NSS Neutrosophic Sets and Systems
{Special Issue: Neutrosophic in Latin America, progress and perspectives}, Vol. 52, 2022
University of New Mexico

Application of Neutrosophy in the Study of the Factors that Influence Ecuadorian Tourism Development

Sharon Diznarda Álvarez Gómez[1], Ariel José Romero Fernández[2] and Manuel Ricardo Rivas Bravo[3]

[1] Universidad Regional Autónoma de los Andes, Matriz Ambato. Ecuador. E-mail: dirfinanciera@uniandes.edu.ec
[2] Universidad Regional Autónoma de los Andes, Matriz Ambato. Ecuador. E-mail: dir.investigacion@uniandes.edu.ec
[3] Universidad Regional Autónoma de los Andes, Matriz Ambato. Ecuador. E-mail: direcciontyg@uniandes.edu.ec

Abstract. Tourism worldwide is one of the most important sectors of the economy, taking into account the sources of employment it generates, as well as the growth of world GDP, which is why it occupies one of the main measures of sustainable development in the countries. Ecuador is one of the countries with the greatest biodiversity on the planet, and it has kept an increase in the arrival of tourists in recent years due to its natural wonders, which include visits to beaches, snow-capped mountains, and even excursions to jungle areas. It is worth mentioning that in all destinations you can appreciate biodiversity in all its splendor. The objective of this scientific paper is to carry out a study of the main factors that influence the development of Ecuador as a tourist destination. Two neutrosophic methods were used for this: (Neutrosophic AHP and DEMATEL) due to their versatility in decision-making and expert criteria processing. The conclusions reached indicate that the factors that need more attention are the prices in the tourist packages and the security of the tourist destination, its correct treatment will guarantee to turn Ecuador into a sustainable tourist destination.

Keywords: Tourism, Ecuador, Neutrosophy, AHP, DEMATEL.

1. Introduction

Ecuador is an important pillar in the tourist development of the Americas. The tourism sector has become a key structure that guarantees one of the four main foreign exchange contributions to the country's economic development. This situation motivates and drives a constant spirit of creativity, innovation, and entrepreneurship towards new ways and means of maintaining and improving this tourism development. It is a mega-diverse country and, without a doubt, one of the richest on the planet, thanks to its great contrasts; in its small territory, they combine four natural regions: Galapagos, Coast, Andes, and Amazon that offer an immensity of soils, climates, mountains, moors, beaches, islands and jungles that are home to thousands of species of flora and fauna [1, 2].

In its provinces, you can find 10,000 species of plants, 8,200 plant species, of which 2,725 belong to the group of orchids, 1,640 species of birds, 4,500 butterflies, 345 reptiles, 358 amphibians, and 258 mammals, etc. To preserve this natural wealth, Ecuador has a heritage of 49 State Protected Areas. UNESCO has recognized the natural wealth of the country, declaring the Marine Reserve, the Galapagos National Park, and the Sangay National Park as "Natural Heritage of Humanity" and cities such as Cuenca and Quito as World Heritage Sites.

One of the most important tourist attractions in the country is the Galapagos Islands, they are unique in the world because they have beautiful beaches and a spectacular climate where you can enjoy accommodation services, food and beverages, transportation, operation, brokerage, hot springs, spas, bowling alleys, skating rinks, racetracks and recreation centers, which allows national and international tourists to enjoy this wonderful place [3, 4]. In addition, it constitutes one of the largest, most complex, diverse, and best-preserved oceanic archipelagos in ecological terms that currently exist on the planet, it is considered the second largest marine reserve in the world behind the Australian Great Barrier Reef.

2 Neutrosophy

2.1 General aspects of neutrosophy

In this paper, Neutrosophy will be used as a calculation tool. Neutrosophy is the branch of philosophy that studies the origin, nature, and scope of neutralities. Logic and Neutrosophic Sets are generalizations of other theories, such as fuzzy sets, intuitionistic fuzzy sets, and interval-shaped fuzzy sets, among others [5].

The use of Neutrosophic Sets allows, in addition to the inclusion of membership functions of truth and falsehood, also membership functions of indeterminacy. This indeterminacy is due to the existence of contradictions, ignorance, and inconsistencies, among other causes due to lack of information, contradictory information, and inconsistent paradox, among others. Neutrosophic logic is a generalization of fuzzy logic based on the concept of Neutrosophy. A neutrosophic matrix, on the other hand, is a matrix where the elements a = (a_{ij}) have been replaced by elements in 〈R∪I〉, where 〈R∪I〉 is an integer neutrosophic ring.

On the other hand, the technique known as AHP (Analytic Hierarchy Process): is an easy-to-apply and effective method, which allows alternatives to be sorted, according to an order calculated from the evaluation of a group of experts. This evaluation is carried out using a scale where the relative relationships between criteria, sub-criteria, and finally the alternatives are evaluated.

Neutrosophic AHP has several advantages over classical AHP, for example, it presents the user with a richer structure framework than classical AHP, fuzzy AHP, and intuitionistic fuzzy AHP. It describes the expert's judgment values efficiently handling vagueness and uncertainty about the fuzzy AHP and the intuitionistic fuzzy AHP because it considers three different degrees: degree of membership, degree of indeterminacy, and degree of non-membership. Another advantage is that it is calculated from linguistic terms, which allows more natural communication with experts.

The method known as DEMATEL (DEcision MAking Trial and Evaluation Laboratory): especially the neutrosophic DEMATEL method, consists of the formation of matrices that include expert evaluations of the cause-effect relationship of a set of selected criteria or factors. The result is a graph where the importance as a cause and as an effect of each of the factors is measured. The neutrosophic DEMATEL includes calculus with neutrosophic sets.

The DEMATEL neutrosophic method allows studying complex cause-effect relationships, where indeterminacy and the use of linguistic terms will be included, which is the natural form of communication of human beings [6].

The objective of this paper is to carry out a study of the main factors that influence the development of Ecuador as a tourist destination. To do this, two neutrosophic methods will be used: (Neutrosophic AHP and Neutrosophic DEMATEL) due to their versatility in decision-making and expert criteria processing.

3 Materials and Methods

This section summarizes the definitions, theories, and methods that will be used to achieve the objective proposed. The techniques known as Neutrosophic AHP and Neutrosophic DEMATEL will be applied, for which it is necessary to start from the evaluation of a group of experts who will intervene in decision-making.

3.1 Neutrosophic AHP Saaty

In this paper, Neutrosophy will be used as a calculation tool. Neutrosophy is the branch of philosophy that studies the origin, nature, and scope of neutralities. Logic and neutrosophic sets constitute generalizations of other theories, such as fuzzy sets, intuitionistic fuzzy sets, and interval-shaped fuzzy sets, among others [5]. For the description of the method it is necessary to expose the following definitions:

Definition 1: ([7, 8]) 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≤inf TA(x)+ inf AI(x) + inf AF(x)≤sup TA(x)+ sup AI(x) + sup FA(x)≤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: ([7, 8]) The *Single-Valued Neutrosophic Set* (SVNS) N over U is A = {<x; AT(x), AI(x), FA(x)>: x∈U} c, where TA:U→[0, 1], AI:U→[0, 1], and FA:U→[0, 1], 0≤AT(x) + AI(x) +FA(x)≤3.

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

Definition 3: 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 ℝ, whose truth, indeterminacy, and falsehood membership functions are defined as follows, respectively:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \le x \le a_2 \\ \alpha_{\tilde{a}}, & a_2 \le x \le a_3 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_3 \le x \le a_4 \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}, & a_2 \leq x \leq a_3 \\ \frac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_3 \leq x \leq a_4 \\ 1, & \text{otherwise} \end{cases} \quad (3)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \gamma_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \gamma_{\tilde{a}}, & a_2 \leq x \leq a_3 \\ \frac{\left(x - a_2 + \gamma_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_3 \leq x \leq a_4 \\ 1, & \text{otherwise} \end{cases} \quad (4)$$

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 $a_1 \leq a_2 \leq a_3 \leq a_4$.

Definition 4: ([7-10]) 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: $\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$ (5)
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:

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

Definitions 3 and 4 refer to *single-valued triangular neutrosophic numbers* when the condition a2 = a3. For simplicity, we use the linguistic scale of triangular neutrosophic numbers, see Table 1 and also compare it with the scale defined in [11]. The Analytical Hierarchy Process was proposed by Thomas Saaty in 1980 [12], [23]. This technique models the problem that leads to the formation of a representative hierarchy of the associated decision-making scheme. The formulation of the decision-making problem in a hierarchical structure is the first and main stage. This stage is where the decision-maker must break down the problem into its relevant components [13], [22]. The hierarchy is constructed so that the elements are of the same order of magnitude and can be related to some of the next levels. In a typical hierarchy, the highest level locates the problem of decision-making. The elements that affect decision-making are represented at the intermediate level, the criteria occupying the intermediate level. At the lowest level, the decision options are understood. The levels of importance or weighting of the criteria are estimated using paired comparisons between them. This comparison is carried out using a scale, as expressed in equation (6) [14].

$$S = \left\{\frac{1}{9}, \frac{1}{7}, \frac{1}{5}, \frac{1}{3}, 1,3,5,7,9\right\} \quad (6)$$

In [11] is the theory of the AHP technique in a neutrosophic framework. Thus, we can model the indeterminacy of decision-making by applying Neutrosophic AHP or NAHP for short. Equation 7 contains a generic neutrosophic pair-wise comparison matrix for NAHP.

$$\tilde{A} = \left| \quad \vdots \quad \ddots \quad \vdots \quad \right| \quad (7)$$

The matrix must satisfy the condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, based on the inversion operator of Definition 4.

To convert neutrosophic triangular numbers into crisp numbers, there are two indexes defined in[11], they are the so-called score and accuracy indexes, respectively, see Equations 8 and 9:

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

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3]\left(2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}\right) \quad (9)$$

Saaty's 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.

Step 1 Select a group of experts.

Step 2 Structure the neutrosophic pair-wise comparison matrix of factors, sub-factors, and strategies, through the linguistic terms shown in Table 1.

The neutrosophic scale is attained according to expert opinions [15]. The neutrosophic pair-wise comparison matrix of factors, sub-factors, and strategies are as described in Equation 7.

Step 3 Check the consistency of experts' judgments.

If the pair-wise comparison matrix has a transitive relation, i.e., $a_{ik} = a_{ij}a_{jk}$ for all i,j, and k, then the comparison matrix is consistent, focusing only on the lower, median, and upper values of the triangular neutrosophic number of the comparison matrix.

Step 4 Calculate the weight of the factors from the neutrosophic pair-wise comparison matrix, by transforming it to a deterministic matrix using Equations 10 and 11. To get the score and the accuracy degree of $\tilde{a}_{ji}$ the following equations are used:

$$S(\tilde{a}_{ji}) = 1/S(\tilde{a}_{ij}) \tag{10}$$

$$A(\tilde{a}_{ji}) = 1/A(\tilde{a}_{ij}) \tag{11}$$

With compensation by the accuracy degree of each triangular neutrosophic number in the neutrosophic pair-wise comparison matrix, we derive the following deterministic matrix:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \tag{12}$$

Determine the ranking of priorities, namely the Eigen Vector X, from the previous matrix:

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

Note that Step 3 refers to considering the use of the calculus of the Consistency Index (CI) when applying this technique, which is a function depending on λ_{max}, the maximum eigenvalue of the matrix. Saaty establishes that consistency of the evaluations can be determined by equation $CI = \frac{\lambda_{max} - n}{n-1}$ [16], where n is the order of the matrix. In addition, the Consistency Ratio (CR) is defined by the equation CR = CI/RI, where RI is given in Table 2.

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

Table 2: RI associated with every order.

If CR≤0.1 it can be assumed that the experts' evaluation is sufficiently consistent and hence we can proceed to use NAHP. We apply this procedure to matrix A in Equation 12.

3.2 Neutrosophic DEMATEL

Definition 1 ([17]) Let X be a space of points (objects) with generic elements in X denoted by x. A single-valued neutrosophic set (SVNS) A in X is characterized by the truth-membership function TA (x), indeterminacy-membership function IA (x), and falsehood membership function FA (x). Then, an SVNS A can be denoted by A = {x, TA(x), IA(x), FA(x) x ∈ X}, where TA (x), IA (x), FA (x) ∈ [0, 1] for each point x in X. Therefore, the sum of TA (x), IA (x) and FA (x) satisfies the condition 0 ≤ TA (x) + IA(x) + FA(x) ≤ 3 [18, 28, 29, 30].

Definition 2 ([19]) Let $E_k = (T_k, I_k, F_k)$ be a neutrosophic number defined for the rating of k-th decision maker. Then, the weight of the k-th decision maker can be written as:

$$\psi_k = \frac{1-\sqrt{[(1-T_k(x))^2+(I_k(x))^2+(F(x))^2]/3}}{\sum_{k=1}^{p}\sqrt{[(1-T_k(x))^2+(I_k(x))^2+(F(x))^2]/3}} \quad (13)$$

Further, in achieving a favorable solution, group decision-making is important in any decision-making process. In the group decision-making process, all the individual decision-maker assessments need to be aggregated into one aggregated neutrosophic decision matrix. This can be done by using a single-valued neutrosophic weighted averaging (SVNWA) aggregation operator proposed by Ye [20], [27].

Definition 3 ([20]) Let $D^{(k)}=(d_{ij}^{(k)})_{mxn}$ be the single-valued neutrosophic decision matrix of the k-th decision maker and $\psi = (\psi_1 \psi_2, \dots, \psi_p)^T$ be the weight vector of decision maker such that each $\psi_k \in [0,1], D = (d_{ij})_{mxn}$ where

$$d_{ij} = \langle 1 - \prod_{k=1}^{p}\left(1 - T_{ij}^{(p)}\right)^{\psi_k}, \prod_{k=1}^{p}\left(I_{ij}^{(p)}\right)^{\psi_k}, \prod_{k=1}^{p}\left(F_{ij}^{(p)}\right)^{\psi_k}\rangle \quad (14)$$

Definition 4 ([19], [21]) Deneutrosophication of SVNS Ñ can be defined as a process of mapping Ñ into a single crisp output for $xf: Ñ \rightarrow \psi^* \in X$. If Ñ is discrete set then the vector of tetrads Ñ = {(x | TÑ(x), IÑ(x), FÑ(x)) | x ∈ X} is reduced to a single scalar quantity $\psi^* \in X$ by deneutrosophication. The obtained scalar quantity $\psi^* \in X$ best represents the aggregate distribution of three membership degrees of neutrosophic element TÑ (x), IÑ (x), FÑ (x). Therefore, deneutrosophication can be obtained as follows.

$$\psi^* = 1 - \sqrt{[(1-T_k(x))^2 + (I_k(x))^2 + (F(x))^2]/3} \quad (15)$$

Decision-making normally involves human language (commonly referred to as linguistic variables). A linguistic variable simply represents words or terms used in human language. Therefore, this linguistic variable approach is a convenient way for decision-makers to express their assessments. Ratings of criteria can be expressed by using linguistic variables such as very influent (VI), influent (I), low influent (LI), not influence (NI), etc. Linguistic variables can be transformed into SVNSs as shown in Table 1.

Integer	Linguistic variable	SVNNs
0	No influence / Not important	(0.1,0.8,0.9)
1	Low influence/important	(0.35,0.6,0.7)
2	Medium influence/important	(0.5,0.4,0.45)
3	High influence/important	(0.8,0.2,0.15)
4	Very high influence/important	(0.9,0.1,0.1)

Table 3: Linguistic variable and Single Valued Neutrosophic Numbers (SVNNs) [19].

DEMATEL (Decision Making Trial and Evaluation Laboratory) is a technique developed in 1972 by Fontela and Gabus at the Geneva Research Center of the Battelle Memorial Institute [18],[19], [24], [26]. Basically, the steps to apply DEMATEL in its neutrosophic variant are listed below using the steps outlined below and can be found in more detail at [17].

- Identify the factors or elements to be analyzed: Through the application of various information collection techniques, a universe of factors or elements of interest can be obtained to be evaluated by the selected method.
- Determine the relative importance of the experts: The group of experts selected for the analysis may have their own importance values according to different circumstances of interest, such as the level of experience and knowledge in the decision problem. In this sense, the weight of each decision-maker may be different from that of other decision-makers. The weight of each decision-maker is considered with linguistic variables and is transmitted in SVNN.
- Get individual evaluations from experts. The experts are then asked to evaluate the direct influence between the factors through paired comparisons, using the score shown in Table 1.
- Convert the linguistic evaluations given by the experts in SVNN: From the individual sharp integer matrices obtained from the evaluations of the experts, the individual neutrosophic matrices of the decision-makers are constructed according to what is indicated in Table 1.

- Obtain the initial direct relationship matrix: To obtain the initial direct relationship matrix that is in the form of sharp numbers, the neutrosophic matrices of the individual decision-makers must be added and deneutrosophicated.
- Identify cause-effect relationships between factors using the DEMATEL method: Based on the aggregate direct relationship matrix A obtained in step 4, the total relationship matrix T can be easily calculated using equations (4-6) as shown below [18], [25]:
-

$$D = A * S \quad (16)$$

where

$$S = \frac{1}{\max_{l \le i \le n} \sum_{j=1}^{n} a_{ij}} \quad (17)$$

And

$$T = D * (I * D) - 1 \quad (18)$$

I: is the identity matrix.

The values tij of the matrix T reflect the direct and indirect interdependence exerted by the row element i on the column element j. Indirect interdependence is that which an element i can exert on another j through third elements of the system. These indirect interdependencies emerge when matrix X is raised to successive powers.

Obtain the Causal Prominence-Relationship Diagram. In this step, the vectors R (sum of rows of T) and C (sum of columns of T) are first calculated. Next, on the horizontal axis of the causal diagram, the “Prominence” is defined as the vector $R + C$. This vector indicates the importance or relevance of each element of the system. The higher the value of $R + C$, the greater the prominence of the element. A high value of $R + C$ indicates that an element:

a) influences a lot on other elements,

b) receives a lot of influence from other elements,

c) influences and is influenced in a balanced way, so the sum of both concepts is high.

If $R + C$ is low, the element is of little "prominence" because both types of influence are low. On the vertical axis, the “Ratio” is defined as the RC vector. This vector establishes the net influence of each element. If $RC > 0$ indicates that the element influences more than it is influenced. This element would be the “cause” (influencer/driver) of influence. If $RC < 0$, it indicates that the element receives more influence than it emits, so it is considered an “effect” (influenced/receiver). Taking these values, a relationship map $(R + C, RC)$ can be created [20], [21].

4 Results and Discussion

In this section, the identification of factors that influence tourism development in Ecuador will be carried out, which are shown below:

1. Formality in tourist services (F1)
2. Adequate tourist promotion and diffusion (F2)
3. Appropriate basic services (F3)
4. The prices of tour packages (F4)
5. Security in the tourist destination (F5)
6. Natural or anthropogenic phenomena (F6)
7. Infrastructure in health services (F7)
8. Promotion of tourist culture (F8)
9. Competent staff with a high degree of knowledge (F9)
10. Tourist attractions offered by the destination (F10)

Once the different previous factors have been identified, the aforementioned techniques will be applied, as follows: with the AHP Neutrosophic method, the weights of the different influencing factors in Ecuadorian tourism development are determined.

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	$\hat{1}$	⟨(6,7,8);0.90,0.10,0.10⟩	(6,7,8);0.90,0.10,0.10⟩	⟨(6,7,8);0.90,0.10,0.10⟩	⟨(6,7,8);0.90,0.10,0.10⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(6,7,8);0.90,0.10,0.10⟩	⟨(6,7,8);0.90,0.10,0.10⟩	⟨(6,7,8);0.90,0.10,0.10⟩	⟨(6,7,8);0.90,0.10,0.10⟩
F2	1/⟨(6,7,8);0.90,0.10,0.10⟩	$\hat{1}$	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(4,5,6);0.80,0.15,0.20⟩

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F3	1/⟨(6,7,8);0.90,0.10,0.10⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1̂	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(2,3,4);0.30,0.75,0.70⟩
F4	1/⟨(6,7,8);0.90,0.10,0.10⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1̂	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(2,3,4);0.30,0.75,0.70⟩
F5	1/⟨(6,7,8);0.90,0.10,0.10⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(1,1,1);0.50,0.50,0.50⟩	1̂	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(2,3,4);0.30,0.75,0.70⟩	⟨(2,3,4);0.30,0.75,0.70⟩
F6	1/⟨(4,5,6);0.80,0.15,0.20⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1/⟨(1,1,1);0.50,0.50,0.50⟩	1/⟨(1,1,1);0.50,0.50,0.50⟩	1̂	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(1,1,1);0.50,0.50,0.50⟩
F7	1/⟨(6,7,8);0.90,0.10,0.10⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(1,1,1);0.50,0.50,0.50⟩	1̂	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(1,1,1);0.50,0.50,0.50⟩	⟨(1,1,1);0.50,0.50,0.50⟩
F8	1/⟨(6,7,8);0.90,0.10,0.10⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1/⟨(1,1,1);0.50,0.50,0.50⟩	1̂	⟨(4,5,6);0.80,0.15,0.20⟩	⟨(1,1,1);0.50,0.50,0.50⟩
F9	1/⟨(6,7,8);0.90,0.10,0.10⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(1,1,1);0.50,0.50,0.50⟩	1/⟨(1,1,1);0.50,0.50,0.50⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1̂	⟨(1,1,1);0.50,0.50,0.50⟩
F10	1/⟨(6,7,8);0.90,0.10,0.10⟩	1/⟨(4,5,6);0.80,0.15,0.20⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(2,3,4);0.30,0.75,0.70⟩	1/⟨(1,1,1);0.50,0.50,0.50⟩	1/⟨(1,1,1);0.50,0.50,0.50⟩	1/⟨(1,1,1);0.50,0.50,0.50⟩	1/⟨(1,1,1);0.50,0.50,0.50⟩	1̂

Table 4: Neutrosophic AHP paired matrix. Source: own elaboration.

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	Weight
F1	0.44	0.72	0.58	0.33	0.38	0.27	0.27	0.26	0.23	0.26	**0.34**
F2	0.06	0.10	0.19	0.23	0.27	0.14	0.19	0.19	0.16	0.21	**0.17**
F3	0.06	0.04	0.08	0.23	0.13	0.29	0.19	0.09	0.16	0.12	**0.14**
F4	0.08	0.02	0.01	0.04	0.05	0.05	0.09	0.09	0.08	0.12	**0.08**
F5	0.06	0.02	0.03	0.05	0.05	0.05	0.09	0.09	0.08	0.12	**0.08**
F6	0.09	0.04	0.01	0.05	0.05	0.05	0.03	0.17	0.03	0.04	**0.06**
F7	0.06	0.02	0.01	0.02	0.02	0.06	0.04	0.06	0.03	0.04	**0.03**
F8	0.06	0.02	0.03	0.02	0.02	0.01	0.04	0.03	0.16	0.04	**0.04**
F9	0.06	0.02	0.01	0.02	0.02	0.06	0.04	0.01	0.03	0.04	**0.03**
F10	0.06	0.02	0.03	0.02	0.02	0.02	0.04	0.04	0.03	0.04	**0.03**

Table 5: Determination of weights of the criteria applying the Neutrosophic AHP method

Criteria	AxWeights	Approximate eigenvalues
F1	4.97	13.10022024
F2	2.08	12.04701762
F3	1.55	11.42619663
F4	0.63	10.67475612
F5	0.66	10.88168554
F6	0.66	11.57857201
F7	0.35	10.09006268
F8	0.46	10.80851719
F9	0.32	10.74705897
F10	0.35	11.25772836
	Eigenvalue = 5.400855	

Table 6: Analysis of the consistency of the paired matrix

The analysis of the consistency of the method exposed that the most influential factors in the development of tourism in Ecuador are the formality in tourist services, mainly in lodging, since it is very common for natural persons to offer lodging services in which a part of their property, or they also offer shared rooms that were not agreed with the client, it is also evident in the intermediation through recruiters, to offer transportation or tourist guidance. Also, adequate dissemination and promotion of the benefits that the tourist destination has, since most of the clients are loyal through social networks, making the client fall in love through the internet ensures an excellent tourist season.

Other important factors are having appropriate services for the population, bearing in mind that if these services are insufficient, not only the population is affected, but also the tourists, since all services are aimed at them, and when there are inconveniences with respect to these services, tourist demand weakens, the price of tourist packages, since it is very important to know what services the reservation includes if the package is all-inclusive, how many services are integrated into the package, etc. since they mark consumption decisions. The security of the destination and that foreigners like to explore and walk through the streets of the city when there are murders that intimidate tourists who prefer to stay in the hotel or simply not return to the country.

After selecting the five most important factors, it is decided to apply the DEMATEL method, it is carried out with the help of five decision-makers involved in providing the evaluation of the indicated factors. They were asked to choose an integer from 0 to 4 that represented the degree of influence of one factor on another factor. The data obtained is analyzed, for which, firstly, the evaluation matrices of each of the decision-makers are obtained. Tables 7, 8, 9, 10, and 11 show the comparison matrices for pairs of criteria according to the evaluations issued by Experts 1, 2, 3, 4, and 5, respectively. Table 12 shows the weights of the decision-makers in their linguistic form and their conversion to SVNN.

	F1	F2	F3	F4	F5
F1	NI	VI	MI	NI	LI
F2	LI	NI	LI	LI	VI
F3	HI	HI	LI	NI	HI
F4	LI	HI	HI	NI	MI
F5	VI	VI	MI	VI	NI

	F1	F2	F3	F4	F5
F1	NI	HI	HI	NI	MI
F2	LI	LI	HI	MI	HI
F3	HI	HI	LI	NI	HI
F4	LI	HI	VI	NI	MI
F5	HI	VI	VI	VI	NI

	F1	F2	F3	F4	F5
F1	NI	HI	LI	NI	LI
F2	LI	NI	MI	NI	HI
F3	MI	VI	NI	NI	VI
F4	LI	VI	VI	HI	MI
F5	HI	HI	VI	VI	NI

Tables 7, 8, y 9: Evaluation made by Experts 1, 2, and 3 by pairs of factors on the degree of direct influence of the factor of the row on the factor of the column.

	F1	F2	F3	F4	F5
F1	NI	VI	MI	NI	LI
F2	LI	LI	LI	MI	HI
F3	VI	HI	LI	LI	MI
F4	LI	HI	VI	NI	MI
F5	HI	HI	HI	VI	NI

	F1	F2	F3	F4	F5
F1	NI	MI	HI	NI	LI
F2	MI	NI	LI	LI	HI
F3	HI	VI	LI	HI	VI
F4	LI	HI	HI	NI	LI
F5	HI	MI	VI	VI	NI

Tables 10 y 11: Evaluation carried out by Experts 4 and 5 by pairs of factors on the degree of direct influence of the factor of the row on the factor of the column.

	Decision-maker 1	**Decision-maker 2**	**Decision-maker 3**	**Decision-mak 4**	**Decision-maker 5**
SVNN	Very important (0.8;0.2;0.15)	moderately important (0.5;0.4;0.45)	Very important (0.8;0.2;0.15)	Very important (0.8;0.2;0.15)	moderately important (0.5;0.4;0.45)
numerical importance	0.2302	0.1548	0.2302	0.2302	0.1548

Table 12: Decision-makers' weights.

After obtaining the evaluations of each expert and their relative importance, the direct relationship matrix A is prepared:

$$\mathbf{A} = \begin{vmatrix} 0.0000 & 0.8409 & 0.6298 & 0.2375 & 0.5489 \\ 0.4119 & 0.0000 & 0.4978 & 0.5164 & 0.8400 \\ 0.8040 & 0.8135 & 0.0000 & 0.3922 & 0.7706 \\ 0.3762 & 0.7938 & 0.8392 & 0.0000 & 0.6117 \\ 0.8400 & 0.8334 & 0.7923 & 0.8742 & 0.0000 \end{vmatrix}$$

Subsequently, the normalized initial direct relationship matrix D is computed, as shown below:

$$\mathbf{D} = \begin{vmatrix} 0.0000 & 0.2518 & 0.1886 & 0.0711 & 0.1644 \\ 0.1233 & 0.0000 & 0.1490 & 0.1546 & 0.2515 \\ 0.2407 & 0.2436 & 0.0000 & 0.1174 & 0.2307 \\ 0.1126 & 0.2377 & 0.2513 & 0.0000 & 0.1831 \\ 0.2515 & 0.2495 & 0.2372 & 0.2617 & 0.0000 \end{vmatrix}$$

Next, the total direct relationship matrix T is shown below:

$$\mathbf{T} = \begin{vmatrix} 0.5190 & 0.8604 & 0.7162 & 0.5150 & 0.7256 \\ 0.6491 & 0.6808 & 0.7145 & 0.6003 & 0.8042 \\ 0.8184 & 0.9859 & 0.6716 & 0.6385 & 0.8850 \\ 0.6997 & 0.9489 & 0.8495 & 0.5125 & 0.8266 \\ 0.9212 & 1.1179 & 0.9772 & 0.8266 & 0.8094 \end{vmatrix}$$

Finally, after obtaining the total direct relationship matrix T, the direct and indirect effects of the factors indicated can be determined by analyzing the prominence and relationship axes for the cause and effect group, as shown in Table 13.

	Ri	**Ci**	**Ri+Ci**	**Ri-Ci**
F1	3.3362	3.6074	6.9436	-0.2712
F2	3.4489	4.5939	8.0428	-1.1450
F3	3.9994	3.9290	7.9284	0.0704
F4	3.8372	3.0929	6.9301	0.7443
F5	4.6523	4.0508	8.7031	0.6015

Table: 13: Axes of prominence and relationship

The data obtained are used for the construction of the causal diagram that is drawn in Fig. 1.

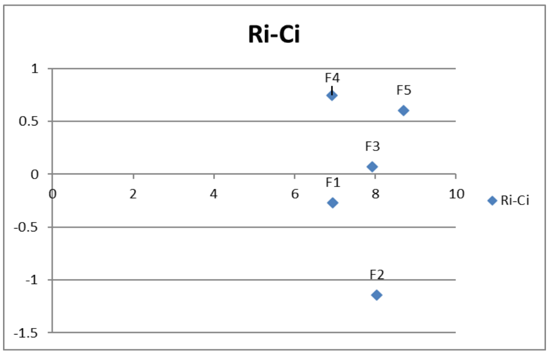

Figure 1: Graphical representation of the pairs (Ri+Ci, Ri-Ci)

According to table 13, the importance of the analyzed factors can be prioritized as F5>F2>F3>F1>F4 according to the values (ri + ci), where the safety of the tourist destination is the most important factor with the value of 8.7031, while the prices of tourist packages are the least important factor with the value of 6.9301. The cause diagram in Figure 1 shows that the prices of tour packages (F4) are the most influential factor. In short, much attention should be paid to the group of causes rather than effects. According to the data obtained, there are only two factors that stand out in the group of causes: the prices of tourist packages (F4) and the safety of the tourist destination (F5). Of the two, the prices of tourist packages (F4) have the highest value (ri - ci) which means that it tends to be the one with the greatest impact among the factors that influence the development of tourism in the country.

Conclusion

With the completion of this study, the following conclusions were reached: neutrosophy is a mathematical tool applicable to many fields of study. The application of the neutrosophic version of the AHP method was carried out to know the most influential factors in the development of the tourism sector in the country and the application of the neutrosophic DEMATEL method to develop the cause-effect relationship between these factors. The most important factor is the formality in tourist services, mainly in lodging services in which a part of their property is offered, or they also offer shared rooms that were not agreed upon with the client, and also in intermediation through recruiters to offer transportation or tourist guidance.

The DEMATEL method was applied in situations of indeterminacy through the application of linguistic variables and a neutrosophic aggregation operator. By processing the data, it was possible to determine the importance of each factor indicated, as well as the causal and effect relationships between them. Through the construction of the visible cause-effect relationship diagram, it was observed that there is a defined group of causal factors (F4, F5, and F3) that are the ones that have the greatest influence on the system, while F1 and F2 constitute the effect group. It is suggested, therefore, that the government dedicate greater efforts to mitigate the rise in prices of tourist packages and increase the safety of the tourist destination, such as basic services of drinking water, electricity, sewage, etc.

References

[1] J. G. Monge and R. M. Yagüe Perales, "El desarrollo turístico sostenible: Tren Crucero del Ecuador," *Estudios y perspectivas en turismo,* vol. 25, pp. 57-72, 2016.

[2] M. Abdel Basset, A. Gamal, R. K. Chakrabortty, and M. Ryan, "A New Hybrid Multi-Criteria Decision-Making Approach for Location Selection of Sustainable Offshore Wind Energy Stations: A Case Study," *Journal of Cleaner Production, Journal Pre-proof,* vol. 51, 2020.

[3] W. P. Proaño Ponce and J. F. Ramírez Pérez, "Modelo de Desarrollo Turístico Sostenible para cantones costeros: herramienta para actores locales de Manabí, Ecuador," *Posgrado y Sociedad Revista Electrónica del Sistema de Estudios de Posgrado,* vol. 15, pp. 65-78, 2017.

[4] C. Zambrano Murillo, J. R. Hechavarría Hernández, and M. Leyva Vázquez, "Environmental Certification Proposal for Sustainable Buildings in the Satellite Parish “La Aurora”, Guayas, Ecuador," in *Advances in Intelligent Systems and Computing* vol. 1214 AISC, ed, 2020, pp. 63-70.

[5] E. G. Caballero, F. Smarandache, and M. Leyva Vázquez, "On Neutrosophic Offuninorms," *Symmetry,* vol. 11, pp. 1136-1136, 2019.

[6] G. George-Ufot, Y. Qu, and I. J. Orji, "Sustainable lifestyle factors influencing industries' electric consumption patterns using Fuzzy logic and DEMATEL: The Nigerian perspective," *Journal of Cleaner Production,* vol. 162, pp. 624-634, 2017.

[7] P. Biswas, S. Pramanik, and B. C. Giri, "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,* vol. 12, pp. 127-138, 2016.

[8] J. Ye, "Trapezoidal neutrosophic set and its application to multiple attribute decision-making," *Neural Computing and Applications,* vol. 26, pp. 1157-1166, 2015.

[9] I. Del, "Operators on Single Valued Trapezoidal Neutrosophic Numbers and SVTN-Group Decision Making," *Neutrosophic Sets and Systems,* vol. 22, pp. 131-150, 2018.

[10] P. Biswas, S. Pramanik, and B. C. Giri, "Distance Measure Based MADM Strategy with Interval Trapezoidal Neutrosophic Numbers," *Neutrosophic Sets and Systems,* vol. 19, pp. 40-46, 2018.

[11] M. Abdel-Basset, M. Mohamed, and F. Smarandache, "An Extension of Neutrosophic AHP-SWOT Analysis for Strategic Planning and Decision-Making," *Symmetry,* vol. 10, p. 116, 2018.

[12] T. L. Saaty, *Toma de decisiones para líderes*: RWS Publications, 2014.

[13] L. K. B. Villanueva, D. A. V. Intriago, L. K. Á. Gómez, and A. M. I. Morán, "Business Plan for Entrepreneurs, Actors and Organizations of Social and Solidarity Economy based on Neutrosophic AHP-SWOT," *Neutrosophic Sets and Systems,* vol. 37, pp. 27-27, 2020.

[14] W. Ho and X. Ma, "The state-of-the-art integrations and applications of the analytic hierarchy process," *European Journal of Operational Research,* vol. 267, pp. 399-414, 2018.

[15] F. Smarandache, J. E. Ricardo, E. G. Caballero, M. Y. Leyva Vázquez, and N. B. Hernández, "Delphi method for evaluating scientific research proposals in a neutrosophic environment," *Neutrosophic Sets & Systems,* vol. 34, 2020.

[16] J. Aczél and T. L. Saaty, "Procedures for Synthesizing Ratio Judgments," *Journal of Mathematical Psychology,* vol. 27, pp. 93-102, 1983.

[17] A. Awang, A. T. A. Ghani, L. Abdullah, and M. F. Ahmad, "A DEMATEL method with single valued neutrosophic set (SVNS) in identifying the key contribution factors of Setiu Wetland's coastal erosion," *AIP Conference Proceedings*, vol. 1974, 2018.

[18] H.-S. Lee, G.-H. Tzeng, W. Yeih, Y.-J. Wang, and S.-C. Yang, "Revised DEMATEL: Resolving the Infeasibility of DEMATEL," *Applied Mathematical Modelling*, vol. 37, pp. 6746-6757, 2013.

[19] A R. Soria Acosta, & Y. C. Hernández Zambrano. “Claves de emergencia obstétrica en la hemorragia post parto”. Universidad y Sociedad, Vol. 14 Num. S2, pp- 445-449, 2022.

[20] M. M Vidal del Río, & A. A. Monsalve Guamán. “La equinococosis canina, una zoonosis de importancia”. Universidad y Sociedad, Vol. 14 Num. S2, pp- 440-444, 2022.

[21] Romero Fernández, A. J., Álvarez Gómez, G. A., & Estupiñán Ricardo, J. “La investigación científica en la educación superior como contribución al modelo educativo”. Universidad Y Sociedad, vol. 13 no. S3, pp 408-415, 2021

[22] García, J. M. B., Ricardo, J. E., & Villalva, I. M. “Acciones didácticas para la autorrealización física integral de los estudiantes de carreras agropecuarias”. Didasc@ lia: Didáctica y Educación, vol. 7 no. 2, pp 57-66, 2016.

[23] Leyva Vázquez, M. Y., Viteri Moya, J. R., Estupiñán Ricardo, J., & Hernández Cevallos, R. E. “Diagnóstico de los retos de la investigación científica postpandemia en el Ecuador”. Dilemas contemporáneos: educación, política y valores, vol. 9 no. (SPE1), 2021.

[24] Ricardo, J. E. (2018). “Estrategia de Gestión en la Educación Superior; pertinencia e impacto en la interrelación de los procesos académicos, de investigación científica y de vinculación con la sociedad en el periodo enero 2016-mayo 2018 en la Facultad de Ciencias Jurídicas, Sociales y de la Educación de la Universidad Técnica de Babahoyo en Ecuador”. Infinite Study, 2018.

[25] Ricardo, J. E., & Vázquez, I. R. S. “La educación sexual para padres de niños con retraso mental, una vía para su consolidación”. Magazine de las Ciencias: Revista de Investigación e Innovación, vol. 4 no. 3, pp 137-144, 2019.

[26] Ramos Sánchez, R. E., Ramos Solorzano, R. X., & Estupiñán Ricardo, J. “La transformación de los objetivos de desarrollo sostenible desde una dinámica prospectiva y operativa de la Carrera de Derecho en Uniandes en época de incertidumbre”. Conrado, vol. 17 no. 81, pp 153-162, 2021.

[27] von Feigenblatt, O. F., Pardo, P., & Cooper, M. “Sufficiency Economy Philosophy (SEP): Thailand's Emic Approach to Governance and Development as Evidence of an Asian-value Oriented Inclusive Leadership Management Philosophy”. Journal of Asia Pacific Studies, vol. 6. No. 2, pp 289-300, 2021.

[28] A. J. Romero Fernández, I. Alfonso González, G. A. Álvarez Gómez & L. F. Latorre Tapia. “Habilidades de investigación de los estudiantes de odontología”. Universidad y Sociedad, vol. 14 no. S3, pp 136-146, 2022.

[29] R. González Salas, M. M Vidal del Río & A. A. Monsalve Guamán. “El ozono y su empleo en la industria para el procesamiento y conservación de alimentos”. Universidad y Sociedad, vol. 14 no. S3, pp 127-135, 2022.

[30] R. E. Olivo Torres, E. S. Cocha Chicaiza & G. C. Romero Paredes. “El uso de ordenadores electrónicos como factor para el desarrollo de astenopia”. Universidad y Sociedad, vol. 14 no. S3, pp 118-126, 2022.

Received: September 13, 2022. **Accepted:** October 31, 2022