Article

A Multiple Criteria Decision-Making Approach to Evaluate the Sustainability Indicators in the Villagers' Lives in Iran with Emphasis on Earthquake Hazard: A Case Study

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Abstract: Natural hazards such as earthquakes take place around the world and when combined with humans create natural disasters. Earthquakes, a form of natural hazard, have, in recent years, caused damage and destruction in many rural areas due to the lack of sustainability in political, economic, social, physical and operational criteria. Thus, to overcome the damage caused by earthquakes in rural areas, an assessment of sustainability status seems necessary to plan and strengthen in relation to the status of sustainability indicators. Data collection was performed through field methods and questionnaires. To test the hypothesis, T statistical methods, correlation method and F-test were performed using SPSS software (V22.0, IBM Corporation, Armonk, NY, USA). The results of the study showed that villages were at a low and undesirable level for all aspects, except social index in terms of sustainability. Comparisons showed that there was a significant mean difference among villages in terms of sustainability. The multi-criteria decision-making analysis has been considered and applied to a ranking of villages in terms of sustainability against the hazard of earthquakes. Finally, in order to improve the sustainability indicators of villages, some strategies have been presented.

Keywords: sustainability indicators; natural hazards; earthquake; ELECTRE

1. Introduction

According to the 2030 Agenda for Sustainable Development, 17 goals and 169 targets have been identified to demonstrate its scale and ambition [1]. Goal 11 [Make cities and human settlements inclusive, safe, resilient and sustainable], in particular, concerns the reduction of environmental risks and improvement of resilience to hazards. Prioritization of sustainability dimensions in seismic risk reduction with a strongly limited budget has become a fundamental topic especially with regard to limited economic resources and their allocation within national, regional or sub-regional territories. This is a typical political and administrative problem and it is a fundamental topic for decision makers [2].

Throughout the history of the development of civilization, human beings have always struggled with natural hazards. In many cases, these hazards cause irreparable damage to human societies [3]. The danger of natural hazards has dramatically increased in recent decades all over the world [4]. In particular, rural areas may be considered especially susceptible to a variety of hazards given their social and economic composition [5,6]. Rural areas, which make up 29% of Iran's current population [7], are of great importance. At the same time, paying attention to their sustainability indicators is important, especially in relation to the issues of natural hazards, because the village, as the production backbone of the Country, if sustained, will promote the power and position of the Country in achieving its development goals. This is why a holistic sustainability strategy includes

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environmental, economic, political, social and cultural aspects and it is a long-term concept based on economic, cultural and biological diversity [8].

Looking at the history of events in Iran, we can see that it has suffered many environmental crises due to special spatial structures and has been among the most vulnerable parts of the world in terms of environmental hazards [9]. Earthquakes are one of the most frequent natural hazards in Iran due to its location on the Alpine-Himalayan seismic belt that often shake different and causes irreparable damage, especially in rural settlements [10]. According to the seismic map of Iran, the studied area is located in a highly seismic area. The aim of this study is to rank the studied villages according to sustainability indicators against earthquakes. In this context, the Multi-Criteria Decision-Making (MCDM) methods seem to be the ideal tools for proper planning. The study will also evaluate the correlations between five dimensions [economic, social, political, physical and operational] in terms of stability against this hazard.

Study Area

Khodabande County, with an area of 4800 km^2, is located at the south of Zanjan province, between 48°35′S and 36°07′E (Figure 1). This county is subdivided into four districts: Central district, Afshar district, BizinehRud district and SojasRud district. The Central district, KharaRud County, was selected as the statistical population. This County has got 30 villages four of which (ZarirnGol, Mahmudabad, Ghushekand and Khaleqabad) were assessed asstudied villages. There were several reasons for choosing these villages, the most important being this area's presence in a seismic zone. The area was also selected because it was the most populous in comparison with other villages. 31.97% of the central district is occupied by and 53.26% of the total population live in the four villages.

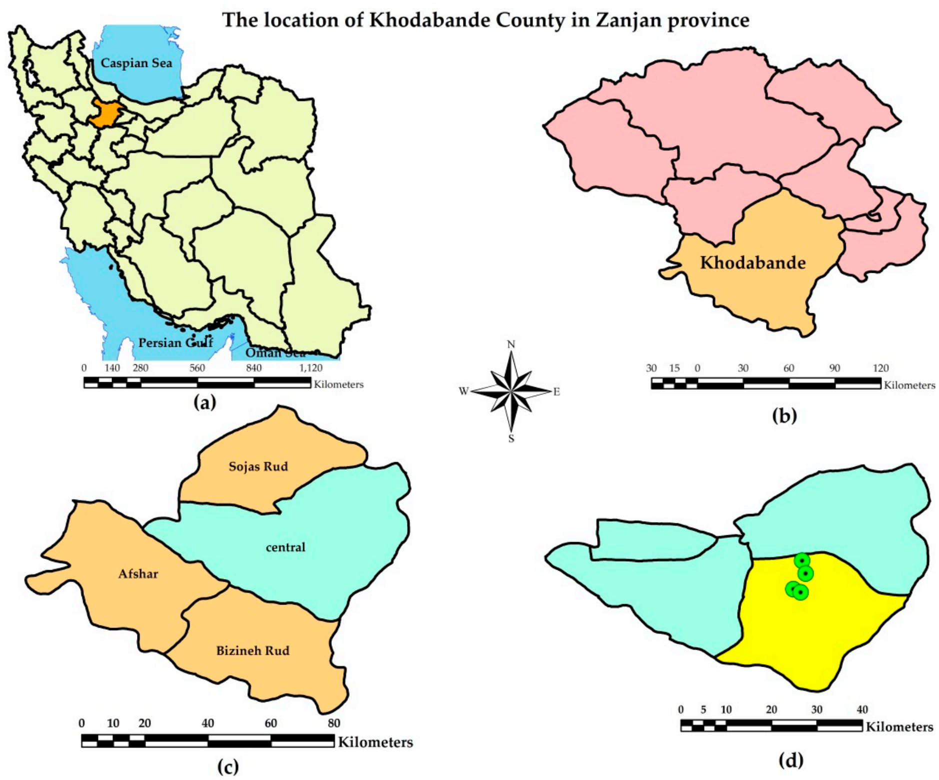

Figure 1. Study area of central district of KharaRud County. (**a**) Map of Iran; (**b**) Khodabande County; (**c**) Central district of KharaRud; (**d**) The studied villages.

2. Literature Review

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In general, measurement or assessment is the process that detects and records the impact of each action on socio-economic and biophysical elements on the environment. Researchers [11,12], have raised the idea that assessment and measurement activities related to sustainability can solve a lot of social, economic and environmental issues. On the topic of indicators, it can be concluded that an index must provide a clue, associated with a major phenomenon which is not immediately recognizable. Indicators should be specific, measurable, attainable, relevant and time-bound. They can support and guide the changes required to governments, international organizations, private sectors, NGOs and other major groups in sustainability [13]. However, it is noteworthy that in the field of sustainability indicators, there has not been a general agreement concerning various aspects of sustainability issues between policy makers [14]. 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 multi-dimensional and holistic thinking about development and for the first time, in the mid-1970s, Barbara Ward raised the idea of sustainable development [15].

In other words, a one-dimensional attitude to sustainability has gradually faded and the integrity of the concept is more acceptable [16]. So, if the index includes parameters or values that make available the best knowledge and information about a phenomenon [17], 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, 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. Due to the lack of attention to the operational-readiness indicators of villagers and physical index, planning for villagers in order to reduce the risks of earthquakes will not be possible.

Therefore, the variety of risks related to earth is relatively high in terms of geological and climate conditions and structural characteristics. In Table 1, the most common types of risks in Iran are presented [18].

Table 1. The common risks in Iran.

Type of Risk	**Conditions for the occurrence**		
	Earthquake	**Rainfall**	**Other**
Earthquake and its related phenomena	•		
Volcano			•
Landslide	•	•	•
Subsidence caused by water harvesting, oil, …			•
Local subsidence (caused by loss of subterranean cavities and shafts)	•	•	•
Subsidence caused by dissolution	•		
Problematic soils		•	•
Non-engineering levee (manual soils)			•
Deep loss		•	•

•: The conditions for the occurrence of common risks.

The natural phenomenon of earthquakes can present a risk when the society is vulnerable to it and is not ready to deal with it [19]. Earthquakes are sudden and quick movements in the earth that originate from a limited area and spread in all directions [20]. The term earthquake includes any type of vibration and earthquakes are often caused by fractures and fault movements. Also, volcanic activity, falling mountains, mine explosions and nuclear tests, could be the starting point of a seismic gap [21]. The 21st century began with a lot of earthquakes, the results of which included economic losses and social turmoil [22].

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3. Materials and Methods

This is a functional study using a quantitative method and it is descriptive-analytical. In conducting this study and in the data collection stage, two documentary (library) and field study methods have been used. In this study, the statistical population is the villagers of central district of Khodabande County. The sample size was calculated using Cochran's formula. Given that the total population of villages is 5749 people (Table 2), a sample size of 360 people was obtained from Cochran's formula. As previously mentioned, 50 per cent of these samples, i.e., 180 (n) people, were randomly examined and then the sample size was determined based on the relative proportional formula according to the population of each village.

$$n = \frac{\frac{t^2pq}{d^2}}{1 + \frac{1}{n}\left(\frac{t^2pq}{d^2} - 1\right)} = \frac{\frac{(1.96)^2 \times (0.5) \times (0.5)}{(0.05)^2}}{1 + \frac{1}{5749}\left(\frac{(1.96)^2 \times (0.5) \times (0.5)}{(0.05)^2} - 1\right)} = 360 = 180$$

Also, the data analysis was conducted using T-test, F-test or ANOVA, DUNCAN Test and finally Correlation test with SPSS software.

Table 2. Investigating the 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	Khodabande	Central	Khara Rud	Mahmud Abad	2906	782
3	Khodabande	Central	Khara Rud	Gushekand	549	132
4	Khodabande	Central	Khara Rud	Khaleqabad	951	253

To assess the reliability of the research, Cronbach's alpha method and SPSS software were used. The Cronbach's alpha coefficient varies between zero and one. The closer the Cronbach's alpha value to one, the higher the reliability of the questionnaire. If the Cronbach's alpha value is greater than 0.7 then the reliability is high, 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.

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

The indicators used in the study differ from other researches. In this study, the indicators were evaluated according to five dimensions: economic, social, political, physical and operational. Indicators are defined 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

Analytical Model Algorithm (ELECTRE)

Multi-criteria decision making (MCDM) approaches deal with the assessment of a set of alternatives in terms of various decision criteria with the objective of providing a choice highlighting the best alternative among the set of options [23]. The ELECTRE (ELimination Et Choice Translating REality) method was first put forward by Bernard Roy (1966) and then it has been developed by Van Delft, Nijkamp 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 then the weak and defeated alternatives are removed [24].

In order to choose the best method using the ELECTRE method, the following steps should be taken:

Step 1. Formation of decision matrix; this matrix contains the values that the criteria assume for each alternative considered [25].

Step 2. Determining the Normalized decision matrix; normalization translates data measured with various units—e.g., points and percentage—into weighted dimensionless values of different criteria [26,27].

Step 3. Determining the weighted normalized decision matrix by formula: $V_{ij} = W_j \times R_{ij}$.

Step 4. Formation of Concordance index; the concordance index, $C(a, b)$ is the sum of all the weights for those criteria where the performance score of alternative "a" is at least as that of alternative "b" [28–30].

Step 5. Formation of Discordance index; the discordance index, $D(a, b)$ measures the degree to which alternative "a" is worse than alternative "b" [31].

Step 6. Concordance Dominance matrix; is calculated by comparing the values of concordance matrix with threshold value $(\overline{c})$.

Step 7. Discordance Dominance matrix; in a similar way, the discordance dominance matrix can be calculated with the help of discordance indices and the threshold value $(\overline{d})$ [32]. The matrix takes on values 0 or 1.

Step 8. Determining the Aggregate Dominance matrix; is the intersection of concordance dominance matrix and discordance dominance matrix [29]. The matrix takes on values 0 or 1.

Step 9. Removing the alternatives with less satisfaction and choose the best alternative [24–33]; ranking the alternatives according to the Aggregate Dominance matrix.

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4. Results and Discussion

4.1. Ranking the Villages of KharaRud Rural District Based on the Sustainability against the Risks of Earthquakes

Multi-criteria decision-making models have been used in order to rank the villages of KharaRud County, since their tools can be used to rank alternatives. A few multi-criteria, analytical tools for performance evaluation and ranking of alternatives are AHP, TOPSIS, DEA PROMETHEE, etc.

In this paper, the ELECTRE method was used to assess the sustainability of villagers against the risks of earthquakes. ELECTRE is a decision-making method and it can be applied after the definition of the decision matrix and criteria weights [34] to rank or prioritize the various alternatives. According to [35] ELECTRE model is most readily applicable to option choice problems for proposed projects and it has a clearer view of alternatives by eliminating less favourable ones [36]. This method was used in different cases of planning, financial estimates, accounting and also geography. To review and analyse sustainability indicators of the villages against the risks of earthquakes, the following steps are operational:

4.1.1 First Step: Formation of Decision Matrix

In this stage, the decision matrix that consists of Alternatives (rows) and Criteria (columns) is formed. This is an (M × N) matrix in which element a_{ij} demonstrates the performance of alternative Ai when it is evaluated in terms of decision criterion C_j [37]. In this research alternatives are villages and criteria are the five ones mentioned and coded (C1 to C5), for example, C2 means the satisfaction rate from physical criteria of villagers against risks of the earthquake (Table 5).

Table 5. 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**
A1	Mahmud Abad	3.060	2.910	2.829	2.450	2.983
A2	Khaleq Abad	3.177	2.841	2.114	2.331	2.761
A3	Gushe Kand	3.340	2.915	2.000	2.294	2.800
A4	Zarian Gol	3.473	2.638	3.240	2.297	2.870

4.1.2. The Second Stage: Normalizing the Decision Matrix

At this stage, it should be attempted to convert criteria with different dimensions to the criteria with no dimension and the normalized decision matrix is defined. There are several methods of normalising. However, the following relation has been used in the ELECTRE method [38] (Table 6):

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

Table 6. Normalized criteria matrix.

Normalized Matrix	C1	C2	C3	C4	C5
A1	0.522	0.523	0.545	0.514	0.468
A2	0.484	0.497	0.407	0.502	0.486
A3	0.490	0.489	0.385	0.515	0.511
A4	0.503	0.490	0.624	0.466	0.532

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4.1.3. 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 and Shannon entropy which are used as necessary. The Entropy method has been used in this study (Table 7). Entropy is a major concept in physical sciences, social sciences and information theory, which reflects the uncertainty of the expected information content of a message. In other words, 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 [39]:

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

where k is a positive constant and it is determined as:

$$k = \frac{1}{\mathrm{Ln}\,(m)} = \frac{1}{1.61} \quad (3)$$

Entropy is calculated from the probability distribution of P_i based on the statistical mechanism. The 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} according to the following formula:

$$p_{ij} = \frac{r_{ij}}{\sum r_{ij}}\ \forall i, j. \quad (4)$$

So that it keeps the value of E_j between zero and one. The degree of diversification (d_j) is calculated from data stating how much information the j-th criteria makes available for the decision maker. If the standardized data are closer to each other then they reflect that the competing alternatives are not significantly different in terms of those criteria. Thus, the role of that index should be reduced as much in decision-making. Therefore [40]:

$$d_j = 1 - E_j;\ \forall j. \quad (5)$$

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

$$w_j = \frac{d_j}{\sum_{j=1}^{n} dj};\ \forall j. \quad (6)$$

Table 7. The entropy method for determining weights of criteria.

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 8. By applying the obtained weights in the normalized matrix, the weighted decision matrix is provided (Table 8).

Table 8. The weighted matrix of criteria.

Weighted Matrix	C1	C2	C3	C4	C5
A1	0.010	0.008	0.479	0.018	0.024
A2	0.009	0.008	0.358	0.018	0.025
A3	0.009	0.008	0.339	0.018	0.026
A4	0.010	0.008	0.549	0.016	0.027

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4.1.4. Forth Stage: Formation of Concordance Matrix of Criteria

At this stage, after weighting the normalized matrix, the concordance matrix (Figure 2) was formed. The concordance matrix was obtained from the sum of criteria weights which are in the concordance set [36,41] (Table 9). The value of the concordance index must be greater than or equal to a given concordance level [42].

$$C\,(a,b) = \frac{1}{W}\sum_{i=0}^{n} w_k \times c_k(a,b) \tag{7}$$

where

W_i –i-th criterion weight index and
$c_k(a, b)$—Concordance index from the point of view of the i-th criterion [43].

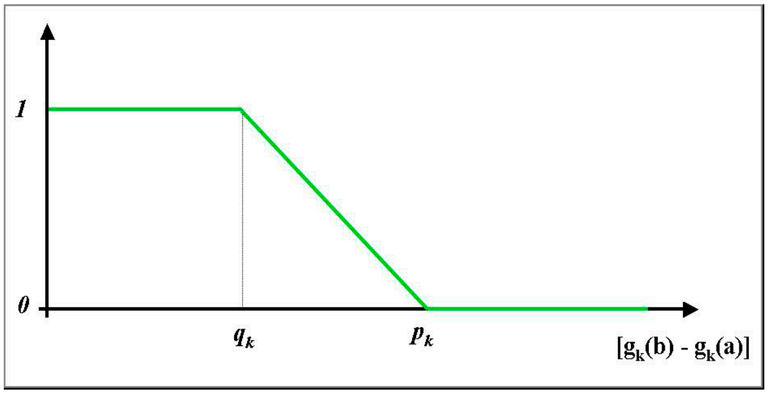

Figure 2. Concordance indices of [g_k(b) – g_k(a)].

Table 9. 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	-----

4.1.5. Fifth Stage: Formation of the Discordance Matrix of Criteria

The discordance (Figure 3) matrix indicates the degree to which an alternative A_k is worse than a competing Alternative A_1 [36,41] (Table 10). The discordance matrix is obtained as follows:

$$d_{kl} = \frac{\max\limits_{j \in D_{kl}} |y_{kj} - y_{lj}|}{\max\limits_{j} |y_{kj} - y_{lj}|} \tag{8}$$

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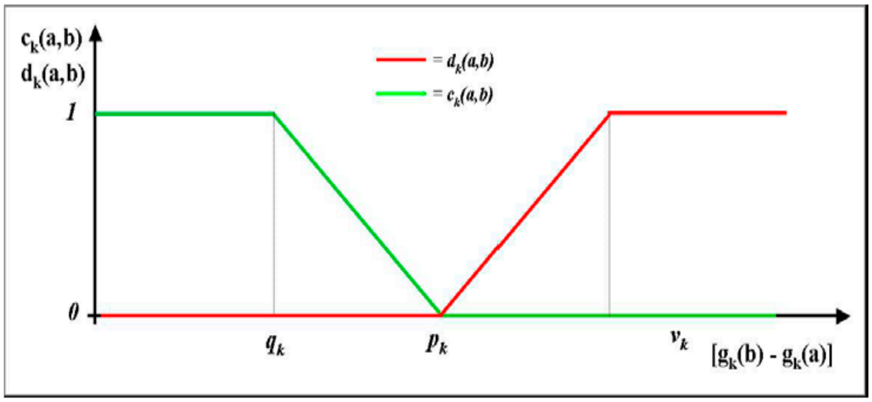

Figure 3. Comparative results of the concordance indices of $[g_k(b) - g_k(a)]$ and discordance.

Table 10. 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	----

4.1.6. Sixth Step: Formation of Concordance Dominance Matrix of Criteria

At this stage, a given value was determined for the concordance index which is called concordance 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 11). The value of the concordance threshold was calculated as follows:

$$\bar{c} = \sum_{\substack{k=1 \\ k\neq e}}^{m} \sum_{\substack{e=1 \\ e\neq k}}^{m} \frac{c_{ke}}{m(m-1)} = \frac{6}{4(4-1)} = \frac{6}{12} = 0.50. \quad (9)$$

According to the threshold value (0.50), the concordance dominance matrix F was determined as follows [36]:

$$f_{kl} = \begin{cases} 1, c_{kl} \geq \bar{c} \\ 0, c_{kl} < \bar{c} \end{cases} \quad (10)$$

Table 11. 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	-

4.1.7. Seventh Stage: Formation of Discordance Dominance Matrix of Criteria

The Discordance Dominance matrix was formed similarly to the concordance dominance matrix. At first, the discordance threshold $(\bar{d})$ should be determined. If the existing value is less than 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. The value of the discordance threshold is calculated as follows:

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$$\overline{d} = \sum_{\substack{k=1 \\ k \neq e}}^{m} \sum_{\substack{e=1 \\ e \neq k}}^{m} \frac{d_{ke}}{m(m-1)} = \frac{6.12}{4(4-1)} = \frac{6.12}{12} = 0.51. \quad (11)$$

And

$$g_{kl} = \begin{cases} 1, d_{kl} \leq \overline{d} \\ 0, d_{kl} > \overline{d} \end{cases}. \quad (12)$$

Therefore= defined a Boolean matrix [41] as shown in Table 12.

Table 12. Discordance Dominance 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	-

4.1.8. Eighth Stage: Determine the Aggregate Dominance Matrix

The final matrix was obtained from multiplying every element of the concordance dominance matrix by the discordance dominance matrix. This matrix is shown in Table 13.

Table 13. 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	-

4.1.9. 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 from those that have mastered more than they have 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 they have beaten were calculated. These are shown in Table 14. The number of dominance indicates the priority of each alternative according to criteria. The greater value of alternatives illustrates better rank.

Table 14. 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 village has a better status than the other districts in terms of stability to earthquake hazards. It has a greater domination number in comparison with the other villages and it is better prepared than the other areas (Figure 4). The ranking is based on the satisfaction rate from sustainability indicators of the villagers against the risk of earthquake. It is also necessary to plan for the unsustainable villages against the hazards.

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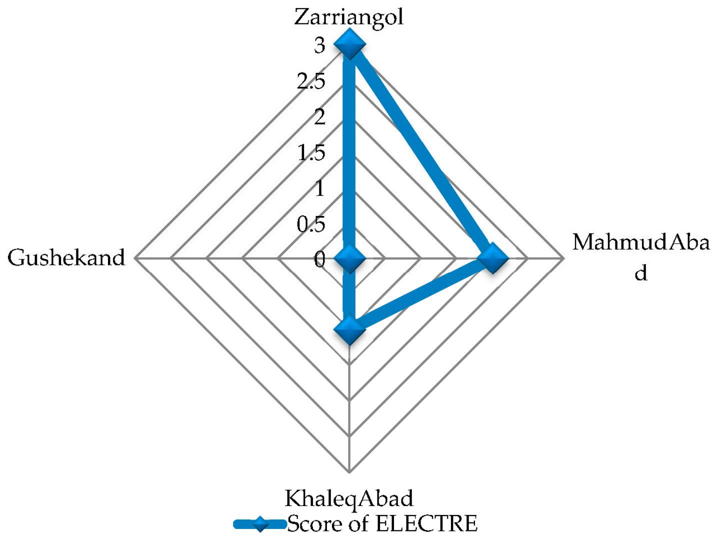

Figure 4. Results of ELECTRE technique and ranking of villages.

5. Conclusions

Hazards are the probability that an event occurs with a certain return period and in a certain area and it concerns natural characteristics of the natural phenomenon [44]. Attention to sustainability indicators in rural areas is particularly important because in many previous disasters, particularly earthquakes, throughout the rural areas in Iran, the vast majority of rural homes were damaged in terms of superficial damage or full destruction. Therefore, attention and support to improve sustainability indicators, including economic, political, social, operational and physical issues can prevent many injuries and breakages in the case of earthquake. Thus, there is no need to spend large amounts of money for reconstructions after the earthquake. Finally, this study states the need for an assessment process for villagers before the outbreak of the crisis in rural areas. We can cause a decrease in 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. Therefore, in this study, the total needs of villagers were considered in the form of sustainability issues against risks (earthquake). Accordingly, two other operational and a physical indicators were considered in addition to the three main social, economic and environmental indicators in the sustainability discussion as the operational index refers to the individual readiness of the villagers before the occurrence of the earthquake and physical index considering the issues related to the housing security. Finally, the results of the research showed that all of the villages (Mahmoud Abad, Khaleqabad, GooshehKand and ZarianGol) were in the lower level of sustainable standards except for social index. The results showed that their greatest 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 and their inability to purchase necessary items at the time of crisis. This inability has a direct impact on the unsustainability of the physical index, because the lack of affordability causes people to use poor-quality materials, raising the antiquity of the buildings non using update architecture powers in designing homes.

Therefore, unsustainability in the economic index has transferred its effects to the physical index. Considering that the political index is in the unsustainable status, means that support from the public sector to provide facilities for retrofitting and modernization of buildings and also, lack of attention to normative housing construction. Furthermore, since governmental agencies did not provide education for the villagers in schools or mosques and the education was very limited in the

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schools, only a small group of students know how to react in the case of earthquake disaster. Therefore, the villagers were in the undesirable level in terms of personal and family readiness and personal skills (operational sustainability). It should be noted that a few of the buildings which have recently been built in the villages use updated architecture, but this culture is still not so 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 and especially the financial support of the government. The status of the social stability index was in the desirable level, 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 in this way. As previously mentioned, there is a correlation between these indexes and the physical index.

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

Future study on the MCDM can be further developed. This study is intended to be employed by academics and managers as a basis for further research into the field of sustainability indicators in the villagers' lives. There are techniques such as the analytical hierarchy process and other robust MCDM methods, which have not been used in the field of earthquake hazards and we suggest using them with a focus on community seismic resilience, social capital and so on. Community seismic resilience is defined as the ability of social units to mitigate hazards, contain the impacts of disasters when they happen, and perform recovery activities so as to minimise social disruption and reduce the effects of future earthquakes [45,46].

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), it is recommended that government agencies use this participation and cooperation and gather people in the mosques to teach them emergency training
- Encouraging and providing financial support (bank facilities) to the villagers in order to build or repair homes to minimize the risks of earthquake
- Strict supervision of the public sector on the construction of houses, in order to retrofit 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 placement ,installation of equipment on the walls and in terms of first-aid with training by Red Crescent departments.

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