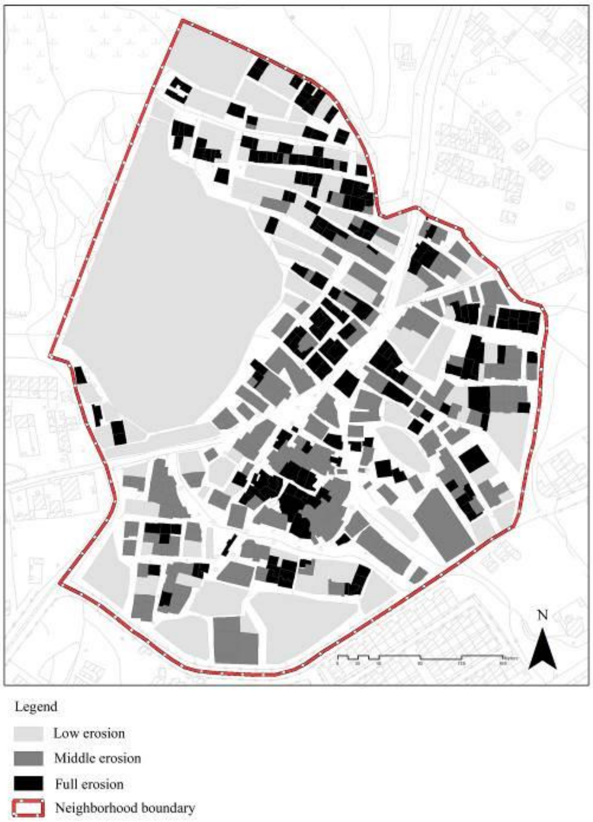

Figure 7. erosion tissue in terms of physical parameters

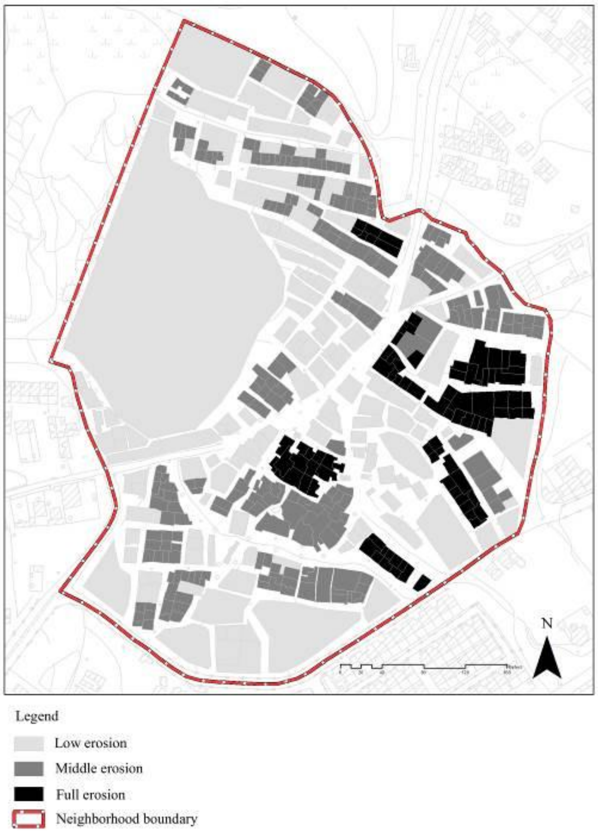

Figure 8. erosion tissue in terms of socio-economic paramete

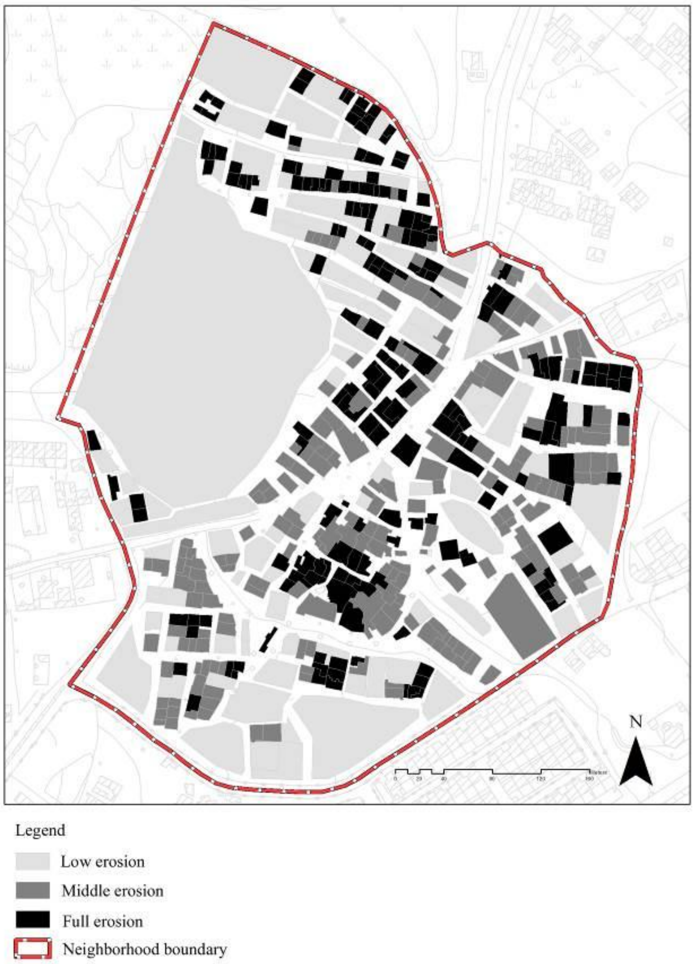

Figure 9. erosion tissue in terms of socio-economic and physical parameter

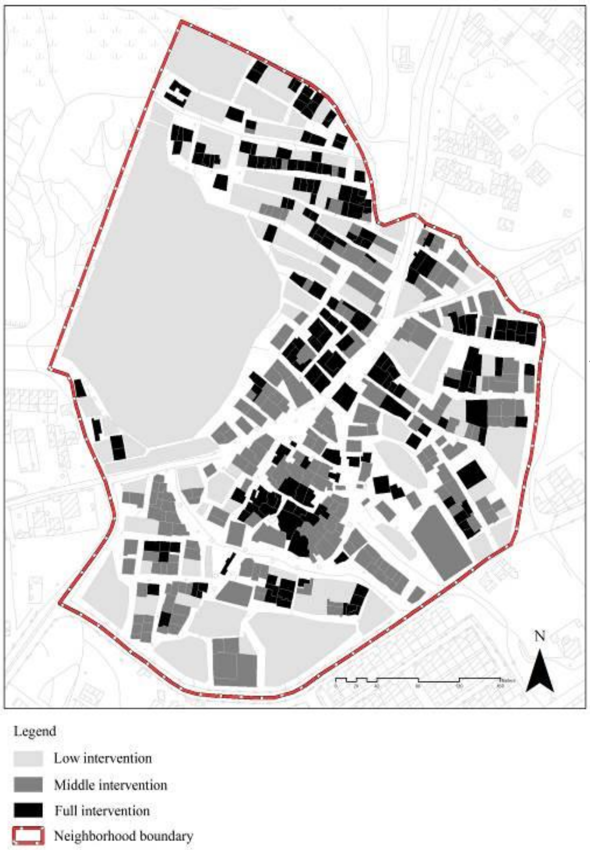

Figure 10. intervention tissue in terms of physical parameters

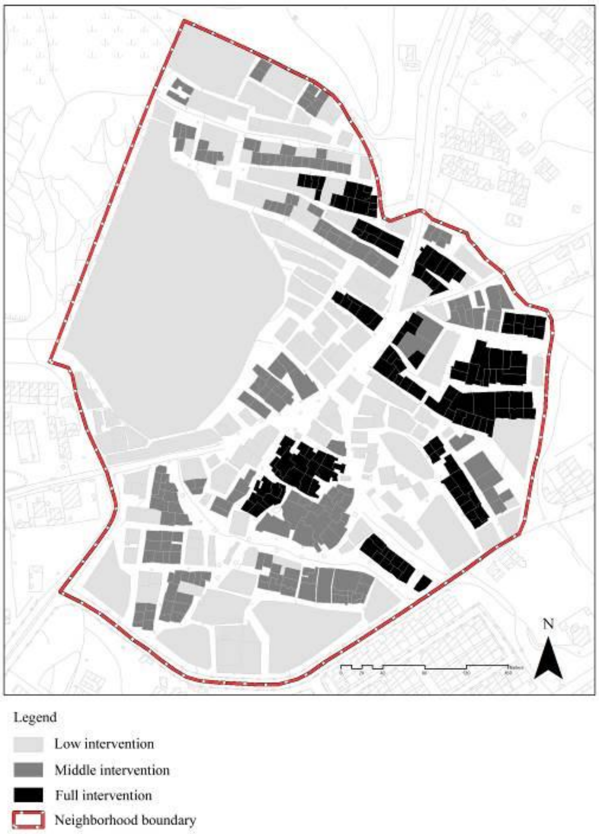

Figure 11. intervention tissue in terms of socio-economic parameters

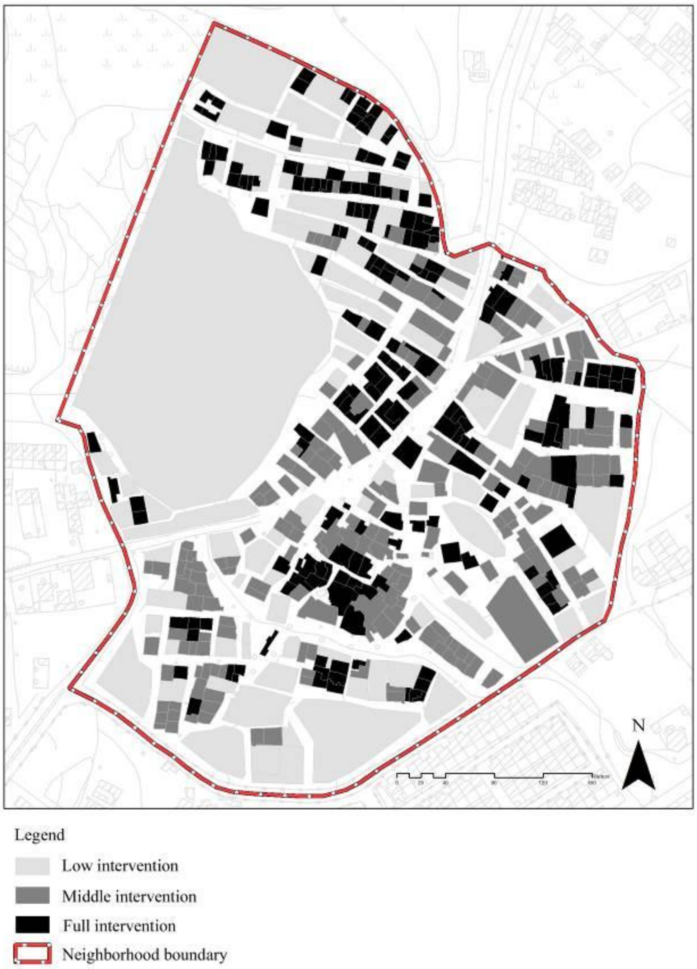

Figure 12. intervention tissue in terms of socio-economic and physical parameters

CONCLUSION

It can, according to the above maps, be concluded that pieces with high erosion level are more vulnerable. Parts having the most erosion and vulnerability are not in a good condition generally. In fact, high population density, high household rate, low building ownership, high occupancy rate, small parcel, narrow and impasse pathway, not having access to open suitable spaces, buildings' being old and low buildings resistance are of characteristics of this area.

The point here is that what methods are effective to reduce the vulnerability of the being studied area. The following strategies and scenarios, according to the area's condition, can be proposed.

- Regularizing hierarchy of the pathways and open spaces of the city reduce vulnerability.
- Distributing appropriations of land use to reduce vulnerability and increase access and repairing vulnerable buildings.
- Assemblage and construction high-building provide suitable skeletal condition.

It should be considered that reducing vulnerability should be done in short-term, average-term, and long-term plans. The short-term plan should be done to repair narrow and inappropriate pathways and decayed usages. In the average-term plan, in addition to the aggregation of erosion parts and parts with high compression, suitable spaces should be constructed. In the long-term plan, a suitable skeletal structure should be considered for the area. Finally, it seems that, according to the land use policy besides other policies, a suitable and flexible structure for natural disasters can be achieved.

Different method for vulnerability reduction in Qaradiyan district include: creating the hierarchy of the pathways and open spaces, considering the land use compatibility, revitalization old and erosion land use, considering law in constructions and considering regulations 2800, increasing facilities to face natural disasters like earthquakes.

REFERENCES

Abdollahi, M. (2004). Crisis managmant in urban area. Tehran: THE URBAN AND RURAL RESEARCH CENTER.

Ardalan, A., Forotan, E., & Aghamohammadi, H. (2006). Modeling for mitigation of earthquake disasters. First Disaster Management Conference. Tehran: University of Tehran.

Aysan, Y., & Davis, I. (1992). Disaster and the Small Dwelling Perspectives for the UN IDNDR. London: James & James (Science Publishers) Ltd.

Azizi, M., & Akbari, R. (2008). Urban Planning Issues in Earthquake Vulnerability. Honar ha ye Ziba, 25-36.

Cova, T. J. (1999). GIS in emergency management. In P. A. Longley, M. F. Goodchild, D. J. Maguire, & D. W. Rhind, Geographical Information Systems: Principles, Techniques, Applications, and Management (pp. 845-858). New York: John Wiley & Sons.

Habibi, K. (2006). Assessment of physical development policies, urban development and rehabilitation and renovation of old tissue by using GIS. Tehran: University of Tehran.

Kreimer, A., Amold, A., & Carlin, A. (2003). Building safer cities, the future disaster risk. Disater risk managment series.

Mileti, D. S. (1999). Disasters by Design: a reassessment of natural hazards in the United States. Washington, D.C.: Joseph Henry Press.

NCNDR. (2005). National report of the Islamic republic of Iran on disaster reduction. World Conference on Disaster Reduction (pp. 1-150). Kobe, Hyogo: United Nations Office for Disaster Risk Reduction.

Ranjbar, M., Eshraghi, M., & Iranmanesh, G. (2006). Preparation of spatial data base model in order to locate allocation sites for the temporary state of the population affected by the earthquake. First Disaster Management Conference. Tehran: University of Tehran.

Rashed, T., & Weeks, J. (2003). Assessing vulnerability to earthquake hazards through spatial multicriteria analysis of urban areas. International Journal of Geographic Information Science, 1-30.

UNDP. (2003). Reducing Disaster Risk: A Challenge for Development.A global report. NewYork: United Nations Development Programme.

UNISDR. (2005). Outcomes of the WCDR. Word Conference on Disaster Reduction. Kobe, Hyogo: United Nations Office for Disaster Risk Reduction.

USAID. (1998). Making Cities work: USAID's Urban strategy. Washington, D.C.: U.S. Agency for International Development.

www.ngdir.ir. (n.d.).

www.sci.org.ir. (n.d.).

Zipf, A., & Leiner, R. (2004). A mobile GIS based flood warning and information system. 12th symposium on location based services and telecartography. Vienna.