Selección de indicadores medioambientales mediante técnicas de decisión multicriterio neutrosóficas.

Selection of environmental indicators using neutrosophic multicriteria decision techniques.

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Resumen. En la actualidad existen dificultades en el país para lograr la sostenibilidad, lo que provoca una situación que repercute negativamente en la gestión ambiental empresarial. Por ello, para completar la implementación del Sistema de Gestión Ambiental de la Empresa Eléctrica Holguín, es necesario establecer indicadores de desempeño operacional como paso para sentar las bases dentro de la evaluación del desempeño ambiental en general. Lo cual es el objetivo de la presente investigación. Con ello se podrá medir la evaluación del desempeño ambiental en los procesos y ayudará a minimizar su impacto ambiental negativo en la zona donde se encuentra, así como potenciar los impactos positivos. Para realizar una selección efectiva de los indicadores operativos para determinar un camino a seguir, se utilizaron las técnicas TOPSIS y AHP Saaty en sus versiones neutrosóficas. Esto garantiza que se tenga en cuenta la incertidumbre de la subjetividad dentro del proceso de toma de decisiones, incluyendo las indeterminaciones.

Palabras clave: AHP Saaty - TOPSIS neutrosófico, evaluación del desempeño ambiental, indicadores operativos.

Abstract. Currently, there are difficulties in the country for achieving sustainability, which causes a situation that has a negative impact on business environmental management. For this reason, in order to complete the implementation of the Environmental Management System of the Holguín Electric Company, it is necessary to establish operational performance indicators as a step to lay the foundations within the evaluation of environmental performance in general. Which is the objective of the present investigation. With this, it will be possible to measure the evaluation of environmental performance in the processes and it will help to minimize its negative environmental impact in the area where it is located as well as to enhance the positive impacts. In order to make an effective selection of the operational indicators to determine a path to follow, TOPSIS and AHP Saaty techniques were used in their neutrosophic versions. This guarantees that the uncertainty of subjectivity is taken into account within the decision-making process, including indeterminacies.

Key words: AHP Saaty - Neutrosophic TOPSIS, environmental performance evaluation, operational indicators.

1 Introduction

One of the most widespread measures in companies is the adoption of a group of international standards that promote the achievement of competitiveness linked to sustainable development. Among which we may find the implementation of an Environmental Management System (EMS) by means of the NC-ISO 14 001 standard. It establishes a set of procedures that define the best way to carry out business activities with the least negative impact on the environment, through the management cycle (PMVA). According to this, the process designed in this way provides a systematic approach and continuous improvement.

In Cuba, there are currently some difficulties in achieving sustainability as well as resistance to change, low environmental perception, the absence of a proactive attitude, concern about the costs of environmental solutions, and ignorance of the link between environmental management and competitiveness. This has led to certain unfavorable situations in the establishment of an adequate Environmental Performance Assessment in companies despite being part of the Business Improvement process and the Plan for confronting climate change of the Cuban government known as “Life task”. Several methodologies have addressed this issue. However, there are always certain limitations in their generalization, so it should always be adapted to the specific characteristics of the organizations under study.

As in the case of the Holguín Electric Company, where there is an Environmental Management System (EMS) implemented at 80%, so it is necessary to refine the design of its indicators for the evaluation of performance and complete its implementation. These indicators must provide comprehensiveness, be in accordance with the objectives defined and the characteristics of the company. They must also be part of a system compatible with NC-ISO 14001: 2015, NC-ISO 14031: 2019 and the National Recognition Methodology exposed by CITMA. These last two being the starting point for the evaluation of the performance within the environmental diagnosis in the entities of the country.

That is why it is necessary to complete the design and implementation of the EMS in the company in question, establish operational performance indicators as a step to lay the foundations within the evaluation of environmental performance in general. This type of indicator is vital because it offers the possibility of measuring, from an operational point of view, how the designed management form has been executed. In other words, it offers a measure of how environmental management really works at the process level. Therefore, it is convenient to pose as

Objective: selecting the operational performance indicators of the EMS of the Holguín Electric Company. With this, it will be possible to measure the evaluation of environmental performance in the processes and it will help to minimize its negative environmental impact in the area where it is located as well as to enhance the positive impacts.

To select the best indicators based on the criteria of experts, the technique called TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was used. This technique is characterized by its effectiveness and the simplicity of its principle in solving multi-criteria decision problems. To enrich this technique, the AHP (Analytic Hierarchy Process) is applied in its neutrosophic version.

Neutrosophy is the branch of philosophy that studies the origin, nature and scope of neutralities. The incorporation of the neutrosophic sets in AHP Saaty and TOPSIS guarantees that the uncertainty of decision-making is taken into account, including indeterminacies. In both techniques, instead of numerical expressions, the experts will make their assessments using linguistic terms, which is the most natural form of measurement for human beings. [1-11]. From now on, this paper will consist of several headings where the materials and methods, results and discussion, and the conclusions, will be presented. For the resolution of the mathematical exercise, the information will be processed as follows:

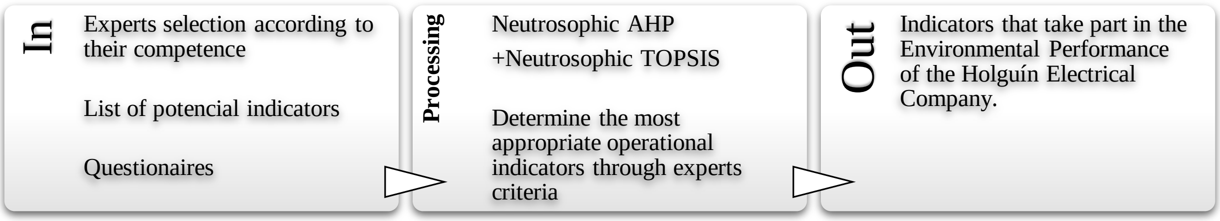


Figure 1. **Process approach**

2 Materials and methods

Selection of experts

The competencies of potential experts are checked. To do so, a competency validation survey was applied, tested by [12], where the degree of knowledge about the subject of each potential expert is self-assessed, on a scale from 1 to 10. The processing of the form was based on the calculation of the rating factor of the experts through the following mathematical expression:

$$K = ((FA + GC)) / 2 = [((SI + EP + IR + FB)) / 4 + GC]/2 \quad (1)$$

Where: SI = your intuition

EP = practical experience | IR = Investigations carried out by you | FB = Consultation of bibliographic sources | CG: degree of knowledge (1-10)

K value	Classification
8-10	High
5-7	Medium
1-4	Low

Analytic Hierarchy Process (AHP Saaty)

It was proposed by Thomas Saaty 1980 [13]. The intermediate levels detail the set of criteria and attributes[14], [fifteen]. For the description of the method, it is necessary to present the following definitions:

- Definition 1: [16, 17] The neutrosophic set N is characterized by three membership functions, which are the true membership function TA, the indeterminacy membership function IA, and the falsehood membership function FA, where U is the Universe of Discourse and ∀X∈U, TA (x), IA (x), FA (x)⊆] -0, 1+ [and -0≤inf TA (x) + inf IA (x) + inf FA (x)≤sup TA (x) + sup IA (x) + sup FA (x)≤3+. Note that according to the definition, TA (x), IA (x), and FA (x) are real standard or non-standard subsets of] -0, 1+ [and therefore TA (x), IA (x) and FA (x) can be subintervals of [0, 1].
- Definition 2: ([16, 17]) The single-valued neutrosophic set (SVNS) N over U is A = {<x; TA (x), IA (x), FA (x)>: x∈U}, where TA: U→[0, 1], IA: U→[0, 1] and FA: U→[0, 1], 0 ≤TA (x) + IA (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: [16-19] the single-valued trapezoidal neutrosophic number, is a neutrosophic set, whose membership functions of truth, indeterminacy, and falsehood are defined as follows, respectively: $\tilde{a} = \langle (a_1, a_2. a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle \mathbb{R}$

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

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

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

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

The hierarchy is built so that the elements are of the same order of magnitude and can be related to some of the next level [20_ENREF_20]. The levels of importance or weighting of the criteria are estimated through paired comparisons among them. This comparison is made using a scale, as expressed in the equation [21_ENREF_21].

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

We may find in [22] the theory of the AHP technique in a neutrosophic framework. Hence, we can model indeterminacy of decision making by applying neutrosophic AHP or NAHP for short. Equation 6 contains a generic paired neutrosophic comparison matrix for NAHP.

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \quad (6)$$

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

To convert neutrosophic triangular numbers to sharp numbers, there are two indexes defined in [22], are the so-called score and precision indices, respectively, see the equations:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (7)$$

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

Table 1. The Saaty scale translated into a triangular neutrosophic scale.

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	Very influential	$\tilde{5} = \langle(4,5,6); 0.80, 0.15, 0.20\rangle$
7	Very 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	$\tilde{2} = \langle(1,2,3); 0.40, 0.65, 0.60\rangle$
		$\tilde{4} = \langle(3,4,5); 0.60, 0.35, 0.40\rangle$
		$\tilde{6} = \langle(5,6,7); 0.70, 0.25, 0.30\rangle$
		$\tilde{8} = \langle(7,8,9); 0.85, 0.10, 0.15\rangle$

Step 1. Select a group of experts.
Step 2. Structure the neutrosophic comparison matrix by pairs of factors, subfactors and strategies, through the linguistic terms shown in Table 1. The neutrosophic scale is obtained according to the opinions of the experts [23]. The neutrosophic comparison matrix for pairs of factors, subfactors, and strategies is described in Equation 6.
Step 3. Check the consistency of the experts' criteria. If the pairwise comparison matrix has a transitive relationship, that is, aik = aij ajk for all i, j, and k, then the comparison matrix is consistent, focusing only on the lower, middle, and upper values of the matrix's triangular neutrosophic number comparison.
Step 4. Calculate the weight of the factors of the neutrosophic pairwise comparison matrix, transforming it into a deterministic matrix using equations 9 and 10. To obtain the score and the degree of precision of the following equations are used: $\tilde{a}_{ji}$. With compensation for the degree of precision of each triangular neutrosophic number in the comparison matrix of neutrosophic pairs, we obtain the following deterministic matrix:

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

Determine the priority ranking, namely the Eigen Vector X, from the above matrix:
1. Normalize the column entries by dividing each entry by the column sum.
2. Obtain the total of the row averages.

In Step 3 recommends considering the use of the Consistency Index (CI) calculation when applying this technique, which is a function that depends on λ_{max}, the maximum eigenvalue of the matrix. Saaty states that the consistency of evaluations can be determined using the equation [24].

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

Where n is the order of the matrix. Furthermore, the coherence index (CR) is defined by the equation:

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

RI is given in Table 2.

Table 2. RI associated with each order.

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

If CR≤0.1 we can consider that the evaluation of the experts is sufficiently consistent and therefore we can proceed to use NAHP. We apply this procedure to matrix "A" in Equation 11.

TOPSIS

In the case of TOPSIS, the selection is based on finding the alternative that is closest to the ideal solution and in turn is as far as possible from the worst solution, it was developed by Hwang and Yoon in the year 1981[25, 26]. This method evolved towards Neutrosophy, so in this article, linguistic terms will be associated with Single Value Neutrosophic Numbers (SVNN), so that experts can carry out their assessments in linguistic terms, which is more natural. Therefore, the scales shown in Table 3 will be taken into account.

Table 3. Linguistic terms that represent the evaluation of the criteria in the alternatives.

Linguistic term	SVNN
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)
Not Important (NI)	(0.35, 0.75, 0.80)
Not Very Important (NVI)	(0.10,0.90,0.90)

The TOPSIS method for SVNN consists of the following, assuming that $A = \{\rho_1, \rho_2, \dots, \rho_m\}$ is a set of alternatives and $G = \{\beta_1, \beta_2, \dots, \beta_n\}$ is a set of criteria, where the following steps will be carried out:

Step 1: In this step we proceed to the construction of the neutrosophic decision matrix of aggregated single values. Which is used to aggregate all individual evaluations. Each dij is calculated as the aggregation of the evaluations given by each expert using the weights of the AHP Saaty of each criterion with the help of equations 7 and 8 and tables 1 and 2. This way, a matrix D = (dij) is obtained ij, where each dij is a SVNN (i = 1,2, .., m; j = 1,2,…, n).$(u_{ij}^t, r_{ij}^t, v_{ij}^t)$

Step 2: Normalize the decision matrix: Suppose that the weight of each criterion is given by W = (w1, w2, wn), where wj denotes the relative importance of the criterion wj. If we are evaluating criterion wj by the t-th expert, then Equation 13 is used to aggregate those to the weights. The construction of the normalized matrix will be as follows:$w_j^t = (a_j^t, b_j^t, c_j^t)w_j^t$

$$w_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^2}} \quad (12)$$

Where: wij is the normalized value for the qualification of alternative i against criterion j and fij is the indicator of each alternative i against each indicator j.

Step 3: We proceed to the construction of the neutrosophic decision matrix of the weighted average of single values with respect to the criteria.

$$D* = D*W, \text{ where } d_{ij}^* = w_j * d_{ij} = (a_{ij}, b_{ij}, c_{ij}) \quad (13)$$

Step 4: Determine the ideal positive and negative solutions.

$$s^+ = (x_1^+, x_2^+, \dots x_{j+l}^+) \text{ that is to say, } s_i^+ = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^+\right)^2 + \left(b_{ij} - b_j^+\right)^2 + \left(c_{ij} - c_j^+\right)^2\right\}\right)^{\frac{1}{2}} \quad (14)$$

$$s^- = (x_1^-, x_2^-, \dots x_{j+l}^-) \text{ that is to say, } s_i^- = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(a_{ij} - a_j^-\right)^2 + \left(b_{ij} - b_j^-\right)^2 + \left(c_{ij} - c_j^-\right)^2\right\}\right)^{\frac{1}{2}} \quad (15)$$

Step 5: Calculation of the distances to the ideal positive and negative SVNN solutions. With the help of Equation 6, the following Equations are calculated:

$$\rho(A^k, A^+) = \|w * (TA^k - TA^+)\| \quad (16)$$

$$\rho(A^k, A^-) = \|w * (TA^k - TA^-)\| \quad (17)$$

Step 6: To calculate the Relative Proximity Index (Ri), the proximity coefficient of each alternative is calculated with respect to the positive and negative ideal solutions.

$$Ri(A^k, A^i) = \frac{\rho(A^k, A^+)}{\rho(A^k, A^+) + \rho(A^k, A^-)} \quad (18)$$

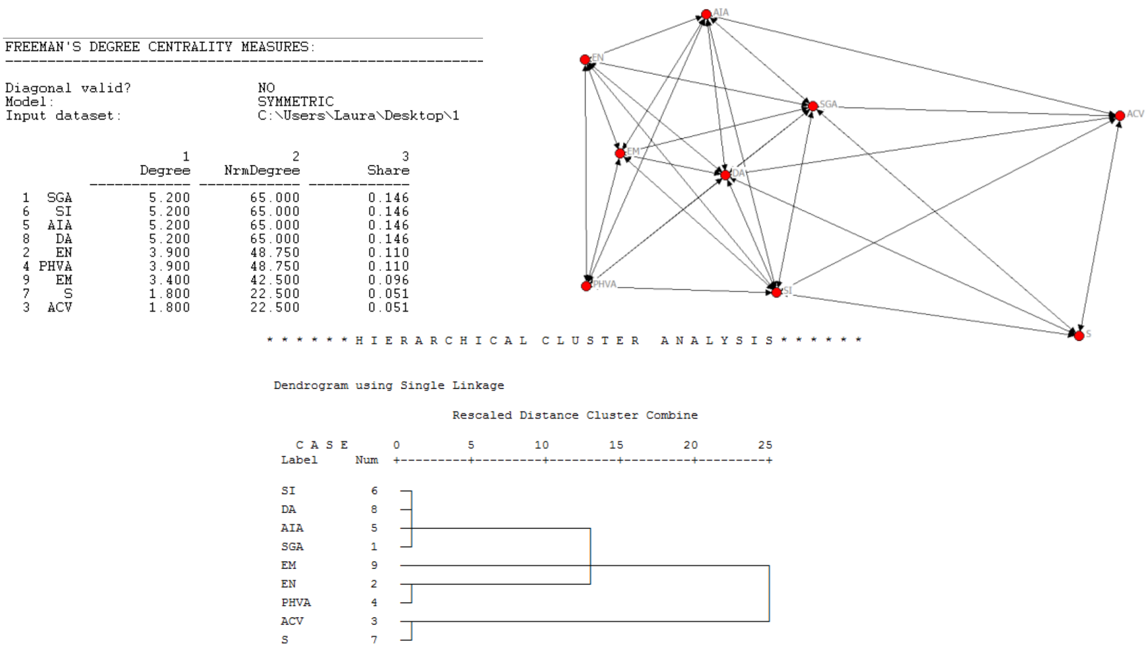
Step 7: The alternatives are ordered from highest to lowest; under the condition that Ri→1 is the optimal solution.

3 Results

Experts were selected according to their competencies, motivation and experience required during the exercise of application of the Environmental Management System from each of their positions. Then, questionnaires were applied to determine the evaluation of their competences using equation 1. Resulting only 10 out of 13 experts. For the establishment of the criteria and indicators, an analysis was carried out according to the variables most treated in the methodologies studied within the EMS.

Their interrelation is as follows: Environmental Management System (EMS), Standardized Approach (EA), Environmental Aspects and Impacts (EAI) and Environmental Diagnosis (ED), have a high interrelation and in a second group: PMVA, and EM respectively. Regarding the variables least used in the methodologies and procedures for Environmental Development Strategy (EDS) we may highlight: sustainability (S). At the same time, the validation of the network was carried out using the hierarchical cluster analysis by variables, where by making a cut in the dendrogram at the distance of fifteen the existence of two groups is corroborated.

The first group made up of the variables with the highest representation in the methodological proposals and another with the least treated variables (sustainability). Taking into account the aspects raised, it is evident that 100% of the authors consulted recognize the importance of establishing an environmental performance evaluation based on standardized approaches and the EMS, ED, SI, EAI stand out as the most used, in that order.


FREEMAN'S DEGREE CENTRALITY MEASURES:

Diagonal valid? NO
Model: SYMMETRIC
Input dataset: C:\Users\Laura\Desktop\1

		1 Degree	2 NrmDegree	3 Share
1	SGA	5.200	65.000	0.146
6	SI	5.200	65.000	0.146
5	AIA	5.200	65.000	0.146
8	DA	5.200	65.000	0.146
2	EN	3.900	48.750	0.110
4	PHVA	3.900	48.750	0.110
9	EM	3.400	42.500	0.096
7	S	1.800	22.500	0.051
3	ACV	1.800	22.500	0.051

Figure 2. Network of relationships and cluster analysis between variables exposed in the studied methodologies.

According to the abovementioned, criteria and indicators must be established to satisfy the most representative variables studied by the consulted authors:

Analysis criteria:

A. Relevance to NC ISO 14031: 2019
B. Relationship with "Life Task"
C. National Environmental Acknowledgement (NEA) methodology support
D. Relevance with EMS-UNE
E. Related to the corporate purpose of the Company
F. Compatible with established environmental objectives

List of potential indicators for the evaluation of operational performance:

I. Compliance with saving programs (water, paper, energy)

II. Treatment of non-conformities
III. Waste recycling (hazardous, non-hazardous, inert)
IV. Training level
V. Compliance with emergency prevention program
VI. Monitoring compliance

We proceed to verify that we are in the presence of an uncertainty problem. So, the following is established:

Criteria set: $C = \{c_1 \dots c_8\}; m \geq 1; \forall Cm \notin \emptyset, 1 \leq m \leq 6$
Expert set: $E = \{e_1 \dots e_{12}\}; n \geq 1; \forall Em \notin \emptyset, 1 \leq m \leq 10$
Set of alternatives: $A = \{a_1 \dots a_{12}\}; k \geq 1; \forall Ak \notin \emptyset, 1 \leq k \leq 6$

This confirms the need for the interaction of Neutrosophy as a science that studies the indeterminacies that may exist in these cases. Then it leads to the execution of multicriteria techniques from the neutrosophic point of view.

AHP Saaty Neutrosófico to determine weights of the criteria on which the experts will be based to assess the alternatives of primary indicators and their level of influence:

Table 4. Neutrosophic AHP Processing

Criteria	A	B	C	D	AND	F	WEIGHTS
A	1	0.90,0.10,0.10	0.90,0.10,0.10	0.90,0.10,0.10	0.85,0.10,0.15	0.70,0.25,0.30	**0.58**
B	$\tilde{7}$	1	0.30,0.75,0.70	0.80,0.15,0.20	0.60,0.35,0.40	0.90,0.10,0.10	**0.21**
C	$\tilde{7}$	$\tilde{3}$	1	0.30,0.75,0.70	0.30,0.75,0.70	0.30,0.75,0.70	**0.13**
D	$\tilde{7}$	$\tilde{5}$	$\tilde{3}$	1	0.50,0.50,0.50	0.30,0.75,0.70	**0.07**
E	$\tilde{8}$	$\tilde{4}$	$\tilde{3}$	$\tilde{1}$	1	0.50,0.50,0.50	**0.05**
F	$\tilde{6}$	$\tilde{7}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	1	**0.05**

The analysis of the consistency of the method showed that its Eigen value is 6.59171, IC = 0.12 and RC = 0.09, so it is confirmed that the exercise was correct.

Neutrosophic TOPSIS where the level of importance of each potential indicator is determined to form the final compound indicator.

Table 6. Neutrosophic matrix (step 1)

Alternatives / Criteria	A	B	C	D	E	F
I.	(0.75,0.25,0.20)	(0.75,0.25,0.20)	(0.75,0.25,0.20)	(0.75,0.25,0.20)	(0.75,0.25,0.20)	(0.75,0.25,0.20)
II.	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)
III.	(0.9, 0.1, 0.1)	(0.75,0.25,0.20)	(0.9, 0.1, 0.1)	(0.9, 0.1, 0.1)	(0.75,0.25,0.20)	(0.9, 0.1, 0.1)
IV.	(0.35,0.75,0.80)	(0.35,0.75,0.80)	(0.35,0.75,0.80)	(0.35,0.75,0.80)	(0.35,0.75,0.80)	(0.35,0.75,0.80)
V.	(0.50,0.50,0.50)	(0.50,0.50,0.50)	(0.50,0.50,0.50)	(0.50,0.50,0.50)	(0.50,0.50,0.50)	(0.50,0.50,0.50)
VI.	(0.9, 0.1, 0.1)	(0.75,0.25,0.20)	(0.75,0.25,0.20)	(0.9, 0.1, 0.1)	(0.75,0.25,0.20)	(0.9, 0.1, 0.1)

Table 7. Weighted normalized matrix, calculation of proximity relative to ideal solution and order (step 2-7)

Alternatives / Criteria	A	B	C	D	E	F	D +	D-	Ri	Order
I.	0.42	0.49	0.40	0.45	0.49	0.43	0.02	0.100	0.772	4
II.	0.48	0.42	0.50	0.48	0.42	0.48	0.00	0.130	1	1
III.	0.48	0.52	0.50	0.48	0.53	0.48	0.01	0.128	0.938	two

IV.	0.19	0.21	0.20	0.09	0.10	0.09	0.12	0.001	0.013	6
V.	0.27	0.28	0.26	0.29	0.30	0.29	0.09	0.035	0.272	5
VI.	0.47	0.42	0.46	0.47	0.42	0.48	0.01	0.124	0.929	3
Pesos	0.48	0.52	0.50	0.48	0.53	0.48	//			

Results: The operational performance indicators should reflect the results of the application of the Environmental Management System during the treatment of non-conformities, the recycling of waste (hazardous, non-hazardous, inert) and compliance with monitoring. In other words, what the state of the EMS outputs reflects. This evaluation is conditioned mainly by the level of environmental management achieved within the Company, since it has resulted in the achievement of an adequate environmental impact. However, it is necessary to raise the operational level to obtain better results in the activity.

Conclusions

The relevance and pertinence of the environmental performance evaluation is manifested in the current situation of the world and Cuba and is included in political, legal and normative documents. The bibliography consulted allowed it identify it as an element of EMS and highlights its importance to make the best organizational environmental decisions. The methodologies encourage the use of indicators. For its design and preparation, references such as NC-ISO 14001: 2015 and NC-ISO 14031: 2019 are used, as well as Cuban legal documents. Although the non-integral nature of the indicators used and the predominance of qualitative assessments stand out in its execution.

The use of environmental indicators provides information that enables effective environmental decision making. Its non-existence makes it difficult to continuously improve environmental performance. Therefore, establishing a system of indicators that serves as a support for the evaluation of environmental performance is an appropriate measure. The methodologies analyzed and taken into account for the design, expose the need to establish indicators related to sustainability and the incorporation of the process approach in the analysis through a standardized approach.

With the support of the AHP Saaty and neutrosophic TOPSIS techniques, the environmental indicators of operational performance were selected based on the establishment of criteria. These techniques allowed evaluating using linguistic terms with quantitative processing where the uncertainty environment is included. Which is typical of subjectivity. Which provides greater certainty to the decision-making process. Once the techniques were applied, it could be determined that the experts consulted in the case of AHP Saaty propose that the selection of indicators be influenced by their level of relevance with respect to NC ISO 14031: 2019, showing a relationship with "Life Task" and compatibility with NEA methodology.

In the case of TOPSIS, a higher level of importance is given to those indicators related to the treatment of non-conformities, the recycling of waste (hazardous, non-hazardous, and inert) and monitoring compliance. It is proposed to extend these methods for the evaluation of the other types of environmental indicators of condition and environmental management exposed by NC-ISO 14031: 2019 and the NEA methodology to establish a system appropriate to the characteristics of the entity for the evaluation of environmental performance .

References

1. L. Albarracin, Jalón, E., Molina, J., & Laverde, J., "Insertion of an automated sprinkler irrigation system for parks in the canton," Conteporáneos Dilemmas, p. 59, 2019.
2. L. Albarracín, Jalón, E., Guerrero, K., & LLanganate, J., "Entrance and exit control prototype for the UNIANDES-Quevedo parking lot," *Contemporary Dilemmas: Education, Politics and Values,* p. 7, 2020.
3. LJMCE José, & Zambrano, JALOA, "Inclusion of Computer Programming as a tool for the development of logical and abstract reasoning in the thinking of children in Basic General Education, Middle Level. Dilemmas.," 2018.
4. KK Kendall Julie, "Systems Analysis and Design," vol. Sixth Edition, 2005.
5. G. Londoño, "Research and problematization: Didactic exercises in university teaching. Bogotá: Universidad de la Salle," 2013.
6. LJ Molina Chalacan, Giler Chango, JL, & Albarracín Zambrano, LO, "Prototype for the inmotic control of UNIANDES Quevedo offices," *Dilemmas Contemporaries: Education, Politics and Values,* p. 7, 2020.
7. FJ Moliner, "Informatics for groups," *Valencia: Generalitat,* 2005.
8. JJ Parsons, "Computing: New Perspectives (Tenth ed.)," 2008.
9. DVP Ruiz, Matute, JCA, Arias, EJJ, Zambrano, LOA, Chalacán, LJM, Quevedo, Í. MS, & Paredes, ARZ, "Softcomputing in neutrosophic linguistic modeling for the treatment of uncertainty in information retrieval. , " *Neutrosophic Sets and Systems,* p. 69, 2019.

10. M. Villa, Roman, D., Roman, A., Albarracin, L., Jalon, E., & Cedeño, D., "ENTREPRENEURSHIP IN THE TRAINING OF THE STUDENT IN THE SUPERIOR TECHNOLOGICAL INSTITUTES," pp. 103-114, 2018.
11. A. Zuñiga, Jalón, E., & Albarracín, L., "Virtual laboratories in the teaching-learning process in Ecuador.," *Contemporary Dilemmas,* 2019.
12. BM González Nuñez, "" Methodology to evaluate environmental performance in a construction process. Hotel Albatros Guardalavaca case "," Thesis presented as an option for a master's degree in Industrial Engineering. , Faculty of Industrial Engineering, University of Holguin "Oscar Lucero Moya", University of Holguin, 2019.
13. TL Saaty, *Decision making for leaders*: RWS Publications, 2014.
14. A. Arquero, M. Alvarez, and E. Martinez, "Decision Management making by AHP (analytical hierarchy process) through GIS data," *IEEE Latin America Transactions,* vol. 7, pp. 101-106, 2009.
15. O. Mar, I. Santana, and J. Gulín, "Competency assessment model for a virtual laboratory system and distance using fuzzy cognitive map," *Operational Research Magazine* vol. 38, pp. 170-178, 2017.
16. P. Biswas, S. Pramanik, and BC 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.
17. J. Ye, "Trapezoidal neutrosophic set and its application to multiple attribute decision-making," *Neural Computing and Applications,* vol. 26, pp. 1157-1166, 2015.
18. I. Del, "Operators on Single Valued Trapezoidal Neutrosophic Numbers and SVTN-Group Decision Making," *Neutrosophic Sets and Systems,* vol. 22, pp. 131-150, 2018.
19. P. Biswas, S. Pramanik, and BC Giri, "Distance Measure Based MADM Strategy with Interval Trapezoidal Neutrosophic Numbers," *Neutrosophic Sets and Systems,* vol. 19, pp. 40-46, 2018.
20. C. Tubet Abramo, "Design of a methodology for evaluating the sustainability of the National Electric Mix, based on the Hierarchical Analytical Process (AHP)," 2016.
21. 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.
22. 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.
23. F. Smarandache, JE Ricardo, EG Caballero, MY Leyva Vázquez, and NB Hernández, "Delphi method for evaluating scientific research proposals in a neutrosophic environment," *Neutrosophic Sets & Systems,* vol. 34, 2020.
24. J. Aczél and TL Saaty, "Procedures for Synthesizing Ratio Judgments," *Journal of Mathematical Psychology,* vol. 27, pp. 93-102, 1983.
25. R. Şahin and M. Yiğider, "A Multi-criteria neutrosophic group decision making method based TOPSIS for supplier selection," *arXiv preprint arXiv: 1412.5077.* ,2014.
26. M. Abdel-Basset, M. Saleh, A. Gamal, and F. Smarandache, "An approach of TOPSIS technique for developing supplier selection with group decision making under type-2 neutrosophic number.," *Applied Soft Computing,* vol. 77, pp. 438-452, 2019.
27. Gómez, G. Á., Moya, J. V., & Ricardo, J. E. (2020). Method to measure the formation of pedagogical skills through neutrosophic numbers of unique value. Revista Asociación Latinoamericana de Ciencias Neutrosóficas. ISSN 2574-1101, 11, 41-48.
28. Ricardo, J. E., Villalva, M. I. M., Padilla, Z. A. O., & Hurtado, L. A. C. (2018). Filosofía de la comunicación, complemento necesario en el aprendizaje de las Ciencias Sociales. Magazine de las Ciencias: Revista de Investigación e Innovación, 3(2), 39-52.

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