Research Article

Development of a Model to reduce Seismic Hazards to Decrease the Vulnerability and Seismic Risk (Case study : Zanjan City, Iran)

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Abstract: Seismic areas, which are always at the risk of encountering earthquake crises and accidents, need recognition of risk and adaptation of human behavior to cope with probable risks. The type of attitude and adaptation of behavior, and the associated strategies include evaluations and environmental perceptions of social, economic, and cultural concepts and values, as well as individual perspectives. Seismic risk assessment can be done based on various seismic scenarios due to the vulnerability of elements exposed to risk. The seismic hazard reduction model should include the occurrence of all probable consequences in different social classes. Because of the difference among the abovementioned factors in different areas, seismic hazard reduction models cannot be the same for all zones. In this study, Zanjan City has been selected as a place to create a safe society against earthquakes. The results obtained from vulnerability and seismic risk assessment of conventional and important buildings of Zanjan have been presented in the frame of tables of urgent measures' instruction for crisis management caused by the earthquake in Zanjan. To develop the final model of seismic hazard reduction in Zanjan, 21 risky zones were identified based on vulnerability and seismic risk assessment in this city. Also, necessary measures were provided to reduce the seismic risks in four steps of earthquake crisis management including prevention, readiness, coping, and rehabilitation to reduce the hazards during 5-10 years.

Keywords: seismic risk, vulnerability, seismic hazards, crisis management

1. Introduction

Iran can be considered as one of the seismic countries of the world because of its location on Alpine-Himalayan seismic belt. The historical studies show that multiple small and large earthquakes have been experienced by this country, and this zone is talented to experience large earthquakes in the future.

Vulnerability is a vital issue in the field of construction to save the life of humans and to prevent financial and economic losses. Hence, it has attracted attention in Iran and all around the world. Seismic assessment of existing structures is developing rapidly. One of the most necessary engineering measures to forecast the vulnerability of existing structures as a result of probable earthquakes in the future is the evaluation of appropriate solutions to reduce seismic risk in urban areas. Many existing structures are valuable, or they can't be renovated for some reason. Also, insufficient recognition of vulnerability and seismic risk of cities makes authorities and urban managers face problems to decide after the earthquake. Hence, conducting studies on vulnerability and seismic risk reduction can act as useful strategic evidence for urban planners and managers to manage the crisis caused by the earthquake.

In this study, the seismic hazard reduction model in Zanjan city was developed to reduce vulnerability and seismic risk using a humanistic, social, economic, and physical approach to identify elements involved in risk-taking. At the first, the main factors dominated the behavior of people in terms of risk and administrative systems, and risk management is specified as the early steps towards adequate regional vulnerability assessment. Then, the revised information evaluated the performance of structures and vulnerability patterns of conventional and important buildings. Afterward, the loss functions were analyzed for various types of buildings. With the determination of vulnerability curves used in risk-taking scenarios and ranking seismic risk elements, various components were analyzed. Also, the vulnerability maps of these components were modeled due to geographical distribution in a GIS system.

Problem statement

Unmatched and non-standard growth of cities over history, especially over the century, has increased vulnerability against probable earthquakes. Construction in the area of faults, inattentiveness to seismic resistance of buildings and vital facilities, heterogeneous and vulnerable extension of urban fabric show that many losses may be caused by a large earthquake in the cities. Unawareness and readiness of people, and insufficiency of required infrastructures for crisis management are also other problems to increase the dimensions of these events.

Hence, comprehensive studies should be conducted in the field of identification of seismic effects in urban areas and recognition of areas with high risk-taking to reduce the seismic hazards in the cities. Planning to reduce losses caused by the earthquake in the areas with high risk-taking can reduce the losses and hazards of an earthquake by reducing the vulnerability of the cities. In this field, many financial and life losses can be prevented with recognition of the seismic vulnerability of urban areas, analysis of imposed losses on buildings, infrastructure, urban body, roads, and integrating them into the way of population distribution, and proper planning.

1. Research objective

The main objective of this study is: Development of a seismic hazard reduction model in Zanjan includes activities associated with retrofitting important buildings, organizing and immunizing vital routes, organization and urban crisis management planning against earthquakes to reduce vulnerability and seismic risk.

The following steps were completed to achieve the main objective:

- Preparing a list of risky elements with studying the situation of the coil, and geotechnical conditions of the region, analysis of technical characteristics of conventional, strategic, and historical buildings, and evaluation of the situation of vital roads of Zanjan City to provide practical solutions to reduce hazards
- Determining the weaknesses of Zanjan against earthquakes with the analysis of effective factors in the vulnerability, or destruction of different zones of Zanjan City
- Risk assessment, and providing a seismic risk-taking map of Zanjan in form of GIS using existing databank, field analyses, and statistical analyses based on different scenarios of earthquake intensity

2. Research questions

- How much is the seismic risk and vulnerability of buildings, strategic centers, and vital arteries of Zanjan against a probable earthquake?
- Whether the existing managerial capacities of Zanjan are sufficient for the management of crises caused by an earthquake?
- Which are vulnerable regions of Zanjan against earthquake based on affective factors in vulnerability?

3. Research hypotheses

- Acceptability of the constructions of the recent years in terms of observing provisions of building regulations (especially 2800 Standard)
- Favorability of vital arteries of Zanjan in terms of local and national standards

4. Methodology

In this study, the type of research and the method used to test the hypotheses is a combination of descriptive, bibliographic, field methods, and content analysis. At first, the status of Zanjan City was analyzed in terms of vulnerability library data, and field investigations. Then, vulnerability assessment methods were used: MicroSeismic, vulnerability index of buildings, strategic centers, and determined vital arteries, and vulnerability curves for various structural types.

5. Procedure

The stepwise procedure of this study has been illustrated in the following Flow Chart .

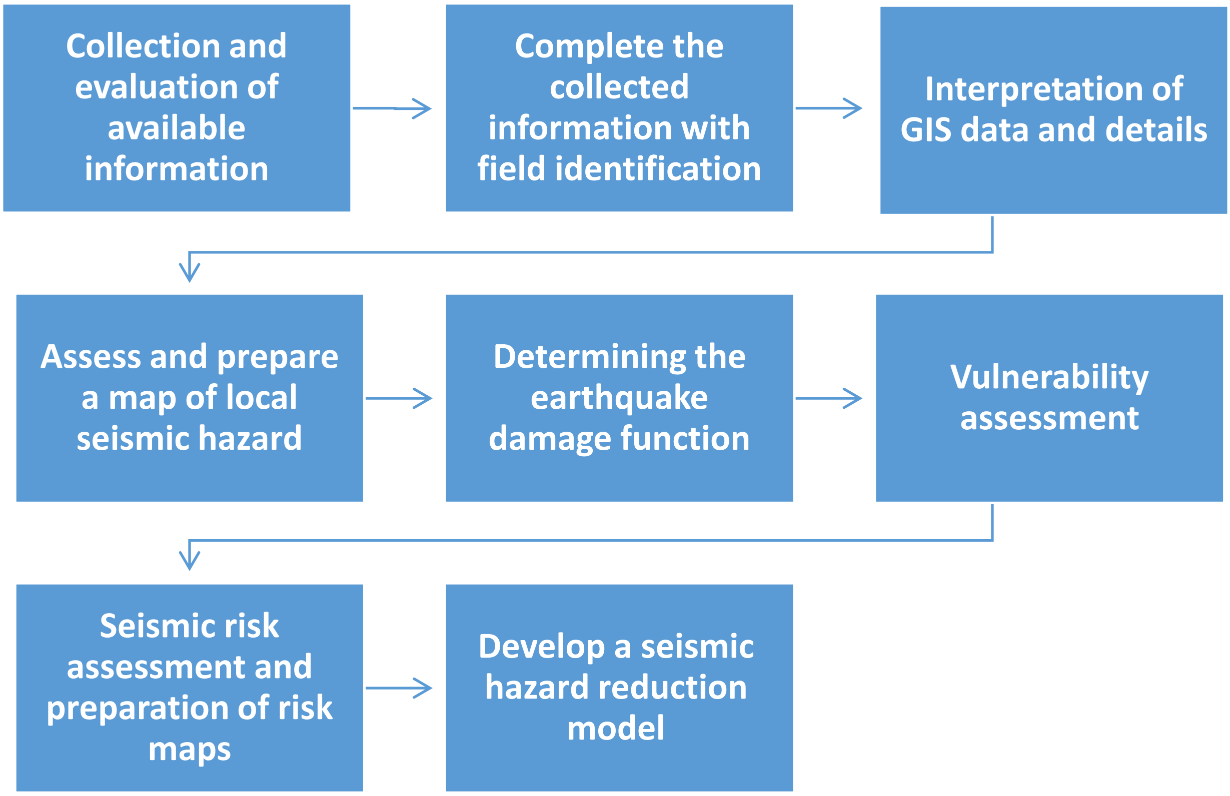

Fig.1. Flow Chart of the study steps

6. Vulnerability assessment of conventional buildings in Zanjan

The buildings in Zanjan were analyzed to identify and classify their special features including ancient buildings, strategic buildings, urban development rate over the past decades, and building vulnerability data. Hence, conventional were classified, and the building typology matrix was also develope4d. To this end, a framework of physical data collection was presented, and a matrix was proposed with an emphasis on building ownership classification. The aim of the building typology matrix is a classification of buildings with the structural system, and similar behavioral traits in the form of predefined classes [21]. Then, loss prediction models can be used to model types of building, which shows the characteristics of average overall building density in each class.

The structural parameters affecting building damage specifications to prepare building typology matrix are:

- Structural parameters affecting the building capacity and response
- Seismic design criteria (based on provisions of national construction regulations)
- Structural materials and system
- Building height (short, mid-rise, and high-rise)
- Nonstructural elements affecting nonstructural damage

After field observations on buildings in Zanjan, and other data, four main groups were selected :

- M : Masonry

- A : Adobe buildings
- S : Steel buildings
- RC : Reinforced Concrete buildings

Each group was divided into two multiple types of groups, and the buildings were separated based on height, and the construction date. Table 1 shows different types identified.

Table 1: Building type matrix

Main type	ID	Structure description	Name	Number of floor
Masonry	M1	Brick walls and wooden beam	Short	2 - 1
	M1M	Brick walls and wooden beam	Mid - rise	5 - 3
	M2L	Brick walls and steel beam	Short	2 - 1
			Mid - rise	5 - 3
	M3L	Brick and steel	Short	2 - 1
	M3M		Mid - rise	5 - 3
	M4L	Semi – coiled masonry (H)	Short	2 - 1
	M4M	Semi – coiled masonry (V)		5 - 3
	M4H	Coiled masonry		0
Adobe	AL	Adobe	Short	2 - 1
Steel	S1L	Non – embraced steel frames	Short	2 - 1
	S1M		Mid - rise	5 - 3
	S1H		High - rise	6
	S2L	Embraced steel frames	Short	2 - 1
	S2M		Mid - rise	5 - 3
	S2H		High - rise	6

	S3L	Moment steel frames	Short	2 - 1
	S3M		Mid - rise	5 - 3
	S3H		High - rise	6

Main type	ID	Structure description	Name	Number of floor
Reinforced Concrete	RC1L	Moment reinforced concrete frames	Short	2 - 1
	RC1M		Mid - rise	5 - 3
	RC1H		High - rise	6
	RC2L	Reinforced frames and shear walls	Short	2 - 1
	RC2M		Mid - rise	5 - 3
	RC2H		High - rise	6

An effective factor in life losses while an earthquake is the collapse of buildings. In this regard, 66.3% of losses in Cobe were caused by the collapse of buildings [10]. Hence, the losses can be decreased by preventing the collapse of buildings and urgent reactions after the earthquake. To this end, it is essential to identify the seismic status of buildings. In this study, vulnerability curves have been used to show the correlation between hazard in terms of seismic intensity, and loss in terms of a moderate degree of damage. The curves showed that the behavior of every building is only dependent on the vulnerability index parameter [19]. Here, proposed and standards vulnerability curves (Risk-UE) have been introduced, and have been then adjusted with the Iranian construction situation based on observed losses in the past earthquakes.

Table 2: Comparison of vulnerability index of Zanjan buildings, and Risk-UE curves

Main type	Description	Present study	Risk project

		Index	Value	Index	Value
Masonry	Brick walls and wooden beams	M1	0.8	M3 1	0.74
		M1	0.704	M3 3	0.704
	Brick and steel	M3	0.6		
	Coiled masonry	M4	0.451	M4	0.451
Adobe	Adobe	A1	0.9	M2	0.84
Steel	Non-braced steel frames	S1	0.84	S3	0.484
	Embraced steel frames	S2	0.3	S	0.287
	Moment steel frames	S3	0.376	S1	0.363

Main type	Description	Present study		Risk project	
		Index	Value	Index	Value
Reinforced concrete	Moment reinforced concrete frames	Rc1	0.45	Rc1	0.422
	Shear reinforced concrete frames	Rc2	0.399	Rc2	0.386

Proposed Risk-UE vulnerability curves

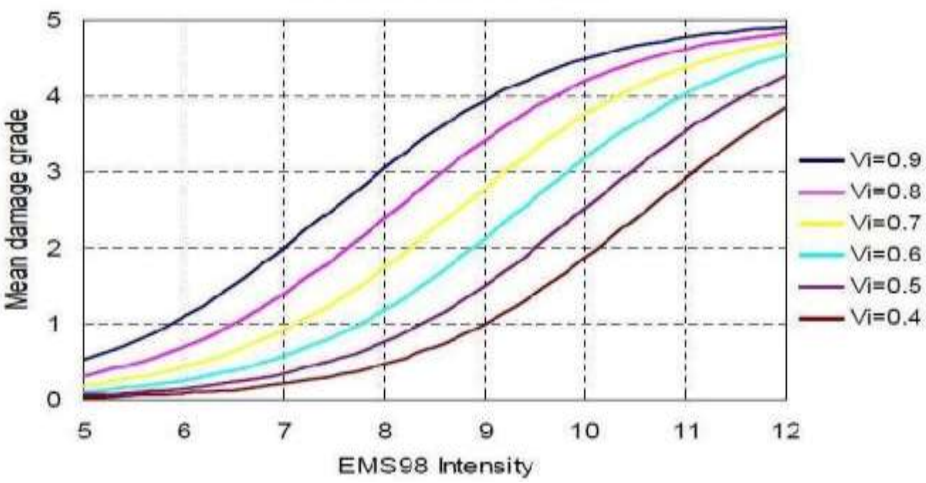

Fig.2. Masonry brick structures with metal columns in the middle show better seismic resistance compared to wooden masonry structures. The effective level of masonry walls in such structures can be reduced by replacing them with middle steel columns.

7. Vulnerability assessment of buildings in Zanjan

In the vulnerability assessment of buildings in Zanjan, the vulnerability of conventional buildings was firstly assessed, and then strategic buildings were analyzed.

In the vulnerability analysis of conventional buildings, the statistical model included the following data:

(a) Height distribution in each area

(b) Structural system distribution in each area

(c) Building distribution in each area

In this study, different types of data were collected through comprehensive investigations done on Zanjan City. Also, field observations were done to control and fulfill the previous data from the city. Some controlling and reforming measures were taken such as comparison of the results of fstudy of Zanjan's data, and comparison of age distribution based on aerial photos with the collected data to refine the data as a final statistical model.

10 . Field observations

To make field observations, homogenous zones were identified based on statistical data. The homogeneous zone means the homogeneous distribution of each type of building in the zone

As a result, 195 zones were defined in the City of Zanjan. Similar zones were assumed as unit zone and were selected as the representative of the statistical population randomly. In a homogeneous zone, the random path shows a part of a whole. Hence, the results obtained from the assessment of buildings were used along this line for an urban unit.

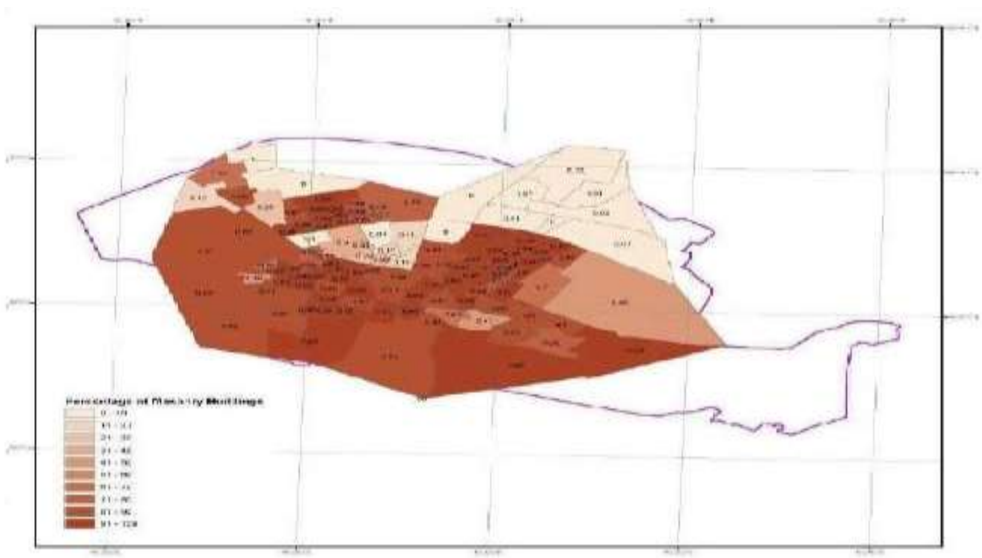

Fig.3. Distribution of masonry buildings in Zanjan

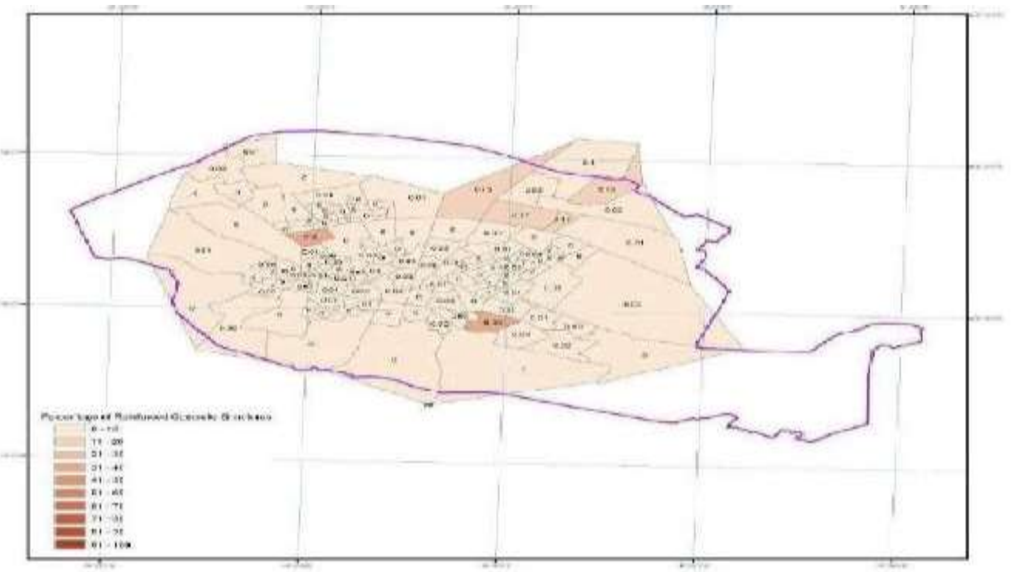

Fig.4. Distribution of reinforced concrete buildings in Zanjan

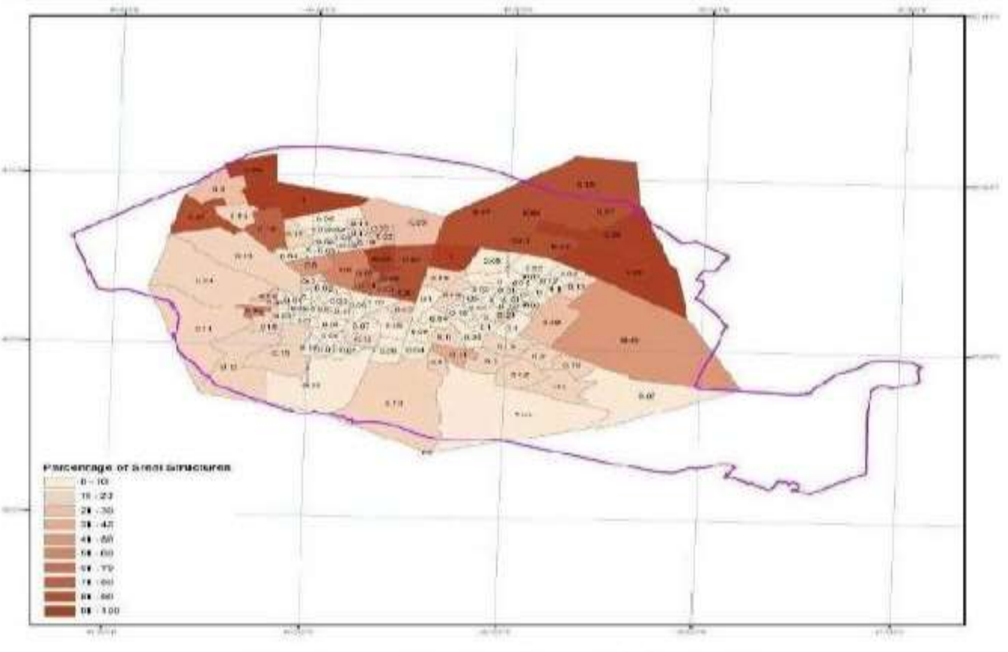

Fig.5. Distribution of steel buildings in Zanjan

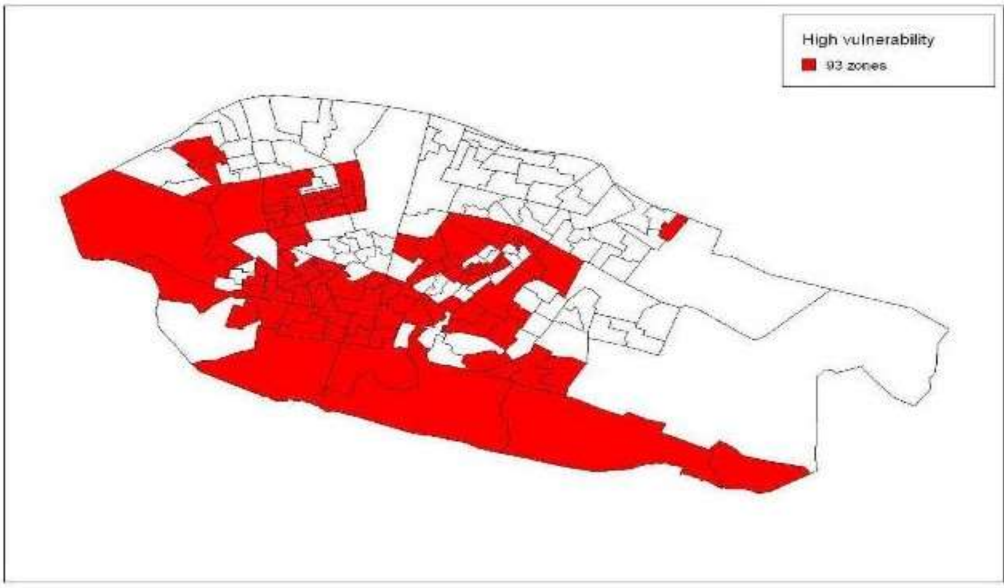

Fig6. The most vulnerable zones in Zanjan

Since there are different types of buildings with different seismic behaviors in a statistical zone, data analysis shows the vulnerability of every zone and the total vulnerability of the city. Fig. 4 illustrates the fundamental map of vulnerability assessment in Zanjan. The most vulnerable zones are those, in which 80% of buildings have a vulnerability index of more than 0.7 ($V_i<0.7$).

Fig.5 illustrates the classification of Zanjan in three vulnerability groups.

(1) The most vulnerable zones, in which 80% of buildings have a vulnerability index of more than 0.7.

(2) Zones with vulnerability, in which 50% of buildings have V_i below 0.3

(3) Other zones are classified with moderate vulnerability.

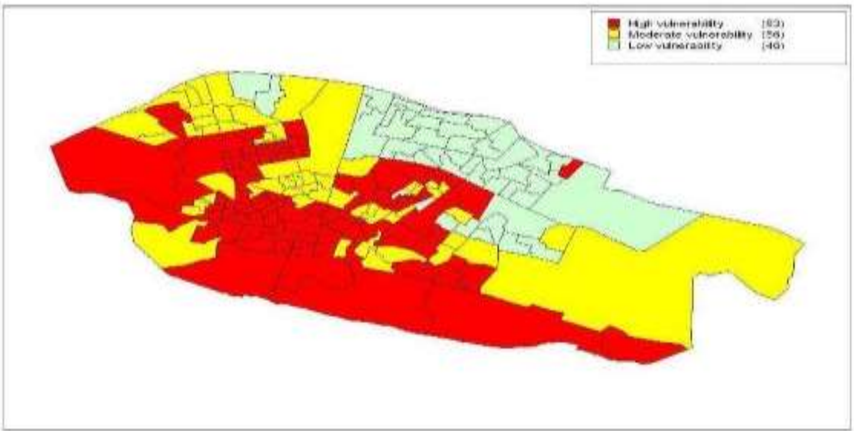

Fig.7. Classification of the vulnerability of Zanjan (red color: most vulnerable zones, yellow: moderate vulnerability, green: low vulnerability)

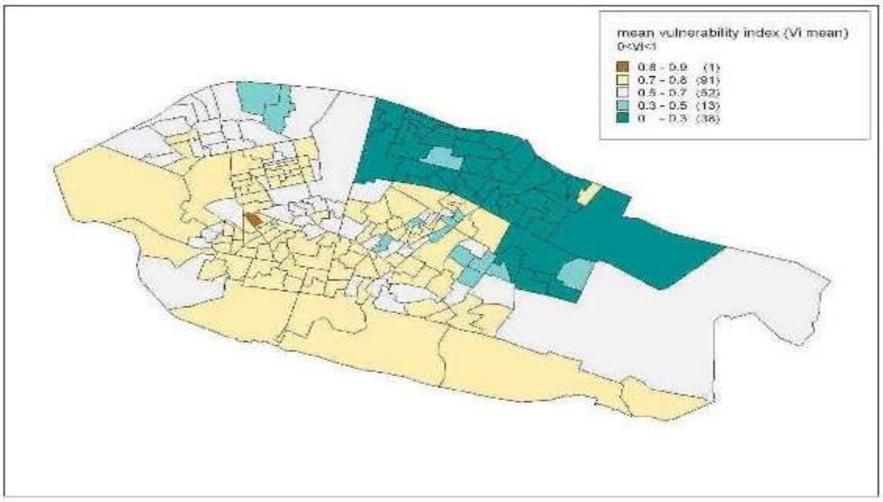

Fig.8. Moderate vulnerability index of Zanjan

Fig.6 illustrates statistical zone classification based on weighted mean values of the vulnerability index.

Because of the significant effect of types of construction materials on structural behavior, the following maps present an independent analysis of the vulnerability index respectively for masonry buildings, steel skeletons, or reinforced concrete.

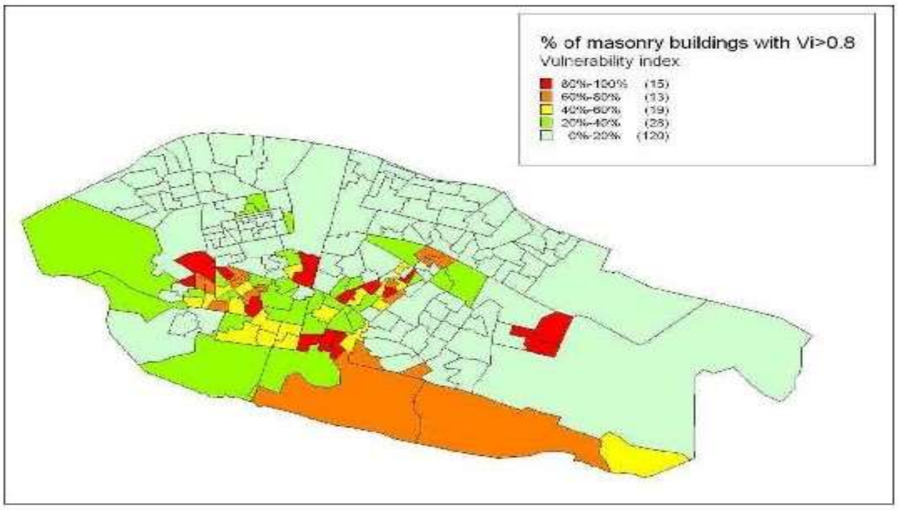

Fig.9. Distribution of masonry buildings with $V_i<0.8$

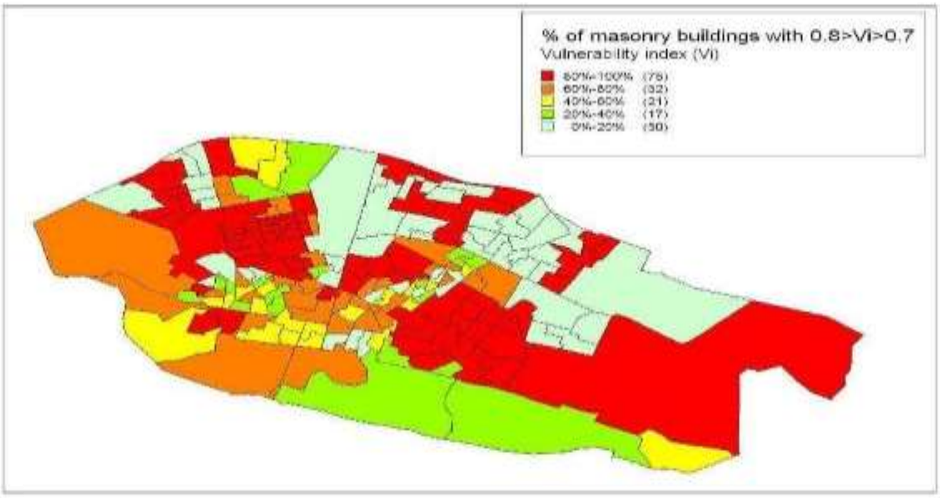

Fig.10. Distribution of masonry buildings with $0.7 < V_i < 0.8$

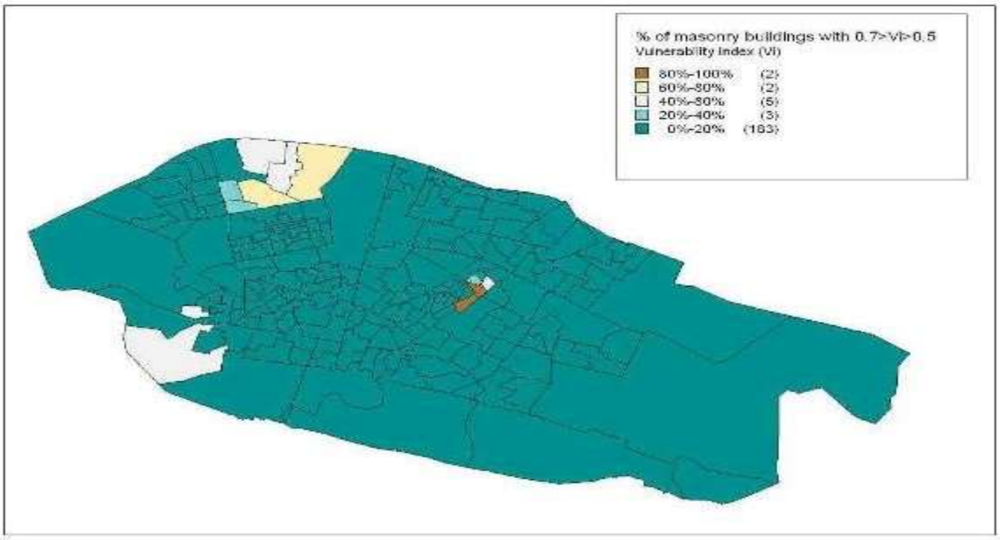

Fig.11. Distribution of masonry buildings with $0.5<V_i<0.7$

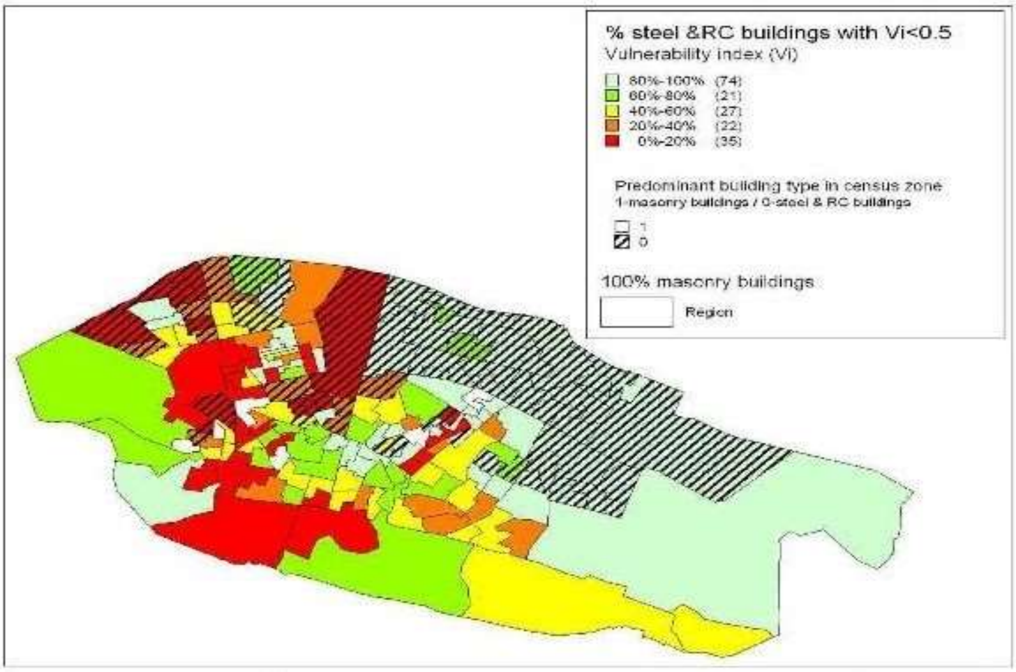

Fig.12. Distribution of RC and steel buildings with $V_i<0.5$

8. Vulnerability assessment of strategic buildings of Zanjan

Firefighting buildings are located in Nawab Street (central station). In stations 2, 3, and 4, strategic buildings are Specialized Hospital of Ayatollah Mousavi, Valiasr Specialized Hospital, Provincial Government building of Zanjan, and railway station, Zanjan's Municipality, and Red Crescent Society Building.

Two phases of assessment were done on these buildings:

(a) Level 1 approach: seismic fog, in which the input was shown in the form of intensity seismic fog parameter, and vulnerability is associated with qualitative parameters.

(b) Level 2 approach: a mechanic, in which the input is shown by spectrum coordinates, and vulnerability is shown by capacity curve obtained by nonlinear analyses.

Analysis level is dependent on the quality and quantity of collected data relevant to each strategic building [2]. A field study was conducted for the buildings without available information. The most underlying architectural and structural characteristics have been also collected.

Seismic risk assessment was done as follows:

(a) Choosing two scenarios of regional seismic risk-taking scenarios (with a return period of 475 and 2475 years) implementation of PGA risk maps of bedrock in Zanjan

(b) Using magnification capacity of alluvium for lithological and topographic effects of the site

(c) Vulnerability assessment of special facilities or every zone of existing buildings. The assessment was done using a statistical attitude of vulnerability index of existing buildings, and the capacity methods of strategic buildings.

(d) Direct life loss assessment (death and injuries as a result of building collapse)

9. Vulnerability assessment of conventional and strategic buildings in Zanjan

In the vulnerability assessment of Zanjan's buildings, six vulnerability levels were defined under the titles of (D_0) – (D_s), and the results were presented in the form of tables.

(D_0) damage level: No damage or ignorable damage

(D_1) damage level: Ignorable to mild damage, without structural or mild structural damage

(D_2) damage level: Moderate vulnerability, moderate structural or nonstructural damage

(D_3) damage level: Considerable to significant damage, moderate structural damage, and significant nonstructural damage

(D_4) damage level: Very significant damage, significant structural damage, and very significant nonstructural damage

(D_5) damage level: Very significant structural damage, debris

For example, the results of the vulnerability assessment of strategic buildings of Zanjan for the earthquake with a return period of 475 years are presented in Table 3. The values in this table present the vulnerability level for each building in present.

Table 3: Results of vulnerability assessment of strategic buildings in Zanjan against earthquake with a return period of 475 years

Building Name	D_0	D_1	D_2	D_3	D_4	D_5
Municipality of Zanjan	0.48	7.47	24.15	35.97	26.59	5.33
Railway station	8.54	32.04	34.95	19.36	4.87	0.24
Provincial government of Zanjan	75.65	19.56	4.19	0.570	0.03	0
Helal Ahmar	24.13	41	25.18	8.41	1.24	0.03
Valiasr Hospital	15.32	38.22	30.83	13.07	2.48	0.08
Mosavi Hospital	75.90	19.38	4.13	0.56	0.03	0
Fire Station No1	9.12	32.80	34.66	18.66	4.55	0.22
Fire Station No2	21.71	40.63	26.69	9.46	1.48	0.04

Fire Station No3	93.45	5.68	0.79	0.08	0	0
Fire Station No4	14.42	37.67	31.42	13.71	2.68	0.1

Table 4 : weaknesses and strengths of earthquake crisis management in the city of Zanjan

	Partial itemes	Strengths	Weaknesses

Crisis management	1- Informing 2- Knowledge 3- Understanding 4- Training 5- Readiness	1.High understanding of risk and building vulnerability 2.There is a Basij station is built in each mosque, which can be used in crises 3.Least equipment is needed 4.The firefighting station has sufficient equipment and personnel 5.There are about 1000 trained individuals for rescue, and there are many volunteers	1. No training (more than 64%) 2. First aid training (5%) 3. Other (5% or below) 4. Insufficient training in the field of retrofitting (5%) 5. Insufficient training in the field of temporary moving (0.5%) 6. Insufficient training on preparing first aid box (5%) 7. No training (51%)
Crisis/knowledge	1- Intention for retrofitting 2- Number of educational items of earthquake 3- Preferred measures during an earthquake 4- Readiness 5- Commenting on safety, physical conditions, and domestic conditions	1.Low-moderate risk perception 2. High intention for retrofitting 3. High-risk understanding about the domestic status 4. Very high earthquake compatibility precautionary measures	1.Insufficient training on earthquake 2. Restricted documents on local groups 3. Low to moderate access to resources 4. Low understanding of individuals about risk in the field of their physical conditions

Training and research	1- Rescue training 2- Self-rescue training 3- Excavation for draining 4- Retrofitting buildings 5- Planning to move 6- First aid training	1. Training in the field of personal protection (11%) 2. Training in the field of rescue (13 %)	1. No training (more than 64%) 2. First aid training (5%) 3. Other (5% or below) 4. Insufficient training in the field of retrofitting (5%) 5. Insufficient training in the field of temporary moving (0.5%) 6. Insufficient training on preparing first aid box (5%) 7. No training (51%)
Readiness	1- Storing the household food at home/neighborhood 2- Water storage at home/place 3- Discussion at home/work 4- Associated measures of the earthquake at home/work 5- House Insurance 6- Household readiness	1.Water and food storage at home (`6%) 2. Written emergency solutions at work (14%) 3. Totally or a little ready (47%) 4. Relatively much discussion on the earthquake at home (30%)	1.No measure is taken to forecast earthquakes at home or work (46-52%) 2. Insured or insuring houses (3%) 3. Insufficient food and water storage at work or home (2%)

10. Crisis management status in Zanjan

Table 4 presents some weaknesses and strengths in the field of earthquake crisis management in the City of Zanjan

11. Emergency operations to reduce seismic hazards in crisis management phases

The emergency measures to reduce seismic hazards in the 4 phases of earthquake crisis management have been presented in Table 5 in detail.

12. Prevention phase

Table 5 Emergency measures to reduce seismic hazards in Zanjan in the prevention phase of crisis management

Row	Plan title	Explanation
1	Land use determination	Preparing the comprehensive project for Zanjan
		Preparing a detailed plan of Zanjan
		Identification of risk-exposed elements for vulnerability assessment
		Study of structural effects
		Psychological investigations
		Mass movement study (landslide, rock falls)
		Checking singular faults
		Checking the vulnerability of the zone
		Checking vulnerability of buildings
		Assessment of the vulnerability of strategic buildings
Row	Plan title	Explanation
2	Control and supervision on construction	Observance of construction regulations and standards in new constructions
		Using required regulations and standards for building retrofitting
		Careful control and supervision on executive operations of constructing buildings
		Organizing and enhancing the role of insurance in construction

13. Readiness phase

Table 6: Emergency measures to reduce seismic hazard in Zanjan in the readiness phase of crisis management

Row	Plan title	Explanation
1	Training and informing	Public training and information
		Specialized and professional training
		Training via visual media
		Training through social media
2	Explaining economic plans and problems	Promoting the insurance industry
		Paying facilities for standards construction and building retrofitting
		Set heavy fines for construction violations
		Encourage construction supervisors and operators by increasing related fees

14. Crisis response phase

Table 7: Emergency measures to reduce seismic hazards of Zanjan in the response phase of crisis management

Row	Plan title	Explanation
1	Emergency measures in early 10 days after the earthquake	Organizing emergency measures with quick response
		Carrying out operations of specialized rescue working groups
		Establishing temporary accommodation camps
		Providing psychological security
		Supplying food and water and hygiene for the survivors
2	Explaining economic plans and problems	Promoting insurance industry
		Paying facilities for standard construction and retrofitting
		Set heavy fines for construction violations

		Encourage construction supervisors and operators by increasing related fees
3	Emergency measured in 10-50 days after the earthquake	Organizing special teams for urgent repair of water pipes, electricity, gas, and telephone lines
		Organizing special teams to reform the vital arteries

15. Reconstruction and rehabilitation phase

Table 8: Emergency measures to reduce seismic hazards in Zanjan in the rehabilitation phase of crisis management

Row	Plan title	Explanation
1	Organizing construction	Using special teams for systematic organization of new constructions regarding the population
		Using special teams for a social organization of population and zones

16. Conclusion and suggestions

The main purpose of this study was to develop a Seismic Hazard Reduction Model for Zanjan City to create a safe community against earthquakes. The model should present some individual and collective operations leading to the systematic and effective reduction of seismic hazards. According to the obtained from seismic risk assessment of conventional and strategic buildings in Zanjan, the seismic hazard reduction model has been presented in the frame of tables and emergency measures for the management of earthquake crisis in the City of Zanjan.

Tale 9: Seismic Hazard Reduction Model for Zanjan during 5-year and 10-year period

Risk-exposed zones	Percentage of losses	Percentage of homelessness	Percentage of collapsed buildings	5-year social plan	10-year social plan	5-year economic plan	10-year economic plan	5-year operating plan	10-year operating plan
1	0.01	27	2.00	PPI 15,27,30	PPI 30 - 27	PPI 1,2,3,4,5,6,7	PPE 9,11	PPF 1,2,3	PPF 3,4
2	0.07	50	3.00	15,19,22 27-30 PPT 5-7	PPI 27-30	1,2,3,4,5,6,7,8	PPT 8 PPE 1-4 PPE 9-11	PPF 1,2,3	PPF 1,3,4
3	0.3	64	4.00	PPI 15,19,22 27-30 PPT 5-7	PPI 20,26,14,16 PPI 27-30	PPI 1,2,3,4,5,6,7,8	PPT 8 PPE 1-4 PPE 9-11	PPF 1,3,4	PPF 1,3,4
4	0.96	43	3.00	PPI 15,19,22 27-30 PPT 5-7	PPI 27-30	PPI 1,2,3,4,5,6,7,8	PPE 9,11	PPF 1,3,4	PPF 1,3,4
5	0.37	52	4.00	PPI 15,19,22 27-30 PPT 5-7	PPI 20,26,14,16 PPI 27-30	PPI 1,2,3,4,5,6,7,8	PPE 9,11 PPT 8	PPF 1,3,4	PPF 1,3,4
6	0.10	23	2.00	PPI 22,19	PPI 27-30	PPI 1,2,3,4,5,6,7,8	PPE 9,11	PPF 1,3,4	PPF 1,3,4
7	0.51	3	1.00	PPI 22,19	PPI 27-30	PPI 1,2,3,4,5,6,7,8	PPE 9,11	PPF 1,3,4	PPF 1,3,4
8	0.14	1	1.00	PPI 22,19	PPI 27-30	PPI 1,2,3,4,5,6,7,8	PPE 9,11	PPF 1,3,4	PPF 1,3,4
9	0.37	8	1.00	PPI 22,19	PPI 27-30	PPI 1,2,3,4,5,6,7,8	PPE 9,11	PPF 1,3,4	PPF 1,3,4

10	**0.64**	**29**	**2.00**	**PPI 15,19,22 27-30**	**PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPE 9,11**	**PPF 1,3,4**	**PPF 1,3,4**
11	**0.44**	**52**	**4.00**	**PPI 15,19,22 27-30**	**PPI 20,26,14,16 PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPE 9,11 PPT 8**	**PPF 1,3,4**	**PPF 1,3,4**
12	**0.33**	**33**	**2.00**	**PPI 15,19,22 27-30**	**PPI 20,26,14,16 PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPE 9,11**	**PPF 1,3,4**	**PPF 1,3,4**
13	**0.44**	**60**	**4.00**	**PPI I5,19,22 27-30 PPT 5-7**	**PPI 20,26,14,16 PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPT 8 PPE 1-4 PPE 9,11**	**PPF 1,3,4**	**PPF 1,3,4**
14	**0.49**	**23**	**1.00**	**PPI 22,19**	**PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPE 9,11**	**PPF 1,3,4**	**PPF 1,3,4**
15	**0.01**	**28**	**2.00**	**PPI 22,19**	**PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPE 9,11**	**PPF 1,3,4**	**PPF 1,3,4**
16	**0.32**	**40**	**3.00**	**PPI 5,19,22 27-30**	**PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPE 9,11**	**PPF 1,3,4**	**PPF 1,3,4**
17	**1.43**	**12**	**1.00**	**PPI ، 15,19,22 27-30**	**PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPE 9,11**	**PPF 1,3,4**	**PPF 1,3,4**
18	**0.13**	**46**	**3.00**	**PPI1 5,19,22 27-30**	**PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPT 8 PP 1-4 PPE 9,11**	**PPF 1,3,4**	**PPF 1,3,4**
19	**0.72**	**55**	**4.00**	**PPI 15,19,22 27-30**	**PPI 20,26,14,16 PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPE 9,11 PPT 8**	**PPF 1,3,4**	**PPF 1,3,4**
20	**0.10**	**44**	**3.00**	**PPI 15,19,22 27-30**	**PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPE 9,11**	**PPF 1,3,4**	**PPF 1,3,4**
21	**0.70**	**34**	**3.00**	**PPI 15,19,22 27-30**	**PPI 27-30**	**PPI 1,2,3,4,5,6,7,8**	**PPE 9,11**	**PPF 1,3,4**	**PPF 1,3,4**

Table 10: Detailed social, economic, and operational plans to reduce seismic hazard in Zanjan within 10 years

Operations	**First year**				**Second year**				**Third year**				**Fouth year**				**Fifth year**				**10 years**
	First quarter	**Second quarter**	**Third quarter**	**Fourth quarter**	**First quarter**	**Second quarter**	**Third quarter**	**Fourth quarter**	**First quarter**	**Second quarter**	**Third quarter**	**Fourth quarter**	**First quarter**	**Second quarter**	**Third quarter**	**Fourth quarter**	**First quarter**	**Second quarter**	**Third quarter**	**Fourth quarter**	
Planning					**PPI 2**				**PPI 3**												
		PPT 1			**PPE 2– PPE 3– PPE4 – PPE 16**																
				PPT 2																	
Tools			**PPI 5**		**PPI 1**		**PPI 12**		**PPI9**			**PPI 15**					**PPI17**				
		PPI14			**PPI16**				**PPI 11**												
					PPI18																
			PPT 3																		

					PPT4															
Implementation				PPI 28			PI 25	PPI 19			PPT 6			PPI 20						
							PT 8 – PPT 9											PPE 8 – PPE 9 PPE 10 - PPE 11		
								PPI 30												
								PPI 27												
								PPI 22												
		PP1 - PP 2 – PP 3						PPF 3 – PPF 4 – PPF5												

The abbreviations used in the tables are explained in Table 11.

Table 11: Explain the abbreviations used in the risk reduction model descriptively

Operations	Abbreviations	Explanations
Planning	PPI 1	Crisis Management Schedule
	PPI 2	Communications
	PPI 3	Safety law at schools and universities
	PPT 1	Preferring educational audience
	PPT 2	Choosing and training teachers

	PPE 1	Cost evaluation of crisis management plan
	PPE 2	Insurance system foundation
	PPE 3	Budgeting for recovery
	PPE 2	Creating loan system for seismic retrofitting in construction
Tools	PPI 5	Study solution in crisis management
	PPI 7	Solution for non-structural courses
	PPI 9	Training courses for media
	PPI 11	Training courses for companies
	PPI 12	Training courses for authorities
	PPI 14	Training courses for construction experts
	PPI 15	Guideline for house preparation
	PPI 16	Earthquake-resistant construction solution
	PPI 18	Visual training aids
	PPT 3	Preparing educational tools
	PPT 4	Training course for intervention teams
	PPE 5	Cost evaluation of education in crisis management
	PPE 6	Cost evaluation of nonstructural educational units
	PPE 7	Educational cost evaluation for media
	PPE 8	Educational cost evaluation for companies
	PPE 9	Educational cost evaluation for authorities
Implementation	PPI 19	Visual aids publishing
	PPI 20	Experiencing historical events
	PPI 25	The social experience of events
	PPI 27	National and local organizations
	PPI 28	Scheduled information program
	PPI 30	Implementation of educational maneuvers in schools
	PPI 22	Implementing memorial programs

The following measures are suggested to enhance productivity and appropriate implementation of seismic hazard model of Zanjan:

(a) Earthquake-resistant construction regulation (2800 Standard) should be applied seriously for land use and construction.

(b) Informing and training people, especially schools and universities, in a wide range

(c) Specialized training for all people involved in construction including architects, engineers, contractors, construction laborers, and other involved individuals.

(d) Implementing operating projects using specialized maneuvers to enhance readiness, and to enhance crisis response

(e) Organizing human force and authorities to show response to the earthquake, and to take rehabilitation after the crisis

(f) Appropriate planning should be taken to use the experiences of other cities of Iran or other countries for purpose of earthquake crisis management

(g) The measures taken to revise and meet weaknesses should be documented .

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