# Using a neutrosophic model to evaluate website usability of a web portal for the commercial management of an advertising company

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**Abstract**. In the field of the development of Information Technology solutions, web applications are the most used tools for the businesses commercial management in their different scales. However, in the company "JM" Advertising, located in the city of Quevedo, Ecuador, does not have a digital medium in this regard, which supports the commercial management. That is, it does not have a digital catalog of products and services, nor orders online or online collections. In this context, web usability plays a key role in the process of developing successful websites. This paper proposes a methodology that allows the evaluation of the usability of two prototypes of web portals in the 'JM' advertising company. This methodology is applicable to other companies of similar functions. The methodology contains tools such as neutrosophic TOPSIS and neutrosophic AHP. Evaluation in the framework of neutrosophy incorporates the indeterminacy that is typical of decision-making processes, while the combination of AHP with TOPSIS allows us to take the advantages of both techniques.

**Keywords:** Publicity, website, neutrosophic AHP, neutrosophic TOPSIS

## 1 Introduction

In recent years, the World Wide Web has undergone major changes, especially since the appearance of Web 2.0 and Web 3.0, which in their elementary composition permits active interaction among users. For the business world this reality has also had new effects and types of participation, social networks are now the important means of disseminating Business Web Portals. However, this is the last step in promoting this virtual space.

In a company that sells goods, products and services, it is necessary to promote business management through the Web, with the construction of web portals that will allow worldwide dissemination of its offer in this increasingly competitive virtual world, but it is necessary to know and evaluate the effectiveness of incurring the expenses of the website.

In Ecuador, small and medium businesses are not yet inserted in the web, mainly in cities such as Quevedo where most businesses and companies do not yet have a presence in the virtual world, at least not in a professional and technical way.

For this reason, the contribution of this work is important, since it offers an easy, fast and flexible way to evaluate the usability of a web portal. The usability of a web portal refers to the ease with which people can use the web portal in order to achieve the proposed objective, see [1-5].

In the research conducted in the company "JM" Advertising, it is evident the lack of online facilities to attract new customers. The lack of communication and location channels wastes the opportunity to attract new customers. The increasing access to the web has made customers look for ways to order different products online, in the case of the advertising company "JM" Advertising despite having an efficient work team, in machinery, production and delivery management, customer s only have the opportunity to place their orders in the offices.

The advertising company "JM", is dedicated to graphic design, mainly of Gigantographies, related products and services, does not have a web portal, like other companies dedicated to the same business in Quevedo, hence one motivation of this work is to make a decision on two prototypes of websites for this company applying neutrosophic techniques.

Web portals are also known as websites. A website is a collection of internet pages related and common to an Internet domain or subdomain on the World Wide Web, it is a set of electronic hypertext documents (web pages) that compose and refer to a particular topic. Normally they are defined by a welcome page (home page), which will be the one that is initially displayed and from which the other pages can be accessed through links.

With its help users can generate and publish news, create taxonomies (classification systems) with which the administrator classifies content, insert logos or personalized or corporate images of the portal, add sections, manage user databases, etc. A content manager that currently has more than 30% of the network content is in WordPress. WordPress.com hosts content from newly initiated bloggers to companies such as Time, CNN and TechCrunch, around the world.

On the other hand, the plugin that helps managing the online store is Woocommerce, which is a plugin that allows users to create an online store. It is created exclusively for WordPress, so it maintains the same usage code, words and functionalities that users use to manage its blog.

Advertising is a form of commercial communication that attempts to increase the consumption of a product or service through the media and propaganda techniques. The main objective of advertising is to sell, achieve short-term results. The first thing the campaign should get is for the consumer to go to the store and buy. And it is perfectly possible to make selling campaigns that, in addition, work in the medium and long term by building the brand which in the future can and should be made invulnerable to the competition.

This research aims to design a methodology to determine the criteria and opinions that constitute the most important aspects to know the usability of the use of websites in the company 'JM' Advertising or in another similar company.

To evaluate the set of criteria surveyed in this selection problem, two techniques have been chosen: AHP and TOPSIS, see [1][6-7]. The first one is used to determine the weight of the importance that each of the attributes has, while the second one is used to determine an ordering of two alternatives in the usability evaluation. The idea of combining these two techniques is recommended in some papers, see [2][8-9]. The use of AHP guarantees a lower bias in decision making because the decision is considered consistent only when the Consistency Ratio (CR) is less than or equal to 10 percent ([3][6, 10-11]). On the other hand, TOPSIS guarantees the objectivity of the decision because it consists in ordering the alternatives based on how close to the ideal solution evaluations are and how far to the undesirable solution they are ([4][9]).

These techniques are combined in the framework of neutrosophy, which allows incorporating indeterminacy that exists in all decision making. A similar methodology was developed by Abdel-Basset et al. in [12] to evaluate supply chain alternatives, where a Neutrosophic ANP-TOPSIS method for decision-making is proposed. Other works propose techniques such as neutronophic TOPSIS and neutrosophic AHP, see [13-15].

This paper is divided as follows, Section 2 of Basic Concepts, is dedicated to briefly expose both, the techniques of neutrosophic AHP and neutrosophic TOPSIS. Section 3 is dedicated to expose the methodology that is proposed to evaluate the usability of two possible web portals of the products of the company 'JM' Advertising, located in the city of Quevedo, Ecuador, as well as the results of such evaluations. The last section is devoted to conclusions.

## 2 Basic Concepts

This section contains the main concepts necessaries to develop the methodology we propose in this paper. Subsection 2.1 describes the basis of Neutrosophic AHP, whereas Subsection 2.2 describes the Neutrosophic TOPSIS.

### 2.1 Neutrosophic AHP

AHP is a technique developed by Thomas Saaty in 1983, and is considered a technique that belongs to the multicriteria family, see [6]. This technique has some advantages; like that it decomposes a problem at different levels, proposing a structure for its solution. On the top the main objective to achieve is placed and in the lower levels the categories and subcategories of them are added, which represents one of the greatest advantages of the technique, since it allows solving complex problems. Another advantage, for what it is widely cited, is that it is based on the quantitative analysis of an assessments set expressed by means of a scale established by Saaty. Additionally, the Consistency Ratio is a measure of the group decision consistency degree.

On the other hand, the neutrosophic AHP technique was developed by Abdel-Basset et al. in [13], with the additional advantages that we cite below:

"Has the same advantages of classical AHP beside the following advantages:

- Provides user with a richer structure framework than the classical AHP, fuzzy AHP and intuitionistic fuzzy AHP.
- Describes the preference judgment values of the decision maker efficiently, handling vagueness and uncertainty over fuzzy AHP and intuitionistic fuzzy AHP because it consider three different grades "membership degree, indeterminacy degree and non-membership degree.

- Point out how to improve inconsistent judgments."

Firstly, neutrosophic AHP technique needs of some previous concepts, which we describe in the following:

**Definition 1**: The *neutrosophic set* N is characterized by three membership functions, which are the truth-membership function $T_A$, indeterminacy-membership function $I_A$, and falsity-membership function $F_A$, where U is the universe of discourse and $\forall x \in U$, $T_A(x)$, $I_A(x)$,$F_A(x) \subseteq ]^-0, 1^+[$, and $^-0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^+$.

See that according to the definition, $T_A(x)$, $I_A(x)$, and $F_A(x)$ are real standard or non-standard subsets of $]^-0, 1^+[$ and hence, $T_A(x)$, $I_A(x)$ and $F_A(x)$ can be subintervals of [0, 1].

**Definition 2**: ([13-14]) The *Single-Valued Neutrosophic Set* (SVNS) N over U is A = {<x; $T_A(x)$, $I_A(x)$, $F_A(x)$>: $x \in U$}[6], where $T_A:U \rightarrow [0, 1]$, $I_A:U \rightarrow [0, 1]$, and $F_A:U \rightarrow [0, 1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

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

**Definition 3:** ([13-14, 16-17]) The *single-valued triangular neutrosophic number*,

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

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

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

$$F_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \gamma_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \gamma_{\tilde{a}}, & x = a_2 \\ \frac{\left(x - a_2 + \gamma_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \text{otherwise} \end{cases} \quad (3)$$

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

**Definition 4**: ([16-17]) Given $\tilde{a} = \langle (a_1, a_2, a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued triangular neutrosophic numbers and λ any non null number in the real line. Then, the following operations are defined:

13. Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
14. Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_3, a_2 - b_2, a_3 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$
15. Inversion: $\tilde{a}^{-1} = \langle (a_3^{-1}, a_2^{-1}, a_1^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, where $a_1, a_2, a_3 \neq 0$.
16. Multiplication by a scalar number:
$$\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases}$$
17. Division of two triangular neutrosophic numbers:

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

18. Multiplication of two triangular neutrosophic numbers:

$$\tilde{a}\tilde{b} = \begin{cases} \langle(a_1b_1,a_2b_2,a_3b_3);\alpha_{\tilde{a}}\wedge\alpha_{\tilde{b}},\beta_{\tilde{a}}\vee\beta_{\tilde{b}},\gamma_{\tilde{a}}\vee\gamma_{\tilde{b}}\rangle, & a_3>0\ and\ b_3>0 \\ \langle(a_1b_3,a_2b_2,a_3b_1);\alpha_{\tilde{a}}\wedge\alpha_{\tilde{b}},\beta_{\tilde{a}}\vee\beta_{\tilde{b}},\gamma_{\tilde{a}}\vee\gamma_{\tilde{b}}\rangle, & a_3<0\ and\ b_3>0 \\ \langle(a_3b_3,a_2b_2,a_1b_1);\alpha_{\tilde{a}}\wedge\alpha_{\tilde{b}},\beta_{\tilde{a}}\vee\beta_{\tilde{b}},\gamma_{\tilde{a}}\vee\gamma_{\tilde{b}}\rangle, & a_3<0\ and\ b_3<0 \end{cases}$$

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

In the following we expose the AHP algorithm defined in [13].

**Step 1.** Decomposition:

The problem is formed hierarchically at various levels. The first level of hierarch represents the overall goal, the second level represents the decision criteria and sub-criteria and third level is composed of all possible alternatives.

**Step 2.** Comparative judgments with neutrosophic values:

After analyzing the complex multi-criteria decision making problem into three levels, the pair-wise comparisons is used to generate neutrosophic judgment matrix. The vagueness of decision makers is represented by triangular neutrosophic numbers $\tilde{a}_{ij}$, given in Table 1.

| Saaty scale | Definition | Neutrosophic Triangular Scale |
|---|---|---|
| 1 | Equally influential | $\tilde{1} = \langle(1,1,1);0.50,0.50,0.50\rangle$ |
| 3 | Slightly influential | $\tilde{3} = \langle(2,3,4);0.30,0.75,0.70\rangle$ |
| 5 | Strongly influential | $\tilde{5} = \langle(4,5,6);0.80,0.15,0.20\rangle$ |
| 7 | Very strongly influential | $\tilde{7} = \langle(6,7,8);0.90,0.10,0.10\rangle$ |
| 9 | Absolutely influential | $\tilde{9} = \langle(9,9,9);1.00,1.00,1.00\rangle$ |
| 2, 4, 6, 8 | Sporadic values between two close scales | $\tilde{2} = \langle(1,2,3);0.40,0.65,0.60\rangle$ |
| | | $\tilde{4} = \langle(3,4,5);0.60,0.35,0.40\rangle$ |
| | | $\tilde{6} = \langle(5,6,7);0.70,0.25,0.30\rangle$ |
| | | $\tilde{8} = \langle(7,8,9);0.85,0.10,0.15\rangle$ |

**Table 1**: Saaty's scale translated to a neutrosophic triangular scale.

Then construct the neutrosophic pair-wise comparison matrix such that:

$$\tilde{A} = \begin{bmatrix} \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \quad (4)$$

Where $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$.

**Step 3.** For calculating overall priority of each alternative and determine final ranking of all alternatives, we should first determine weights of each criterion from the corresponding pair-wise comparison matrix.

**Step 4.** To determine the weight of each criterion from corresponding neutrosophic pair-wise comparison matrix, we first transform neutrosophic pair-wise comparison matrix to numeric pair-wise comparison matrix, using the following equations:

Let $\tilde{a} = \langle(a_1,a_2,a_3);\alpha_{\tilde{a}},\beta_{\tilde{a}},\gamma_{\tilde{a}}\rangle$ be a single valued triangular neutrosophic number, then,

$$S(\tilde{a}) = \frac{1}{8}[a_1+a_2+a_3](2+\alpha_{\tilde{a}}-\beta_{\tilde{a}}-\gamma_{\tilde{a}}) \quad (5)$$

$$\mathbf{A}(\tilde{a}) = \frac{1}{8}[a_1+a_2+a_3](2+\alpha_{\tilde{a}}-\beta_{\tilde{a}}+\gamma_{\tilde{a}}) \quad (6)$$

They are called the score and accuracy degrees of $\tilde{a}_{ij}$, respectively. To get score and accuracy degree of $\tilde{a}_{ji}$ we use the following equations, respectively:

$$S(\tilde{a}_{ji}) = 1/S(\tilde{a}_{ij}) \quad (7)$$

$$\mathbf{A}(\tilde{a}_{ji}) = 1/\mathbf{A}(\tilde{a}_{ij}) \quad (8)$$

With compensation by score value of each triangular neutrosophic number in neutrosophic pair-wise comparison matrix, we have the following deterministic matrix:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (9)$$

From the previous matrix we can easily find a ranking of priorities, namely the Eigen Vector X as follows:

1. Normalize the column entries by dividing each entry by the sum of the column.
2. Take the totality row averages.

**Step 5.** To measure an inconsistency within the judgments in each comparison matrix and for the entire hierarch, AHP methodology provides a consistency index (CI). To discern if there is any inconsistency in neutrosophic judgment matrix, AHP utilizes consistency index and consistency ratio (CR). If CR is greater than 0.1, the judgments are untrustworthy because they are too near to randomness and the exercise is incorrect or must be repeated.

To calculate CI and CR do the following steps:

1. Calculate the eigenvalues of the matrix obtained in Step 4.
2. Let us call $\lambda_{max}$ the maximum eigenvalue.
3. Compute the consistency index(CI) as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (10)$$

where n is the number of items being compared.

4. Compute the consistency ratio, which is defined as:

$$CR = \frac{CI}{RI} \quad (11)$$

Where RI is the consistency index of a randomly generated pair-wise comparison matrix, according to Table 2.

| Order (n) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.52 | 0.89 | 1.11 | 1.25 | 1.35 | 1.40 | 1.45 | 1.49 |

**Table 2:** RI associated to every order.

**Step 6.** Calculate overall priority of each alternative and determine final ranking of all alternatives.

### 2.2 Neutrosophic TOPSIS

First of all we expose the definition of *Single Valued Neutrosophic Weighted Average Operator*.

Let $\{A_1, A_2, \ldots, A_n\}$ be a set of n SVNNs, where $A_j = (a_j, b_j, c_j)$ (j = 1, 2, …, n), then the *Single Valued Neutrosophic Weighted Average Operator* (SVNWAO) on the set is calculated with the following Equation ([15]):

$$\sum_{j=1}^{n} \lambda_j A_j = \left(1 - \prod_{j=1}^{n} (1 - a_j)^{\lambda_j}, \prod_{j=1}^{n} {b_j}^{\lambda_j}, \prod_{j=1}^{n} {c_j}^{\lambda_j}\right) \quad (12)$$

Where $\lambda_j$ is the weight of $A_j$, $\lambda_j \in [0, 1]$ and $\sum_{j=1}^{n} \lambda_j = 1$.

Let $A^* = (A_1^*, A_2^*, \cdots, A_n^*)$ be a vector of n SVNNs such that $A_j^* = (a_j^*, b_j^*, c_j^*)$ (j = 1, 2, …, n) and $B_i = (B_{i1}, B_{i2}, \cdots, B_{im})$ (i = 1, 2, …, m) are m vectors of n SVNNs such that $B_{ij} = (a_{ij}, b_{ij}, c_{ij})$ (i = 1, 2, …, m) (j = 1, 2, …, n). Then the *Separation Measure* between $B_i$s and $A^*$ is calculated by the following Equation:

$$s_i = \left(\frac{1}{3} \sum_{j=1}^{n} \left\{ (a_{ij} - a_j^*)^2 + (b_{ij} - b_j^*)^2 + (c_{ij} - c_j^*)^2 \right\}\right)^{\frac{1}{2}} \quad (13)$$

(i = 1,2,…, m).

The TOPSIS method for SVNNs consists of the following:

Let us assume that $A = \{\rho_1, \rho_2, \cdots, \rho_m\}$ is a set of alternatives and $G = \{\beta_1, \beta_2, \cdots, \beta_n\}$ is a set of criteria, the following steps will be carried out:

**Step 1:** Determine the weight of the experts.

For this, specialists evaluate according to the linguistic scale that appears in Table 3, and the calculations are made with their associated SVNN, let us call $A_t = (a_t, b_t, c_t)$ the SVNN corresponding to the $t^{th}$ decision maker ($t = 1, 2, \ldots, k$). The weight is calculated by the following formula:

$$\lambda_t = \frac{[illegible]}{[illegible]} \quad (14)$$

$\lambda_t \geq 0$ and $\sum_{t=1}^{k} \lambda_t$.

| Linguistic terms | SVNSs |
|---|---|
| Very important (VI) | (0.9, 0.1, 0.1) |
| Important (I) | (0.75,0.25,0.20) |
| Medium (M) | (0.50,0.50,0.50) |
| Unimportant (UI) | (0.35,0.75,0.80) |
| Very unimportant (VUI) | (0.10,0.90,0.90) |

**Table 3.** Importance weight as linguistic variables.

**Step 2:** Create the neutrosophic decision matrix of aggregated SVNNs.

This matrix is defined as $D = \sum_{t=1}^{k} \lambda_t D^t$, where $d_{ij} = (u_{ij}, r_{ij}, v_{ij})$ and it is used to aggregate all the individual assessments according to the terms given in Table 4.

| Linguistic terms | SVNSs |
|---|---|
| Extremely good (EG)/extremely high (EH) | (1,0,0) |
| Very very good (VVG)/very very high (VVH) | (0.9, 0.1, 0.1) |
| Very good (VG)/very high(VH) | (0.8,0.15,0.20) |
| Good (G)/high (H) | (0.70,0.25,0.30) |
| Medium good (MG)/medium high (MH) | (0.60,0.35,0.40) |
| Medium (M)/fair(F) | (0.50,0.50,0.50) |
| Medium bad (MB)/medium low(ML) | (0.40,0.65,0.60) |
| Bad (B)/low(L) | (0.30,0.75,0.70) |
| Very bad (VB)/very low (VL) | (0.20,0.85,0.80) |
| Very very bad (VVB)/very very low (VVL) | (0.10,0.90,0.90) |
| Extremely bad (EB)/extremely low (EL) | (0,1,1) |

**Table 4:** Linguistic terms used to provide the assessments

$d_{ij}$ is calculated as the aggregation of the evaluations given by each expert $(u_{ij}^t, r_{ij}^t, v_{ij}^t)$, using the weights $\lambda_t$ of each expert based on Equation 12.

In this way a matrix $D = (d_{ij})_{ij}$, is obtained, where each $d_{ij}$ is a SVNN ($i = 1,2,.., m$; $j = 1,2,\ldots, n$).

**Step 3:** Determination of the Criteria Weights.

Suppose that the weight of each criterion is given by $W = (w_1, w_2,\ldots, w_n)$, where $w_j$ denotes the relative importance of the criterion $\beta_j$, if $w_j^t = (a_j^t, b_j^t, c_j^t)$ is the evaluation of the criterion $\beta_j$ by the $t^{th}$ expert.

Then Equation 12 is used, to aggregate the $w_j^t$s with the weights $\lambda_t$.

**Step 4:** Construction of the neutrosophic decision matrix of the SVNWAO with respect to the criteria.

$D^* = D \otimes W$, where $d_{ij}^* = W_j \otimes d_{ij} = (a_{ij}, b_{ij}, c_{ij})$

**Step 5:** Calculation of the ideal SVNN positive and negative solutions.

The criteria can be classified as cost or benefit type.

Let $G_1$ be the set of criteria type benefits and $G_2$ the criteria type cost. The ideal alternatives will be defined as follows:

$$\rho^{+} = \left(a_{\rho^{+}w}(\beta_j), b_{\rho^{+}w}(\beta_j), c_{\rho^{+}w}(\beta_j)\right) \tag{15}$$

Denotes the positive ideal solution, corresponding to $G_1$.

$$\rho^{-} = \left(a_{\rho^{-}w}(\beta_j), b_{\rho^{-}w}(\beta_j), c_{\rho^{-}w}(\beta_j)\right) \tag{16}$$

Denotes the negative ideal solution, corresponding to $G_2$.

Where:

$$a_{\rho^{+}w}(\beta_j) = \begin{cases} \max_i a_{\rho_i w}(\beta_j), \text{if } j \in G_1 \\ \min_i a_{\rho_i w}(\beta_j), \text{if } j \in G_2 \end{cases}, b_{\rho^{+}w}(\beta_j) = \begin{cases} \max_i b_{\rho_i w}(\beta_j), \text{if } j \in G_1 \\ \min_i b_{\rho_i w}(\beta_j), \text{if } j \in G_2 \end{cases}, c_{\rho^{+}w}(\beta_j) = \begin{cases} \max_i c_{\rho_i w}(\beta_j), \text{if } j \in G_1 \\ \min_i c_{\rho_i w}(\beta_j), \text{if } j \in G_2 \end{cases}.$$

On the other hand, $a_{\rho^{-}w}(\beta_j) = \begin{cases} \min_i a_{\rho_i w}(\beta_j), \text{if } j \in G_1 \\ \max_i a_{\rho_i w}(\beta_j), \text{if } j \in G_2 \end{cases}$, $b_{\rho^{-}w}(\beta_j) = \begin{cases} \min_i b_{\rho_i w}(\beta_j), \text{if } j \in G_1 \\ \max_i b_{\rho_i w}(\beta_j), \text{if } j \in G_2 \end{cases}$, $c_{\rho^{-}w}(\beta_j) = \begin{cases} \min_i c_{\rho_i w}(\beta_j), \text{if } j \in G_1 \\ \max c_{\rho_i w}(\beta_j), \text{if } j \in G_2 \end{cases}$.

**Paso 6:** Calculation of distances to the positive and negative ideal SVNN solutions.

With the support of Equation 13, the following equations are calculated:

$$s_i^{+} = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^{+}\right)^2 + \left(b_{ij} - b_j^{+}\right)^2 + \left(c_{ij} - c_j^{+}\right)^2\right\}\right)^{\frac{1}{2}} \tag{17}$$

$$s_i^{-} = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^{-}\right)^2 + \left(b_{ij} - b_j^{-}\right)^2 + \left(c_{ij} - c_j^{-}\right)^2\right\}\right)^{\frac{1}{2}} \tag{18}$$

**Step 7:** Calculation of the *Closeness Coefficient* (CC).

The CC of each alternative is calculated with respect to the positive and negative ideal solutions.

$$\tilde{\rho}_j = \frac{s^{+}}{s^{+} + s^{-}} \tag{19}$$

Where $0 \leq \tilde{\rho}_j \leq 1$.

**Step 8:** Determination of the order of the alternatives.

## 3 Methodology for evaluating the usability of the portal web

### 3.1 Methodology

The criteria that will be considered in this paper to measure the web portal usability follow the rules that a usable web must fulfill, these are:

$C_1$. **Quick Charge**: This aspect is related to the time the portal pages are loaded. Pages should load in an average time of 4 seconds. A long wait can cause the user to cancel the visit to the site.

$C_2$. **Simplicity**: The portal should be as simple as possible; it should not force users to learn different paths or schemes for navigation in different parts of the site. The overwhelming use of animations should be avoided.

$C_3$. **Researchable**: The actual text must be accessible to search engines. The presence of graphics and programming codes are not taken into account by search engines and should be avoided as much as possible.

$C_4$. **For the Majority**: Sites must be used in any browser and computer. That is why the technical compatibility of the portal with any platform is needed. It is recommended to use plain and simple HTML.

$C_5$. **Updating**: An outdated site loses credibility that is why it must be periodically updated.

Apart from these criteria we add another one that summarizes several aspects in a single non-technical one of the web portal, we refer to it as *Aesthetics*, and this is the following:

$C_6$: It is comprehensible, novel, understandable, intelligent, and attractive.

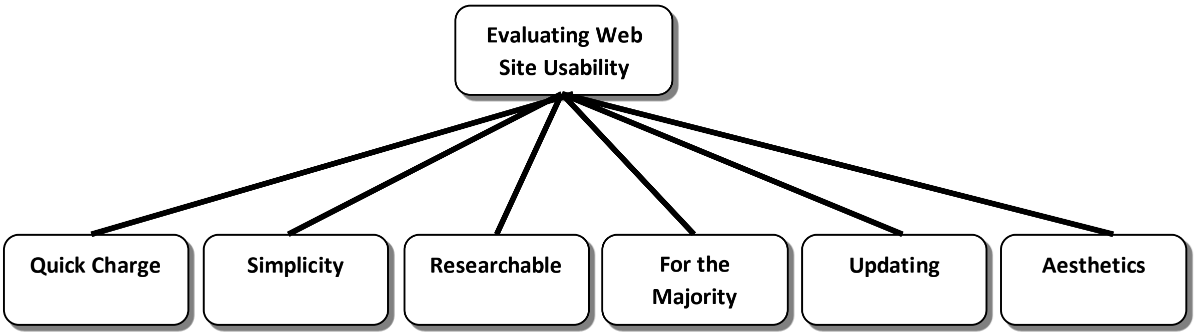


**Figure 1:** Hierarchical tree representing the criteria for evaluating web usability.

The algorithm that we propose to solve the problem of evaluating the usability of the web portal is the following:

1. The neutrosophic AHP technique is applied to the tree of Figure 1 to obtain the weights of criteria $C_1$, $C_2$, $C_3$, $C_4$, $C_5$, and $C_6$, which will be denoted by $w_1$, $w_2$, $w_3$, $w_4$, $w_5$, and $w_6$, respectively. To do this, one or more specialists must perform the evaluations.
2. Neutrosophic TOPSIS method with weights $w_1$, $w_2$, $w_3$, $w_4$, $w_5$, and $w_6$, is applied for each of the criteria. Evaluations can be carried out by advertising specialists, or experimentally with users' presence, or both of them.

## 2.2 The case 'JM' Company

To study the case of 'JM' Company, three specialists were hired who evaluated by consensus the preference by pairs of criteria $C_1$, $C_2$, $C_3$, $C_4$, $C_5$, and $C_6$ according to Table 1. The resulting matrix is given in Table 5.

| Criterion | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| $C_1$ | $\tilde{1}$ | $\tilde{3}$ | $\tilde{1}$ | $\tilde{1}$ | $\tilde{2}$ | $1/\tilde{5}$ |
| $C_2$ | $1/\tilde{3}$ | $\tilde{1}$ | $1/\tilde{3}$ | $\tilde{3}$ | $1/\tilde{3}$ | $1/\tilde{5}$ |
| $C_3$ | $\tilde{1}$ | $\tilde{3}$ | $\tilde{1}$ | $\tilde{1}$ | $\tilde{3}$ | $1/\tilde{5}$ |
| $C_4$ | $\tilde{1}$ | $1/\tilde{3}$ | $\tilde{1}$ | $\tilde{1}$ | $\tilde{1}$ | $1/\tilde{5}$ |
| $C_5$ | $1/\tilde{2}$ | $\tilde{3}$ | $1/\tilde{3}$ | $\tilde{1}$ | $\tilde{1}$ | $1/\tilde{5}$ |
| $C_6$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{5}$ | $\tilde{1}$ |

**Table 5**: The neutrosophic comparison matrix of usability criteria in 'JM' Company.

Table 6 contains the results of applying Formula 6 on the values of Table 5, to obtain crisps values.

| Criterion | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| $C_1$ | 1 | 2.5312 | 1 | 1 | 1.7625 | 0.18713 |
| $C_2$ | 0.39506 | 1 | 0.39506 | 2.5312 | 0.39506 | 0.18713 |
| $C_3$ | 1 | 2.5312 | 1 | 1 | 2.5312 | 0.18713 |
| $C_4$ | 1 | 0.39506 | 1 | 1 | 1 | 0.18713 |
| $C_5$ | 0.56738 | 2.5312 | 0.39506 | 1 | 1 | 0.18713 |
| $C_6$ | 5.3438 | 5.3438 | 5.3438 | 5.3438 | 5.3438 | 1 |

**Table 6**: Crisp values of the neutrosophic comparison matrix of usability criteria in 'JM' Company.

The matrix represented in Table 6 satisfies CR = 0.084139 <0.1, therefore the group evaluations are consistent. We used Octave 4.2.1 software for calculations, especially the *eig* function for eigenvalue calculation, see [18].

The obtained vector of weights is: $w = [0.120151, 0.083023, 0.130799, 0.084749, 0.090803, 0.490475\,]$.

Next we apply the neutrosophic TOPSIS method to determine the evaluation of the Company 'JM' in each of the previous criteria.

Two alternatives of websites prototypes are considered to evaluating, they are:

**$A_1$**: The website must be mainly designed using texts with a privileged position in search engines.

**$A_2$**: The website must be designed with graphics, animations and videos that show the work of the company, which appears in an intermediate position in the search engines.

The alternative of designing a visually very attractive web portal with a privileged position in search engines could entail a high cost to the enterprise, thus, this alternative is not considered.

The three experts gave their opinion on each of the alternatives. It was considered they have a weight expressed in linguistic terms as Very Important (VI), then the numerical weights of each of them is the same and equal to 1/3.

Tables 7-12 contain the evaluations of the three experts for each of the criteria.

| **Quick Charge** | | | |
|---|---|---|---|
| **Alternative** | **Expert 1** | **Expert 2** | **Expert 3** |
| $\mathbf{A_1}$ | VVH | EH | VVH |
| $\mathbf{A_2}$ | H | H | H |

**Table 7**: The ratings of the alternatives for Quick Charge

| **Simplicity** | | | |
|---|---|---|---|
| **Alternative** | **Expert 1** | **Expert 2** | **Expert 3** |
| $\mathbf{A_1}$ | VH | VH | VVH |
| $\mathbf{A_2}$ | F | MH | MH |

**Table 8**: The ratings of the alternatives for Simplicity

| **Researchable** | | | |
|---|---|---|---|
| **Alternative** | **Expert 1** | **Expert 2** | **Expert 3** |
| $\mathbf{A_1}$ | VVH | VH | VH |
| $\mathbf{A_2}$ | F | H | F |

**Table 9:** The ratings of the alternatives for Researchable

| **For the Majority** | | | |
|---|---|---|---|
| **Alternative** | **Expert 1** | **Expert 2** | **Expert 3** |
| $\mathbf{A_1}$ | VH | VVH | VVH |
| $\mathbf{A_2}$ | MH | MH | MH |

**Table 10**: The ratings of the alternatives for For the Majority

| **Updating** | | | |
|---|---|---|---|
| **Alternative** | **Expert 1** | **Expert 2** | **Expert 3** |
| $\mathbf{A_1}$ | MH | MH | F |
| $\mathbf{A_2}$ | VH | VH | VH |

**Table 11**: The ratings of the alternatives for Updating

| **Aesthetics** | | | |
|---|---|---|---|
| **Alternative** | **Expert 1** | **Expert 2** | **Expert 3** |
| $\mathbf{A_1}$ | L | F | L |
| $\mathbf{A_2}$ | VH | VVH | VH |

**Table 12**: The ratings of the alternatives for Aesthetics

Table 13 contains the Aggregated SVN decision matrix.

| | $\beta_1$ | $\beta_2$ | $\beta_3$ | $\beta_4$ | $\beta_5$ | $\beta_6$ |
|---|---|---|---|---|---|---|
| $\mathbf{A_1}$ | <1 , 0, 0> | <0.84, 0.13, 0.16> | <0.84, 0.13, 0.16> | <0.87, 0.11, 0.13> | <0.57, 0.39,0.43> | <0.37, 0.66, 0.63> |
| $\mathbf{A_2}$ | <0.7,0.25, 0.3> | <0.57, 0.39, 0.43> | <0.58, 0.40, 0.42> | <0.60, 0.30, 0.40> | <0.80, 0.15, 0.20> | <0.84, 0.13, 0.16> |

**Table 13**: Aggregated SVN decision matrix**.**

Table 14 contains the Aggregated weighted SVN decision matrix.

| | $\beta_1$ | $\beta_2$ | $\beta_3$ | $\beta_4$ | $\beta_5$ | $\beta_6$ |
|---|---|---|---|---|---|---|
| $\mathbf{A_1}$ | <0.12, 0.00, | <0.07, 0.01, 0.01> | <0.11, 0.02, 0.02> | <0.07, 0.01, 0.01> | <0.05, 0.04, 0.04> | <0.18, 0.32, 0.31> |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 0.00> | | | | | |
| **$A_2$** | <0.08, 0.03, 0.04> | <0.05, 0.03, 0.04> | <0.08, 0.05, 0.05> | <0.05, 0.03, 0.03> | <0.07, 0.01, 0.02> | <0.41, 0.06, 0.08> |

**Table 14**: Aggregated weighted SVN decision matrix**.**

Table 15 summarizes the SVN-PIS and SVN-NIS values, which are the positive ideal and negative ideal values.

| | SVN-PIS | SVN-NIS |
|---|---|---|
| $\beta_1$ | <0.12, 0.00, 0.00> | <0.08, 0.03, 0.04> |
| $\beta_2$ | <0.07, 0.01, 0.01> | <0.05, 0.03, 0.04> |
| $\beta_3$ | <0.11, 0.02, 0.02> | <0.08, 0.05, 0.05> |
| $\beta_4$ | <0.07, 0.01, 0.01> | <0.05, 0.03, 0.03> |
| $\beta_5$ | <0.07, 0.01, 0.02> | <0.05, 0.04, 0.04> |
| $\beta_6$ | <0.41, 0.06, 0.08> | <0.18, 0.32, 0.31> |

**Table 15**: SVN-PIS and SVN-NIS.

Table 16 contains the separation measures and the Closeness Coefficient of each alternative.

| **Alternative** | **$S^-$** | **$S^+$** | **CC** | **Ranking** |
|---|---|---|---|---|
| **$A_1$** | 0.056862 | 0.24159 | 0.80948 | 1 |
| **$A_2$** | 0.24159 | 0.056862 | 0.19052 | 2 |

**Table 16**: Separation measures and the Closeness Coefficient of each alternative.

Therefore, it is concluded that $A_1 \succ A_2$.

## Conclusion

This paper was dedicated to evaluating two prototypes of websites for the company 'JM', an advertising company from the city of Quevedo in Ecuador, based on the usability of web portals. Currently, this company does not advertise its products online. There were three experts who evaluated the alternatives, the evaluation tools used were neutrosophic AHP and neutrosophic TOPSIS. This combination guarantees consistency by the use of AHP and the objectivity of the decision by the use of TOPSIS. The framework of neutrosophy allows greater accuracy in the decision, because uncertainty is taken into account in the decision-making process and also indeterminacy. It was concluded that the best option is: "Design a website mainly containing texts with a privileged position in search engines" over "Design a website with graphics, animations and videos that show the work of the company, which appears in an intermediate position in the search engines". It is recommended to use this methodology to evaluate usability of websites of similar companies. Future work will concentrate in extenddong the proposal with new ways of handle vagueness and uncertainty of the initial information [25-30].

## References


[1] Conte, T., Massollar, J., Mendes, E., and Travassos, G. H.(2007) *Usability Evaluation Based on Web Design Perspectives* Paper presented at the First International Symposium on Empirical Software Engineering and Measurement, IEEE, 146-155.

[2] Molina, F., and Toval, A. (2009). Integrating usability requirements that can be evaluated in design time into Model Driven Engineering of Web Information Systems. *Advances in Engineering Software, 40*, 1306–1317.

[3] Mascheroni, M., Greiner, C., Petris, R., Dapozo, G., & Estayno, M. (2012). *Software quality and Usability Engineering (Calidad de software e Ingeniería de Usabilidad)(In Spanish)* Paper presented at the XIV Workshop de Investigadores en Ciencias de la Computación.

[4] Mascheroni, M., Greiner, C., Dapozo, G., and Estayno, M. (2013). *Automation of the evaluation of Software Usability (Automatización de la evaluación de la Usabilidad del Software)(In Spanish)*. Paper presented at the XV Workshop de Investigadores en Ciencias de la Computación.

[5] Perurena-Cancio, L., and Moráguez-Bergues, M. (2013). Usability of Web sites, methods and evaluation techniques (In Spanish). *Revista Cubana de Información en Ciencias de la Salud 24*(2), 176-194.

[6] Aczél, J. and Saaty, T. L. (1983). Procedures for Synthesizing Ratio Judgments. *Journal of Mathematical Psychology, 27*(1), 93-102.

[7] Ricardo, J.E., et al., *EL ASSESSMENT CENTER PARA LA EVALUACIÓN DE LAS COMPETENCIAS ADQUIRIDAS POR LOS ESTUDIANTES DE NIVEL SUPERIOR*. Investigación Operacional, 2019. **40**(5): p. 638-643

[8] Hwang, C. L. and Yoon, K. (1981). *Multiple attribute decision making – method and applications: a state-of-the-art survey*. New York: Springer-Verlag.

[9] Chakladar, N. D., and Chakraborty, S. (2008). A combined TOPSIS-AHP-method-based approach for non-traditional machining processes selection. *Journal of Engineering Manufacture 222*, 1613-1623.

[10] Collan, M., Fedrizzi, M., and Luukka, P. (2013). A multi-expert system for ranking patents: An approach based on fuzzy pay-off distributions and a TOPSIS–AHP framework. *Expert Systems with Applications, 40*, 4749–4759.

[11] Buckley, J. J. (1985). Fuzzy hierarchical analysis. *Fuzzy Sets and Systems, 17*, 233-247.

[12] Buckley, J. J., Feuring, T. and Hayashi, Y. (2001). Fuzzy hierarchical analysis revisited. *European Journal of Operational Research, 129*, 48-64.

[13] Abdel-Basset, M., Mohamed, M., and Smarandache, F. (2018). A Hybrid Neutrosophic Group ANP-TOPSIS Framework for Supplier Selection Problems. *Symmetry, 10*, 226.

*[14]* Abdel-Basset, M., Mohamed, M., Zhou, Y. and Hezam, I. (2017). Multi-criteria group decision making based on neutrosophic analytic hierarchy process. *Journal of Intelligent & Fuzzy Systems 33(6), 4055–4066*.

[15] Abdel-Basset, M., Mohamed, M. and Smarandache, F. (2018). An Extension of Neutrosophic AHP-SWOT Analysis for Strategic Planning and Decision-Making. *Symmetry, 10*(4), 116.

[16] Leyva-Vázquez, M., F. Smarandache, and J.E. Ricardo, *Artificial intelligence: challenges, perspectives and neutrosophy role.(Master Conference).* Dilemas Contemporáneos: Educación, Política y Valore, 2018. **6**(Special).

[17] Hernandez, N.B. and J.E. Ricardo, *Gestión empresarial y posmodernidad*. 2018: Infinite Study.

[18] VÁZQUEZ, M.L., N.B. HERNANDEZ, and F. SMARANDACHE, *MÉTODOS MULTICRITERIOS PARA DETERMINACIÓN DE LA EFECTIVIDAD DE LA GESTIÓN PÚBLICA Y EL ANÁLISIS DE LA TRASPARENCIA*. Infinite Study.

[19] Hernandez, N.B., M.B. Ruilova Cueva, and B.N. Mazacón, *Prospective analysis of public management scenarios modeled by the Fuzzy Delphi method.* Neutrosophic Sets and Systems, 2019. **26**(1): p. 17.

[20] Estupiñan Ricardo, J., et al., *Neutrosophic model to determine the degree of comprehension of higher education students in Ecuador.* Neutrosophic Sets & Systems, 2019. **26**.

[21] Şahin, R., and Yiğider, M. (2016) A Multi-criteria neutrosophic group decision making method based TOPSIS for supplier selection. *Applied Mathematics*, *10*(5), 1-10.

[22] Biswas, P., Pramanik, S. and Giri, B. C. (2016). Value and ambiguity index based ranking method of single-valued trapezoidal neutrosophic numbers and its application to multi-attribute decision making. *Neutrosophic Sets and Systems, 12*, 127-138.

[23] Abdel-Basset, M., Mohamed, M., Hussien, A. N. and Sangaiah, A. K. (2018). A novel group decision-making model based on triangular neutrosophic numbers. *Soft Computing, 22*(20), 6629-6643.

[24] Eaton, J. W., Bateman, D., Hauberg, S. and Wehbring, R. (2017). GNU Octave: A high-level interactive language for numerical computations version 4.2.1. Available at: http://www.gnu.org/software/octave/doc/interpreter.

[25] . I. Deli , Y. Şubaş, Some weighted geometric operators with SVTrN-numbers and their application to multi-criteria decision making problems, Journal of Intelligent & Fuzzy Systems, 32(1) (2017) 291-301, DOI:10.3233/JIFS-151677.

[26] İ. Deli, A novel defuzzificationmethod of SV-trapezoidal neutrosophic numbers and multi-attribute decision making: a comparative analysis, Soft Computing 23 (2019) 12529–12545.

[27] I. Deli , Y. Şubaş, A ranking method of single valued neutrosophic numbers and its applications to multiattribute decision making problems, International Journal of Machine Learning and Cybernetics, 8 (2017) 1309–1322. DOI: 10.1007/s13042-016-0505-3.

[28] İ. Deli, Some operators with IVGSVTrN-numbers and their applications to multiple criteria group decision making, Neutrosophic Sets and Systems, 25 (2019) 33-53.

[29] I. Deli, Operators on Single Valued Trapezoidal Neutrosophic Numbers and SVTN-Group Decision Making, neutrosophic set and system, 22 (2018) 131-151. f. İ. Deli, E.K. Öztürk, A defuzzification method on single-valued trapezoidal neutrosophic numbers and multiple attribute decision making, Cumhuriyet Sci. J., 41(1) (2020) 22-37

[30] İ. Deli, E.K. Öztürk, Neutrosophic Graph Theory and Algorithms, Chapter 10: Two Centroid Point for SVTN-Numbers and SVTrN-Numbers: SVN-MADM Method, IGI Global (Publisher), (2020) 279-307.

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