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Neutrosophy Used to Measure the Legal and Socioeconomic Effect of Debtors

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Abstract: As a part of a bad economic planning, people sometimes have to declare themselves debtors. Debts are a legal effect that causes a socio-economic impact. The present work proposes a method to measure the legal and socioeconomic effect in debtors. The method operates based on Neutrosophic logic and user experience. We use the trapezoidal neutrosophic numbers to model the assessment of experts in four rules. The result is obtained using the inference system based on neutrosophic sets. A case study was implemented in the canton of Pastaza with the aim of measuring the socioeconomic legal effect from which we obtained a working tool for decision-making.

Keywords: legal and socioeconomic effect, single-valued trapezoidal neutrosophic number, neutrosophic inference, neutrosophic system.

1. Introduction

As a consequence of a low level in terms of financial culture, many people are declared as debtors. Debts entail facing a set of legal actions that can end with the auction of the assets or in the declaration of insolvency that generates legal and economic repercussions.

Insolvency is not only a judicial, but also social and obviously economic consequence, as a result of the lack of incomes. In Ecuador, an individual is declared insolvent when he/she incurs in the breach of an obligation or contract and is submitted to the jurisdictional decision, in which he/she is sentenced to pay the amount that he/she owed.

Insolvency has constituted one of the most imprecise legal concepts in its meaning, because it includes relatively heterogeneous meanings: equity insufficiency, inability to pay, lack of liquidity, over-indebtedness, assets less than liabilities, among others [1, 2].

Being insolvent represents a recurring feature linked to an economic situation in which a debtor finds himself/herself unable to satisfy his creditor, consequently causing an inability to pay. The moratorium causes an injury to the credit right with the consequent origin of a liability of the debtor.

In accounting or financial terms, it does not seem very difficult to determine who is solvent and who is not, since an arithmetically conclusive answer is obtained not in purely legal terms, since what is decisive is the capacity and the realization value of the assets [3, 4].

The declaration of insolvency is the consequence of the implementation of a judicial process that determines in sentence the payment of what is owed. The procedures established in this regard are contemplated in the General Organic Code of processes; these procedures can be ordinary and executive.

The procedure is considered as the action to proceed before the judicial authority by means of the respective demand to obtain effective judicial protection, being a system of actions or set of acts that include the orderly development of judicial proceedings [5-7].

The procedures used are the methods established by law to regulate the process. It is clear then that a *process* and a *procedure* are not the same thing because the process has several elements that make it up, according to our General Organic Code of Processes.

Insolvency has been approached in the scientific literature from different perspectives, affecting different sectors [8, 9]. The Constitution of Ecuador, in its article 168, states: "The administration of justice, in the fulfillment of its duties and in the exercise of its powers, will apply the following principles: The substantiation of the processes in all matters, instances, stages and procedures will be carried out through the oral system, in accordance with the principles of concentration and contradiction"[10-12].

Based on the aforementioned problems, this research defines a solution in which we propose a method to measure the legal and socioeconomic effect of debtors using neutrosophic logic. We use the trapezoidal neutrosophic numbers to model the assessment of experts in four rules. The result is obtained using the inference system based on neutrosophic sets. The advantage is that Neutrosophy is more accurate, but less determinate, than fuzzy logic. The case study, which consists of one enterprise's evaluation of Pastaza canton, in Ecuador, illustrates the applicability of the method.

The research is divided into the following sections: Materials and methods, where the main theoretical references of the research are presented and the inference process is described. Results and discussions present an example of the implementation of neutrosophic logic based on user experience to measure the legal and socioeconomic effect on debtors.

2. Materials and Methods

This section contains the main concepts of Neutrosophic sets and neutrosophic inference.

Neutrosophy is an evolution form Paradoxism, an international movement in science and art, founded by Florentin Smarandache in 1980s, based on excessive use of antitheses, oxymoron, contradictions, and paradoxes [13]. In 1995, the author extended the Paradoxism (based on opposites) to a new branch of philosophy called Neutrosophy (based on opposites and their neutral) that originated many scientific branches, such as: neutrosophic logic, neutrosophic set, neutrosophic probability and statistics, etc. [14].

Definition 1: [15, 16] The Neutrosophic set N is characterized by three membership functions, which are the truth-membership function TA, indeterminacy-membership function IA, and falsehood-membership function FA, where U is the Universe of Discourse and $\forall x \in U$, TA(x), IA(x),FA(x) $\subseteq]^-0, 1^+[$, and $^-0 \leq \inf$ TA(x)+ inf IA (x) + inf FA (x) $\leq$sup TA(x)+ sup IA (x) + sup FA (x)$\leq 3^+$.

Notice that according to the definition, TA(x), IA(x) and FA(x) are real standard or non-standard subsets of $]^-0, 1^+[$ and hence, TA(x), IA(x) and FA(x) can be subintervals of [0, 1].

Definition 2: [15, 16] The Single-Valued Neutrosophic Set (SVNS) N over U is A = {<x; TA(x), IA(x), FA(x)>: $x \in U$}, where TA:U$\rightarrow$[0, 1], IA:U$\rightarrow$[0, 1], and FA:U$\rightarrow$[0, 1], $0 \leq$TA(x) + IA(x) +FA(x) ≤ 3.

The *Single-Valued Neutrosophic number* (SVNN) is represented by N = (t, i, f), such that $0 \leq t, i, f \leq 1$ and $0 \leq t + i + f \leq 3$.

Definition 3: [15-18] The *single-valued trapezoidal neutrosophic number*,

$\tilde{a} = \langle (a_1, a_2.a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on $\mathbb{R}$, whose truth, indeterminacy and falsehood membership functions are defined as follows, respectively:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}}, & a_2 \leq x \leq a_3 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_3 \leq x \leq a_4 \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}, & a_2 \leq x \leq a_3 \\ \frac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_3 \leq x \leq a_4 \\ 1, & \text{otherwise} \end{cases} \quad (2)$$

$$F_{\tilde{a}}(x) = \quad (3)$$

$$\begin{cases} \dfrac{\left(a_2 - x + \gamma_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \le x \le a_2 \\ \gamma_{\tilde{a}}, & a_2 \le x \le a_3 \\ \dfrac{\left(x - a_2 + \gamma_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_3 \le x \le a_4 \\ 1, & \text{otherwise} \end{cases}$$

Where $\alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \in [0,1]$, $a_1, a_2, a_3, a_4 \in \mathbb{R}$ and $a_1 \le a_2 \le a_3 \le a_4$.

Definition 4: [15-18] Given $\tilde{a} = \langle (a_1, a_2, a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3, b_4); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued trapezoidal neutrosophic numbers and λ any non-null number in the real line. Then, the following operations are defined:

1. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
2. Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
3. Inversion: $\tilde{a}^{-1} = \langle ({a_4}^{-1}, {a_3}^{-1}, {a_2}^{-1}, {a_1}^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, where $a_1, a_2, a_3, a_4 \neq 0$.
4. Multiplication by a scalar number:

$$\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3, \lambda a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_4, \lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases}$$

5. Division of two trapezoidal neutrosophic numbers:

$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle \left(\frac{a_1}{b_4}, \frac{a_2}{b_3}, \frac{a_3}{b_2}, \frac{a_4}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 > 0 \ \textit{and} \ b_4 > 0 \\ \langle \left(\frac{a_4}{b_4}, \frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 < 0 \ \textit{and} \ b_4 > 0 \\ \langle \left(\frac{a_4}{b_1}, \frac{a_3}{b_2}, \frac{a_2}{b_3}, \frac{a_1}{b_4}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, a_4 < 0 \ \textit{and} \ b_4 < 0 \end{cases}$$

6. Multiplication of two trapezoidal neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle (a_1 b_1, a_2 b_2, a_3 b_3, a_4 b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 > 0 \ \textit{and} \ b_4 > 0 \\ \langle (a_1 b_4, a_2 b_3, a_3 b_2, a_4 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 < 0 \ \textit{and} \ b_4 > 0 \\ \langle (a_4 b_4, a_3 b_3, a_2 b_2, a_1 b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle, & a_4 < 0 \ \textit{and} \ b_4 < 0 \end{cases}$$

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

Definitions 3 and 4 refer to *single-valued triangular neutrosophic number* when the condition $a_2 = a_3$ holds, [19-21].

Neutrosophic numbers are defined as: be $N = \{(T, I, F) : T, I, F \subseteq [0, 1]\}$, a neutrosophic valuation is a mapping of a group of formulas proportional to N, this is that for every sentence p have:

$$v\ (p) = (T, I, F) \tag{4}$$

With the purpose of facilitating the practical application to decision-making and engineering problems, the proposal of the Single-Valued Neutrosophic Set was made (SVN) [22],[23],[24], which allow the use of linguistic variables [25-27] increasing the way of interpreting the recommendation models and the use of indeterminacy.

Definition 5. The *Neutrosophic Logic* (NL) is the generalization of the fuzzy logic, where a logical proposition P is characterized by three components:

$$NL(P) = (T,I,F) \tag{5}$$

Where the neutrosophic component T is the degree of truthfulness, F is the degree of falsehood, and I is the degree of indeterminacy ([6]).

Definition 6. Let (T_1, I_1, F_1) and (T_2, I_2, F_2) be elements of NL where the sum of the elements of the triplet is 1. The logical connectives of { $\neg$, $\wedge$, $\vee$ } can be defined in the following way:

$\neg(T_1,I_1,F_1) = (F_1,I_1,T_1)$

$(T_1,I_1,F_1) \wedge (T_2,I_2,F_2) = (T = \min\{T_1,T_2\}, I = 1 - (T+F), F= \max\{F_1,F_2\})$

$(T_1,I_1,F_1) \vee (T_2,I_2,F_2) = (T = \max \{T_1,T_2\}, I =1- (T + F), F = \min \{F_1,F_2\})$.

This Neutrosophic Logic is denoted by NL_1.

Definition 7. Suppose that A = (T_1,I_1,F_1) and that A → B = (T_2,I_2,F_2) in NL1. Then we can infer B with the values B = (T_3, I_3, F_3) where:

$T_3 = T_2$ if $T_2 > F_1$

$T_3 = 0$ if $F_1 \leq T_2$

$F_3 = F_2$ if $F_2 < T_1$

F3 = 0 if $F_2 \geq T_1$

$I_3 = 1 - T_3 - F_3$.

This inference rule is the *modus ponens rule* for NL1 (MPNL1).

The purpose of *de-neutrosophication* is to convert an ordinary neutrosophic set (a type-1 neutrosophic set) obtained by neutrosophic type reduction to a single real number which represents the real output. The de-neutrosophication process consists of three steps, see [12].

Step 1. Neutrosophic type reduction.

Given an interval neutrosophic set B with $T_B(y)$, $I_B(y)$; $F_B(y) \subseteq [0, 1]$, then, the neutrosophic type reduction transforms each interval into one number, see Equations 6, 7 and 8.

$$T'_B(y) = \frac{(\inf T_B(y) + \sup T_B(y))}{2} \quad (6)$$

$$I'_B(y) = \frac{(\inf I_B(y) + \sup I_B(y))}{2} \quad (7)$$

$$F'_B(y) = \frac{(\inf F_B(y) + \sup F_B(y))}{2} \quad (8)$$

Step 2. *Synthesization*: It is the process to transform an ordinary neutrosophic set (a type-1 neutrosophic set) B into a fuzzy set B . It can be expressed using the following function:

$f(T'_B(y), I'_B(y), F'_B(y)): [0,1] \times [0,1] \times [0,1] \to [0,1]$, f can be defined as follows:

$$T''_B(y) = a * T'_B(y) + b * \left(1 - F'_B(y)\right) + c * \frac{I'_B(y)}{2} + d * \left(1 - \frac{I'_B(y)}{2}\right) \quad (9)$$

Where $0 \leq a, b, c, d \leq 1$ and $a + b + c + d = 1$.

The purpose of synthesization is to calculate the overall truth degree according to three components: truth-membership function, indeterminacy-membership function and falsehood-membership function. The component truth-membership function gives the direct information about the truth-degree, so it is directly used in the formula. The component falsehood-membership function gives the indirect information about the truth-degree, so (1-F) is used in the formula.

Step 3. Calculation of a typical neutrosophic value: one of the methods of calculation is given, the *center of area*. This method is sometimes called the *center of gravity method* or *centroid method*, the *de-neutrosophicated value*, $dn(T_B(y))$ is calculated by the formula 10:

$$dn(T_B(y)) = \frac{\int_\alpha^\beta T_B(y) y dy}{\int_\alpha^\beta T_B(y) dy} \quad (10)$$

To model using SVNN allows to make calculations based on linguistic terms, see Table 1. This table contains the association of linguistic terms with SVNNs.

Linguistic term	**SVNN**
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0.15,0.20)
Good(G)	(0.70,0.25,0.30)
Medium good (MDG)	(0.60,0.35,0.40)
Medium(M)	(0.50,0.50,0.50)
Medium bad (MDB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Table 1: Linguistic terms applied in [13-14] associated with a SVNN.

3. Results

This section is devoted to expose the method of Neutrosophic logic used to measure the legal and socioeconomic effect of debtors. Finally, we provide the results of the case study.

To measure the legal and socioeconomic effect of debtors using neutrosophic logic, the scale defined in Table 2 will be taken as linguistic variables. These indicators are:

Ind_1: "Job stability"

Ind_2: "History of previous debts"

Ind_3: "Consistency in payments of previous debts".

The legal and socioeconomic evaluation of debtors is the output variable. It was defined that each of these input or output variables will have associated the labels of Low, Medium, High and Excellent. To assess the impact that linguistic labels have on the output variable, see Table 2.

Label	Impact	SVTNN
Low	Debts can be paid in several months	$\langle(-1, 0, 4, 5); 0.60, 0.35, 0.40\rangle$
Medium	Debts can be paid in one month	$\langle(4, 5, 6, 7); 0.80, 0.15, 0.20\rangle$
High	Debts can be paid in one week	$\langle(6, 7, 8, 9); 0.85, 0.10, 0.15\rangle$
Excellent	Debts can be paid immediately	$\langle(8, 9, 10, 11); 1.00, 1.00, 1.00\rangle$

Table 2. Impact of the input and output variable labels, and their associated SVTNNs.

Using the assessment of experts in the field, we defined the production rules. These rules guarantee that the evaluation of the legal and socioeconomic effect of debtors is always largely determined by the lowest evaluation obtained in the input indicators:

R1: IF Ind_1 is low AND Ind_2 is low AND Ind_3 is low, THEN "the legal and socioeconomic effect of debtors" is low.

R2: IF Ind_1 is medium AND Ind_2 is medium AND Ind_3 is medium, THEN the "legal and socioeconomic effect of debtors" is medium.

R3: IF Ind_1 is high AND Ind_2 is high AND Ind_3 is high, THEN "the legal and socioeconomic effect of debtors" is high.

R4: IF Ind_1 is excellent AND Ind_2 is excellent AND Ind_3 is excellent, THEN "the legal and socio-economic effect of debtors" is excellent.

Figure 1 shows the general scheme of neutrosophic logic to measure the legal and socio-economic effect in debtors.

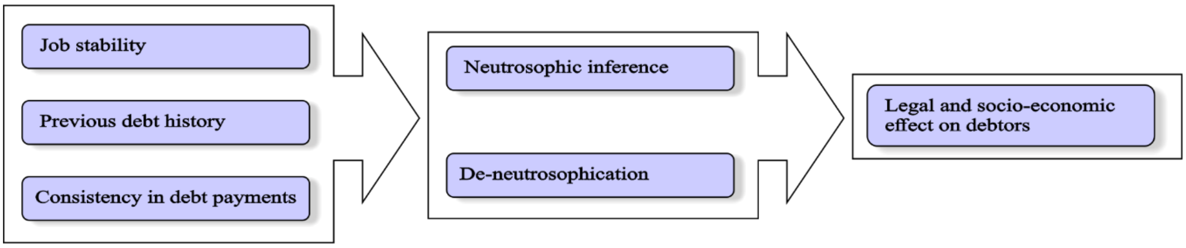

Figure 1. General scheme of the neutrosophic logic of the proposed method.

This is the algorithm for using the method:

1. The input values are the evaluation of x for the three indicators Ind_i (i = 1, 2, 3) using the linguistic scale in Table 1, then, the values of SVTNNs are associated, let us call them $\tilde{s}_1$, $\tilde{s}_2$, and $\tilde{s}_3$.
2. Apply the accuracy index of Equation 10, for each of the values $\tilde{s}_1$, $\tilde{s}_2$, and $\tilde{s}_3$.

$$A(\tilde{a}) = \frac{1}{16}[a_1 + a_2 + a_3 + a_4](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (11)$$

We call these crisp values as s_1, s_2, and s_3.

3. Evaluate s_1, s_2, and s_3 in the four rules, and apply the de-neutrosophication method, which consists in the following:

   3.1. Truncate for each rule R1, R2, R3, and R4, the SVTNNs according to the obtained values s_1, s_2, and s_3, as it is usual in fuzzy systems. Thus, new single-valued neutrosophic sets are obtained for the premises.

3.2. Apply the steps of a fuzzy system method (Mamdani fuzzy model, Sugeno fuzzy model, etc.) for each truthfulness, indeterminacy, and falseness, independently. The de-fuzzification step is not applied. Then, a neutrosophic set B is obtained.
3.3. Apply to B the de-neutrosophication algorithm previously described. The output is the evaluation of the evaluations using the four rules. It is crisp value, let us call it v.
3.4. The linguistic term is obtained evaluating v in SVTNN shown in Table 1, and associating it with the linguistic term where v is a maximum using formula 12.

$$S(\mathrm{T,I,F}) = \frac{1}{3}(2 + \mathrm{T} - \mathrm{I} - \mathrm{F}) \tag{12}$$

Where, T is the truth value of v, I is the indeterminate value and F is the false value, when v is evaluated in the SVTNN of Table 1.

To evaluate the results of the present investigation, an experiment will be carried out. The main objective of the experiment will be to demonstrate the applicability of neutrosophic logic based on user experience to measure the legal and socioeconomic effect on debtors. To do this, the process will be tested based on the location of the Pastaza canton. Once this process is completed, the results of the experimentation will be discussed.

One enterprise of the Pastaza canton, let us call it E, is evaluated in the three indicators, the results are shown in Table 3.

Linguistic Variables\Label	Low	Medium	High	Excellent
1- Job stability		X		
2- Previous debt history	X			
3- Consistency in payments of previous debts	X			

Table 3. Degrees of membership of input values to neutrosophic sets.

We obtained $s_1 = s_2 = 0.92500$, $s_3 = 3.3687$. After applying the proposed method we obtained v = 1.29816. Which is associated with the linguistic term Low, thus, the legal and socioeconomic effect of debtors of E is low.

Conclusions

The neutrosophic logic theory applied to perform the analysis and evaluation of the Socioeconomic and Legal Effect generates and delivers accurate data compared to other qualitative methods. This gives the main managers in charge of administrative and economic management the possibility of a better interpretation, free of other subjectivities. Once the research results have been analyzed, a method of evaluating the legal and socioeconomic effect is obtained, contributing to a tool for the analysis of the phenomenon using neutrosophic logic capable of quantifying the variable under study. Neutrosophic logic guarantees an alternative for the development of systems and tools that support business and administrative decision-making for the analysis of different phenomena.

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