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Neutrosophic Analytic Hierarchy Process for the Control of the Economic Resources Assigned as Alimony

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Abstract: Currently, the right to food for children and adolescents is constituted as the duty imposed and recognized by the Law to provide the necessary resources for integrity protection. The control of the economic resources assigned as alimony represents a sensitive task to be insured by The State. This investigation proposes a solution to the posed problem through the implementation of a method for the control of the economic resources assigned as alimony. The method we recommend operates through a multicriteria approach with the use of the Neutrosophic Analytic Hierarchy Process.

Keywords: Alimony; Neutrosophy; Neutrosophic Analytic Hierarchy Process; Control of economic resources.

1. Introduction

The right to food is focused on the protection and guarantee of rights. It is established by the current Organic Code for Children and Adolescents. It is convenient to highlight the intimate relationship between the right to food and the right to life, and the development of children and adolescents [1], [2], [3]. The Organic Code of Children and Adolescents states in its Article 1: "the integral protection that The State, society and the family must guarantee to all children and adolescents living in Ecuador, in order to achieve their integral development and the full enjoyment of their rights, within a framework of freedom, dignity and equity" [4], [5].

The State sets an alimony that allows the subsistence of the children and adapts to the reality of economic income [6], [7], [8]. The problem lies in the absence of a rule that regulates the use of the money given as alimony. Sometimes, the person in charge of the care and protection of the child or adolescent uses this resource in expenses that do not correspond to the essence of the alimony, letting aside priority needs of the child or adolescent [9], [10].The control of the economic resources assigned as alimony represents a social problem to solve.

In the 1980s, the international movement called Paradoxism [11], based on the occurrence of contradictions in science and literature, was founded by Smarandache, who then extended it to Neutrosophy, based on contradictions and their neutrals. Using this approach, new extension to classical decision methods have been proposed such as the Neutrosophic Analytic Hierarchy Process (NAHP) [12, 13].

In this research, we develop a method for the control of the economic resources assigned as alimony through a multi-criteria approach with the use of the NAHP. This method allows us to rank four criteria according to four experts' assessments.

This paper has the following structure: section 2 contains the main concepts of Neutrosophy, section 3 describes the NAHP technique and the procedure we will follow to make the decision. In section 4 we make the calculus. At the end, we present the conclusion.

2. Preliminaries

This section makes an approximation of the main concepts associated with the problem domain. In addition, we describe the different concepts that facilitate the understanding of the research. We also make a description of the food rights of girls, boys and adolescents in Ecuador. The Neutrosophic Analytic Hierarchy Process is appropriate to represent uncertainty in decision-making problems.

2.1 The Food Law of children and adolescents in Ecuador.

The non-existence of a regulation to control the economic resources assigned as alimony, is opposed to the best interests of the child typified in article 11 of the Organic Code of Children and Adolescents [14], [15].

The legal duty to provide food in Ecuador has been introduced many years ago, and at the moment in the Constitution of the Republic it is mentioned in its article 11, numeral 9 that the highest duty of The State is to respect and enforce the rights enshrined in the Constitution [16], [17]. In accordance with this provision, it must be understood that the main duty of The State is to ensure respect for all rights, especially those in which priority care groups such as children and adolescents are involved. Those rights are in full accordance with the provisions of article 44 of the Constitution of the Republic of Ecuador that declares: “The State, society and the family will promote as a priority the integral development of children and adolescents, and will ensure the full exercise of their rights; the principle of their best interests will be met and their rights will prevail over that of other people”.

2.2 The Neutrosophic Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was proposed by Thomas Saaty in 1980 [18]. It is one of the most widespread methods to solve multi-criteria decision-making problems.

This technique models the problem that leads to the establishment of a hierarchy representative of the associated decision-making scheme [19, 20]. This hierarchy presents, at the upper level, the goal pursued in solving the problem and, at the lower level, the different alternatives from which a decision must be taken. The intermediate levels detail the set of criteria and attributes considered [21], [22].

AHP is a method that selects alternatives based on a series of criteria or hierarchical variables, which usually have contradictions between them. In this hierarchical structure, the final objective is at the highest level, and the criteria and sub-criteria at the lower levels. Figure 1 shows the hierarchical structure of AHP [23], [24].

In a typical hierarchy the highest level locates the decision making problem. The elements that affect decision-making are represented at the intermediate level. At the lowest level appear the decision options or alternatives [25], [26], [27].

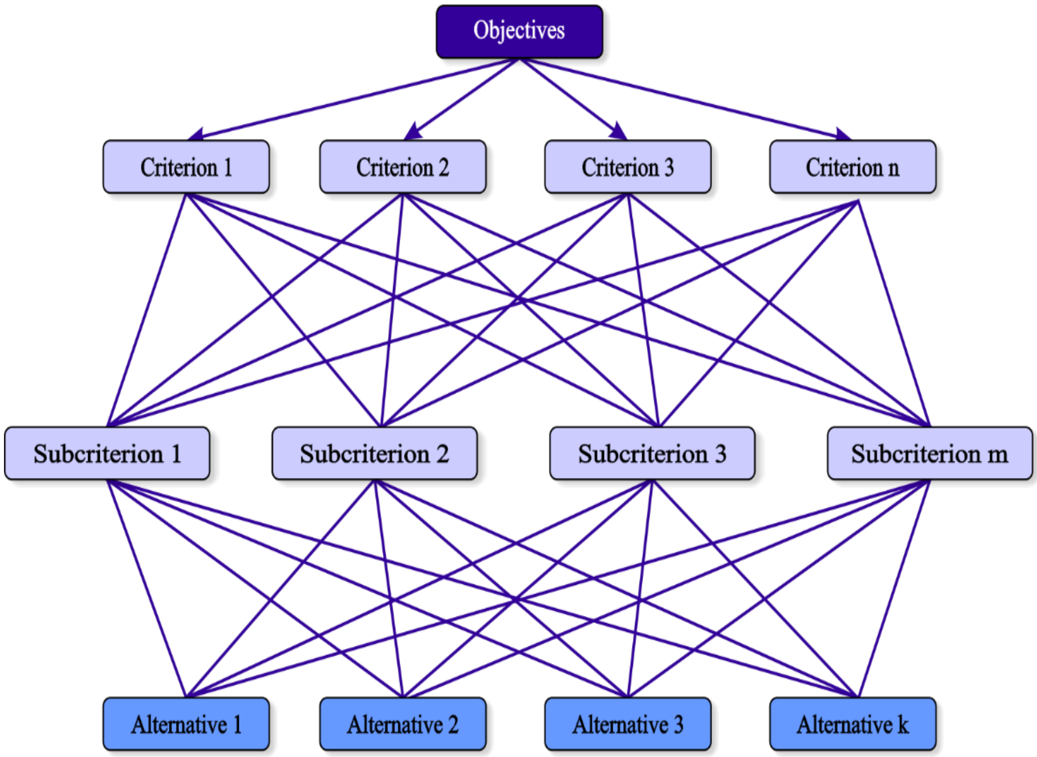

Figure 1. Scheme of a generic tree representing an Analytic Hierarchy Process.

Once the hierarchical structure is defined, the criteria of each group of the same hierarchical level are compared and the direct pairwise comparison of the alternatives with respect to the criteria of the lower level. For this, we used pairwise comparison matrices with a Fundamental Scale [28].

The comparison of the different alternatives with respect to the criteria of the lower level of the hierarchical structure, such as the comparison of the different criteria of the same hierarchical level generates a square matrix, known as the decision matrix.

The Neutrosophic Analytic Hierarchy Process (NAHP) extends the AHP method to a neutrosophic environment [12]. Neutrosophic set does not only mean truth-membership and falsehood-membership but also considers indeterminacy which is very common in real life situations like the control of the economic resources assigned as alimony[13]. This method is based on the Single-Valued Neutrosophic (SVNN) number, the main definitions on Neutrosophy related to this concept are given below:

Definition 1 [29]: The neutrosophic set N is characterized by three membership functions, which are the truth-membership function T_A, indeterminacy-membership function I_A and falsehood-membership function F_A, where U is the Universe of Discourse and $\forall x \in U$, $T_A(x), I_A(x), F_A(x) \subseteq\ ]^-0, 1^+[$ and $^-0 \leq inf\ T_A(x) + inf\ I_A\ (x)\ +\ inf\ F_A\ (x) \leq sup\ T_A(x) +\ sup\ I_A\ (x)\ +\ sup\ F_A\ (x) \leq 3^+$.

Notice that according to the definition, $T_A(x)$, $I_A(x)$ and $F_A(x)$ are real standard or non-standard subsets of $]^-0, 1^+[$ and hence, $T_A(x)$, $I_A(x)$ and $F_A(x)$ can be subintervals of [0, 1]. $^-0$ and 1^+ belong to the set of hyper-real numbers.

Definition 2 [30],[20]: The Single Valued Neutrosophic Set (SVNS) N over U is $A = \{< x, T_A(x), I_A(x), F_A(x) >: x \in U\}$, where $T_A: U \rightarrow [0, 1]$, $I_A: U \rightarrow [0, 1]$ and $F_A: U \rightarrow [0, 1]$. $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

The Single Valued Neutrosophic (SVN) number is represented by

N = (t, i, f), such that $0 \leq t, i, f \leq 1$ and $0 \leq t + i + f \leq 3$.

Definition 3 ([31]): The single valued triangular neutrosophic number,

$\tilde{a} = \langle (a_1, a_2. a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on $\mathbb{R}$, whose truth, indeterminacy and falsehood membership functions are defined as follows:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}}, & x = a_2 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_2 < x \leq a_3 \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{(a_2 - x + \beta_{\tilde{a}}(x - a_1))}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}, & x = a_2 \\ \frac{(x - a_2 + \beta_{\tilde{a}}(a_3 - x))}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \text{otherwise} \end{cases} \quad (2)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{(a_2 - x + \gamma_{\tilde{a}}(x - a_1))}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \gamma_{\tilde{a}}, & x = a_2 \\ \frac{(x - a_2 + \gamma_{\tilde{a}}(a_3 - x))}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \text{otherwise} \end{cases} \quad (3)$$

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

Definition 3 [32]: Given $\tilde{a} = \langle (a_1, a_2, a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued triangular neutrosophic numbers and λ any non-null number in the real line. Then, the following operations are defined:

Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$

Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_3, a_2 - b_2, a_3 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$

Inversion: $\tilde{a}^{-1} = \langle (a_3^{-1}, a_2^{-1}, a_1^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, where $a_1, a_2, a_3 \neq 0$.

Multiplication by a scalar number:

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

Division of two triangular neutrosophic numbers:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle\left(\frac{a_1}{b_3},\frac{a_2}{b_2},\frac{a_3}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, a_3 > 0 \ \ and \ \ b_3 > 0 \\ \langle\left(\frac{a_3}{b_3},\frac{a_2}{b_2},\frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, a_3 < 0 \ \ and \ \ b_3 > 0 \\ \langle\left(\frac{a_3}{b_1},\frac{a_2}{b_2},\frac{a_1}{b_3}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, a_3 < 0 \ \ and \ \ b_3 < 0 \end{cases}$$

Multiplication of two triangular neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle(a_1b_1, a_2b_2, a_3b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_3 > 0 \ \ and \ \ b_3 > 0 \\ \langle(a_1b_3, a_2b_2, a_3b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_3 < 0 \ \ and \ \ b_3 > 0 \\ \langle(a_3b_3, a_2b_2, a_1b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_3 < 0 \ \ and \ \ b_3 < 0 \end{cases}$$

Where $\wedge$ is a t-norm and $\vee$ is a t-conorm.

3. Proposal of a method for the control of the economic resources assigned as alimony

The method is structured in three stages: input, processing and output of information. The input stage feeds the method selection criteria, subsequently; in the processing stage the multi-criteria evaluation is implemented. The output stage visualizes the inference proposed by the method as a result of the evaluation process. The method operates based on a Neutrosophic Analytic Hierarchy Process. Figure 2 shows the general structure of the proposed method.

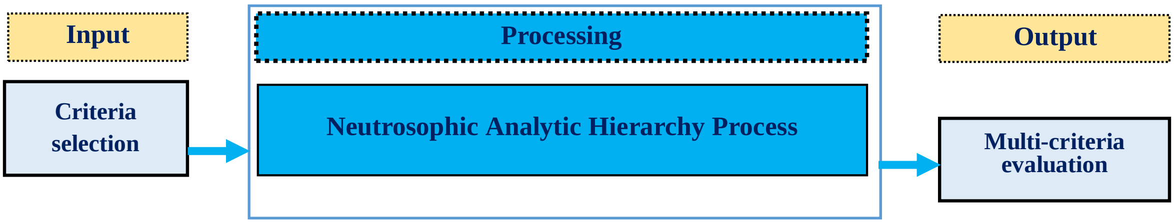

Figure 2. General structure of the proposed method.

Once the evaluation criteria have been identified, the method performs a process of comparison between criteria[33], [33]. The levels of importance or weights associated with each criteria are established [34-36]. They are estimated by means of pairwise comparisons between each criterion. This comparison is carried out using a scale, as expressed by the equation (1) [37], [38].

$$S = \left\{\frac{1}{9},\frac{1}{8},\frac{1}{7},\frac{1}{6},\frac{1}{5},\frac{1}{4},\frac{1}{3},\frac{1}{2},1,2,3,4,5,6,7,8,9\right\} \tag{1}$$

In the case of n attributes, the pairwise comparison of the element i with the element j is placed in the aij position of the matrix A of pairwise comparisons, as shown in equation (2).

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \tag{2}$$

The reciprocal values of these comparisons are obtained from the comparison process [39]. The values obtained are placed in the a_{ji} position of A, in order to preserve the consistency of the judgment [40-42]. The decision process must compare the relative importance of an element with respect to a second, using the 9 point scale shown in table 1.

Matrix $\tilde{A}$ must satisfy the condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, based on the operator of aggregation for converting neutrosophic triangular numbers into crisp numbers, there are two indexes defined in [43], they are the so-called score and accuracy indexes, respectively, see Equations 5 and 6:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \tag{3}$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \tag{4}$$

For item 1 that was rated with strong dominance over item 2, this relationship is expressed as a result in position a_{12}, by placing a 5 in that position and reciprocally in a_{21} we placed a 1/5.

Saaty 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 into a neutrosophic triangular scale.

On the other hand, Saaty established that Consistency Index (CI) should depend on λmax, the maximum Eigenvalue of the matrix. He defined the equation

$$\mathrm{CI} = \frac{\lambda_{\max} - \mathrm{n}}{\mathrm{n} - 1} \qquad (5)$$

where n is the order of the matrix. Additionally, he defined the Consistency Ratio (CR) through equation CR = CI/RI, where RI is given in Table 2.

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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 AHP [44-46].

AHP aims to score criteria, sub-criteria and alternatives, and to rank every alternative according to these scores [33, 47]. For more details about this technique [27], [34], [36] can be consulted.

AHP can also be used in group assessment. In such a case, the final value is calculated by the weighted geometric mean, see Equations 5 and 6.

$$\bar{\mathrm{x}} = \left(\prod_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{x}_{\mathrm{i}}^{\mathrm{w}_{\mathrm{i}}}\right)^{1/\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{w}_{\mathrm{i}}} \qquad (6)$$

If expert's weights sum up one, i.e. $\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{w}_{\mathrm{i}} = 1$., Equation 5 converts to Equation 6,

$$\bar{\mathrm{x}} = \prod_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{x}_{\mathrm{i}}^{\mathrm{w}_{\mathrm{i}}} \qquad (7)$$

4. Implementation of the method for the control of the economic resources assigned as alimony

The main elements on which the implementation is based are described below.

To obtain the information, the proposed method uses a multi-expert multi-criteria approach.

In this step, the group of experts involved in the decision-making problem participates as defined below:

$E = \{e_1, e_2, e_3, e_4\}$

The set of criteria that characterize the control of the economic resources assigned as alimony in the decision-making problem is identified so that:

$C = \{c_1, c_2, .., c_m\}, m \geq 2, \forall c_m \notin \emptyset, 1 \leq m \leq i$

As a result, the proposed evaluation criteria are:

c_1: The sustenance is guaranteed in favor of the pensioner.

c_2: Minimum accommodation conditions are guaranteed.

c_3: At least socially appropriate clothing is guaranteed.

c_4: An adequate education is guaranteed.

The evaluation process is described below:

The four matrices are obtained in pairs corresponding to the criteria of each expert who intervened in the process. The matrices obtained are summarized in Tables 3, 4, 5 and 6. Note that the values are expressed in correspondence with the scale given in Table 1, using linguistic values. We make reference to the number assigned to the criterion and not to the description in words.

Criteria	c_1	c_2	c_3	c_4
c_1	$\tilde{1}$	$\tilde{3}$	$\tilde{5}$	$\tilde{5}$
c_2	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$
c_3	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{2}$
c_4	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$

Table 3. Matrix resulting from the comparison of the criteria given by expert e_1.

The weight vector of the criteria is:

$$W_F = \begin{bmatrix} 0.554805 \\ 0.240180 \\ 0.117195 \\ 0.087820 \end{bmatrix}$$

Where CR = 0.016680.

Criteria	c_1	c_2	c_3	c_4
c_1	$\tilde{1}$	$\tilde{3}$	$\tilde{7}^{-1}$	$\tilde{5}^{-1}$
c_2	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{9}^{-1}$	$\tilde{9}^{-1}$
c_3	$\tilde{7}$	$\tilde{9}$	$\tilde{1}$	$\tilde{2}^{-1}$
c_4	$\tilde{5}$	$\tilde{9}$	$\tilde{2}$	$\tilde{1}$

Table 4. Matrix resulting from the comparison of the criteria given by expert e_2.

The weight vector of the criteria is:

$$W_F = \begin{bmatrix} 0.080247 \\ 0.038968 \\ 0.399124 \\ 0.481660 \end{bmatrix}.$$

Where CR = 0.039495.

Criteria	c_1	c_2	c_3	c_4
c_1	$\tilde{1}$	$\tilde{3}$	$\tilde{2}$	$\tilde{5}^{-1}$
c_2	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{5}^{-1}$
c_3	$\tilde{2}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{7}^{-1}$
c_4	$\tilde{5}$	$\tilde{5}$	$\tilde{7}$	$\tilde{1}$

Table 5. Matrix resulting from the comparison of the criteria given by expert e_3.

The weight vector of the criteria is defined as:

$$W_F = \begin{bmatrix} 0.167695 \\ 0.120590 \\ 0.071251 \\ 0.640464 \end{bmatrix}$$

Where CR = 0.069705.

Criteria	c_1	c_2	c_3	c_4
c_1	$\tilde{1}$	$\tilde{4}$	$\tilde{2}$	$\tilde{4}$
c_2	$\tilde{4}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{2}$
c_3	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}$
c_4	$\tilde{4}^{-1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$

Table 6. Matrix resulting from the comparison of the criteria given by expert e_4.

The weight vector of the criteria is:

$$\bar{W}_F = \begin{bmatrix} 0.32187 \\ 0.16259 \\ 0.20867 \\ 0.30688 \end{bmatrix}$$

Table 5 summarizes the priority vector of the four criteria by using the geometric mean with weights w_i = ¼, see Equation 10, and later it was normalized. The results are shown in Table 7.

Criterion	priority vector	Ranking
c_1	0.32187	1
c_2	0.16259	4
c_3	0.20867	3
c_4	0.30688	2

Table 7. Criteria priority vectors and final order.

According to the results shown in Table 7, the criteria are ordered by priority level as follows: $c_1 \succ c_4 \succ c_2 \succ c_3$. This means that the highest incidence is represented by the criterion "The sustenance is guaranteed in favor of the pensioner".

Conclusions

This investigation evaluated the control of the economic resources assigned as alimony. The research used the Neutrosophic Analytic Hierarchy Process technique. A group decision process approach is developed using mean as aggregation operator of individual assessments.

The research was applied for the evaluation of the control of the economic resources assigned as alimony. Criteria are prioritized and sorted based on group evaluation who determined to give more importance to "The sustenance is guaranteed in favor of the pensioner". Future work will concentrate on developing a consensus process and using linguistic information based on 2-tuples representation. The obtained result is useful for improving the performance of the assignment of alimony. To model with NAHP allowed us to include the indeterminacy, which is typical in every decision-making.

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