A Neutrosophic Analysis of Ecuador's Traffic Injury Legislation

Acurıo H. Germán Fabrıcıo [*1], Vıctor Lucero Salcedo [2], Vıllacres D. Oscar Fabıan [3]

[1] Universidad Regional Autónoma de los Andes ,Santo Domingo, Ecuador
[2] Universidad Regional Autónoma de los Andes ,Tulcán, Ecuador
[3] Universidad Regional Autónoma de los Andes ,Ambato, Ecuador
Emails: us.germanacurio@uniandes.edu.ec; ut.victorlucero@uniandes.edu.ec; ua.oscarvillacres@uniandes.edu.ec

Abstract

This study offers a comprehensive analysis of the perceptions regarding the gaps in traffic injury laws and the level of judicial security in Ecuador. By employing a neutrosophic approach, which incorporates degrees of truth, indeterminacy, and falsity, the study synthesizes data from legal professionals to assess the need for legislative reform. The use of the Indeterminate Likert Scale and the Triple Refined Indeterminate Neutrosophic Sets (TRINS) enriches the evaluation of nuanced opinions on traffic injuries that result in minimal disability. The resulting insights reveal a significant recognition of the inadequacies within the current legal framework and highlight a societal demand for enhanced legal measures and improved trust in judicial processes. This study underscores the urgency for legal reforms that would bridge the current legislative voids, ensuring justice and protection for traffic injury victims, thereby strengthening the legal system's accountability and public confidence.

Keywords: Traffic Injury Law; Legal Anomie; Judicial Security; Neutrosophic Similarity; Indeterminate Likert Scale

1. Introduction

In this study, we delve into the realm of traffic injury laws in Ecuador[1], with a focused lens on two pivotal constructs: Perceived Anomie in Traffic Injury Cases, and Perceived Legal Protection and Judicial Security. The former explores the public's perception of the disintegration of social norms, particularly due to the lack of concrete legislation addressing traffic injuries resulting in minimal disability. The latter evaluates the confidence in the current legal framework's capability to uphold legality principles and provide judicial security, with a specific focus on safeguarding the rights of those affected by minor disability traffic injuries[2].

Employing a non-experimental methodology, our research engaged a sample of 94 lawyers at a legal fair through a structured questionnaire utilizing the Indeterminate Likert Scale. The scale's design is primed to capture the subjective nature of opinion, accounting for both uncertainty and the indeterminacy of the respondents' views. It leans on the triple refined indeterminate neutrosophic sets (TRINS)[3] for heightened precision in understanding the level of agreement or disagreement on specific items, such as the adequacy of Activities cost and Financial management within the legal practices.

To examine the interrelation between these variables, we employ the neutrosophic similarity measure—a nuanced extension of fuzzy similarity—incorporating elements of uncertainty, indeterminacy, and falsity to surpass the accuracy offered by traditional fuzzy sets. We specifically adapt this measure to accommodate the TRINS framework, thus incorporating two additional components for a total of five[4,5].

This article is structured methodologically, beginning with the 'Materials and Methods' section that introduces the essential concepts of the Indeterminate Likert Scale and Neutrosophic Similarity. We then transition to the 'Results' section, presenting the empirical findings of our inquiry. The discussion culminates in the 'Conclusions' section, drawing insightful inferences from the data.

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2. Material and Methods

This part provides a concise overview of the key theoretical frameworks applied in our research. Initially, it introduces the fundamental ideas pertaining to the Indeterminate Likert Scale. Following that, the subsequent subsection revisits the core principles of Neutrosophic Similarity

Definition 1 ([6]). 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 $T_A: U \to [0,1]$, $I_A: U \to [0,1]$, and $F_A: U \to [0,1]$, $0 \le T_A(x) + I_A(x) + F_A(x) \le 3$.

Definition 2 ([7]). The *refined neutrosophic logic* is defined such that: a truth T is divided into several types of truths: $T_1, T_2, \ldots, T_p$, I into various indeterminacies: $I_1, I_2, \ldots, I_r$ and F into various falsities: $F_1, F_2, \ldots, F_s$, where all $p, r, s \ge 1$ are integers, and $p + r + s = n$.

Definition 3 ([6]). A *triple refined indeterminate neutrosophic set* (TRINS) A in X is characterized by positive $P_A(x)$, indeterminacy $I_A(x)$, negative $N_A(x)$, positive indeterminacy $I_{P_A}(x)$ and negative indeterminacy $I_{N_A}(x)$ membership functions. Each of them has a weight $w_m \in [0,1]$ associated with it. For each $x \in X$, there are $P_A(x), I_{P_A}(x), I_A(x), I_{N_A}(x), N_A(x) \in [0,1]$, $w_P^m(P_A(x)), w_{IP}^m(I_{P_A}(x)), w_I^m(I_A(x)), w_{IN}^m(I_{N_A}(x)), w_N^m(N_A(x)) \in [0,1]$ and $0 \le P_A(x) + I_{P_A}(x) + I_A(x) + I_{N_A}(x)(x) + N_A(x) \le 5$. Therefore, a TRINS A can be represented by $A = \{\langle x;\ P_A(x), I_{P_A}(x), I_A(x), I_{N_A}(x), N_A(x)\rangle | x \in X\}$.

Let A and B be two TRINS in a finite universe of discourse, $X = \{x_1, x_2, \ldots, x_n\}$, which are denoted by:

$A = \{\langle x;\ P_A(x), I_{P_A}(x), I_A(x), I_{N_A}(x), N_A(x)\rangle | x \in X\}$ and $B = \{\langle x;\ P_B(x), I_{P_B}(x), I_B(x), I_{N_B}(x), N_B(x)\rangle | x \in X\}$,

Where $P_A(x_i), I_{P_A}(x_i), I_A(x_i), I_{N_A}(x_i), N_A(x_i), P_B(x_i), I_{P_B}(x_i), I_B(x_i), I_{N_B}(x_i), N_B(x_i) \in [0,1]$, for every $x_i \in X$. Let w_i(i = 1,2,...,n) be the weight of an element x_i (i = 1,2,...,n), with $w_i \ge 0$ (i = 1,2,...,n) and $\sum_{i=1}^{n} w_i = 1$.

The *generalized TRINS weighted distance* is ([6, 8]):

$$d_\lambda(A,B) = \left\{\frac{1}{5}\sum_{i=1}^{n} w_i \left[|P_A(x_i) - P_B(x_i)|^\lambda + \left|I_{P_A}(x_i) - I_{P_B}(x_i)\right|^\lambda + |I_A(x_i) - I_B(x_i)|^\lambda + \left|I_{N_A}(x_i) - I_{N_B}(x_i)\right|^\lambda + |N_A(x_i) - N_B(x_i)|^\lambda\right]\right\}^{1/\lambda} \qquad (1)$$

Where $\lambda > 0$.

The Indeterminate Likert Scale comprises these five components:

– Negative membership,
– Indeterminacy leaning towards negative membership,
– Indeterminate membership,
– Indeterminacy leaning towards positive membership,
– Positive membership.

These values substitute the classical Likert scale with values:

–Strongly disagree,
– Disagree,
–Neither agree or disagree,
– Agree,
–Strongly agree.

Participants are requested to rate their level of agreement on a scale from 0 to 5, covering the spectrum from "Strongly disagree" to "Strongly agree".

2.2. Some Notions on Neutrosophic Similarity

Definition 4: ([9-12]) The *degree of similarity* between two single-valued neutrosophic sets A and B is a mapping $S: \mathcal{N}(X) \times \mathcal{N}(X) \to [0,1]^3$, where $\mathcal{N}(X)$ is the set of all single-valued neutrosophic sets in $X = \{x_1, x_2, \cdots, x_n\}$, such that $S(A,B) = (S_T(A,B), S_I(A,B), S_F(A,B))$ satisfies conditions (S1)-(S4).

(S1) $S(A,B) = S(B,A)$, $\forall A, B \in \mathcal{N}(X)$,
(S2) $S(A,B) = \underline{1} = (1,0,0)$ if and only if $A = B$,
(S3) $S_T(A,B) \ge 0, S_I(A,B) \ge 0, S_F(A,B) \ge 0$, $\forall A, B \in \mathcal{N}(X)$,
(S4) If $A \subseteq B \subseteq C$, then $S(A,B) \ge S(A,C)$ and it satisfies $S(B,C) \ge S(A,C)$.

Definition 5: ([10-11]) Let $A, B \in \mathcal{N}(X)$ in $X = \{x_1, x_2, \cdots, x_n\}$, then a measure of similarity between A and B is calculated by $S(A,B) = (S_T(A,B), S_I(A,B), S_F(A,B))$, where $S_T(A,B)$ is the degree of similarity of truthfulness, $S_I(A,B)$ is the degree of similarity of indeterminacy, and $S_F(A,B)$ is the degree of similarity of falsity. The

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formulas for similarity are the following:

$$S_T(A,B) = \left(\sum_{i=1}^{n}\left[\frac{min\,(T_A(x_i),T_B(x_i))}{max\,(T_A(x_i),T_B(x_i))}\right]\right)/n \qquad (2a)$$

$$S_I(A,B) = 1 - \left(\sum_{i=1}^{n}\left[\frac{min\,(I_A(x_i),I_B(x_i))}{max\,(I_A(x_i),I_B(x_i))}\right]\right)/n \qquad (2b)$$

$$S_F(A,B) = 1 - \left(\sum_{i=1}^{n}\left[\frac{min\,(F_A(x_i),F_B(x_i))}{max\,(F_A(x_i),F_B(x_i))}\right]\right)/n \qquad (2C)$$

$\forall x_i \in X.$

Definition 6: ([9-10]) Suppose that for each $x_i \in X = \{x_1, x_2, \cdots, x_n\}$ a weight $w_i \in [0,1]$ is associated such that $\sum_{i=1}^{n} w_i = 1$. Let $A, B \in \mathcal{N}(X)$, then a weighted similarity measure between A and B is calculated by $S_w(A,B) = \left(S_w^T(A,B), S_w^I(A,B), S_w^F(A,B)\right)$, where $S_w^T(A,B)$ is the degree of similarity of truthfulness, $S_w^I(A,B)$ is the degree of similarity of indeterminacy, and $S_w^F(A,B)$is the degree of similarity of the falsehood. The formulas for similarity are the following:

$$S_w^T(A,B) = \sum_{i=1}^{n} w_i \left[\frac{min\,(T_A(x_i),T_B(x_i))}{max\,(T_A(x_i),T_B(x_i))}\right] \qquad (3a)$$

$$S_w^I(A,B) = 1 - \sum_{i=1}^{n} w_i \left[\frac{min\,(I_A(x_i),I_B(x_i))}{max\,(I_A(x_i),I_B(x_i))}\right] \qquad (3b)$$

$$S_w^F(A,B) = 1 - \sum_{i=1}^{n} w_i \left[\frac{min\,(F_A(x_i),F_B(x_i))}{max\,(F_A(x_i),F_B(x_i))}\right] \qquad (3c)$$

$\forall x_i \in X.$

Definition 7: ([9-10]) Let $A, B \in \mathcal{N}(X)$ in $X = \{x_1, x_2, \cdots, x_n\}$, then a measure of similarity between A and B is calculated by $L(A,B) = \left(L_T(A,B), L_I(A,B), L_F(A,B)\right)$, where $L_T(A,B)$ is the degree of similarity of truthfulness, $L_I(A,B)$ is the degree of similarity of indeterminacy, and $L_F(A,B)$ is the degree of similarity of falsity. The formulas for similarity are the following:

$$L_T(A,B) = 1 - \frac{\sum_{i=1}^{n}|T_A(x_i) - T_B(x_i)|}{\sum_{i=1}^{n}|T_A(x_i) + T_B(x_i)|} \qquad (4a)$$

$$L_I(A,B) = \frac{\sum_{i=1}^{n}|I_A(x_i) - I_B(x_i)|}{\sum_{i=1}^{n}|I_A(x_i) + I_B(x_i)|} \qquad (4b)$$

$$L_F(A,B) = \frac{\sum_{i=1}^{n}|F_A(x_i) - F_B(x_i)|}{\sum_{i=1}^{n}|F_A(x_i) + F_B(x_i)|} \qquad (4c)$$

$\forall x_i \in X.$

Definition 8: ([10-11]) Let $A, B \in \mathcal{N}(X)$ in $X = \{x_1, x_2, \cdots, x_n\}$, then a measure of similarity between A and B is calculated by $M(A,B) = \left(M_T(A,B), M_I(A,B), M_F(A,B)\right)$, where $M_T(A,B)$ is the degree of similarity of truthfulness, $M_I(A,B)$ is the degree of similarity of indeterminacy, and $M_F(A,B)$ is the degree of similarity of falsity. The formulas for similarity are the following:

$$M_T(A,B) = \frac{1}{n}\sum_{i=1}^{n}\left(1 - \frac{|T_A(x_i) - T_B(x_i)|}{2}\right) \qquad (5a)$$

$$M_I(A,B) = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{|I_A(x_i) - I_B(x_i)|}{2}\right) \qquad (5b)$$

$$M_F(A,B) = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{|F_A(x_i) - F_B(x_i)|}{2}\right) \qquad (5c)$$

$\forall x_i \in X.$

Definition 9: ([10-11]) Let $A, B \in \mathcal{N}(X)$ where $X = \{x_1, x_2, \cdots, x_n\}$, then a measure of similarity based on the distance between A and B is calculated by:

$$S^1(A,B) = \frac{1}{1 + d(A,B)} \qquad (6)$$

Such that $d(A,B)$ is a distance function between the two single-valued neutrosophic sets.

Let us recall that the distance function satisfies the following axioms $\forall A, B, C \in \mathcal{N}(X)$:

(1) $d(A,B) \geq 0$ and $d(A,B) = 0$ if and only if $A = B$,

(2) $d(A,B) = d(B,A)$,

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(3) $$d(A,C) \leq d(A,B) + d(B,C).$$

3. Results

First, we establish the similarity formula that we use in data processing. We start with the generalized Triple Refined Indeterminate Neutrosophic weighted distance with the help of Equation 1. $\lambda = 1,2$ are the two values that define the Hamming and Euclidean distances, respectively.
We define the neutrosophic similarity on the TRINS using formula 6 combined with the distance in (1).
To collect the data, 94 attorneys in private practice registered with the Ambato Forum and the Bar Association of Tungurahua were selected.
The survey must be evaluated for each question for each of the possible evaluations on a scale of 0-5 as shown in Figure 1. 0 indicates that the given evaluation grade is not accepted and 5 means the maximum grade for such evaluation, this step must be done on every possible evaluation. Figure 2 shows an example to rely on.

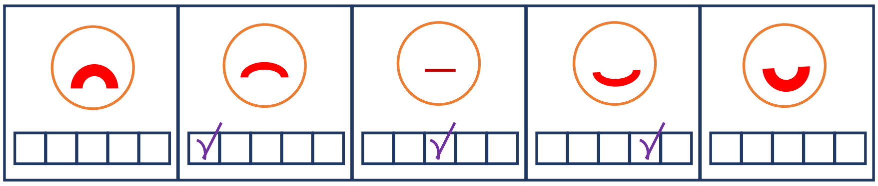

Figure 1: Example of the graphic use of the proposed Indeterminate Likert Scale.

The illustration in Figure 1 demonstrates the respondent's varied level of agreement, with a rating of 0 for both "strongly disagree" and "strongly agree," a 1 for "disagree," a 3 for "neutral," and a 4 for "agree." This approach enhances the accuracy of reflecting the respondent's views, recognizing that reactions to statements often comprise a blend of agreement and disagreement levels rather than a single stance.The steps to follow are those:

1. Evaluate at all levels of opinion the degree of agreement-disagreement in the variable "Perceived Anomie in Traffic Injury Cases", This variable would measure the extent to which respondents feel there is a breakdown of social norms and a state of normlessness due to the lack of legislation for traffic injuries causing minimal disability.
2. Evaluate at all levels of the opinion of the degree of agreement-disagreement about Perceived Legal Protection and Judicial Security.This variable would gauge respondents' opinions on how well the current legal system upholds the principle of legality and ensures judicial security, particularly concerning victims' rights in minimal disability traffic injury cases.
3. Each grade selected for each agreement-disagreement is associated with a value of 0.2. In the example in Figure 2, it is true that "Strongly disagree" has a value of $0(0.2) = 0$, "Disagree" has a value of $1(0.2) = 0.2$, "Neutral" is $3(0.2) = 0.6$, and so on. Finally, in the example, we have a TRINS equal to $(0,0.2,0.6,0.8,0)$.
4. Each of the 94 lawyer is consulted about their opinion. The data is collected and converted into the form of TRINS. Let $C(X)$ be the TRINS on "Activity cost" and $M(X)$ denotes the TRINS on "Financial management", for each of the respondents $X = \{x_1, x_2, \dots, x_{141}\}$.
5. It is calculated $d_2(C, M)$ (Equation 1) with $\omega_i = \frac{1}{94}\ \forall x_i \in X$, and then the degree of similarity (Equation 6). This last index is the one required to determine the relationship between one variable and another.

Figures 3 and 4 contain the bar graphs with the degree of satisfaction-dissatisfaction for each of the two variables.

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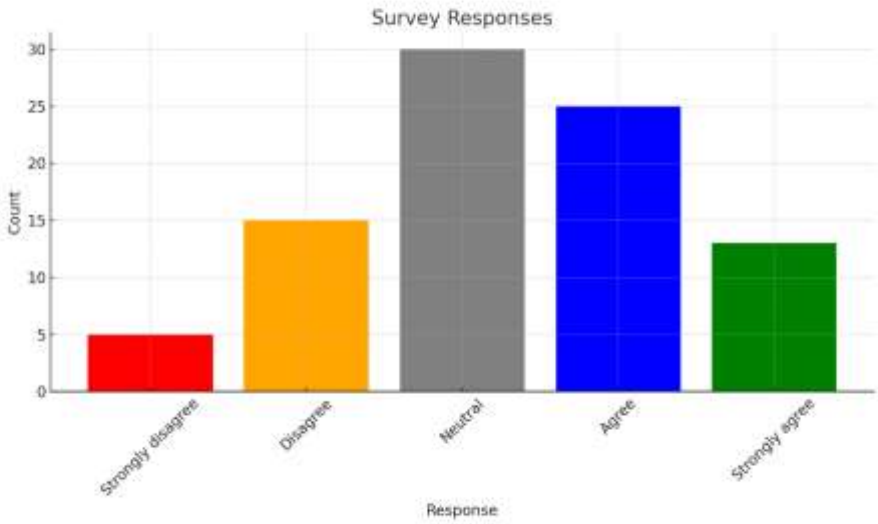

Figure 2: Bar chart on the degree of agreement-disagreement regarding "Adequate cost for activities" in percentage.

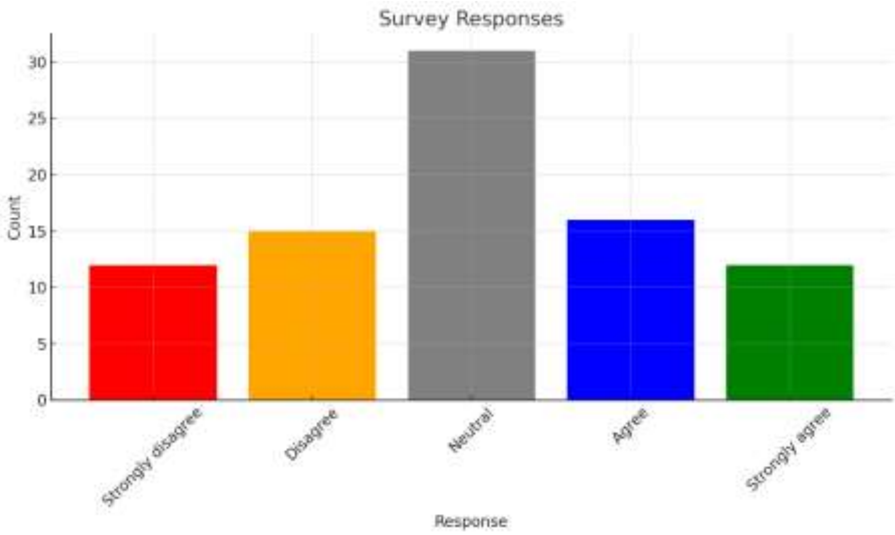

Figure 3: Bar chart on the degree of agreement-disagreement regarding "Appropriate financial management" in percentage.

The graphs in Figures 2 and3 do not add up to 100% of the respondents. This is because the percentage of each of the opinions is calculated in terms of what each respondent thinks, who may have contradictory opinions when $T_A(x_i) + I_{T_A}(x_i) + I_A(x_i) + I_{F_A}(x_i) + F_A(x_i) > 1$.

Specifically, the degree of "Strongly agree" was calculated by $\sum_{i=1}^{94} T_A(x_i)$, the degree of "Agree" by $\sum_{i=1}^{94} I_{T_A}(x_i)$, the degree of "Neutral" by $\sum_{i=1}^{94} I_A(x_i)$, the degree of "Disagree" by $\sum_{i=1}^{94} I_{F_A}(x_i)$, and the degree of "Strongly disagree" by $\sum_{i=1}^{94} F_A(x_i)$.

Each of these values was divided by 94 and multiplied by 100 and this is how the percentages shown in both figures were obtained.

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We calculate the $d_2(C, M) = 0.391$This distance is a measure of dissimilarity; the smaller the distance, the more similar the two sets are. To convert this into a similarity measure, we use the function $S^1(C, M) = \frac{1}{1+0.391} = 0.719$.

In the context of measured variables, this implies that there is a strong relationship between them. In practical terms, this could mean that the responses measured by variables A and B are closely related, perhaps indicating that they are responses to similar stimuli or are measuring similar attitudes or perceptions [13]

Because the similarity measure is significantly higher than 0.5 (which we might consider as a threshold for average similarity), we can say that the relationship is above average. This indicates that any actions or interpretations based on one set of variables should be relevant to the other set as well, given their strong relationship.

6. Conclusion

This study has cast light on the nuanced perceptions surrounding traffic injury laws in Ecuador. Through the data collected, it is evident that there exists a significant perception of anomie with respect to traffic injury cases that result in minimal disability. This is indicative of a societal need for enhanced legislative frameworks that address these specific incidents more effectively. Moreover, the data reveal a palpable demand for bolstering the public's trust in legal protection and judicial security, particularly when it comes to upholding victims' rights in these cases.

The application of the Indeterminate Likert Scale, underpinned by triple refined indeterminate neutrosophic sets (TRINS), has allowed for a more refined and nuanced collection and interpretation of data. This methodology has proven effective in capturing the complex gradations of legal practitioners' opinions and the inherent uncertainties present in such subjective assessments.

The adoption of neutrosophic similarity measures has provided an innovative lens through which to assess the relationship between perceived anomie and perceived legal protection and judicial security. This approach has demonstrated that when dealing with indeterminate and complex concepts, traditional binary measurements fall short, thereby validating the efficacy of neutrosophic methods in legal sociological research.

Ultimately, the findings of this study underscore the need for ongoing reform and dialogue concerning Ecuador's traffic injury laws. There is a clear imperative to develop legal structures that not only address the current gaps in legislation but also restore and reinforce public confidence in the legal system's capacity to deliver justice, especially for the less grievous yet impactful traffic-related injuries. It is hoped that this research will contribute to informed policymaking and foster a more robust legal response to the realities of traffic injury cases in Ecuador.

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