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A composite Index of Social Vulnerability to Earthquake Hazard in Canton Atacames

Marco Fernando Saltos Salgado[1], German Fabricio Acurio Hidalgo[2] and Simón Bolívar Gallegos Gallegos[3]

[1] Universidad Regional Autónoma de los Andes (UNIANDES), Avenida La Lorena, Santo Domingo, CP. 230101. Ecuador. Email: us.marcosaltos@uniandes.edu.ec
[1] Universidad Regional Autónoma de los Andes (UNIANDES), Avenida La Lorena, Santo Domingo, CP. 230101. Ecuador. Email: us.germanacurio@uniandes.edu.ec
[1] Universidad Regional Autónoma de los Andes (UNIANDES), Avenida La Lorena, Santo Domingo, CP. 230101. Ecuador. Email: us.simongallegos@uniandes.edu.ec

Abstract. The Atacames Canton in Ecuador is a locality deeply affected by earthquakes and requires an analysis of its social vulnerability to achieve resilience and proactivity to mitigate the damage caused. Since the phenomena involved are under an environment of uncertainty, their analysis depends on a combination of factors whose most appropriate processing is the neutrosophic multicriteria decision-making methods, because they integrate multiple data sets with scoring areas according to criteria. Therefore, the objective of this research is to develop a composite neutrosophic indicator for the analysis of the social vulnerability of earthquakes in the Canton Atacames. For the study, social vulnerability was divided into three components under an environment of uncertainty.

Keywords: earthquakes, social vulnerability, resilience, uncertainty, composite neutrosophic indicator

1 Introduction

Earthquake studies date back to the Chinese Dynasty thirty centuries ago. In this way, each society has been able to prevent itself from the effect of earthquakes. Ecuador is a country with a high seismic index due to its location in a subduction zone between the Pacific Plate and the South American Plate [1]. On average, it has a major earthquake every forty years and it is assumed that an average Ecuadorian, who lives his entire life within those borders, must experience at least two large earthquakes in situ in his life. Therefore, they are working on the relationship between natural disaster and the right to life as part of the human rights of Ecuadorians.[1, 2]. To do this, the identification of vulnerabilities to earthquakes is carried out, which allows preparation and response programs for specific disasters to reduce the social impact of an earthquake.[1-4].

These analyzes are generally based on decision-making methods that integrate multiple data sets. [2, 3, 5, 6]. The choice of evaluation criteria has been different since multicriteria evaluation was adopted as a problem-solving and decision support tool, and most of the studies focused on geophysical factors [7-9]; others have built-in social vulnerability[10, 11]. They provide simple unit comparisons that can be used to illustrate the complexity of dynamic environments in wide-ranging fields. Several authors affirm that multicriteria techniques are highly suitable in multidimensional frameworks by adding unique indicators in a composite one, as it involves making choices by combining criteria of different natures, and requires a series of steps in which decisions must be made.[12-14].

With these studies, it is guaranteed that situations such as what happened on April 16, 2016, in which countless human lives were lost, are not repeated. It is known that the damage caused will not be repaired and that these disasters are unpredictable; but it is important to be proactive as a way to comply with human rights: the right to life[1]. Therefore, the objective of this research is to develop a composite neutrosophic indicator for the analysis of the social vulnerability to earthquakes in the Canton Atacames. In order to comply with the stated above, the following specific objectives are formulated in the sections that comprise this article:

a) Characterize the Atacames Canton seismic zone
b) Determine the indicators that intervene in the social vulnerability of earthquakes

c) Define the composite neutrosophic indicator for the analysis of the social vulnerability of earthquakes in the Atacames Canton (section 3 of this document)

It is intended with the study of the social vulnerability of earthquakes in the Atacames Canton by means of the construction of a compound neutrosophic indicator to enable the early detection of social phenomena that occurred after the occurrence of this natural disaster. What leads to the mitigation of the adverse effects on the lives of residents and therefore their quality of life, after the disaster. In addition, with this indicator, we would achieved proactivity and it will allow us to prevent the loss of human life even when they are in an area of uncertainty due to the unpredictability of the natural phenomenon in question.

1.1 Characterization of the Atacames Canton seismic zone

The Atacames region is located along a tectonic fault with high seismic activity. Due to this, in the earthquake that occurred on April 16, 2016, Atacames was among the cantons with the greatest impact along with Muisne. It is the fourth largest and most populated city in the Esmeraldas Province with approximately sixteen thousand (16 000) inhabitants. Having an excellent economic level due to its tourist development and having one of the largest beaches in Ecuador. Due to this, a large number of attracted people remain in the territory. Which presupposes a greater number of people exposed to the risk of suffering the adverse consequences of an earthquake.

Figure 1. Region under study. Source: Google Maps.

1.2 Indicators of social vulnerability of earthquakes

[2-11] agree in the treatment of the uncertainty imposed by the phenomenon of earthquakes, the social factors that they carry out for their analysis and in addition to the spatial variations in these components result in different levels of vulnerability to an earthquake [4]. Therefore, indicators that reflect these phenomena will intervene, which by their nature are based on empirical and theoretical evidence[15]. Social vulnerability depends on a combination of factors that affect their resilience [2-6]. Due to this, its analysis is divided into three components, which will be translated into indicators. They are listed below:

- physical damage based on geological features and the built environment;
- socio-economic barriers to resilience and recovery;
- and access to trauma and other support services.

It should be noted that the ability of a disadvantaged population to recover from an earthquake is affected by limited economic and political capital. [15]. Numerous studies examining social vulnerability use quantitative indices, often modeled with census data [16-21]. Most of this literature originates from the United States and therefore tends to emphasize the proportion of minority populations as an explanatory variable. The most used indicators of social vulnerability according to the bibliography consulted are [2-5, 15, 20, 22]:

1. Age
2. Time spent in a specific place
3. Percentage of people who moved in the last year
4. Average income for each family
5. Single parent families
6. Seniors living alone
7. Residents who are homeowners
8. Educational level
9. Dependent population
10. Percentage of unemployed

1.3 Construction of a multi-criteria evaluation model

According to the reviewed literature, we can say that certain authors [2, 23-25] present algorithmically sophisticated multi-criteria evaluation models where hierarchical techniques such as AHP Saaty are used in conjunction with other heterogeneous methods related to decision-making. In addition, all the methods used are based on the criteria of experts in a majority way. To carry out this research, we also decided to opt for a strategic, effective and simple technique for solving multi-criteria decision problems: TOPSIS (Technique for Order Preference by Similarity to Ideal Solution). Since this method determines the alternative closest to the ideal solution and, in turn, farthest from the worst solution [26].

Both techniques will be used in their neutrosophic versions because this research will take into account the environment of uncertainty and possible indeterminacies that this social phenomenon brings along. Since Neutrosophy is the branch of philosophy that studies the origin, nature and scope of neutralities. Its incorporation guarantees that the uncertainty of decision-making is taken into account, including indeterminacies where experts will issue their criteria evaluating linguistic and non-numerical terms, which constitutes the most natural form of measurement in human being [27-33].

2 Materials and methods

The following section describes the theoretical and empirical methods used throughout the current research to achieve the specific objectives set. The methods used are listed below:

- Inductive, deductive: to verify the factors raised regarding the research topic in addition to structuring the research profile for its application.
- Analytical-synthetic: to compare all the phenomena involved in the research
- Historical-logical and descriptive-systematic: to analyze the problem situation of the research, it is intended to make a current observation of the phenomena for their interpretation.
- Surveys and interviews: it will be applied to the sample made up of the target population and selected experts (residents, Public Officials and Authorities of the Atacames Canton).

Questionnaires aimed at obtaining information about the real problem and issuing possible solutions were prepared to obtain valid conclusions and support the results.

Sample: part of the population of the Atacames Canton according to the formula that allows obtaining the sample size of a finite population.

Calculation sample (1)$n = \frac{N}{(E)2(N-1)+1}$

Where
n = sample size
N = Population or Universe
E = margin of error 0.1%

- AHP Saaty Neutrosophic: for the description of the method, the following definitions must be presented:

Definition 1: The Neutrosophic set N is characterized by three membership functions, which are the truth-membership function TA, indeterminacy-membership function IA, and falsehood-membership function FA, where U is the Universe of Discourse and $\forall x \in U$, TA (x), IA (x), FA (x)$\subseteq$] -0, 1+ [, and -0≤inf TA (x) + inf IA (x) + inf FA (x)≤sup TA (x) + sup IA (x) + sup FA (x)≤3+.

Notice that, according to the definition, TA (x), IA (x) and FA (x) are real standard or non-standard subsets of] -0, 1+ [and hence, TA (x), IA (x) and FA (x) can be subintervals of [0, 1].

Definition 2: [34, 35] The Single-Valued Neutrosophic Set (SVNS) N over U is A = {<x; TA (x), IA (x), FA (x)>: x∈U}, where TA: U→[0, 1], IA: U→[0, 1], and FA: U→[0, 1], 0 ≤TA (x) + IA (x) + FA (x)≤ 3.

The Single-Valued Neutrosophic Number (SVNN) is represented by N = (t, i, f), such that 0 ≤t, i, f ≤ 1 and 0 ≤t + i + f≤ 3.

Definition 3: [34-37] the single-valued trapezoidal neutrosophic number, $\tilde{a} = \langle (a_1, a_2. a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on $\mathbb{R}$, whose truth, indeterminacy and falsehood membership functions are defined as follows, respectively: $\tilde{a} = \langle (a_1, a_2. a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle \mathbb{R}$

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \le x \le a_2 \\ \alpha_{\tilde{a}}, & a_2 \le x \le a_3 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_3 \le x \le a_4 \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\beta_{\tilde{a}}(x-a_1))}{a_2-a_1}, & a_1 \le x \le a_2 \\ \beta_{\tilde{a}}, & a_2 \le x \le a_3 \\ \frac{(x-a_2+\beta_{\tilde{a}}(a_3-x))}{a_3-a_2}, & a_3 \le x \le a_4 \\ 1, & \text{otherwise} \end{cases} \quad (3)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\gamma_{\tilde{a}}(x-a_1))}{a_2-a_1}, & a_1 \le x \le a_2 \\ \gamma_{\tilde{a}}, & a_2 \le x \le a_3 \\ \frac{(x-a_2+\gamma_{\tilde{a}}(a_3-x))}{a_3-a_2}, & a_3 \le x \le a_4 \\ 1, & \text{otherwise} \end{cases} \quad (4)$$

Where, and. $\alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \in [0,1]$ $a_1, a_2, a_3, a_4 \in \mathbb{R} a_1 \leq a_2 \leq a_3 \leq a_4$

Definition 4: [34-37] given $\tilde{a} = \langle (a_1, a_2, a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3, b_4); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued trapezoidal neutrosophic numbers and λ any non-null number in the real line. Then, the following operations are defined:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
2. Subtraction: (5)$\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
3. Inversion: where.$\tilde{a}^{-1} = \langle (a_4{}^{-1}, a_3{}^{-1}, a_2{}^{-1}, a_1{}^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle a_1, a_2, a_3, a_4 \neq 0$
4. Multiplication by a scalar number:

$$\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3, \lambda a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_4, \lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases}$$

Definitions 3 and 4 refer to single-valued triangular neutrosophic number when the condition a2 = a3, [38-40]. For simplicity, we use the linguistic scale of triangular neutrosophic numbers, see Table 1 and also compare with the scale defined in [41].

The hierarchical analytical process was proposed by Thomas Saaty 1980 [27]. This technique models the problem that leads to the formation of a hierarchy representative of the associated decision-making scheme[28, 29]. The formulation of the decision-making problem in a hierarchical structure is the first and main stage. This stage is where the decision maker must break down the problem into its relevant components[30], [31, 32]. The hierarchy is constructed so that the elements are of the same order of magnitude and can be related to some of the next level. In a typical hierarchy the highest level locates the problem of decision making. The elements that affect decision-making are represented at the intermediate level, the criteria occupying the intermediate levels. At the lowest level the decision options are understood [33]. The levels of importance or weighting of the criteria are estimated by means of paired comparisons between them. This comparison is carried out using a scale, as expressed in equation (6)[42].

$$S = \left\{\frac{1}{9}, \frac{1}{7}, \frac{1}{5}, \frac{1}{3}, 1,3,5,7,9\right\} \tag{6}$$

We can find in [41]the theory of AHP technique in a neutrosophic framework. Thus, we can model the indeterminacy of decision-making by applying neutrosophic AHP or NAHP for short. Equation 7 contains a generic neutrosophic pair-wise comparison matrix for NAHP.

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \tag{7}$$

Matrix must satisfy condition, based on the inversion operator of Definition 4.$\tilde{A}$ $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$

To convert neutrosophic triangular numbers into crisp numbers, there are two indexes defined in [41], they are the so-called score and accuracy indexes, respectively, see Equations 8 and 9:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \tag{8}$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \tag{9}$$

Saaty's scale	Definition	Neutrosophic Triangular Scale
1	Equally influential	$\tilde{1} = \langle (1,1,1); 0.50, 0.50, 0.50 \rangle$
3	Slightly influential	$\tilde{3} = \langle (2,3,4); 0.30, 0.75, 0.70 \rangle$
5	Strongly influential	$\tilde{5} = \langle (4,5,6); 0.80, 0.15, 0.20 \rangle$
7	Very strongly influential	$\tilde{7} = \langle (6,7,8); 0.90, 0.10, 0.10 \rangle$
9	Absolutely influential	$\tilde{9} = \langle (9,9,9); 1.00, 1.00, 1.00 \rangle$
2, 4, 6, 8	Sporadic values between two close scales	$\tilde{2} = \langle (1,2,3); 0.40, 0.65, 0.60 \rangle$
		$\tilde{4} = \langle (3,4,5); 0.60, 0.35, 0.40 \rangle$
		$\tilde{6} = \langle (5,6,7); 0.70, 0.25, 0.30 \rangle$
		$\tilde{8} = \langle (7,8,9); 0.85, 0.10, 0.15 \rangle$

Table 1: Saaty's scale translated to a neutrosophic triangular scale.

Step 1 Select a group of experts.

Step 2 Structure the neutrosophic pair-wise comparison matrix of factors, sub-factors and strategies, through the linguistic terms shown in Table 1.

The neutrosophic scale is attained according to expert opinions[43]. The neutrosophic pair-wise comparison matrix of factors, sub-factors and strategies are as described in Equation 7.

Step 3 Check the consistency of experts' judgments.

If the pair-wise comparison matrix has a transitive relation, ie, $a_{ik} = a_{ij}a_{jk}$ for all i,j and k, then the comparison matrix is consistent, focusing only on the lower, median and upper values of the triangular neutrosophic number of the comparison matrix.

Step 4 Calculate the weight of the factors from the neutrosophic pair-wise comparison matrix, by transforming it to a deterministic matrix using Equations 10 and 11. To get the score and the accuracy degree of the following equations are used:$\tilde{a}_{ji}$

$$S(\tilde{a}_{ji}) = 1/S(\tilde{a}_{ij}) \quad (10)$$

$$A(\tilde{a}_{ji}) = 1/A(\tilde{a}_{ij}) \quad (11)$$

With compensation by accuracy degree of each triangular neutrosophic number in the neutrosophic pair-wise comparison matrix, we derive the following deterministic matrix:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (12)$$

Determine the ranking of priorities, namely the Eigen Vector X, from the previous matrix:

1. Normalize the column entries by dividing each entry by the sum of the column.
2. Take the total of the row averages.

Note that Step 3 refers to consider the use of the calculus of the Consistency Index (CI) when applying this technique, which is a function depending on λ_{max}, the maximum eigenvalue of the matrix. Saaty establishes that consistency of the evaluations can be determined by equation$CI = \frac{\lambda_{max}-n}{n-1}$[44], where n is the order of the matrix. In addition, the Consistency Ratio (CR) is defined by equation CR = CI / RI, where RI is given in Table 2.

Order (n)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Table 2: RI associated to every order.

If CR≤0.1 we can consider that experts' evaluation is sufficiently consistent and hence we can proceed to use NAHP. We apply this procedure to matrix A in Equation 12.

- TOPSIS:

The TOPSIS method was developed by Hwang and Yoon in 1981 and is based on the concept that it is desirable for a given alternative to be located at the shortest distance from an ideal alternative that represents the best (positive ideal or simply ideal), and at the greatest distance from an ideal alternative that represents the worst (negative ideal or anti-ideal) [26, 45]. It is based on the following diagram:

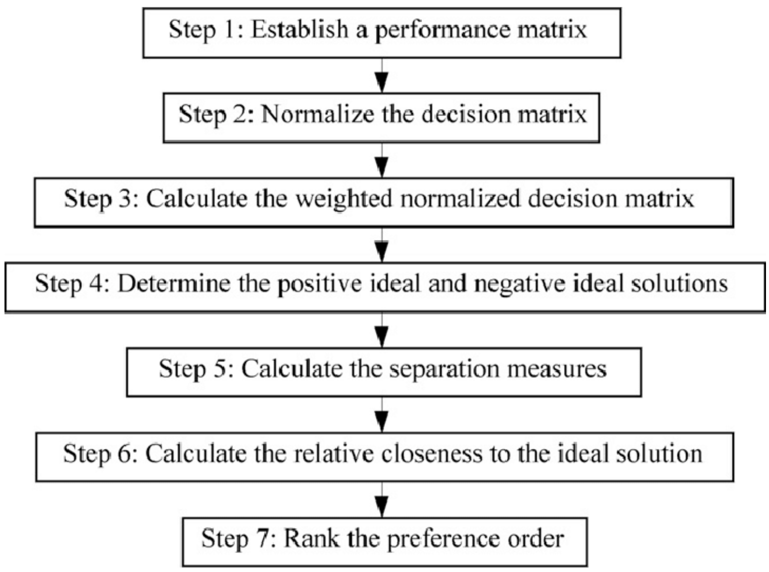

Figure 2. TOPSIS steps.

The construction of the normalized matrix will be as follows:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^2}} \quad (13)$$

Where: r_{ij} is the normalized value for the qualification of alternative i against criterion j and is the indicator of each alternative i against each indicator j.

For the minimum distance to the positive ideal solution and the maximum distance to the negative ideal solution, it is done according to equations 14 and 15.

$$A^{+} = (x_1^{+}, x_2^{+}, \dots x_{j+l}^{+}) \quad (14)$$

$$A^{-} = (x_1^{-}, x_2^{-}, \dots x_{j+l}^{-} \quad (15)$$

With the normalized values, we proceed to calculate the Euclidean distances of each of the alternatives to the positive ideal solutions and the negative ideal solutions, as shown in 16 and 17:

$$\rho(A^k, A^+) = \|w * (TA^k - TA^+)\| \quad (16)$$

$$\rho(A^k, A^-) = \|w * (TA^k - TA^-)\| \quad (17)$$

Finally, to calculate the Relative Proximity Index (RCi) it is done as follows:

$$RC(A^k, A^i) = \frac{\rho(A^k, A^+)}{\rho(A^k, A^+) + \rho(A^k, A^-)} \quad (18)$$

- Paretto diagram:

The Pareto Chart is a bar graph that illustrates the causes of problems in order of importance and frequency (percentage) of appearance, cost or performance. The Pareto Diagram also allows you to compare the frequency, cost and performance of various categories of a problem. Allows before/after comparison, helping to quantify the impact of actions taken to achieve improvements. It promotes teamwork since the participation of all individuals related to the area is required to analyze the problem, obtain information and carry out actions for its solution. The Pareto Chart is also used to express the costs of each type of defect and the savings achieved through the corrective effect carried out through certain actions. It is a simple and graphic method of analysis that allows to discriminate between the most important causes of a problem (the few and vital) and those that are less so (the many and trivial) so it makes decisions based on the 80-20 proportion [46].

3 Results

As a starting point, questionnaires were prepared in order to determine the primary indicators or bases of the composite indicator. To solve this exercise, we made the following:

1. Determination of the actors (respondents and sample size) as follows:
   - Population: Public Officials: 10%, Authorities: 10%, Atacames Population: 80%
   - Sample: n $= \frac{40000}{(0.1)^2(4000-1)+1} = \frac{40000}{0.01(39\,999)+1} = 99.75 \approx 100\ personas$
2. Verification that an uncertainty problem is present (verified):

Criteria set: $C = \{c_1 \dots c_8\}; m \geq 1; \forall Cm \notin \emptyset, 1 \leq m \leq 6$

Expert set: $E = \{e_1 \dots e_{12}\}; n \geq 1; \forall Em \notin \emptyset, 1 \leq m \leq 100$

Set of alternatives: $A = \{a_1 \dots a_{12}\}; k \geq 1; \forall Ak \notin \emptyset, 1 \leq k \leq 10$

3. Neutrosophic AHP Saaty to determine weights of the criteria on which the experts will be based to evaluate the alternatives of primary indicators:

Criteria	C1	C2	C3	C4	C5	C6
C1	**1**	**❬6,7,8); 0.90,0.10,0.10❭**	**❬6,7,8); 0.90,0.10,0.10❭**	**❬6,7,8); 0.90,0.10,0.10❭**	**❬7,8,9); 0.85,0.10,0.15❭**	**❬5,6,7); 0.70,0.25,0.30❭**
C2	$\tilde{7}$	**1**	**❬2,3,4); 0.30,0.75,0.70❭**	**❬4,5,6); 0.80,0.15,0.20❭**	**❬3,4,5); 0.60,0.35,0.40❭**	**❬6,7,8); 0.90,0.10,0.10❭**
C3	$\tilde{7}$	$\tilde{3}$	**1**	**❬2,3,4); 0.30,0.75,0.70❭**	**❬2,3,4); 0.30,0.75,0.70❭**	**❬2,3,4); 0.30,0.75,0.70❭**
C4	$\tilde{7}$	$\tilde{5}$	$\tilde{3}$	**1**	**❬1,1,1); 0.50,0.50,0.50❭**	**❬2,3,4); 0.30,0.75,0.70❭**
C5	$\tilde{8}$	$\tilde{4}$	$\tilde{3}$	$\tilde{1}$	**1**	**❬1,1,1); 0.50,0.50,0.50❭**
C6	$\tilde{6}$	$\tilde{7}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	**1**

Criteria	C1	C2	C3	C4	C5	C6	WEIGHT	A x Weight	Eigenvalues approx
C1	0.60	0.79	0.62	0.42	0.48	0.30	0.51381037	3.92	7.632215878
C2	0.08	0.10	0.21	0.30	0.22	0.37	0.214848659	1.46	6.77524613
C3	0.08	0.04	0.08	0.14	0.14	0.12	0.114387057	0.73	6.384170759
C4	0.08	0.02	0.03	0.06	0.05	0.12	0.064888957	0.40	6.151204195
C5	0.07	0.03	0.03	0.06	0.05	0.05	0.04821942	0.31	6.491604374
C6	0.10	0.01	0.03	0.02	0.06	0.05	0.043845539	0.27	6.115818517

eigen value	6.59171
IC	0.12
RC	0.09

Table 3 and 4. Determination of weights of the criteria applying the Neutrosophic AHP method. Source: self made

4. Next, the TOPSIS method is applied to verify the level of participation of the alternatives in the Social Vulnerability composite indicator according to the average evaluations of the evaluation criteria given by the experts consulted.

Alternatives	C1	C2	C3	C4	C5	C6
Percentage of people who moved in the last year	8	8	7	8.5	9	8.9
Average income for each family	8	9	9.5	9.4	8.9	9
Single parent families	10	9.9	10	9	9.5	9.8
Seniors living alone	10	10	10	10	10	10
Residents who are homeowners	10	9.8	9	9.5	9	9.4
Educational level	9.8	9.6	9.7	9.9	9.2	9
Age	5	6	6.1	5.9	5.6	4.9
Percentage of unemployed	7.1	7.9	8.1	8.8	7.4	7
Dependent population	8	7.8	9	8.9	8.6	9.1
Time spent in a specific place	4	5	4.2	4.5	5	4.9
Weights	**0.51381037**	**0.21484866**	**0.11438706**	**0.06488896**	**0.04821942**	**0.04384554**

PIS	NIS
0.197117015	0.078846806
0.197117015	0.098558507
0.197117015	0.082789146
0.197117015	0.088702657
0.197117015	0.098558507
0.197117015	0.096587337

D +	D-	RCi	Priority
0.05575311	0.11150622	0.666666667	6
0.0440767	0.12621647	0.741171637	5
0.00197117	0.16587136	0.988255836	2
0	0.16725933	1	1
0.00394234	0.1644953	0.97659466	3
0.00881534	0.15892082	0.947445196	4
0.12621647	0.0440767	0.258828363	9
0.0705778	0.09820306	0.581837641	8
0.0586071	0.1087543	0.649817095	7
0.15395331	0.0197117	0.113504161	10

Table 5 and 6. TOPSIS data processing. Source: self-made.

For the final discrimination, the experts decided to apply a Paretto, according to the results shown in table 6. From the analysis it was obtained that the most important indicator alternatives for the calculation of the Social Vulnerability composite indicator are:

- Seniors living alone
- Single parent families
- Residents who are homeowners
- Educational level
- Average income for each family
- Percentage of people who moved in the last year
- Dependent population

Conclusion

Once the investigation was completed, the following conclusions were reached:

1. The objective of the investigation is fulfilled since A Neutrosophy composite index of social vulnerability analysis to earthquake hazard in Canton Atacames was determined according to the criteria of experts (officials, specialists and population of the canton).
2. With the inclusion of a composite indicator for the analysis of social vulnerability to disaster preparation and response programs, stakeholder participation initiatives can be taken.
3. The integration of multi-criteria methods under an environment of uncertainty is positive since it provides greater precision to the analysis. In addition, it transforms the values in linguistic terms, which facilitates the obtaining of information by the respondents.
4. The inclusion of expert-determined weights can facilitate the adoption of multicriteria neutrosophic methodologies in disaster planning.

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