



## Neutrosophic Cognitive Maps for Mediation as a Conflict Resolution Method in Traffic Conflicts

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### Abstract

This study investigated the dynamics of interaction between key variables in traffic accident mediation and how the inherent indeterminacy in these interactions influences the outcomes of mediation. Neutrosophic Cognitive Maps and neutrosophic logic were used to model and quantify the centrality and influence of such variables. The results highlighted the importance of negotiation strategies and emotional management as factors of high centrality in the mediation process. Based on these findings, the implementation of targeted training programs and the adoption of advanced analytical tools to improve mediation practices were recommended. The study underscores the need for a multidimensional approach that considers the complexity and uncertainty in mediator training, supporting efficiency and effectiveness in resolving traffic disputes.

**Keywords:** neutrosophy; neutrosophic cognitive maps; traffic accident mediation; network analysis; indeterminacy; conflict resolution.

### 1. Introduction

Mediation offers an effective and humane approach to resolving conflicts of almost any kind, highlighting the importance of dialogue, mutual understanding, and restorative justice. The literature supports its effectiveness in providing quick, satisfactory, and equitable solutions, thus promoting a more empathetic and less litigious conflict resolution culture. Its importance is underscored by its ability to reach mutually beneficial solutions, reducing the need for prolonged judicial intervention and fostering a sense of restorative justice.

Studies have shown that resolving traffic accident cases through mediation, rather than traditional judicial procedures, can offer a more direct and humane path to reconciliation and repair of harm. For example, Setiadi, Hasibuan, and Maryano [1] illustrate how the application of restorative justice, which includes mediation between victim and offender, offers a viable alternative to resolving traffic offenses through the criminal justice system. This approach promotes a more personalized and comprehensive solution to conflicts, allowing both parties to reach more satisfactory agreements that better reflect their specific needs and circumstances.

Another study by Juhari & Kastubi on criminal mediation in traffic accident cases highlights how mediation not only resolves conflicts efficiently but also ensures fair compensation for the victims,

maintaining balance and the principles of quick, simple, and cost-effective justice [2]. The implementation of mediation in resolving traffic offenses that result in minor injuries can be particularly effective when offenders are minors. Adopting the principle of alternative dispute resolution reflects a consideration towards rehabilitation over punishment, emphasizing the importance of a conflict resolution that is educational and constructive for those involved.

Mediation in traffic accidents emerges as a crucial mechanism in dispute resolution, standing out for its ability to navigate the complex networks of relationships and factors inherent in these cases. This complexity arises not only from the unique circumstances of each incident but also from the varied perceptions and emotions of the involved parties. The indeterminate nature of decision-making, fueled by the ambiguities and inaccuracies inherent in real life, demands an approach that can adapt and respond to these variations with sensitivity and adaptability.

By focusing on dialogue and mutual understanding, mediation allows a detailed examination of the underlying factors to reach a consensus. These factors may include, but are not limited to, environmental conditions at the time of the incident, potential distractions faced by those involved, and the psychological dynamics influencing their decision-making. As the literature suggests, a detailed analysis of these dimensions can reveal not only the direct causes of an incident but also the complexities that characterize human interactions in high-pressure contexts. By addressing these aspects, mediation offers a platform for a more holistic and fair resolution that recognizes human limitations and vulnerabilities.

Mediation stands out as an effective tool against legal uncertainties and variations in the interpretation of traffic regulations. By facilitating a space for direct negotiation, it allows parties to reach customized agreements that consider the specific context of each case, thus avoiding generalizations and standardized outcomes often resulting from traditional judicial procedures. This approach is not only more efficient in terms of resources but also promotes satisfaction and emotional closure for the involved parties, aspects that are difficult to achieve in court.

The application of neutrosophy in the legal context has emerged as an innovative tool for dealing with the indeterminacies and inaccuracies inherent in these cases [3]. Neutrosophy, a branch of philosophy that extends into logic and mathematics, is based on the idea that every entity has a portion of truth, falsehood, and neutrality, allowing for a more nuanced analysis of complex situations [4]. This perspective can be especially useful in traffic accident mediation, where ambiguity and a multiplicity of perspectives and factors complicate dispute resolution. [5], [6]

The use of cognitive maps in this context provides a framework for visualizing and understanding the relationships and dynamics among various factors involved in a traffic accident. Cognitive maps, by graphically representing causal connections between elements, facilitate the identification of underlying influences and the possible outcomes of different actions or decisions [7]. However, traditional cognitive maps often fail to capture the full complexity and indeterminate nature of human interactions and events in the real world. [8]

The integration of neutrosophy in creating cognitive maps, leading to neutrosophic cognitive maps, overcomes this limitation [9]. By incorporating dimensions of truth, falsehood, and indeterminacy, these maps offer a more accurate and holistic representation of situations [10]. In fuzzy logic-based cognitive maps, relationships are quantified only by numerical values, which restricts their capacity to capture nonlinear interactions between different events. Nevertheless, neutrosophy emerges as a robust option for dealing with data that are indeterminate or inconsistent, a capability that neither traditional fuzzy sets nor intuitive fuzzy sets effectively address [11]. By introducing indeterminacy as an integral component, neutrosophic cognitive maps extend the boundaries of fuzzy cognitive maps, offering a more accurate and holistic view of the complexity of reality. [12]

This study proposes to explore and analyze the potential of Neutrosophic Cognitive Maps in the specific context of traffic accident mediation in Ecuador. The main purpose of this study is to investigate the dynamics of interaction among various variables in the field of traffic accident mediation, particularly emphasizing how the inherent indeterminacy in these interactions influences the outcomes obtained from mediation processes. This analysis seeks to unravel and understand the complex relationships between human, procedural, and environmental factors underlying traffic accident mediation, aiming to identify fundamental patterns and connections that can contribute to the formulation of more refined mediation strategies tailored to the specificities of each case.

In this sense, the study aspires to make a significant contribution to understanding the mediation process in traffic accident cases, providing a basis for the development of mediation methods that are not only effective in terms of conflict resolution but also capable of handling the ambiguity and indeterminacy characteristic of these situations. Through analyzing how variables interact with each other under conditions of uncertainty, it is hoped to identify approaches that allow mediators to more effectively address the inherent complexity in traffic accidents, thus improving mediation outcomes for both the parties involved and the justice system as a whole.

**2. Preliminaries**

**Definition 1.** Consider  $N = \{(T, I, F): T, I, F \in [0,1]\}C$  as a set encompassing neutrosophic evaluations. The function.  $v: P \rightarrow N$  acts as a conduit, assigning each propositional formula within a collection  $P$  a corresponding value within  $N$ . Thus, for any proposition  $p \in P$  it is assigned a triplet in  $N$ , delineating the degree to which  $p$  is  $T\%$  true,  $I\%$  indeterminate, and  $F\%$  false, as delineated by Equation 1.

$$v(p) = (T, I, F) \tag{1}$$

Hence, neutrosophic logic constitutes an augmentation of fuzzy logic, anchored in the tenets of neutrosophy as elucidated in [13].

**Definition 2.** Let  $K$  denote the set of all real numbers. The algebraic structure formed by the union  $K \cup I$  is designated as a neutrosophic ring if it encapsulates the element  $I$  representing indeterminacy, satisfying the relations  $I^2 = I$ ,  $I + I = 2I$ , and in general, a finite summation,  $I + I + \dots + I = nI$ . For any scalar  $k \in K$ , the multiplication with  $I$  is defined as  $k * I = kI$ , and  $0I = 0$ . This neutrosophic ring is denoted by  $K(I)$ , which is generated by  $K \cup I$ , that is,  $K(I) = \langle K \cup I \rangle$ , where  $\langle K \cup I \rangle$  denotes the ring generated by  $K$  and  $I$ .

**Definition 3.** A neutrosophic matrix is characterized as a matrix  $A = [a_{ij}]_{ij}$   $i = 1, 2, \dots, m$  and  $j = 1, 2, \dots, n$ ;  $m, n \geq 1$ , such that each  $a_{ij} \in K(I)$ , where  $K(I)$  is a neutrosophic ring, see [14].

It is worth noting that an element of the matrix can take the form  $a + bI$ , where "a" and "b" are real numbers, while  $I$  represents the indeterminacy factor. The standard operations of neutrosophic matrices can be extended from classical matrix operations. This representation allows for capturing the uncertain nature of some elements in the matrix, which can be crucial for modeling and understanding complex phenomena in various fields of study.

Therefore, by extending classical matrix operations to neutrosophic matrices, manipulation and analysis of data including both certainty and uncertainty are permitted. This facilitates the application of matrix tools in situations where uncertainty plays a significant role, thereby expanding the scope and usefulness of matrices in various scientific and technological fields. For example,

$$\begin{pmatrix} -1 & I & 5I \\ I & 4 & 7 \end{pmatrix} \begin{pmatrix} I & 9I & 6 \\ 0 & I & 0 \\ -4 & 7 & 5 \end{pmatrix} = \begin{pmatrix} -21I & 27I & -6 + 25I \\ -28 + I & 49 + 13I & 35 + 6I \end{pmatrix}$$

Moreover, a neutrosophic graph is defined as a graph containing at least one edge or node characterized by indeterminacy, as shown in Figure 1. The neutrosophic adjacency matrix, an extension of the traditional adjacency matrix in graph theory, serves to represent the relationships between nodes. In this matrix,  $a_{ij} = 0$  indicates that nodes  $i$  and  $j$  are not connected,  $a_{ij} = 1$  signifies

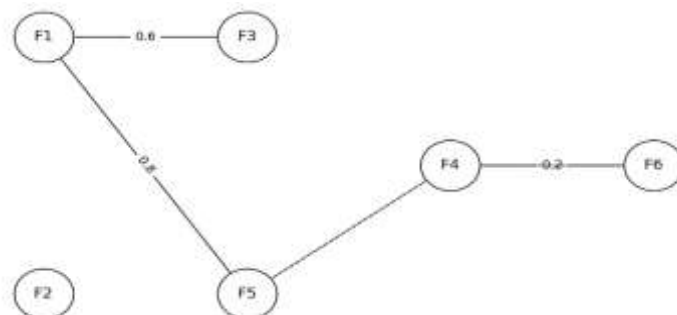


Figure 1: Neutrosophic Graph.

a connection between these nodes, and  $a_{ij} = I$  denotes an indeterminate connection status, where it is unknown whether a connection exists or not. Notably, fuzzy set theory lacks such distinctions and representations.

Conversely, when indeterminacy is incorporated into a cognitive map, the resulting map is termed a neutrosophic cognitive map, which proves particularly advantageous in representing causal knowledge. Its formal definition is provided in Definition 4.

**Definition 4.** A Neutrosophic Cognitive Map (NCM) constitutes a graph directed by neutrosophic principles, wherein nodes represent diverse concepts such as policies and events, and edges embody causalities or elements of indeterminacy. This structure models the causal interconnectivity among the concepts.

The forthcoming metrics are incorporated within the model based on the absolute values present in the adjacency matrix:

- Outdegree ( $v_i$ ) encapsulates the aggregate of the row values within the neutrosophic adjacency matrix, signifying the magnitude of the emanating relationships ( $c_{ij}$ ) from the variable.

$$od(v_i) = \sum_{j=1}^n c_{ij} \quad (2)$$

- Indegree ( $v_i$ ) is the cumulative of the column values, delineating the intensity of the incoming relations ( $c_{ij}$ ) towards the variable.

$$id(v_i) = \sum_{j=1}^n c_{ji} \quad (3)$$

- Total centrality (total degree  $td(v_i)$ ), is the arithmetic sum of the variable's indegree and outdegree.

$$td(v_i) = od(v_i) + id(v_i) \quad (4)$$

The execution of static analysis necessitates the deployment of the adjacency matrix, considering the absolute weightings. In neutrosophic cognitive maps, static analysis initially integrates neutrosophic numbers represented as  $a + bI$ , with  $I$  denoting indetermination. This analysis mandates a de-neutrosophication process, as indicated in [15], where  $I$  within  $[0, 1]$ , is replaced by its respective maximum and minimum magnitudes.

Conclusively, the computation employs the mean of these extremities, as elucidated through Equation 5, described in [11]. This approach is instrumental in distilling a singular value that is employed to discern the salient characteristics, guiding the prioritization based on the factors elucidated in our case study.

$$\lambda([a_1, a_2]) = \frac{a_1 + a_2}{2} \quad (5)$$

Then,

$$A > B \Leftrightarrow \frac{a_1 + a_2}{2} > \frac{b_1 + b_2}{2} \quad (6)$$

### 3. Method

This study adopts a mixed-methodological approach, focusing on modeling Neutrosophic Cognitive Maps (NCM) to investigate the dynamics of interaction between critical variables in traffic accident mediation and how inherent indeterminacy affects the outcomes of these processes. The research is characterized by an exploratory design, employing a panel of experts to identify, evaluate, and model the causal relationships between selected variables. This approach allows for a deep and nuanced understanding of the complexity and uncertainties present in traffic accident mediation.

For the data collection phase and evaluation of causal relationships, a panel consisting of five experts in traffic accident mediation was formed. Selection criteria included practical experience in mediation,

specialized knowledge in traffic legislation, and familiarity with decision theory applications under uncertainty. The diversity of experiences and perspectives of the selected experts ensures a comprehensive and detailed evaluation of the variables under study.

Initially, eight key factors were identified through a consultation process with the expert panel, using brainstorming and Delphi techniques to achieve consensus. These factors were chosen based on their perceived relevance in the dynamics of traffic accident mediation and their potential influence on mediation outcomes. Subsequently, the NCM was constructed, articulating the causal relationships between the identified factors. This stage involved the conceptualization and graphical representation of complex interrelations, facilitating the visualization of how indeterminacy affects the interaction between variables.

Using the developed NCM, data were collected from the experts to assess the strength and nature of the connections established in the map. Experts were asked to assign neutrosophic values to each link in the NCM. This assignment of values was carried out through structured questionnaires and follow-up discussions, allowing the capture of expert judgments on the complexity and uncertainty inherent in each causal relationship.

The collected information was consolidated into a neutrosophic adjacency matrix, providing a quantitative basis for analyzing the relationships between the variables. This matrix facilitates the application of network analysis algorithms to explore the structure and dynamics of the modeled system, allowing for the identification of patterns, critical points of influence, and potential effects of mediation interventions. The interpretation of the adjacency matrix was carried out with the support of specialized software in network analysis and decisions under uncertainty, complementing expert judgment with advanced analytical techniques.

This methodological approach offers a rigorous framework for the study of traffic accident mediation, highlighting the importance of indeterminacy and the complex interaction between variables. By applying principles of neutrosophic theory and cognitive maps in a mediation context, the study aims to enrich the understanding and practice of mediation in situations of high uncertainty and complexity.

#### **4. Results**

The elements identified and selected by the experts revolve around several fundamental axes for mediation in traffic accidents, providing a framework for analyzing and improving the effectiveness of this process. Below, an argument is outlined in scientific language for each of these elements:

1. **Influence of the Perceptions and Emotions of the Involved Parties:** Analyzing how perceptions and emotions impact communication between the involved parties is essential. A competent mediator uses this understanding to promote constructive and empathetic dialogue, effectively addressing concerns and expectations, which is crucial for the success of the mediation process.
2. **Knowledge of the Legal and Regulatory Framework:** A comprehensive understanding of relevant legislation and regulations is vital for guiding discussions toward legitimate and achievable solutions. This ensures that agreements not only satisfy the involved parties but also align with the current legal framework.
3. **Importance of Non-Verbal Communication:** The ability to correctly interpret non-verbal cues provides the mediator with a deeper understanding of emotional states and attitudes not verbally expressed. This ability is indispensable for adjusting the mediation methodology and enhancing empathy and mutual understanding between the parties.
4. **Expectations and Needs of the Parties:** Understanding the underlying expectations and needs of the parties is fundamental to steering the mediation process toward satisfactory and lasting outcomes. The mediator must use this knowledge to facilitate agreements that reflect the interests and desires of all involved parties.
5. **Analysis of the Behavioral History of the Parties:** Assessing the previous behavior and background of the involved parties is crucial for discerning behavior patterns that may be relevant during the mediation process. This allows the mediator to focus the dialogue on key aspects and promote well-founded agreements.

6. Dynamics of Power and Social Roles: Recognizing the dynamics of power and the influence of social roles in the interactions between the parties is essential for ensuring a balanced discussion. The mediator must strive to ensure that all parties are fairly heard, thus contributing to the fairness of the mediation process.
7. Negotiation Strategies and Conflict Resolution: Familiarity with a wide range of negotiation strategies and conflict resolution enables the mediator to customize their approach according to the specifics of the case in question. This is key to identifying innovative solutions acceptable to all parties.
8. Relevance of the External Conditions of the Accident: Considering external variables, such as weather conditions, time of day, and accident location, is fundamental for proper contextualization of the facts. The mediator can use this information to facilitate a more accurate narrative and seek equitable solutions, considering how these factors influence the perception of events and the attribution of responsibilities.

These factors constitute a solid foundation for analyzing the complexities inherent in mediation in traffic accidents, allowing mediators to adopt more informed and effective approaches to resolving such conflicts.

The generated adjacency matrix, which incorporates the neutrosophic values given by the expert panelists, is detailed below. This matrix emerges as a fundamental instrument for the exploration and discernment of causal connections within the framework of the proposed study. The assignment of neutrosophic values to each link between variables allows for a nuanced representation of the uncertainty and indeterminacy characteristic of the analyzed interactions, thus facilitating a more accurate and in-depth evaluation of the complex dynamics present in traffic accident mediation.

$$A = \begin{pmatrix} 0 & 0.8 & I & 0 & 0 & 0 & 0 & 0 \\ 0.1 & 0 & 0 & 0 & 0 & 0 & 0.5 & 0.3 \\ 0 & 0 & 0 & I & I & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & I \\ 0.4 & I & 0 & 0 & 0 & 0.3 & 0 & 0 \\ 0.2 & I & 0 & 0 & 0 & 0 & 0 & 0 \\ I & 0 & 0 & 0 & 0 & I & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & I & 0 \end{pmatrix}$$

Figure 2: shows the corresponding graph obtained.

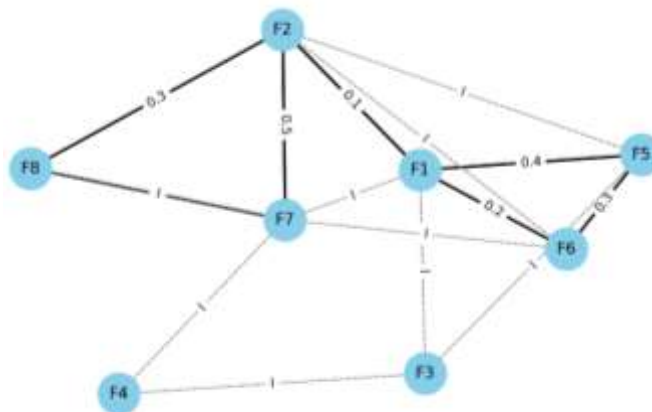


Figure 3: Modeled Neutrosophic Graph

Using this methodological framework, Table 1 presents the calculated centrality metrics. These measures provide a quantitative assessment of the relative importance of each node within the network fabric, being crucial for analyzing the dynamics and impact of the various components in the system under study. This approach allows for the identification of key nodes that exert greater influence or that occupies a strategic position in the network, thereby facilitating an understanding of the complex interaction structures and patterns characteristic of mediation in traffic accidents.

Table 1: Calculated centrality measures for each factor

Factors	$od(v_i)$	$id(v_i)$	$td(v_i)$
Influence of the Perceptions and Emotions of the Parties Involved	0.8+I	0.7+I	1.5+2I
Knowledge of the Legal and Regulatory Framework	0.9	0.8+2I	1.7+2I
Importance of Non-Verbal Communication	2I	I	3I
Expectations and Needs of the Parties	I	I	2I
Analysis of the Conduct History of the Parties	0.7+I	I	0.7+2I
Power Dynamics and Social Roles	0.2+I	0.3+I	0.5+2I
Negotiation and Conflict Resolution Strategies	1+2I	0.5+2I	1.5+4I
Relevance of the External Conditions of the Accident	I	1.3+0I	1.3+I

In the context of analysis using NCM, the initial assessment generates neutrosophic values that incorporate the element of indeterminacy. Given this scenario, it becomes imperative to implement a deneutrosophication method, according to the methodology proposed by Salmerón and Smarandache [16]. This method involves replacing the indeterminacy parameter I, which is in the range [0, 1], with its maximum and minimum value extremes. This step is revealed to be crucial for deriving more defined and exact results, which are essential for an effective interpretation of the evaluated interconnections within the study framework.

The implementation of this procedure allows for the generation of a quantitative metric that efficiently condenses relevant information, providing a more comprehensive and detailed view of the analyzed elements. The results achieved through this technique are displayed in Table 4, thus facilitating an improved visualization and understanding of the dynamics at play.

Figure 3 provides a visual representation of the average centrality assessment of the factors involved in the evaluation conducted. Each bar corresponds to one of the factors listed, from the Influence of the Perceptions and Emotions of the Involved Parties (F1) to the Expectations and Needs of the Parties (F8).

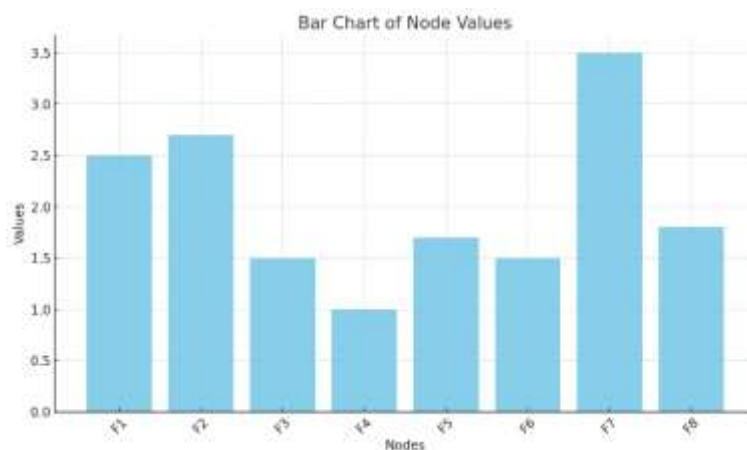


Figure 4: Average rating of the centrality of the evaluated factors

The analysis conducted suggests that nodes F1 and F7 show the highest scores, indicating greater centrality and, therefore, a more significant role in the traffic accident mediation network according to experts' perspectives. On one hand, negotiation strategies and conflict resolution present the highest valuation, suggesting that the tactics employed during negotiation and dispute resolution play a critical role in the mediation process. This highlights the importance of a solid understanding and application of various negotiation strategies by the mediator, which is essential for achieving a satisfactory conflict outcome.

On the other hand, the factor considering the influence of perceptions and emotions of the involved parties also shows high centrality, indicating that subjectivity and the emotional state of individuals are crucial components that directly affect the process and success of mediation. This emphasizes the need for mediators to possess advanced emotional and interpersonal skills to effectively manage such aspects.

In contrast, factors F3, F4, and F5, related to the importance of non-verbal communication, the expectations and needs of the parties, and the analysis of the behavioral history of the parties, respectively, have lower scores. This could suggest that although these elements are relevant, their direct influence on the mediation process might be lesser compared to other factors. However, it is important to consider that their indirect impact and interaction with other factors can be significant and deserve detailed evaluation.

The analysis of factors F2, F6, and F8, covering the knowledge of the legal and regulatory framework, dynamics of power and social roles, and the relevance of the accident's external conditions, respectively, shows that each contributes variably to traffic accident mediation. These results evidence the complexity and multifactorial nature of mediation, where each factor plays a role in influencing the process and outcomes.

The interpretation of these data provides valuable insight into the critical elements in traffic accident mediation. For mediators, these findings can translate into a more directed focus on developing key competencies, such as negotiation skills and emotional intelligence, while maintaining awareness of the legal, social, and personal aspects that shape the context of each mediation case.

Based on the gathered data, a scheme of strategic interventions aimed at optimizing both the interpretation and execution of mediation practices applied to traffic accident situations is suggested. This scheme is designed to refine the mechanisms by which mediators approach cases, enhancing the effectiveness and efficiency of the mediation process and promoting more consistent and equitable outcomes in this specific field.

### **Improvement Plan for the Understanding and Implementation of the Mediation Process in Traffic Accidents:**

#### 1. Capacity Building in Mediators

- Develop a training curriculum focused on the areas of greatest influence identified, such as negotiation strategies and emotion management.
- Organize role-playing sessions and simulations based on the most common scenarios in traffic accidents to enhance practical skills.

#### 2. Incorporation of Analytical Tools:

- Implement the use of neutrosophic cognitive map software that allows mediators to better visualize and understand the dynamics of interaction between parties.

#### 3. Improvement of Mediation Protocols:

- Review current mediation protocols to ensure they align with the practices and key factors identified in the study.
- Adjust mediation procedures to ensure that the factors with the highest scores are proactively addressed.

#### 4. Continuous Data Collection and Analysis:

- Establish a feedback system where mediators can report on the applicability of the identified factors and the effectiveness of the implemented strategies.
- Analyze this data to continuously adjust and update mediation strategies.

#### 5. Communication and Education:

- Create educational and outreach material that summarizes the study's findings and offers concrete strategies for addressing each key factor.

- Conduct workshops and webinars to educate all involved parties about the importance of each factor in the mediation process.

#### 6. Multidisciplinary Integration:

- Encourage collaboration between mediators, psychologists, lawyers, and road safety experts to enrich the mediation process with a variety of perspectives and knowledge.

#### 7. Evaluation and Continuous Improvement:

- Implement periodic evaluations of the mediation process to identify areas for improvement and the effectiveness of the adopted measures.
- Establish key performance indicators based on the results of the analysis to monitor progress toward the improvement plan's goals.

This plan should be dynamic and subject to periodic reviews, allowing adjustments based on observed effectiveness and changes in the legal and social environment. The ultimate goal is to improve not only the understanding of the mediation process but also its practical execution, contributing to the effective and efficient resolution of conflicts arising from traffic accidents.

### 5. Conclusion

This study elucidated the complex interactions between variables involved in the mediation process of traffic accidents. Network analysis methods and neutrosophic logic tools were applied to capture the multidimensionality and uncertainty intrinsic to these events. Through the construction and evaluation of neutrosophic cognitive maps, it was possible to graphically represent and quantify the influence and centrality of specific factors affecting mediation. The use of an expert panel provided a base of specialized and empirical knowledge for assigning neutrosophic values to the relationships between variables, which was fundamental in capturing the indeterminacy characteristic of mediation situations in this field. The analysis made it possible to determine the relevance of negotiation strategies and conflict resolution, as well as the influence of the perceptions and emotions of the involved parties, which showed high centrality in the network. Based on these findings, it is inferred that an integrated approach that enhances the mediators' ability to navigate and manage these complex and often undefined variables can significantly improve the quality and success of mediation in traffic accidents. The strategies emerging from this study suggest the need for ongoing training and professional development of mediators, as well as the implementation of analytical tools that support real-time decision-making. The use of neutrosophic cognitive maps had significant implications for the study by facilitating an understanding of the cases. This allows mediators to identify more effective and personalized solutions.

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