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Mesías Elías Machado Maliza

Janneth Ximena Iglesias Lola

Ximena Cangas Oña

Salah Hasan Saleh Al-subhi

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A Model for Recommending Custody of Minors based on Neutrosophic Cognitive Map

Mesías Elías Machado Maliza[1], Janneth Ximena Iglesias[2] Lola Ximena Cangas Oña[3] and Salah Hasan Saleh Al-subhi[4]

[1] Docente de la carrera de Derecho de la Universidad Regional Autónoma de los Andes (UNIANDES), Avenida José Lizarzaburo. Riobamba, CP 060150, Chimborazo, Ecuador. Email: ur.mesiasmachado@uniandes.edu.ec

[2] Docente de la carrera de Derecho de la Universidad Regional Autónoma de los Andes (UNIANDES), Avenida José Lizarzaburo. Riobamba, CP 060150, Chimborazo, Ecuador. Email: ur.jannetiglesias@uniandes.edu.ec

[3] Docente de la carrera de Derecho de la Universidad Regional Autónoma de los Andes (UNIANDES), Avenida José Lizarzaburo. Riobamba, CP 060150, Chimborazo, Ecuador. Email: ur.lolacangas@uniandes.edu.ec

[4]The Combined Security Group (CSG), Fahaheel Mekka St, Alanoud Complex, Kuwait. Email: salahcuba@yahoo com

Abstract. Minors can be left without legal custody due to many different reasons. When a minor is in distress he/she is at the mercy of the decision of the competent entity for the granting of his/her guardian. However, based on the affective relationships established by the different family members, determining parental responsibility constitutes a highly important decision. This research proposes a solution to the problem described by means of a recommendation system to assign parental responsibility and its incidence in the best interests of minors. The proposed method bases its operation on the use of Neutrosophic Cognitive Maps (NCM) to model the uncertainty in causal relationships. A case study is presented to demonstrate the applicability of the proposal.

Keywords: Parental responsibility; recommendation; Neutrosophic Cognitive Map; custody of minors

1. Introduction

The well-being of boys and girls in all their aspects such as health, physical and mental state, home, family, social condition and education is an international priority. In 1953, the United Nations General Assembly established that United Nations Children's Fund (UNICEF) is a permanent body, to later expand its scope to minor issues, being the starting point to create the second Declaration of the Rights of the child [1, 2]. The Declaration of the Rights of the Child indicates that children need special care, establishing adequate legal protection, before and after birth [3]. This statement mentions:

- The right to equality, without distinction of race, religion or nationality.
- The right to have special protection for the child's physical, mental and social development.
- The right to adequate food, shelter and medical care.
- The right to education and special treatment for those children who suffer from a mental or physical disability.
- The right to protection against any form of abandonment, cruelty and exploitation.

In Ecuador, from the moment it was constituted as a Republic, two legal bodies have been drafted. These are: the Juvenile Code with its respective reforms and the Childhood and Adolescence Code [4].

The latter has had to go through several changes, since what is sought is to confer a norm that is appropriate to the comprehensive protection of children and adolescents. Under the provisions of this norm, they will enjoy equality according to the law and there will be no discrimination because of the sex, religion, social origin, political ideology, affiliation, health, sexual orientation, disability or any other condition, whether of the minor, his/her parents, representatives or family members. Childhood and Adolescence Code, which the National Congress described as an "organic law" based on the article 142 of the Constitution, in its first part establishes the protection that The State, society and the family must provide to the minor, to the full enjoyment of their rights, establishing that this code protects all people from their prenatal state until they turn eighteen [5, 6].

Article 44 of our Carta Magna refers to the principle of the best interest of the child, in which various precepts are enshrined that require the state and society to respect in all areas the rights of minors, promoting their comprehensive development. Article 45 indicates a list of rights, such as: the right to health, education and family life, in which through this research project it we may corroborate that sometimes children are deprived of this right.

The constitution of the Republic of Ecuador must ensure equality in opportunities and rights to all those who make up the family nucleus, since it consecrates the family as the fundamental nucleus of society, therefore, the rights of each person must be protected. One of them promoting a responsible parental relationship giving children care, upbringing and education, protecting their rights and well-being in the event of being left without legal custody [7, 8].

The constitution itself mentions the best interests of the child, and it exalts all the measures that public and private entities must take, always protecting the best interests of the child. Based on this, administrators of justice, especially those in charge of childhood issues, must make their decisions independently of social pressures. When solving a controversy where the minor is involved, the well-being of the boy or girl will always come first.

When a minor is in distress, he/she is at the mercy of the decision for the granting of his/her custody. However, based on the affective relationships established by the different family members, determining parental responsibility constitutes a highly important decision. In our society, we often have to deal with the problems that arise at the moment in which the competent entity of justice has to choose the family that will assume the care and protection of the minor. In these cases the law does not have a tacit interpretation, but it is necessary to analyze various aspects that generally finish in decision-making under uncertainty.

Judges, or justice administrators in general, are in an environment of uncertainty regarding the granting of legal custody. A minor requires care and attention both affective and emotional, satisfying his/her needs and taking good care of his/her interests. A hasty decision will affect both its emotional and psychological state in short and long terms.

This research proposes a solution to the problem described, through a method for recommending the custody of minors based on parental responsibility and its incidence in the best interests of minors.

In 1980s, the international movement called Paradoxism based on contradictions in science and literature, was founded by Romanian polymath Florentin Smarandache, who then extended it to Neutrosophy, based on contradictions and their neutrals [9]. A Neutrosophic Cognitive Map (NCM) is used to represent and model the causal relationships among the factors which determine the performance of the custody of minors. This technique generalizes the Cognitive Maps and Fuzzy Cognitive Maps (FCM) in a neutrosophic framework, such that these causal relationships include the symbol I, which represents the indeterminacy usually contained in the knowledge and information of decision-makers. Thus, NCM is more trustworthy than fuzzy or crisp cognitive maps, because it contains indeterminacy. The importance of this work is that the proposed method is useful as a decision-support system for recommending custody of minors

The research is divided into several sections: Materials and Methods, Results and Conclusions. In the introduction, a state of the art is made on the different situations in which a child can be left without legal custody and the existing legal codes and procedures have to assign him/her a legal custody. In the Materials and Methods session, a method for recommending custody of minors based on parental responsibility is presented, which consists of four basic activities and is based on a Neutrosophic Cognitive Map to model uncertainty in causal relationships. The Results show a case study to demonstrate the applicability of the proposal.

2. Materials and Methods

This section describes the details of the method for recommending child custody based on parental responsibility. The method models the causal relationships between the different concepts [10] using a neutrosophic cognitive map.

The method supports the following principles:

- Integration of causal knowledge using the Neutrosophic Cognitive Map (NCM) for recommending custody of minors.
- Identification of causal relationships through the team of experts.
- Orientation of information towards the well-being of the minor.

The design of the method is structured for the recommendation of custody of minors. It has three basic stages: input, processing and output. Figure 1 shows the general outline of the proposed method.

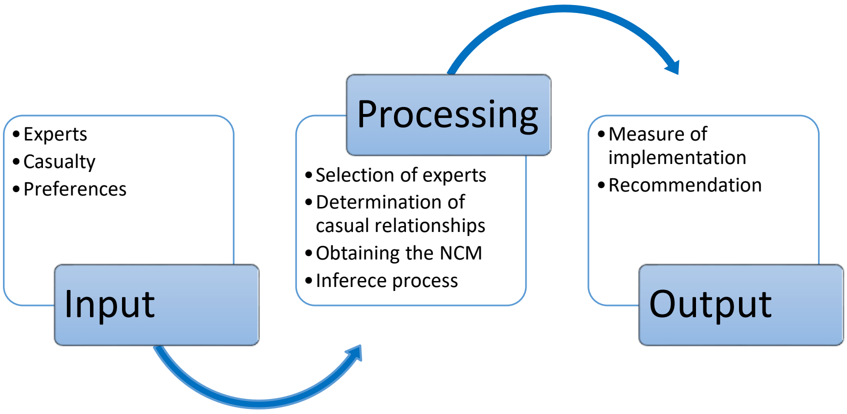

Figure 1. Structure of the proposed method.

The proposed method is structured to support the management of the inference process for recommending custody of minors. We use a multi-criteria approach as the basis for inference, which helps experts to feed the base of knowledge, [11-13].

The set of evaluative indicators represent one of the inputs of the method that is required for the inference activity. The inference activity represents the core for the reasoning of the method. It bases its processing on the modeling of causal relationships with the use of a Neutrosophic Cognitive Map [14-16].

2.1 Description of the method

This section provides a description of the proposed method. The activities that guarantee the inference of the processing stage are detailed. These activities are: identifying the evaluation criteria, determining the causal relationships, obtaining the NCM resulting from the causal relationships and the inference process.
Figure 2 shows the flow of the processing stage.

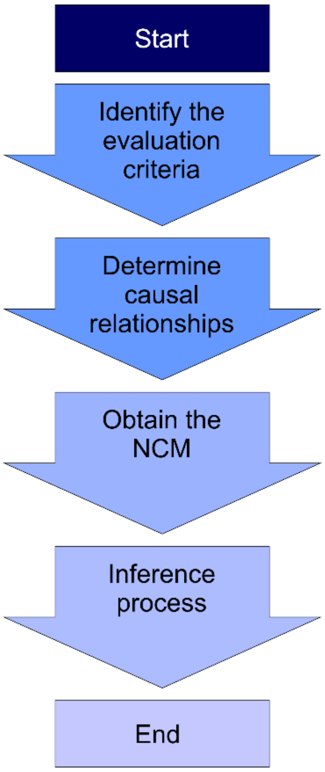

Figure 2. Processing stage workflow.

Activity 1: Identification of the evaluation criteria

The activity begins with the identification of the experts involved in the process. The experts group determines the criteria that will be taken into account for the inference process.

The activity uses a work group system using a multi-criteria approach. Formally, the problem of recommending the custody of minors can be defined based on parental responsibility through:

The impact criteria for the custody process are denoted by $C = \{C_1, \dots, C_n\}$.

The number of experts involved in multi-criteria assessment is denoted by $E = \{E_1, \dots E_n\}$:

Activity 2: Determinations of the causal relationships of the criteria

Once the impact criteria for the custody process are obtained, the causal relationships are determined [17]. Causal relationships are the expression of causality between the impact criteria for the custody process [18].

The determination of the causal relationships consists of establishing from the work group the implication among concepts. The resulting information represents the primary knowledge to feed the inference process. Causal relationships are represented by fuzzy variables expressed as linguistic terms [19, 20].

In linguistic models, sets of linguistic labels with granularity not greater than 13 are generally used. It is common to use sets of odd granularity, where there is a central label and the rest of the labels are symmetrically distributed around it [21, 22]. Figure 3 shows the set of linguistic terms used for this investigation.

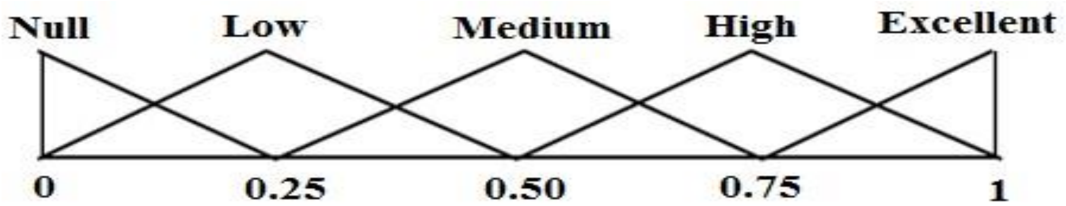

Figure 3. Linguistic labels set.

Activity 3: Obtaining the NCM

During the knowledge engineering stage each expert expresses the relationship between each pair of concepts C_i and C_j of the map. So, for each causal relationship, K-rules are obtained with the following structure: If C_i is A then C_j is B and the weight W_{ij} is C.

The theory of NCM is the following:

Definition 1: ([9]) Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow \,]^-0, 1^+[$, which satisfy the condition $^-0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3^+$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indetermination and falseness of x in A, respectively, and their images are standard or non-standard subsets of $]^-0, 1^+[$.

NS are useful only as a philosophical approach, so *Single-Valued Neutrosophic Set* is defined to guarantee the applicability of Neutrosophy, see Definition 2.

Definition 2:([9]) Let X be a universe of discourse. A *Single-Valued Neutrosophic Set* (SVNS) A on X is an object of the form:

$$A = \{\langle x, u_A(x), r_A(x), v_A(x)\rangle : x \in X\} \quad (1)$$

Where $u_A, r_A, v_A : X \rightarrow [0,1]$, satisfy the condition $0 \leq u_A(x) + r_A(x) + v_A(x) \leq 3$ for all $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the membership functions of truthfulness, indetermination and falseness of x in A, respectively. For convenience, a *Single-Valued Neutrosophic Number* (SVNN) will be expressed as $A = (a, b, c)$, where $a, b, c \in [0,1]$ and satisfies $0 \leq a + b + c \leq 3$.

Neutrosophic Logic (NL) extends fuzzy logic. As stated by Florentin Smarandache, a proposition P is characterized by three components; see [23]:

$$NL(P) = (T, I, F) \quad (2)$$

Where component T is the degree of truthfulness, F is the degree of falsehood and I is the degree of indetermination. T, I, and F belong to the interval [0, 1], and they are independent from each other.

A *neutrosophic number* is formed by the algebraic structure a+bI, where I = indetermination. Below, we formally describe some important concepts.

Definition 3: ([24]) Let R be a ring. The *neutrosophic ring* $\langle R \cup I \rangle$ is also a ring, generated by R and I under the operation of R, where I is a neutrosophic element that satisfies the property $I^2 = I$. Given an integer n, then, n+I and nI are neutrosophic elements of $\langle R \cup I \rangle$ and in addition $0 \cdot I = 0$. Also, I^{-1}, the inverse of I is not defined.

E.g., a neutrosophic ring is $\langle \mathbb{Z} \cup I \rangle$ generated by $\mathbb{Z}$, which is the set of integers.

Some operation using I is $I + I + \ldots + I = nI$.

Definition 4: ([25]) A *neutrosophic number* N is also defined as a number as follows:

$$N=d+I \quad (3)$$

Where d is the *determined part* and I is the *indeterminate part* of N.

Let $N_1 = a_1 + b_1 I$ and $N_2 = a_2 + b_2 I$ be two neutrosophic numbers, then some operations between them are :

1. $N_1 + N_2 = a_1 + a_1 + (b_1 + b_2)I$ (Addition),
2. $N_1 - N_2 = a_1 - a_1 + (b_1 - b_2)I$ (Difference),
3. $N_1 \times N_2 = a_1 a_2 + (a_1 b_2 + b_1 a_2 + b_1 b_2)I$ (Multiplication),
4. $\frac{N_1}{N_2} = \frac{a_1 + b_1 I}{a_2 + b_2 I} = \frac{a_1}{a_2} + \frac{a_2 b_1 - a_1 b_2}{a_2(a_2 + b_2)} I$ (Division).

A *neutrosophic matrix* is a matrix whose components are elements of $\langle R \cup I \rangle$.

Thus, it is possible to generalize the operations between vectors and matrices on R to the ring $\langle R \cup I \rangle$.

A *neutrosophic graph* is a graph with at least one neutrosophic edge linking two nodes, that is to say, there is an edge with an indetermination on its two nodes connection, [9], see Figure 4.

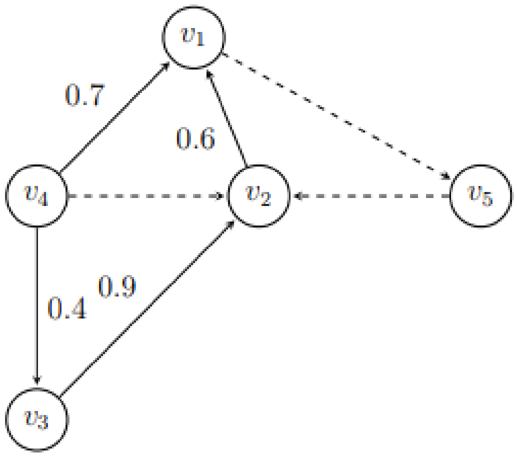

Figure 4: Example of neutrosophic graph. Source[9].

The de-neutrosophication process was introduced by Salmeron and Smarandache in [25], which converts a neutrosophic number into a numeric value. This process provides a range of numbers for centrality using as a base the maximum and minimum values of $I = [a_1, a_2] \subseteq [0, 1]$, based on Equation 4:

$$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2} \quad (4)$$

Each node constitutes a causal concept; this characteristic makes the representation flexible to visualize human knowledge. The adjacency matrix is obtained from the values assigned to the arcs. Figure 4 shows a representation of the NCM and the adjacency matrix [26-28].

The values obtained by the group of experts are aggregated, conforming to the general knowledge of the relationships between the criteria. Activity results in a NCM [29-31]. Then we carry out the static analysis of the assessment of the causal relationships. The knowledge stored in the adjacency matrix is taken as a reference. For the development of the proposed method, we work with the degree of output as shown by Equation 5, [32-34].

$$id_i = \sum_{i=1}^{n} \left\| I_{ji} \right\| \quad (5)$$

Activity 4: Inference process

A system modeled by an NCM will evolve over time, where the activation of each neuron will depend on the degree of activation of its antecedents in the previous iteration. This process is normally repeated until the system stabilizes or a maximum number of iterations is reached.

Inference process consists of calculating the state vector over time, for an initial condition A^0, [35].

Analogously to other neural systems, the activation of C_i will depend on the activation of neurons that directly affect the $C_i$concept and the causal weights associated with that concept. Equation 6 shows the expression used for processing.

$$A_i^{(K+1)} = f\left(A_i^{(K)} \sum_{i=1;\, j\neq i}^{n} A_i^{(K)} * W_{ji}\right) \quad (6)$$

Where:

$A_i^{(K+1)}$: is the value of the concept $C_i$in the step k+1 of the simulation,

$A_i^{(K)}$: is the value of the concept $C_j$in the step k of the simulation,

W_{ji}: is the weight of the connection that goes from the concept $C_j$to the concept C_i and f (x) is the activation function.

Unstable systems can be totally chaotic or cyclical and are frequent in continuous models. In summary, the inference process in an NCM may show one of the following characteristics [17, 36]:

Stability states: if $\exists t_k \in \mathbb{N}: A_i^{(t+x)} = A_i^{(t)} \forall t > t_k$, therefore, after iteration t_k the NCM will produce the same state vector. This configuration is ideal, as it represents the encoding of a hidden pattern in causality [37, 38].

Cyclical states: if $\exists t_k, P \in \mathbb{N}: A_i^{(t+p)} = A_i^{(t)} \forall t > t_k$. The map has a cyclical behavior with period p. In this case the system will produce the same state vector every P-cycle of the inference process [39, 40].

Chaotic state: The map produces a different state vector in each cycle. Concepts always vary their trigger value [41, 42].

3. Results

This section illustrates the implementation of the proposed method. A case study is described for recommending the custody of minors based on parental responsibility. The proposal used as a scenario of implementation a reference case of canton of Patate in Ecuador. The results of the study are described below:

Activity 1: Identification of the evaluation criteria

For the development of the study, 5 experts who are licensed Law workers were consulted. The group represents the basis to define the impact criteria in the custody process and causal relationships.

The experts group identified the set of criteria. Table 1 shows those criteria:

Index	Criterion
1	Acceptance degree by the boy or girl
2	Affectivity with the boy or girl
3	Income level
4	Social suitability

Table 1. Impact criteria in the custody process

Activity 2: Determination of the causal relationships of the criteria

For the identification of causal relationships, we obtained information from the group of experts participating in the process. As a result, 5 adjacency matrices were identified with the knowledge expressed by each expert. The matrices were aggregated and a resulting adjacency matrix is generated as the median of the

5-experts opinions. Where there is a symbol I for some expert, we evaluated as I = [0, 1] the aggregated result. Table 2 shows the adjacency matrix yielded by the process.

	C_1	**C_2**	**C_3**	**C_4**
C_1	0	1	I	1
C_2	1	0	0.75	I
C_3	0.25	0	0	1
C_4	0	0.25	1	0

Table 2. Adjacency matrix of the impact criteria in the custody process

Then, $Id_1 = 2+I = [2, 3]$; $Id_2 = 1.75+I = [1.75, 2.75]$, $Id_3 = 1.25$, and $Id_4 = 1.25$.

Using formula 4, we have $\lambda(Id_1) = 2.5$; $\lambda(Id_2) = 2.25$, $\lambda(Id_3) = 1.25$, and $\lambda(Id_4) = 1.25$.

The normalized weights of the criteria are:

$w_1 = 0.32$, $w_2 = 0.29$, $w_3 = 0.195$, and $w_4 = 0.195$. Therefore, when sorting the de criteria we have $C_1 \succ C_2 \succ C_3 \sim C_4$.

Activity 3: Obtaining the NCM

Once the impact criteria for the custody process and their corresponding causal relationships in Activity 2 have been obtained, the knowledge is represented in the resulting NCM. See Figure 5.

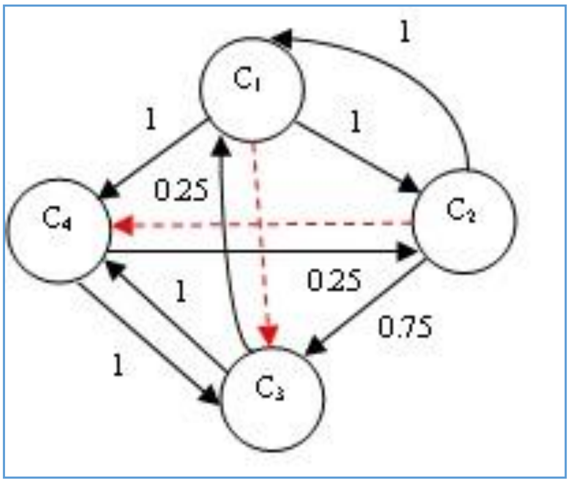

Figure 5. Resulting neutrosophic cognitive map.

Activity 4: Inference process

The adjacency matrix has the necessary information to determine the weights attributed to each indicator. Equation 5 is used to calculate the weights. Table 3 shows the results of the calculation.

Criteria	**Evaluation indicators**	**Weights**
C_1	Acceptance level by the boy or girl	0.32
C_2	Affectivity with the boy or girl	0.29
C_3	Income level	0.195
C_4	Social suitability	0.195

Table 3. Weight attributed to the indicators.

Once the weights of the indicators have been determined. The preferences of the object of analysis of the proposal are determined. For this case, 3 degrees of relationship were analyzed (Aunt, Grandmother and Sister). Tables 4, 5 and 6 show the results of the calculation made for each degree of relationship. The preferences are calculated according to the mean of experts' evaluation in the scale 0-10.

Criteria	Weights	Aggregated preferences according to experts' experience
C_1	0.32	8.5
C_2	0.29	6.5
C_3	0.195	10
C_4	0.195	6.5

Table 4. Calculation of preferences attributed to the degree of "aunt" relationship.

Table 4, presented the processing carried out for the degree of "aunt" relationship , based on the criteria referred to in Table 1, the degree of relationship preferences is determined, subsequently the process of information aggregation is carried out as part of the inference process.

Criteria	Weights	Aggregated preferences according to experts' experience
C_1	0.32	7.5
C_2	0.29	7.5
C_3	0.195	8.8
C_4	0.195	10

Table 5. Calculation of preferences attributed to the degree of "grandmother" relationship.

Table 5, presented the processing carried out for the degree of "grandmother" relationship , based on the criteria referred to in Table 1, the degree of relationship preferences is determined, subsequently the process of information aggregation is carried out as part of the inference process.

Criteria	Weights	Aggregated preferences according to experts' experience
C_1	0.32	6.0
C_2	0.29	5.0
C_3	0.195	8.8
C_4	0.195	7.2

Table 6. Calculation of preferences attributed to the degree of "sister" relationship.

Table 6, presented the processing carried out for the degree of "sister" relationship, based on the criteria referred to in Table 1, the degree of relationship preferences is determined, subsequently the process of information aggregation is carried out as part of the inference process.

The weighted mean of the results in Tables 4-6 are calculated and we obtained an index of 7.8225 for the "aunt" relationship, 8.2410 for the "grandmother" relationship, and 6.4900 for the "sister" relationship. Thus, it is likely that grandmothers are preferred over aunts and sisters in case of the custody of minors.

Conclusions

Through the development of the proposed research, we obtained a method for recommending the custody to minors based on parental responsibility. The method requires a group of experts to identify criteria with a multi-criteria approach. With the implementation of the method, the resulting aggregated Neutrosophic Cognitive Map is obtained, which expresses the knowledge of the group of experts with the representation of the causal relationships on the evaluation criteria. The knowledge stored in the Neutrosophic Cognitive Map represents the basis for the inference of the operation of the proposed method that guarantees the recommendations on child custody based on parental responsibility. The application of the method in the case under study demonstrates the applicability to recommend the custody of minors from parental responsibility taking into account the set of criteria previously defined.

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