Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1

*Article*

# The Assessment of Sustainability Indicators in the Villagers' Lives in Iran with Emphasis on Natural Hazards: A Case Study

**Beniamino Murgante [1,*], Mohamad Salmani [2], Mohamad Molaei Qelichi [2] and Mehdi Hajiloo [2]**

[1] School of Engineering, University of Basilicata, Potenza 85100, Italy
[2] Faculty of Geography, University of Tehran, Tehran, Iran; Msalmani@ut.ac.ir (M.S.); Molaei1@ut.ac.ir (M.M.Q.); Mehdihajilo1@yahoo.com (M.H.)
* Correspondence: Beniamino.murgante@unibas.it; Tel.: +39-320-423-8518

**Abstract:** Natural hazards such as earthquakes take place around the world and when combined with human create natural disasters. Earthquake, as one of natural hazards, in recent years has caused the damage and the destruction of many rural areas with major losses in rural areas for the lack of sustainability in political, economic, social, physical and operational criteria. Thus, to overcome the damage caused by earthquakes in rural areas, the assessment of sustainability status seems necessary to plan and strengthen according to desirability of the status of sustainability indicators. This is a descriptive-analytical study; and data collection was conducted through field methods and questionnaires. To test the hypothesis, T statistical methods, correlation method and F-test were performed using SPSS software. The results of the study showed that villages were at a low and undesirable level under all aspects, except social index in terms of sustainability. Comparisons showed that there was a significant mean difference among villages in terms of sustainability. Also, the research concerns ranking of villages in terms of sustainability against earthquake hazard using multi-criteria decision methods. Finally, in order to improve sustainability indicators at the level of villages, some strategies were presented.

**Keywords:** sustainability indicators, natural hazards, earthquake, ELECTRE

## 1. Introduction

Natural hazards are becoming increasingly meaningful these days [1]. Throughout the history of the development of civilization, the human being has been always struggling with natural hazards. In many cases, irreparable damages caused by these hazards incur on human societies[2]. In fact, natural disasters have taken the lives of millions of people and have brought huge material losses. Among natural disasters, earthquake is one of the most common and it has been reported as the world's deadliest incident in 2001 [3].

Geological science shows that the earth has been always severely threatened throughout its life by the forces of nature; earthquake is perhaps the most destructive of them. The earthquake is one of the phenomena of our planet that kills thousands of people around the world and leaves considerable property damages [4]. Hence, earthquake is a phenomenon in which a lot of energy is released in the earth due to intense tectonic movements. As a result, it may causes elevation changes on the Earth's crust, liquefaction, fragmentation, gaps and horizontal displacement of the Earth [5]. In this context, development of indicators and appropriate methods for measuring sustainability are necessary for sustainable planning.

Rural areas may be considered especially susceptible to a variety of hazards given their social and economic composition [6] [7]. Rural areas are also considered more susceptible to hazards than urban areas

 doi:10.20944/preprints201703.0154.v1



because of relative lack of infrastructure, resources, and political clout [8] [7]. Attention to rural areas making up to 29% of the Iran's current population (Statistical Centre of Iran, 2011) is of great importance. At the same time, paying attention to their sustainability indicators especially in relation to the issues of natural hazards is important, because the village, as the production backbone of the country, if sustained, will promote power and position of the country in achieving development goals. This is why holistic sustainability strategy includes environmental, economic, political, social and cultural aspects and it is a long-term concept that is based on economic, cultural and biological diversity [9].

According to the seismic map of Iran, the studied area is located in a highly seismic area. Therefore, paying attention to the status of sustainability indicators of the villagers whose severity of injury is high seems very necessary. The aim of this study is to answer the following key questions:

- Have KharaRud Rural District villages of Khodabande city got the desirable sustainability indicators against natural hazards (earthquakes)?
- Have these villages got sensible differences in terms of stability against natural hazards (earthquakes)?
- Are there any significant relationships and correlations among sustainability indicators against natural hazards (earthquakes)?
- Which villages can be considered sustainable against natural hazards?

## 2. Literature Review

### *2.1. Measurement and Assessment of Sustainability Indicators*

In general, measurement or assessment is the process that detects and records the impact of each action on socio-economic and biophysical elements in the environment.

Researchers as Radcliffe and Goodman (1991), Singh and Astryngland (1993), Desailly (1998) have raised the idea that assessment and measurement activities related to sustainability can solve a lot of social, economic and environmental issues and problems [10].

On the topic of indicators, it can be concluded that an index must provide a clue, associated with a major and important phenomenon which is not immediately recognizable. Indicators should be specific, measurable, attainable, relevant and time-bound [7]. Indicators can support and guide the changes required to governments, international organizations, private sectors, NGOs and other major groups in sustainability [12].

However, it is noteworthy that in connection with sustainability indicators, there has not been a general agreement concerning various aspects and all policy makers in the sustainability issues [13]. Such a definition, agreed upon by the majority, contains three main economic, social and environmental issues.

Therefore, the environmental, social, and spatial consequences of traditional strategies shaped the multi-dimensional and holistic thinking about the development and for the first time in the mid-1970s, BarbaraWard raised the idea of sustainable development [14].

In other words, one-dimensional attitude to the sustainability is gradually faded and the integrity of the concept is more acceptable[15]. So, if the index includes parameters or values that make available the best knowledge and information about a phenomenon [16], it is clear that all of the different parameters cannot be evaluated in the form of environmental, social and economic triple sustainability. In this regard, considering the issue of working in order to assess its stability is very important.

According to the research topic that assesses the sustainability indicators of villagers against the risks of earthquake, taking into account other indicators such as physical-operational index is very important in addition to the main indicators in order to realize sustainability. Because the lack of attention to the operational-readiness indicators of villagers and physical index to plan for villagers in order to reduce the risks of earthquakes won't be possible.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



*2.2. Natural Hazards with an Emphasis on Earthquake*

In fact, natural hazards with different types and extent of their influence have always existed as repeatable and destructive phenomena during the life of the planet and they have been a serious threat to humans since the dawn of mankind. Accordingly, it can be said that no society can claim the immunity from natural hazards and people always faced with the harmful subjective and objective effects [17].

The occurrence of natural hazards leads to changes in environmental conditions which in turn interrupted the normal life of the people and causes a devastating impact on their habitat [18].

Therefore, the variety of risks relating to the earth is relatively high in terms of geological, climate conditions and structural characteristics. In Table 1, the most common types of risks in Iran are presented[19].

**Table 1.**The common risks in Iran

| Type of risk | Occurrence conditions | | |
|---|---|---|---|
| | Earthquake | Rainfall | Etc. |
| Earthquake and its related phenomena | • | | |
| Volcano | | | • |
| Landslide | • | • | • |
| Subsidence caused by water harvesting, oil and… | | | • |
| Local subsidence (caused by loss of subterranean cavities, shafts) | • | • | • |
| Subsidence caused by the dissolution | • | | |
| Problematic soils (swamps, erodible, soft, swelling soils) | | • | • |
| Non-engineering levee (manual soils) | | | • |
| Deep loss | | • | • |

In fact, natural disasters are often a sudden and severe event that cause catastrophic financial and felon losses and paralyze the life of communities. With an overview of the history of events occurring in our country, we can see that Iran has suffered many environmental crisis due to special spatial structures and was among the most vulnerable parts of the world against environmental hazards [20].

In the meantime, earthquake is one of the most frequent natural hazards in Iran due to its location on the Alpine-Himalayan seismic belt that shakes different areas of the country so often and causes irreparable damages especially in rural settlements [21].

Therefore, earthquake as a natural phenomenon is risky when the society is vulnerable to it and is not ready to deal with it [22]. So, earthquake is sudden and quick movements in the earth that originates from a limited area and spreads in all directions[23].

The earthquake word contains any type of vibration and earthquakes are often caused by fractures and faults movement. Also, volcanic activities, falling mountains, mines explosion and nuclear tests are the starting point of seismic gap [24].

Accordingly, 21st century began with a lot of earthquakes that its great results include economic losses and social turmoil [25]and occurs when a large mass moves near the fault and this earthquake is known as a stage in the long-term and it was referred as the period of active fault [26].

Then, in connection with the issue, a number of domestic and foreign researchers conducted studies in some indicators which are as follows:

Jalalian and Dadgar (2015) in a study entitled “Vulnerability mapping of rural settlements against earthquake with AHP model in a case study of GIS environment in Chavarzaq district in Tarom city” investigated the vulnerability of the region against earthquake and addressed the environmental and demographic indicators of rural settlements against earthquake using hierarchical analysis model and

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



spatial multi-criteria analysis method. The results showed that the major part of the Tarom city and the rural settlements of the zone are in the fields with high risk of 45.71% and very high risk of 14.71 per cent [27].

Zaheri et al (2015) in a study entitled "the vulnerability assessment of rural areas of earthquake risk (case study: the central district of Marand city)" analysed the vulnerability of rural settlements of central district in Marand and finally showed that there are high and very high vulnerability in more than 30 percent of the villages in the study that 29.33 % and 44 % of villages have high and very high vulnerability in terms of spatial-physical and economic-social aspect, respectively. Therefore, given that the vulnerability of the study area is mainly affected by the physical-spatial vulnerability, so changes in physical-spatial characteristics of the study area was found to improve the situation in order to reduce vulnerability[28].

Becker et al (2011) assessed the readiness and information of people about earthquake and their perception with 48 interviews. They have used three sources of information in an interview: passive information (newspapers, magazines and ...), interactive information (social, school and work activities), the experimental data (for example, experienced a serious event and respond to it), the results of this study indicate that most people deal with the last two types of information[29].

## 3. Materials and Methods

This is a functional study with quantitative method and it is as descriptive-analytical. In conducting this study and in the data collection stage, two documentary (library) and field studies methods have been used. In this study, the statistical population is the villagers of central district of Khodabande city, KharaRud County. In this regard, given that KharaRud County has 30 villages, so due to impossibility of selection of all of the villages as a sample, the villages were categorized based on the population into two demographic groups with more than thousand and less than thousand people. Two villages were selected as a sample from any demographic group. In this regard, a number of villages were in each classification. Finally, two Gushekand and Khaleqabad villages were classified as villages with population of less than a thousand and Mahmudabad and Zaringol villages were classified as villages with population more than a thousand based on the random sampling method.

The statistical society of the research was villagers of the studied villages and the sample size was calculated using Cochran's formula. Given that the total population of villages is 5749 people so the sample size was 360 people in the Cochran's formula. As previously mentioned, 50 per cent of these samples, i.e. 180 people were randomly examined as a sample due to the lack of access to all of the specimens as for time constraints and then the sample size was determined based on the relative proportional formula according to the population of each village. Also, data analysis was conducted using T-test, F- test or ANOVA, DUNCAN Test and finally Correlation test with SPSS software.

**Table 2.** Investigating demographic status of studied villages

| No. | City | District | County | Village | Total population | Number of households |
|---|---|---|---|---|---|---|
| 1 | Khodabande | Central | Khara Rud | Zarian Gol | 1343 | 372 |
| 2 | ″ | ″ | ″ | Mahmud Abad | 2906 | 782 |
| 3 | ″ | ″ | ″ | Gushekand | 549 | 132 |
| 4 | ″ | ″ | ″ | Khaleqabad | 951 | 253 |

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



$$n = \frac{(1/96)(0/50)(0/50)(0/05)^2}{1 + 15749(1/96)^2(0/50)(0/50)(0/05)^2 - 1} = 360 = 180$$

To assess the reliability of research, Cronbach's alpha method and SPSS software were used. The Cronbach's alpha coefficient is between zero and one. The more closer the Cronbach's alpha value to one, the more is the reliability of the questionnaire. If the Cronbach's alpha value is greater than 0.7 then reliability is good and if it is between 0.5 and 0.7 then the reliability is medium and if it is less than 0.5 then the questionnaire is lacking in necessary reliability. Thus, the reliability of the questionnaire for each of the indicators is as follows which indicates that the reliability of the questionnaire is in the desirable high condition (table 3). To assess the validity of the study in pre-test stage, 12 questionnaires were completed by geography and rural planning experts and also experts in the field of risk and their reliability were confirmed with the opinions of professors.

**Table 3.** The reliability of used components

| Index | Cronbach's alpha |
|---|---|
| Social | 0.701 |
| Physical | 0.737 |
| Operational | 0.750 |
| Economic | 0.687 |
| Political | 0.664 |

Indicators used in the study are different with regard to the issue of any research. In this study, indicators were evaluated in five dimensions: economic, social, political, physical and operational. Each of the indicators has statements as follows (Table 4).

**Table 4.** Investigating the indicators used in the research

| Sustainability indicators | The studied statements |
|---|---|
| Social index | Participation - social base - belief or non-belief in fatalism to the occurrence of earthquake - the rate of interest to attend training classes – the rate of interest to transfer their experiences to others |
| Physical index | Housing conditions (type of material - Antiquity of the building, quality of the building, number of floors) – existence of safe neighbourhoods, having necessary facilities |
| Political index | Public sector support in connection with the financing, the necessary permits for construction, supervision in construction, issues related to congestion, public awareness through the media, training courses by government and related organs |
| Operational index | Individual consciousness, individual skills, individual readiness, The training of children and families by household head, the classes that attended ever for training, help the wounded and injured people in the event of a crisis |
| Economic index | Affordability to build or repair and retrofit housing – Affordability to buy essential facilities in times of crisis (having first aid kits, etc.), the financial strength necessary to insure the building |

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



*3.1. Analytical Model Algorithm (ELECTRE III)*

The ELECTRE[1]method has been presented by Benayoun, and then it has been developed by Van Delft, Nijkamp, Roy and other colleagues. In the ELECTRE method, the dominance concept was implicitly used. In this method, the alternatives are compared with each other as a couple and dominant and weak (or dominant and recessive) alternatives are identified and then the weak and defeated alternatives are removed [30].

If there are **n** criteria and **m** alternatives in a multi-criteria decision problem, in order to choose the best method using ELECTRE method, the following steps should be taken:

- Formation of decision matrix
- Determine the Normalized decision matrix
- Determine the weighted normalized decision matrix
- Formation of Concordance matrix
- Formation of Discordance matrix
- Concordance Dominance matrix
- Discordance Dominance matrix
- Determine the Aggregate Dominance matrix
- Removing the alternatives with less satisfaction and choose the best alternative[30]-[31].

*3.2. Study Area*

Khodabande County with an area of 4800 square kilometres located at the south of the Zanjan province, between eastern longitude of 48 degrees and 35 minutes and northern latitude of 36 degrees and 7 minutes. This county is subdivided into four districts: the central distruct, Afshar district, BizinehRud district and SojasRud district. The Central district, KharaRud County, was selected as statistical population. This County has 30 villages that four villages (ZarirnGol, Mahmudabad, Ghushekand and Khaleqabad) with total population of 5749 people were assessed as studied villages.

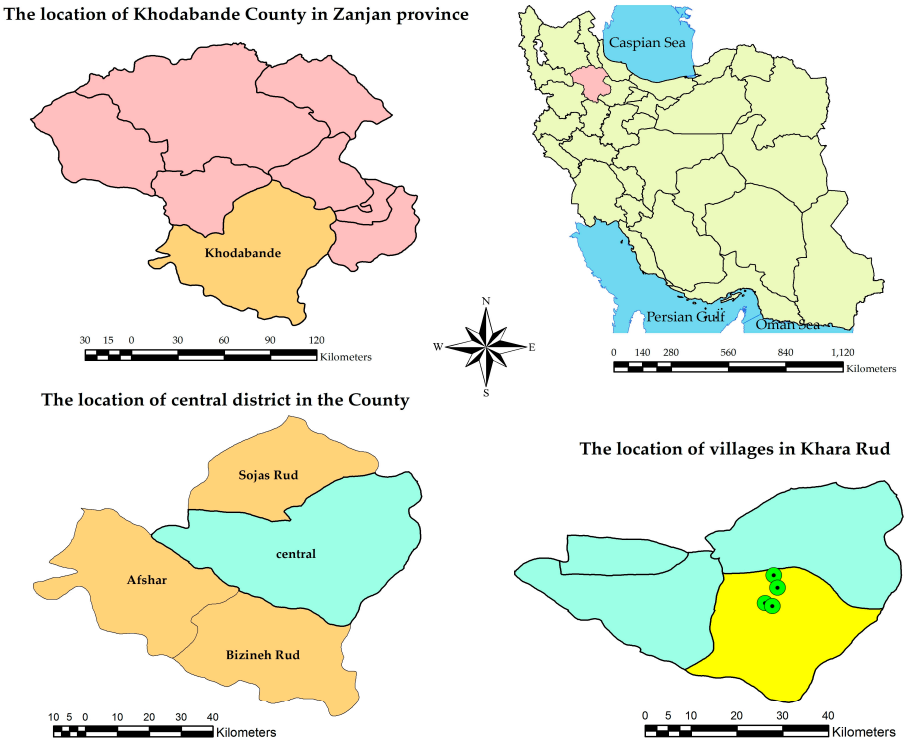



**Figure 1.**Study area of central district of KharaRud County

[1] Elimination et Choice Translating Reality

 doi:10.20944/preprints201703.0154.v1



## 3. Results and Discussion

In connection with the individual characteristics of respondents, the results of the study showed that the major respondents were in the age range of 41-50 years with an average of 34.4 per cent and the lowest cohort were people less than 20 years with an average of 3.3 per cent associated with the age characteristic. In connection with the characteristics of the respondent's gender, the results of data analysis showed that the majority of respondents were male with an average of 71.1 per cent and the others were women with an average of 28.9 per cent.

Finally, in connection with the academic features of respondents, the results showed that the majority of respondents were in cycles and lower education level with an average of 36.1 per cent and the lowest number of respondents was at the graduate level education and above with an average of 4.4 per cent. The results of inferential findings for each of the indicators are as follows:

In association with operational index, the statements such as the response of the person to the emergency training courses, reading rescue books, personal knowledge, personal skill, the ability to train emergency assistance to the families were evaluated. The results showed that the significance level of the villages was 0.000 that indicates the significant relationship, but since the mean was 2.5955 that were less than the desirable limit of 3.1, so it was concluded that the stability index of villagers against the risks of earthquakes is not good.

The second index was economic index and the statements such as person's income, the individual's financial ability to build or repair and retrofit housing, affordability to purchase necessary facilities for times of crisis, affordability of the person to insure the constructions were evaluated. The results showed that the significance level was 0.000 that confirms the significant relationship. Since the mean was 2.3435 that were less than the desirable limit of 3.1 so we can conclude that the villagers were in the sustainability level against the risks of earthquake in association with the stability of economic index.

The third index is a political index in which the statements such as public sector supports in association with the provision of housing facilities, training courses to educate villagers by government agencies, awareness through the media, monitoring in construction, oversight of government agencies in providing permits for construction were evaluated. The results showed that the significance level was 0.000 that confirms the significant relationship. But, since the mean was 2.8641 that was less than the desirable limit of 3.1 so we can conclude that the villagers were in unsustainable condition against the risks of earthquake in terms of political index.

The other index is social index in which the statements such as measuring belief in fatalism against natural disasters (earthquake), education, interest in participation, social base were evaluated. The results showed that the significance level was 0.003 that confirms the significant relationship. Also, since the mean in higher than the desirable limit of 3.1 we can conclude that the villagers were in the sustainable and desirable status in terms of social index.

The last index is physical index in which the statements such as housing conditions (type of materials, antiquity of building, quality of building, number of stories), safe neighbourhoods and places for use in emergency cases, having necessary medical equipment at home and… were evaluated. The results showed that the significance level was 0.000 that confirms the significant relationship. But, since the mean was 2.8243 that was less than desirable limit of 3.1 so we can conclude that the villagers were in unsustainable and undesirable level in terms of physical index (table 5).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



**Table 5.** The assessment of sustainability indicators of villagers against risks of earthquake

| | The standard rate of test 3.1 | | | | | | |
|---|---|---|---|---|---|---|---|
| | t | Sample size | Mean | Significance level | Standard deviation | The reliability difference 95% | |
| | | | | | | Low limit | High limit |
| operational | 8.487 | 178 | 2.5955 | 0.000 | 0.79305 | -0.6218 | 0.3872 |
| Economic | 22.734 | 178 | 2.3435 | 0.000 | 0.44395 | 0.8222 | 0.6908 |
| Political | 5.894 | 180 | 2.8641 | 0.000 | 0.53695 | 0.3149 | 0.1569 |
| Social | 2.973 | 180 | 3.2722 | 0.003 | 0.77714 | 0.579 | 0.2865 |
| Physical | 7.075 | 178 | 2.8243 | 0.000 | 0.51994 | 0.3526 | 0.1988 |

Furthermore, in order to compare the mean difference of desired indicators in the level of villages, the DUNCAN test was used. The results showed that the significance level was 0.000 in the ANOVA table that was below 0.005. This confirms the significance and in the other words the mean difference in the level of villages in terms of stability index against the risks of earthquake (Table 6).

**Table 6.** The results of ANOVA test for sustainability index in the level of villages

| | Sum of squares | Degree of freedom | Average of squares | F | Significance level |
|---|---|---|---|---|---|
| Between groups | 2.010 | 3 | 0.670 | 9.843 | 0.000 |
| Among groups | 11.573 | 170 | 0.068 | | |
| Total | 13.583 | 173 | | | |

Then, the studied villages were classified into two groups as factors using DUNCAN test. The results showed that the highest and best stability index for villagers was in the ZarianGol village with the average of 2.9037 which has higher stability status compared to the other villages in all of the operational, economic, political, social and physical indicators. Although its interval with the optimum range is little. The second village that is located in the second column was Mahmoudabad village with the average rate of 2.8482. It can be said that it is in a same level of stability with ZarianGol village. The Khaleqabad village is the third village in terms of the stability against the risks of the earthquake. Its average rate is 2.6660 which is in the first column. Finally, Gushekand village is in the lowest rate of stability against the risks of earthquake with the mean of 2.6642 that indicates the undesirable status in this area (Table 7).

**Table 7.**The DUNCAN test- comparing the villages in terms of stability index against the risks of earthquake

| Studied villages | Categorization of columns | |
|---|---|---|
| | 1 | 2 |
| Gushe Kand | 2.6642 | |
| Khaleq Abad | 2.6660 | |
| Mahmud Abad | | 2.8482 |
| Zarian Gol | | 2.9037 |
| **Significance level** | **0.974** | **0.328** |

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



The correlation test was used to investigate the correlation between stability indicators with each other. The results of analysis showed that the social index is correlated with the physical index. The significance level is 0.000 that confirms the significant relationship. This correlation showed that to some extent the rate of stability is increased in the social index including collaborative and education discussions and so on, then the rate of stability will increase in the physical index of the villagers against the risks of earthquake in the villages.

In other words, the villagers will have desirable status in physical indicators such as (improve housing conditions in terms of materials, the quality of the building, providing essential equipment such as first-aid kit, flashlight and ...). Also, the results of the correlation between other indicators showed that there is a significant correlation between political index and physical index. The significance level was equal to 0.022 which shows that there is a positive and significant correlation between these two indicators. So that whatever the status of the political index improved in the villages in terms of stability then the physical index such as (improve the status of housing in terms of materials, the quality of the building, providing essential equipment such as first-aid kit, flashlight) will be desirable equally. Also, there is a positive and significant correlation between physical index and economic index. The significance level was equal to the 0.021 which indicates that as much as the status of the villagers improved in terms of the economic index then their tendency to improve the physical index such as (improve the status of housing in terms of materials, the quality of the building, providing essential equipment such as first-aid kit, flashlight) will be desirable (Table 8).

**Table 8**. Investigating the correlation status among stability indicators

| | | Political | Physical | Social | Economic | Operational |
|---|---|---|---|---|---|---|
| Political | Pearson correlation | 1 | 0.171* | 0.087 | 0.050 | 0.077 |
| | Significance level | | 0.22 | 0.246 | 0.503 | 0.307 |
| | Sample size | 180 | 178 | 180 | 178 | 178 |
| Physical | Pearson correlation | 0.171* | 1 | 0.266** | 0.174* | -0.79 |
| | Significance level | 0.22 | | 0.000 | 0.21 | 0.299 |
| | Sample size | 178 | 178 | 178 | 176 | 176 |
| Social | Pearson correlation | 0.087 | 0.266** | 1 | 0.139 | 0.053 |
| | Significance level | 0.246 | 0.000 | | 0.065 | 0.481 |
| | Sample size | 180 | 178 | 180 | 178 | 178 |
| Economic | Pearson correlation | 0.050 | 0.174* | 0.139 | 1 | 0.043 |
| | Significance level | 0.503 | 0.021 | 0.065 | | 0.567 |
| | Sample size | 178 | 176 | 178 | 178 | 176 |
| Operational | Pearson correlation | 0.077 | 0.079 | 0.053 | 0.043 | 1 |
| | Significance level | 0.307 | 0.299 | 0.481 | 0.567 | |
| | Sample size | 178 | 176 | 178 | 176 | 178 |
| *. Correlation is significant at the 0.05 level (2-tailed). | | | | | | |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | | | | |

### *3.1. Ranking the Villages of Khara Rud Rural District Based on the Sustainability against the Risks of Earthquakes*

The multi-criteria decision-making models are used in order to rank the villages of the KharaRud County. In multi-criteria decision-making models, the tools can be used to rank the alternatives.

Many multi-criteria analytical tools for performance evaluation and ranking of alternatives are AHP, TOPSIS, DEA, PROMETHEE, etc.

In this article, the ELECTRE method was used to assess the sustainability of villagers against the risks of earthquakes. ELECTRE was a decision-making method and it was used to rank or prioritize the

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



various alternatives using the criteria weight. This method was used in different cases of planning, financial estimates, accounting and also geography and so on. To review and analysis of sustainability indicators of the villages against the risks of earthquakes, the following steps are operational:

First Step: Formation of Decision Matrix

In this stage, the decision matrix that consists of Alternatives (rows) and Criteria (columns) has been formed. At this research Alternatives are villages and Criteria are five that were mentioned and coded (C1 to C5), for example, C5 means political criteria (Table 9).

**Table 9.** The status quo matrix based on the satisfaction rate from sustainability indicators of villagers against risks of the earthquake

| Alternative/ criteria | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| | Social | Physical | Operational | Economic | Political |
| Mahmud Abad | 3.060 | 2.910 | 2.829 | 2.450 | 2.983 |
| Khaleq Abad | 3.177 | 2.841 | 2.114 | 2.331 | 2.761 |
| Gushe Kand | 3.340 | 2.915 | 2.000 | 2.294 | 2.800 |
| Zarian Gol | 3.473 | 2.638 | 3.240 | 2.297 | 2.870 |

The Second Stage: Normalizing the Decision Matrix

At this stage, it is tried to convert criteria with different dimensions to the criteria with no dimension and the normalized decision matrix is defined. There are several methods to normalizing. However, the following relation is used in the ELECTRE method [32] (Table 10):

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (1)$$

**Table 10.**Normalized criteria matrix

| Normalized matrix | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| Mahmud Abad | 0.522 | 0.523 | 0.545 | 0.514 | 0.468 |
| Khaleq Abad | 0.484 | 0.497 | 0.407 | 0.502 | 0.486 |
| Gushe Kand | 0.490 | 0.489 | 0.385 | 0.515 | 0.511 |
| Zarian Gol | 0.503 | 0.490 | 0.624 | 0.466 | 0.532 |

The Third Stage: Formation of Weighted Criteria Matrix

At this stage, weighting of criteria (W) was done after normalizing the decision matrix. For this purpose, there are various compilation methods such as AHP, ANP, Shannon entropy, which are used as necessary. Entropy method is used in this study (Table 11). Entropy is a major concept in the physical sciences, social sciences and information theory, so that reflects the uncertainty of the expected information content of a message. In other words, the entropy is a criterion in the information theory that indicates the uncertainty expressed by a discrete probability distribution. This uncertainty can be described as follows [33]:

$$E = -k\sum_{i=1}^{n}[p_i \times \mathrm{Ln}\, p_i] \quad (2)$$

Where K is a positive constant and it is determined as if we have:

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



E.0 ≤ E ≤ 1 is calculated from the probability distribution of $P_i$ based on the statistical mechanism. Decision-making matrix of multi-attribute models contains information that entropy can be used as a criterion for its evaluation. The information content of the matrix is calculated as $P_{ij}$ in the following.

$$p_{ij} = \frac{r_{ij}}{\sum r_{ij}} \qquad \forall i, j \tag{3}$$

And we will have for $E_j$per criteria:

$$E_j = -k \sum_{i=1}^{n} [p_i \times \mathrm{Ln}\, p_{ij}]; \quad \forall j \tag{4}$$

$$k = \frac{1}{\mathrm{Ln}(m)} \tag{5}$$

So that it keeps the value of $E_j$ between zero and one.

The uncertainty or deviation degree $(d_j)$ is calculated from data stating that how much useful information does the $j^{th}$ criteria make available for the decision-maker? If the standardized data be closer to each other then it reflects that the competing alternatives are not significantly different in terms of that criteria. Thus, the role of that index should be reduced as much in decision-making. Therefore [34]:

$$d_j = 1 - E_j; \quad \forall j \tag{6}$$

And finally, for weights $(W_j)$ of the criteria, we have:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} dj}; \quad \forall j \tag{7}$$

**Table 11.**The weight of criteria in entropy

| Code | Criteria | Weight |
|---|---|---|
| C1 | Social | 0.051 |
| C2 | Physical | 0.035 |
| C3 | Operational | 0.879 |
| C4 | Economic | 0.016 |
| C5 | Political | 0.019 |

Weights obtained for each of the criteria are presented in Table 12. By applying the obtained weights in the normalized matrix, the weighted decision matrix is provided (Table 12).

**Table 12.** The weighted matrix of criteria

| Weighted matrix | Social | Physical | Operational | Economic | Political |
|---|---|---|---|---|---|
| Mahmud Abad | 0.010 | 0.008 | 0.479 | 0.018 | 0.024 |
| Kheleq Abad | 0.009 | 0.008 | 0.358 | 0.018 | 0.025 |
| Gushe Kand | 0.009 | 0.008 | 0.339 | 0.018 | 0.026 |
| Zarian Gol | 0.010 | 0.008 | 0.549 | 0.016 | 0.027 |

Forth Stage: Formation of Concordance Matrix of criteria

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



At this stage, after weighting normalized matrix, the concordance matrix was formed. The concordance matrix is obtained from the sum of criteria weights which are in the concordance set [35][36](Table 13):

$$C(a,b) = \frac{1}{W}\sum_{i=0}^{n} w_k * c_k(a,b) \quad (8)$$

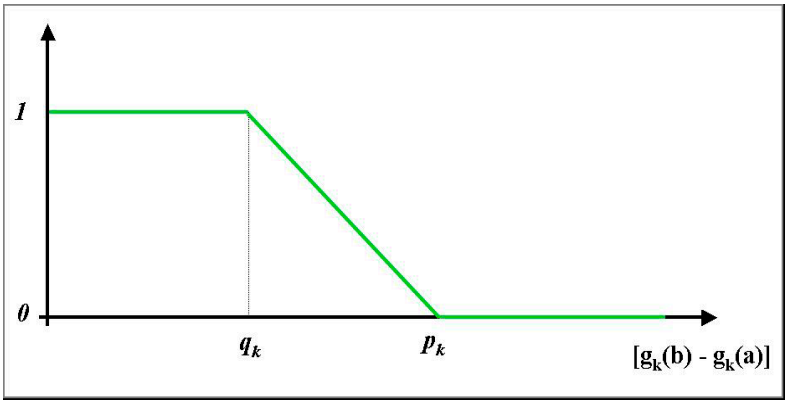



**Figure 2.**Concordance indices of Ck (a, b)

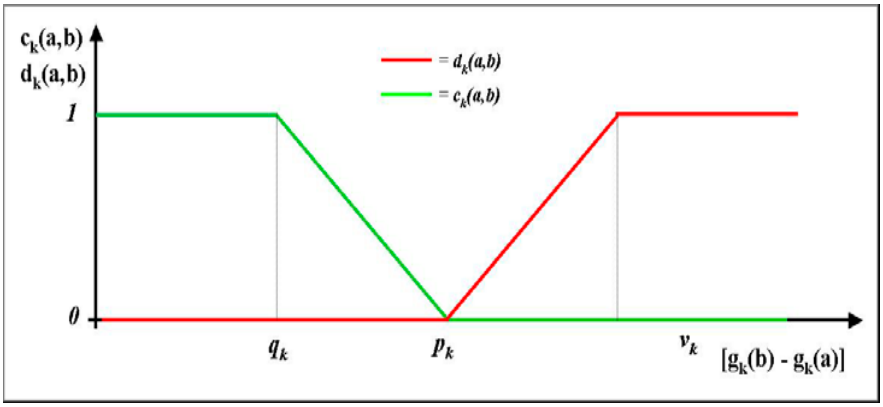
**Table 13.** Formation of Concordance Matrix of Criteria

| Concordance Matrix | A1 | A2 | A3 | A4 |
|---|---|---|---|---|
| A1 | ----- | 0.949 | 0.914 | 0.070 |
| A2 | 0.051 | ----- | 0.895 | 0.051 |
| A3 | 0.086 | 0.105 | ----- | 0.035 |
| A4 | 0.930 | 0.949 | 0.965 | ----- |

Fifth Stage. Formation of Discordance Matrix of criteria

The discordance matrix indicates the degree that an alternative $A_k$ is worse than a competing Alternative $A_1$ [35][36]. The discordance matrix is obtained as follows:

$$d_{kl} = \frac{\max\limits_{j \in D_{kl}} |y_{kj} - y_{lj}|}{\max\limits_{j} |y_{kj} - y_{lj}|} \quad (9)$$



Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



**Figure 3.**Comparative results of the concordance indices of Ck (a, b) and discordance

**Table 14.**Formation of Discordance Matrix of Criteria

| Discordance Matrix | A1 | A2 | A3 | A4 |
|---|---|---|---|---|
| A1 | ---- | 0.007 | 0.015 | 1 |
| A2 | 1 | ---- | 0.065 | 1 |
| A3 | 1 | 1 | ----- | 1 |
| A4 | 0.0242 | 0.006 | 0.008 | ---- |

Sixth Step: Formation of Concordance Dominance Matrix of criteria

At this stage, a given value is determined for the concordance index that is called discordance threshold and it is shown as($\bar{c}$). If the existing value is greater than the concordance threshold in comparing alternatives in the concordance matrix then it will assign one to itself and if it is less than the concordance threshold then it will assign zero (Table 15). The value of concordance threshold is calculated as follows:

$$\bar{c} = \sum_{\substack{k=1 \\ k\neq e}}^{m} \sum_{\substack{e=1 \\ e\neq k}}^{m} \frac{c_{ke}}{m(m-1)} \tag{10}$$

According to the threshold value, the concordance dominance matrix F is determined as follows[35]:

$$f_{kl} = \begin{cases} 1, & c_{kl} \geq \bar{c} \\ 0, & c_{kl} < \bar{c} \end{cases} \tag{11}$$

**Table 15.**Concordance Dominance Matrix of criteria

| Concordance Dominance Matrix | A1 | A2 | A3 | A4 |
|---|---|---|---|---|
| A1 | --- | 1 | 1 | 0 |
| A2 | 0 | --- | 1 | 0 |
| A3 | 0 | 0 | --- | 0 |
| A4 | 1 | 1 | 1 | --- |

Seventh Stage: Formation of Discordance Dominance matrix of criteria

The Discordance Dominance matrix is formed similar to the concordance dominance matrix. At first, Discordance threshold $(\bar{d})$ should be determined. If the existing value is less than the discordance threshold in comparing alternatives in the discordance matrix then it will assign *1* to itself and if it is greater than the discordance threshold then it will assign *0*. Therefore defined a binary matrix [36] as shown in Table 16.The value of discordance threshold is calculated as follows:

$$\bar{d} = \sum_{\substack{k=1 \\ k\neq e}}^{m} \sum_{\substack{e=1 \\ e\neq k}}^{m} \frac{d_{ke}}{m(m-1)} \tag{12}$$

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



And:

$$g_{kl} = \begin{cases} 1, & d_{kl} \geq \bar{d} \\ 0, & d_{kl} < \bar{d} \end{cases} \quad (13)$$

**Table 16.** DiscordanceDominance matrix of criteria

| Discordance Dominance matrix | A1 | A2 | A3 | A4 |
|---|---|---|---|---|
| A1 | --- | 1 | 1 | 0 |
| A2 | 0 | --- | 1 | 0 |
| A3 | 0 | 0 | --- | 0 |
| A4 | 1 | 1 | 1 | ---- |

Eighth Stage: Determine the Aggregate Dominance Matrix

The final matrix is obtained from multiplying every elements of concordance dominance matrix by discordance dominance matrix. This matrix is shown in Table 17.

**Table 17.**Aggregate Dominance Matrix of criteria

| Aggregate Dominance matrix | A1 | A2 | A3 | A4 |
|---|---|---|---|---|
| A1 | ---- | 1 | 1 | 0 |
| A2 | 0 | --- | 1 | 0 |
| A3 | 0 | 0 | --- | 0 |
| A4 | 1 | 1 | 1 | --- |

Ninth Stage: Removing the alternatives with less satisfaction and choose the best alternative

The matrix of domination number calculation states the minor preferences of alternatives. The alternative must be selected that have mastered more than it gets lost and the alternatives can be rated in this sense. According to this matrix, the number of dominance that every alternative has dominated and the number of dominance that have been beaten were calculated. These are shown in table 18.

**Table 18.** The domination number matrix of criteria

| The domination number matrix | Alternative | Result |
|---|---|---|
| 3 | A4 | Zariangol |
| 2 | A1 | Mahmudabad |
| 1 | A2 | Khaleqabad |
| 0 | A3 | Gushekand |

The results of the ELECTRE model indicate that ZarianGol County has better status than the other districts in terms of stability to earthquake hazards. It is necessary to plan for the unsustainable villages against the hazards.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 20 March 2017 doi:10.20944/preprints201703.0154.v1



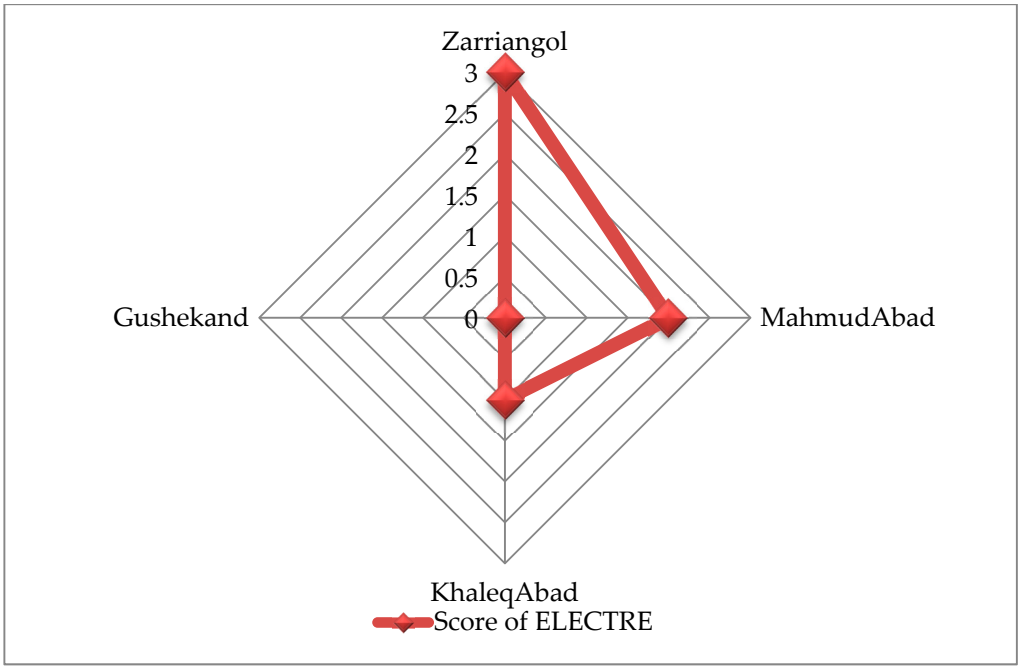



**Figure 3.**Results of ELECTRE technique and ranking of villages

## 5. Conclusions

Attention to the sustainability indicators in rural areas is particularly important because in many of the occurred hazards, particularly earthquakes throughout the rural areas of the country, the vast majority of rural homes are damaged and sometimes it leads to superficial damage or full destruction. This removes the incentives and desirability of villagers to continue living in these areas and they have not any willingness to stay in the village. Because this factor brings the foreground of a lot of damages in the life cycle of the other parts and specially cities through rural migration, their unhealthy occupations and releasing the agricultural sectors. So, attention and help to improve sustainability indicators which includes economic, political, social, operational and physical issues in this research can prevent many injuries and destructions in the case of earthquake or the other risks. Thus, there is no need to spend huge costs for reconstructions after the earthquake. Therefore, this study states a need assessment process before the outbreak of the crisis in rural areas from villagers. We will see the lack of physical risks for the villagers by strengthening the weaknesses. This will be a planning validation before the crisis.

As was mentioned, there is no consensus regarding the sustainability indicators. In all studies, the researchers tried to state sustainability indicators based on their subject. So, in this study, the total needs of the villagers are considered in the form of sustainability issues against risks (earthquake). Accordingly, two other operational and physical indicators are considered in addition to the three main social, economic and environmental indicators in the sustainability discussion. Because operational index refers to the personal readiness of the people (villagers) before the occurrence of the earthquake which includes separate items and physical index consider the issues related to the housing and their neighborhood security which is the most important issue to the villagers. Finally, the results of the research showed that the total villages (Mahmoud Abad, khaleqabad, GooshehKand and ZarianGol) were in the lower level of sustainable standards except social index. The results showed that their most weakness in the economic index relates to their lack of financial capability. In other words, it is the most unsustainable index among the other indicators. This leads to their lack of motivation to strengthen homes, insure them or cannot afford to buy some of the needs at the time of crisis. This inability have a direct impact on the unsustainability of the physical index because the lack of affordability causes to use

poor-quality materials, raising the antiquity of the buildings, non-use of update architecture powers in designing homes.

Therefore, unsustainability in the economic index has been transferred its effects to the physical index. Considering that the political index is in the unsustainable status, it means that supports by the public sector to provide facilities for retrofitting, modernization of the building are very few and also, lack of attention to the normative housing construction and considering that governmental agencies did not provide education in the schools, mosques and … for villagers or educations were very limited in the schools that includes very little population of the students to show how to react in the case of earthquake disaster, so the villagers were in the undesirable level in terms of personal and family readiness, personal skills (operational sustainability). It should be noted that a few of buildings which are recently built in the villages use update architecture but this culture is still not pervasive that all of the villagers have the ability to build resistant buildings against earthquake. Of course, this requires the cooperation of the public sector especially the financial support of the government in this field. The status of the social stability index was in the desirable level that was slightly higher than the assumed standard. It represents the spirit of the villagers to participate in the discussion of cooperation, lack of belief in fatalism issues in relation to the risks and so on. The other stability indicators can be improved through this way. As previously, it was referred to the correlation between these indexes with physical index.

The villages were ranked in terms of the stability indicators against the risks of earthquake using multi-criteria ELECTRE decision-making method. Two points are mentioned in relation to this method:

First point: Situation of some of the villages at high levels does not represent the ideal status and only specifies the areas mentioned in relation to the other villages.

Second point: In this study, determination of satisfaction based on the stability against the risks has been taken by five indicators. Obviously, this rating will be changed by considering the other different indicators. Finally, there are some recommendations to improve the stability status of the indicators of the villagers with an emphasis on the risks of the earthquake:

- Due to the fact that the participation and cooperation rate in the level of the villages was high (the desirability of the social stability index), so it is recommended that government agencies use this participation and cooperation of villagers and gather them in the mosques and learn emergency trainings to them.
- Encourage and provide financial support (bank facilities) to the villagers in order to build or repair homes with update architecture to minimize the risks of earthquake.
- Strict supervision of the public sector to the construction of houses, in order to retrofit the rural houses.
- Since two villages of Gushekand and Khaleqabad are in an undesirable status in terms of the stability compared to the other two villages, it is suggested to train these villages in terms of the placement, the installation of equipment on the wall, familiarity with first aid kits by Red Crescent departments.

**Author Contributions:** Beniamino Murgante and Mohamad Salmani conceptualized and designed the study, analysed the data, and wrote the paper. Mohamad Molaei Qelichi did the computation and analysed the results. Mehdi Hajiloo collected the data. All authors read and approved the final manuscript.

**Conflicts of Interest:**The authors declare no conflicts of interest.

## References

[1] G. Berz *et al.*, "World Map of Natural Hazards – A Global View of the Distribution and Intensity of Significant Exposures," *Nat. Hazards*, vol. 23, no. 2/3, pp. 443–465, 2001.

[2] M. Ghadiry and N. Nasabi, "An Analysis on the Differences of Mental- Perception Readiness of Families to Earthquake, Shiraz City," *Sci. J. Manag. Syst.*, vol. 3, no. 2, pp. 227–245, Jun. 2015.

[3] M. Arab, H. Zeraati, F. Akbari Haghighi, and R. Ravangard, "A study on the executive

managers' knowledge and performance, and their hospitals preparedness against earthquake events and their relationships at public hospitals (affiliated by Tehran University of Medical Sciences (TUMS) 2005-2006)," *J. Heal. Adm.*, vol. 11, no. 34, pp. 7–14, Jan. 2009.

[4] V. Heidari Sarban, "Analysis of the Effects of Earthquake in Rural Areas (Case study: Varzeghan)," *Geogr. Environ. HAZARDS; Vol 3, No 11(2014)*, Oct. 2014.

[5] A. Meshkini, S. Ghaed Rahmati, and R. Shabanzadeh namini, "Analysis of urban fabric vulnerability against earthquake. (Case study: Tehran,District 2).," *Hum. Geogr. Res.*, vol. 46, no. 4, pp. 843–856, Feb. 2015.

[6] S. L. Cutter, B. J. Boruff, and W. L. Shirley, "Social vulnerability to environmental hazards," *Soc. Sci. Q.*, vol. 84, no. 2, pp. 242–261, 2003.

[7] A. J. Prelog and L. M. Miller, "Perceptions of Disaster Risk and Vulnerability in Rural Texas," *J. Rural Soc. Sci.*, vol. 28, no. 3, pp. 1–31, 2013.

[8] M. A. Brennan and C. G. Flint, "Uncovering the Hidden Dimensions of Rural Disaster Mitigation: Capacity Building through Community Emergency Response Teams," *South. Rural Sociol.*, vol. 22, no. 2, pp. 111–126, 2007.

[9] C. I. D. A. CIDA, "Sustainable Development," Ottawa, 1991.

[10] arastoo yarihesar, seyed ali badri, mehdi poortaheri, and hassan ali faraji sabokbar, "The Measurement and of Sustainability Assessment of Tehran Metropolitan Rural Areas," *Rural Res.*, vol. 2, no. 8, pp. 12–89, Feb. 2012.

[11] D. Kumar and S. S. Katoch, "Sustainability indicators for run of the river (RoR) hydropower projects in hydro rich regions of India," *Renew. Sustain. Energy Rev.*, vol. 35, pp. 101–108, 2014.

[12] N. B. Moghaddam, M. Nasiri, and S. M. Mousavi, "An appropriate multiple criteria decision making method for solving electricity planning problems, addressing sustainability issue," *Int. J. Environ. Sci. Technol.*, vol. 8, no. 3, pp. 605–620, Jun. 2011.

[13] A. Colantonio, "Social Sustainability: Exploring the Linkages Between Research, Policy and Practice," in *European Research on Sustainable Development*, Berlin, Heidelberg: Springer Berlin Heidelberg, 2011, pp. 35–57.

[14] H. Motiei, *Rural Planning with an emphasis on Iran*. Mashhad: SID, 2003.

[15] Tavakoli.J; Rostami. B;, "Sustainability of Rural Settlements in Takab County," *2*, vol. 16.

[16] S. Pourebrahim, "Assessing of the Contribution of Sustainability Indicators in a Healthy Urban City (case study: Arak city, Iran)," *Hum. Environ.*, vol. 12, no. No. 28 Spring 2014, pp. 63–73, Mar. 2014.

[17] M. Ghafory-Ashtiany, "Earthquake Risk management Strategies: The Iranian Experience," *Unesco & Iiees*. 2005.

[18] B. Wisner, *At risk : natural hazards, people's vulnerability, and disasters*. Routledge, 2004.

[19] G. Fazelniya, S. Y. Hakimdoost, and M. Yarmohammadi, "Natural Disaster Risk Zoning in Rural Areas Using Gis with Emphasis on Landslides Factor (Case Study: Dohezar Dehestan of Tonekaon County)," *J. Res. Rural Planning; Vol.4, No.2 (2015), Ser. No.10*, Sep. 2015.

[20] mehdi taherkhani, hamdollah sojasi qeydari, and tahereh sadeghloo, "Comparative Assessment of Ranking Methods for Natural Disasters in Rural Regions (Case Study: Zanjan Province)," *Rural Res.*, vol. 2, no. 7, pp. 31–54, Jan. 2012.

[21] mehdi poortaheri, ali Hajinejad, ahadollah fatahi, and reza nemati, "Physical vulnerability assessment of rural habitats against natural hazards (earthquakes) with a decision model (

KOPRS) (Case study Chalan Cholan villages, Dorud Township)," *Sci. Res. Journals Spat. Plan.*, vol. 18, no. 3, pp. 29–52, Dec. 2014.

[22] M. Farajzadeh, M. Ahadnezhad, and J. Amini, "The Vulnerability Assessment of Urban Housing in Earthquake against (A Case Study: 9th district of Tehran municipality)," *J. Urban - Reg. Stud. Res.*, vol. 3, no. 9, pp. 19–36, Aug. 2011.

[23] K. Omidvar, *Natural Hazards*, 1st ed. Yazd: Yazd University Press, 2011.

[24] S. SavadKuhifar, *Prinnciples of civil, urban crisis management projects*. Tehran: University of Imam Hussein, 2007.

[25] P.-Z. Zhang and E. R. Engdahl, "Great earthquakes in the 21st century and geodynamics of the Tibetan Plateau," *Tectonophysics*, vol. 584. pp. 1–6, 2013.

[26] C. Doglioni, S. Barba, E. Carminati, and F. Riguzzi, "Role of the brittle–ductile transition on fault activation," *Phys. Earth Planet. Inter.*, vol. 184, no. 3, pp. 160–171, 2011.

[27] H. andAWT_TAG Jalalian H. andDadgar, "Rural Settlements Vulnerability Zoning for the Earthquake Risk Using AHP Model in GIS Software, a Case of Chavarzagh District in Tarom Township (Iran)," *2*, vol. 26.

[28] M. Zaheri, M. Aghayari Hir, and kolsoum zakeri Miab, "Vulnerability Assessment of Rural Areas' Regarding Earthquake Risk (Case Study: The Central District of Marand County)," *J. Res. Rural Planning; Vol.4, No.1 (2015), Ser. No.9*, Jul. 2015.

[29] J. S. Becker, D. Paton, D. M. Johnston, and K. R. Ronan, "A model of household preparedness for earthquakes: how individuals make meaning of earthquake information and how this influences preparedness," *Nat. Hazards*, vol. 64, no. 1, pp. 107–137, Oct. 2012.

[30] B. Roy, "The outranking approach and the foundations of electre methods," *Theory Decis.*, vol. 31, no. 1, pp. 49–73, Jul. 1991.

[31] M. Ataei, "Atayi.M.; Selecting Alumina - Cement Plant Location By ELECTRE Approach, International Journal of Engineering, 2008 ,19, pp. 55-63.," *Int. J. Eng.*, pp. 55–63, 2008.

[32] M. Tille and A.-G. Dumont, "Methods of multicriteria decision analysis within the road projects like an element of the sustainability," *Proc. 3rd STRC Swiss Transp. Res.*, 2003.

[33] H. S. Sudhira, T. V. Ramachandra, K. S. Raj, and K. S. Jagadish, "Urban growth analysis using spatial and temporal data," *J. Indian Soc. Remote Sens.*, vol. 31, no. 4, pp. 299–311, Dec. 2003.

[34] J. F. Affisco and M. N. Chanin, "An Empirical Investigation of Integrated Multicriteria Group Decision Models in a Simulation/Gaming Context," *Simul. Gaming*, vol. 21, no. 1, pp. 27–47, Mar. 1990.

[35] E. Triantaphyllou and B. Shu, "Multi-criteria decision making: an operations research approach," *Encycl. Electr. Electron. Eng.*, vol. 15, pp. 175–186, 1998.

[36] A. Lapucci, "Lapucci.pdf," University of Pisa, 2000.