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Legal Causal Reasoning. Cause-effect Analysis using a Neutrosophic Environment

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Abstract. Causal reasoning is implicit in all areas of human life, which is why it is strongly applied within the legal framework. This is valid in both criminal and civil proceedings. For the construction of legal causal models, moral reasoning and understanding of the subject are required. It is a process that implies subjectivity and neutrality. Therefore, it is intended to illustrate the usefulness of causal analysis techniques for decision-making in the dynamics of legal reasoning in a neutrosophic environment given the subjectivity of the process. For that purpose, the methods applicable to this research will be enunciated and will be illustrated in a case study. With the use of the Ishikawa Diagram, Pareto analysis, and Neutrosophic Cognitive Maps, we were able to establish the cause-effect tree as well as the main conclusions concerning legal causal reasoning applied to the increment of traffic accidents in Ecuador.

Keywords: legal causal reasoning, decision making, subjectivity, neutrosophic environment

1. Introduction

Detecting and reasoning with causal relationships are essential for daily life. For this reason, the concept of causality and its wide variety of phenomena occupies a central place in many areas of psychological knowledge: from the study of perception and learning, reasoning and judgment, to comparative studies of language, social cognition, and the research methodology. This may be affected by age since some authors affirm that adults show a type of reasoning guided by a different nature [1].

Two types of competencies come into play in adult causal inferences. These may serve common purposes but are different [1]:

- ✓ one, of the general domain that allows the identification of conditional probabilistic relationships between events and their updating based on the results of systematic interventions;
- ✓ another, metacognitive and highly sensitive to the context, which makes possible the representation of new information dissociated from the domain and previous knowledge.

The first arises early in childhood, the second does not, but appears spontaneously at some specific point during physical and mental development [1].

In general, it can be said that, in all reasoning, premises are the starting point of the inference and the foundation for the conclusion. The inferential process is responsible for the nexus between the two components. Inferential processes operate when questions are resolved by appealing to available information or knowledge. From the knowledge that one has regarding a certain problem situation, ideas can be related to each other, but for this, it is not enough to have all the necessary information to reach a valid conclusion [2].

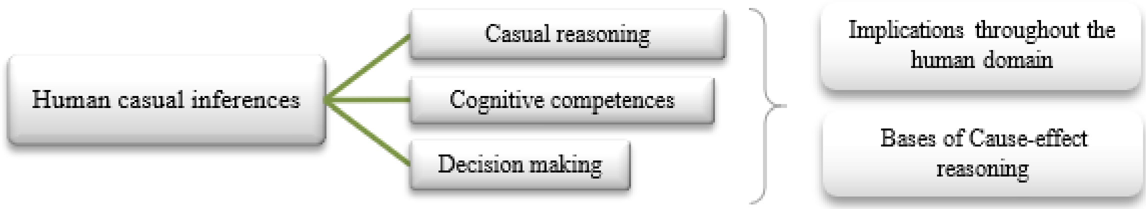

Figure 1: Adult causal inferences.

Causal reasoning is ubiquitous in law. This is valid in both criminal and civil proceedings. Thus, criminal offenses are analyzed in terms of two key elements: the action of the accused (criminal law) and the accused's mental state at the time of the action [3]. This is endorsed in what is stated by [4, 5]:

Legal reasoning is the ability to legally qualify facts that generate legal controversies to resolve them on legal-objective bases with legal, logical and rational validity. (p. 15). (...) To reason legally, then, is to build a solution or "solutions" or vehicles to conflicts that people are not capable of solving by themselves, in the application of rational bases solidly established by the legal system (p. 17)

Figure 2 illustrates the dependence of legal and moral reasoning on causal understanding and the relatively sophisticated use of counterfactual reasoning. The notion of causality is embedded in legal doctrine and also implicit in moral reasoning. Although it is said that it is not clear precisely what this notion of causality is equivalent to, how it relates to scientific or everyday conceptions of causality, and how it supports our legal and moral decisions. It can be argued that legal decisions should be consistent with moral judgments, and the latter is based on common sense principles [3].

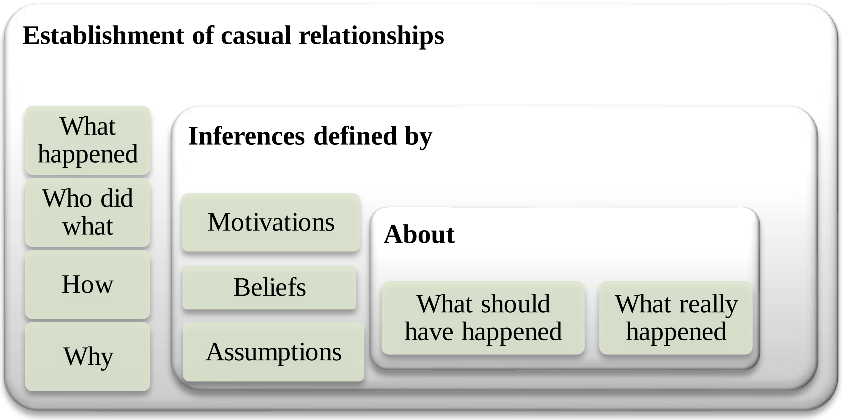

Figure 2: Construction of causal models for legal reasoning.

Legal casual analysis operates with two notions: factual and legal or proximate causation. They are supposed to work in two stages: initially, the factual causes of a case are identified; then one (or more) of them is selected as a legal cause. The separability of these steps has been questioned, both for theoretical reasons and in terms of the actual practice of first instance judges. But the conceptual distinction is standard in legal texts [3, 4]. Factual causation is assumed to correspond to what happened in the case, regardless of any legal assessment or judgment. Knowing this depends on the details of the case, the evidence and arguments presented, and everyday assumptions about how people and things work. These are complemented by expert knowledge (for example, in medical or scientific contexts). The standard test of causation is the test *but/for* which is defined as the action of the defender is a factual cause of the result. Which is essential for making a final decision [3].

There is no room for prejudices, stereotypes, or false generalizations in judicial work, since incurring them would imply an unacceptable error of appreciation [4]. However, this type of reasoning does have a high level of subjectivity implicit. For its management under uncertainty and for its objective of explaining why a particular conclusion is reached, causal models can be used. These models are very useful in making decisions under uncertainty and can be used to carry out evidential reasoning [6-8] as exposed by [4]:

Legal research can be divided into three distinct but interrelated phases:

1. Explanatory: What happened?
2. Evidential: What is the evidentiary support? Proof?
3. Attributive: Who or what is responsible?

Therefore, causal models are practical tools to understand these complex systems and establish causes to predict their effects. It can then be said that causal reasoning is useful in decision-making for two fundamental reasons: it is natural and easy to understand and it is convincing [6-8].

Due to its versatility in factor research, the Neutrosophic Cognitive Maps are used from the theory of Neutrosophy proposed by Florentin Smarandache. Neutrosophy is a useful theory that is increasing the inclusion of this theory enriches the possibilities of analysis, mainly due to two issues: the addition of the notion of indeterminacy and the possibility of calculating using linguistic terms [7, 8]. The decision to apply this technique lies in the fact that this represents knowledge through a directed graph. In which, the value in modulus of the value measures the strength between the relationship. Which will enrich the causal legal reasoning.

Based on the above, this article aims to illustrate the usefulness of causal analysis techniques for decision-making in the dynamics of legal reasoning in a neutrosophic environment given the subjectivity of the process.

For this, the methods applicable to this research will be enunciated and will be illustrated in a case study. From now on this article is made up of several sections with the explanation of the methods to be used, the presentation of the case study, and the demonstration of the main objective of the research. Finally, the discussion of the case and the conclusions reached based on the results obtained.

2 Methods

For the resolution of the problem, techniques of cause-effect analysis are used in a neutrosophic environment to illustrate its usefulness in legal reasoning. Due to which the notions of interest for this article are detailed below:

2.1 Tools for the analysis of causes

2.1.1 Ishikawa diagram

A Cause and Effect diagram represents various elements (causes) of a system that can contribute to a problem (effect). It was developed in 1943 by Professor Kaoru Ishikawa in Tokyo. It is sometimes called the Ishikawa or Fishbone Diagram. It is an effective tool for studying processes and situations and developing a data collection plan [9]. It is used to identify the possible causes of a specific problem. The graphical nature of the Diagram allows groups to organize large amounts of information about the problem and determine exactly the possible causes. Finally, the probability of identifying the main causes increases. The Cause and Effect Diagram should be used when people can answer “yes” to one or both of the following questions:

1. Is it necessary to identify the main causes of a problem?
2. Are there ideas and/or opinions about the causes of a problem?

Frequently, people closely associated with the problem under study have formed opinions about the causes of the problem. However, these opinions may conflict or fail to express the main cause. The use of a Cause and Effect Diagram makes it possible to bring all these ideas together for study from different points of view.

The development and use of Cause and Effect Diagrams are most effective after the process has been described and the problem is well defined. By that time, team members will have a good idea of what factors should be included in the Diagram. They can also be used for purposes other than root cause analysis. The format of the tool lends itself to planning. For example, a group could brainstorm the “causes” of a successful event, such as a seminar, conference, or wedding. As a result, they would produce a detailed list grouped into the main categories of things to do and include for a successful event.

Although this technique does not offer an answer to a question, as other tools such as Pareto Analysis and Histograms do, it is a vehicle to help teams have a common conception of a complex problem. For this, all its elements and relationships must be visible at any level of detail required.

2.1.2 Pareto analysis

Pareto diagram was presented in 1930 by Jurán in his Quality Control Manual based on what was described in 1909 by Vilfredo Pareto under the principle of "the few vital, the many trivial". This diagram is based on problem analysis and is used to present data, drawing attention to the causes of the greatest incidence in the problem at hand. Aims to determine 20% of the causes that provoke 80% of the problems [10, 11]. Its main advantages are:

- ✓ It allows focusing on the aspects whose improvement will have the most significant impact, thus optimizing efforts.
- ✓ Provides a quick and easy view of the relative importance of issues.
- ✓ It helps prevent some causes from getting worse by trying to fix other less significant ones.
- ✓ His graphical view of the analysis is easy to understand and encourages the team to continue with improvement.

The following algorithm is run to execute it:

a) Collect the data and tabulate it.
b) Calculate absolute and cumulative frequency, relative unit, and cumulative frequency.
c) Graph by locating all the causes along the coordinate axis ordered from highest to lowest incidence and correspond with their percentages along the ordinate axis. Finally, the cumulative polygonal line is constructed, and the causes that are up to 80% will be those with the highest incidence.

2.2 Neutrosophic Cognitive Maps

Starting from the previous elements, in this particular work, the use of Neutrosophic Cognitive Maps (NCMs) is proposed considering the advantages that this technique offers compared to other soft-computing techniques, in terms of interpretability, scalability, aggregation of knowledge, dynamism, and its ability to represent feedback and indeterminacy relationships [12-14]. NCMs were introduced by [15] in 2003. NCMs are an integration of the Fuzzy Cognitive Maps (FCMs) introduced by Kosko in 1986 and the Neutrosophic Sets (NSs) introduced by Smarandache in 1995 [16]. This technique overcomes the inability of traditional FCMs to represent indeterminacy. The inclusion of indeterminacy establishes that neutrality and ignorance are also forms of uncertainty[13, 17-25].

[16] exposes that FCMs constitute a technique that has received increasing attention due to its possibilities for representing causality. The following is a set of definitions necessary for working with NCMs. Firstly, let formally expose the original definition of neutrosophic logic as it is shown in [26].

Hence, the neutrosophic logic is a generalization of fuzzy logic, based on the concept of neutrosophy according to [27, 28].

Definition 1. (See [29, 30]) Let K be the ring of real numbers. The ring generated by K∪I is called a *neutrosophic ring* if it involves the indeterminacy factor in it, where I satisfies $I^2 = I$, I+I = 2I, and in general, I+I+...+I = nI, if k∈, then k.I = kI, 0I = 0. The neutrosophic ring is denoted by K (I), which is generated by K∪I, i.e., K(I) = <K∪I>, where <K∪I> denotes the ring generated by K and I.

Definition 2. A *neutrosophic matrix* is a matrix $A = [a_{ij}]_{ij}$ i =1, 2, …, m and j = 1, 2, …, n; m, n≥1, such that each a_{ij}∈K(I), where K(I) is a neutrosophic ring, see [31].

Let us observe that an element of the matrix can have the form a + bI, where "a" and "b" are real numbers, whereas I is the indeterminacy factor. Then, the usual operations of neutrosophic matrices can be extended from the classical matrix operations.

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

Additionally, a *neutrosophic graph* is a graph that has at least one indeterminate edge or one indeterminate node [26, 32]. The *neutrosophic adjacency matrix* is an extension of the adjacency matrix in classical graph theory. $a_{ij} = 0$ means nodes i and j are not connected, $a_{ij} = 1$ means that these nodes are connected and $a_{ij} = I$, which means the connection is indeterminate (unknown whether it is or not). Fuzzy set theory does not use such notions.

On the other hand, if the indetermination is introduced in a cognitive map as it is referred to in [33], then this cognitive map is called a *neutrosophic cognitive map*, which is especially useful in the representation of causal knowledge [27, 34]. It is formally defined in Definition 4.

Definition 3. A *Neutrosophic Cognitive Map* (NCM) is a neutrosophic directed graph with concepts like policies, events, among others, as nodes and causalities or indeterminacy as edges. It represents the causal relationship between concepts.

The measures described below are used in the proposed model, they are based on the absolute values of the adjacency matrix [33]:

- ✓ Outdegree (v_i) is the sum of the row elements in the neutrosophic adjacency matrix. It reflects the strength of the outgoing relationships (c_{ij}) of the variable.
$$od(v_i) = \sum_{i=1}^{n} c_{ij} \quad (1)$$
- ✓ Indegree (v_i) is the sum of the column elements. It reflects the strength of relations (c_{ij}) outgoing from the variable.
$$id(v_i) = \sum_{i=1}^{n} c_{ji} \quad (2)$$
- ✓ Total centrality (total degree $td\ (vi)$), is the sum of the indegree and the outdegree of the variable.
$$td(v_i) = od(v_i) + id(v_i) \quad (3)$$

The variables are classified according to the following criteria, see [35]:

a) The transmitting variables are those with od (vj)> 0 and id (vi) = 0.
b) The receiving variables are those with od (vj) = 0 and id (vi)> 0.
c) Ordinary variables satisfy both od (vj) ≠ 0 and id (vi) ≠ 0.

The static analysis is applied using the adjacency matrix, taking into consideration the absolute value of the weights [32]. Static analysis in Neutrosophic Cognitive Maps (NCM), see [34], initially contains the neutrosophic number of the form (a + bI, where I = indetermination) [36]. It requires a process of de-neutrosophication as proposed in [33], where I ∈ [0, 1] and it is replaced by their values maximum and minimum.

Finally, we work with the average of the extreme values, which is calculated using Equation 5, which is useful to obtain a single value as it is referred to in [37]. This value contributes to the identification of the characteristics to be attended, according to the factors obtained, for our case study.

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

Then,

$$A \succ B \Leftrightarrow \frac{a_1 + a_2}{2} > \frac{b_1 + b_2}{2} \quad (5)$$

3 Case study "Traffic Accidents"

The Ecuadorian present is threatened with the occurrence of traffic accidents, especially those that take human lives. Every year, about 1,200 people die as a result of a traffic accident. In this situation, young people are more exposed: most of their deaths in Ecuador are caused by traffic accidents. According to statistics, diseases, HIV, homicides, or suicide have lower death rates than traffic accidents. The figures correspond to the Births and Deaths report, prepared by the NISC (National Institute of Statistics and Censuses) [38-46]. This was the main cause for 19.2% of adolescents (10 to 19 years) to lose their lives, as well as 26.8% of young people (20 to 30 years). The report date back to 2018, the last year published by this institution on its website.

More than 300 thousand traffic accidents were registered in the last 10 years. Despite the restrictions due to the COVID-19 pandemic, traffic accident statistics are on the rise. An increase in the amount was perceived when several cantons went into the yellow phase and added about 500 car crashes between May and June in the canton of Guayas. On a national scale, the figures are similar. During April, one of the months with the greatest impact of the coronavirus in the coastal provinces, there were 512 traffic accidents in the country. In June the figure rose to 1,165.

According to the National Traffic Agency, the five leading causes of accidents are:

- ✓ Using the cell phone, watching video screens, or putting on makeup behind the wheel.
- ✓ Speeding.
- ✓ Failure to maintain a safe distance from the vehicle in front.
- ✓ Sudden lane changes.
- ✓ Do not walk through security zones.

Drivers are to blame for the majority of traffic accidents in Ecuador, according to NISC. The *inexperience and irresponsibility of the driver* with 49.6% is the first cause of accidents. It is followed by *speeding* (15.9%), *disrespect for traffic signs* (11.9%), *drunkenness* or *drugs* (7.5%), *bad crossing/invading lane* (6.2%), the *irresponsibility of the pedestrian* (4.5%), and *other causes* (4.3%).

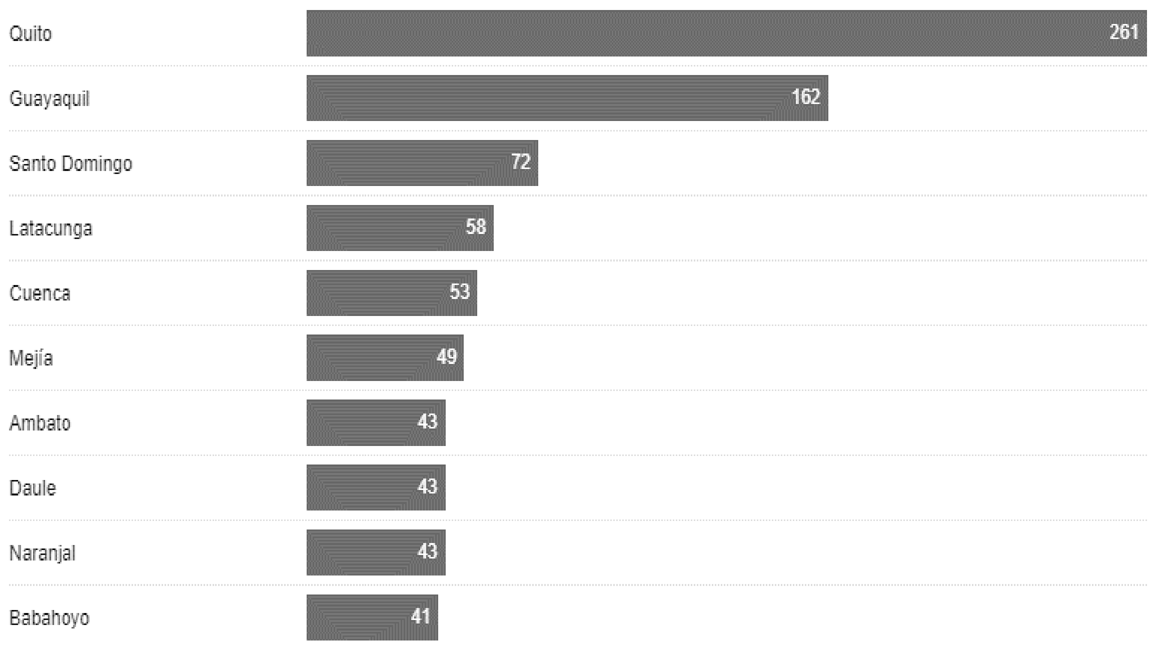

Figure 3: Cantons with the biggest number of deaths caused by traffic accidents. Source: [39]

In Ecuador, there are sanctions for offenders who commit these violations, but according to what the experts have stated, this does not prevent the causes, it only mitigates the occurrence of the event. In themselves, most take place due to the irresponsibility of the authors. An example of this is the provisions of article 106 of the Organic Law of Land and Road [47]: Traffic offenses are actions or omissions that, while being able to be foreseen, but not wanted by the perpetrator, are verified due to negligence, irresponsibility, or inexperience, or due to non-observance of the laws, regulations, resolutions and other traffic regulations. (p. 55)

4 Results

The methods described will be applied to direct the causal legal reasoning to the possible solution of the following problem: increase in traffic accidents in Ecuador.

4.1 Ishikawa diagram

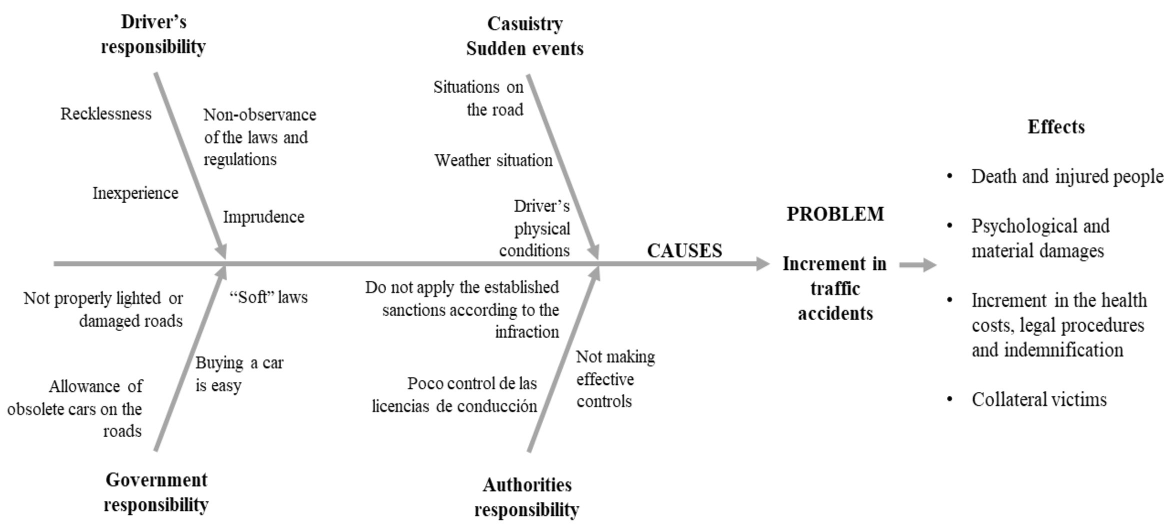

Figure 3: Ishikawa diagram and cause-effect tree.

4.2 Pareto analysis

To obtain the data, we searched for the statistical information of the accidents that occurred in the period analyzed in [40]. As can be seen in figure 4, the causes that provoke the highest level of incidence (83.33% accumulated frequency) are effective control (EC), vehicle acquisition (VA), license control (Lic), non-observance of the law (NL), negligence (N), inexperience (In), imprudence (Imp), *soft* application (SL) of the law as well as failure to punish drivers as established for the offense committed (NP).

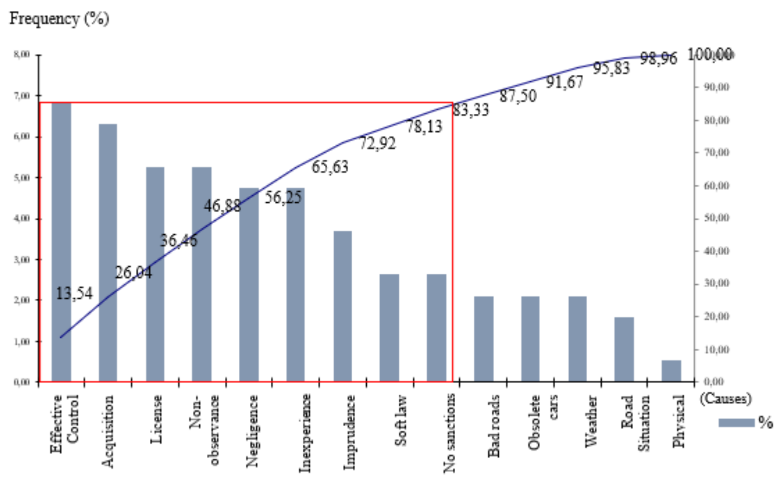

Figure 4: Pareto analysis.

4.3 Neutrosophic Cognitive Map

The causes that lead to 80% of the problems diagnosed through Pareto analysis will be chosen. To simplify its graphical representation, the following coding will be adopted for the nodes:

1. Effective control (EC)
2. Vehicle acquisition (VA)
3. Control over license (Lic)
4. Non-observance of the law (NL)
5. Negligence (N)
6. The inexperience (In)
7. Recklessness (Imp)
8. Soft law enforcement (SL)
9. Failure to punish drivers as established for the offense committed (NP)

For the construction of the map, a selection was made from a panel of experts made up of 3 lawyers, 2 traffic policemen, 4 young drivers. For the information processing, the resulting neutrosophic matrix and its centrality analysis were elaborated using equations 1-4. Figure 5 shows the network of nodes and their weights according to the previous calculations.

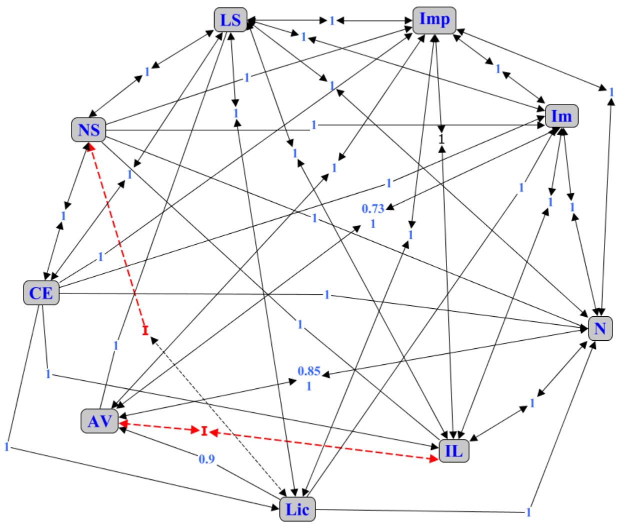

Figure 5: Neutrosophic cognitive map.

	CC	VA	Lic	NL	N	In	Imp	SL	NP
CC	0	0	1	1	1	1	1	1	1
VA	0	0	0	I	0.85	0.73	1	0	0
Lic	1	0.9	0	0	1	1	1	1	I
NL	0	I	0	0	1	1	1	1	0
N	0	1	0	1	0	1	1	1	0
In	0	1	0	1	1	0	1	1	0
Imp	0	1	1	1	1	1	0	1	0
SL	1	1	1	1	1	1	1	0	1
NP	1	1	1	1	1	1	1	1	0

Table 1: Neutrosophic adjacency matrix.

Equation 4 is used for de-neutrosophication and calculation of centrality.

Nodes	*od*	*id*	*td*	*Ranking*
EC	7	3	10	5
VA	2.58 + I	5.9 + I	5.24	9
Lic	5.9 + I	4	7.45	7
NL	4 + I	6 + I	6	8
N	5	7.85	12.85	3
In	5	7.73	12.73	4
Imp	6	8	14	2
SL	8	7	15	1
NP	8	2 + I	9.5	6

Table 2: Centrality analysis.

From the centrality analysis it can be observed that id = od ≠ 0; therefore it can be said that the nodes are all ordinary, that is, they are cause and effect at the same time. In such a way that they transmit information when they are activated as well as when they receive it. Which implies a causal phenomenon.

5 Legal causal reasoning of the case study

The type of traffic offense requires that the vehicle's driver has put the life or physical integrity of the people in concrete danger. Therefore, taking into consideration the information processed, it can be said that the imposition of severe penalties would mitigate the situation but should not be taken as the solution to the problem, since other causes are not related. The legislation should consider that for a person to obtain a driver's license they should have experience since it is not always a requirement. For prevention, a training system must be adopted from educational centers, in the future these students would-be drivers with sufficient basic knowledge.

Conclusion

- ✓ Causal reasoning is implicit in all areas of human life, which is why it is strongly applied within the legal framework. Due to its characteristics, it is very useful in decision-making.
- ✓ For the construction of legal causal models, moral reasoning and understanding of the subject are required. It is a process that implies subjectivity and neutrality. Therefore, it is convenient to study it using cause-effect analysis techniques in a neutrosophic environment. The usefulness of the tools is denoted.
- ✓ Traffic accident rates are high, especially in young people, and their causes are variable.
- ✓ Of the 14 causes determined as probable, according to the statistics consulted we determined that 9 of them are vital (83%) and 5 trivial (17%).
- ✓ The main causes determined by the experts and the legislation are the following: negligence, recklessness, inexperience, and casuistry. By their nature, the first three constitute a non-observance of the legislation. From them, in consideration of the criteria set forth and the processing using the neutrosophic technique, it can be said that there is the following hierarchical order:
  1. Soft law enforcement (SL)
  2. Imprudence (Imp)
  3. Negligence (N)
  4. The inexperience (In)
  5. Effective control (EC)
  6. Failure to punish drivers as established for the offense committed (NP)
  7. Control over license (Lic)
  8. Non-observance of the law (NL)
  9. Vehicle acquisition (VA)

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