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Neutrosophic Approaches to Environmental Law and Policy

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Abstract. Currently, the environmental approach is included in the legal regulations of countries to achieve sustainable development. The development of public policies that demand the care and preservation of the environment is an urgency for the territories. In Ecuador, social and legal transformations led to the inclusion of the environmental perspective in the Constitution of the Republic, and subsequently to the development of the Organic Code of the Environment (CODA). Environmental principles are considered in the various legislations; however, no priority is established among them. The objective of this work is to determine the priority established in the environmental principles of CODA. For this, it was necessary to consult experts and, based on their criteria, the Pareto Diagram technique was applied, the fundamental principles were selected, and a hierarchical order was determined based on the Analytic Hierarchy Process, AHP Saaty, with a neutrosophic approach, for the decision making. The most relevant principles were Comprehensive Responsibility, Best Available Technology and Best Environmental Practices, and Comprehensive Repair.

Keywords: Laws, Politics, Environment, Ecuador, Neutrosophic AHP

1 Introduction

Caring for the environment is fundamental for the development of the economic, social, and political processes that take place in society. The Rio Declaration on Environment and Development seeks to achieve sustainable development, recognizing the right of human beings to a healthy life in harmony with the environment. Furthermore, it points out how states must preserve the environment and use its resources according to their environmental and development policies.[1]

Today it is essential to have laws, policies, and programs for the care and preservation of the environment. This is why the 2030 Agenda for Sustainable Development, which aims to achieve transformation, places the equality and dignity of people at the center of action, and calls for a change in the style of development in search of sustainability, inclusion, and respect for the environment. Nine of its 17 goals take into account the protection and care of the environment, directly or indirectly (SDGs 2, 6, 7, 8, 8, 11, 12, 13, 14, 15) [2].

For this reason, the "environmental" approach to law must be considered in the legislation of the countries since it implies the consideration not only of the instituted social logic but the historical and political contexts that originated or transformed them. The environmental issue is conducive to serving as a catalyst for questioning both political and academic discourses, even the most established ones. [3]

One of the branches of law that have been inserted into legislation is environmental law, which consists of "the set of legal norms that regulate human behavior that can influence in a relevant way the interaction processes that take place between environmental systems, living organisms, and their environmental systems, by generating effects that are expected to significantly modify the conditions of existence of those organisms".[4]

In the Latin American area, research has been carried out to analyze the legal regulations that consider the environmental approach [3.5-6]. Ecuador is a country that in recent decades has made changes to its legal regulations. The environmental approach is considered in the country's Magna Carta promulgated in 2008. Article 395, Section 1, recognizes that "The State will guarantee a sustainable development model, environmentally balanced and respectful of cultural diversity, which conserves biodiversity and the natural regeneration capacity of ecosystems and ensures the satisfaction of the needs of present and future generations" [7]. Many laws stand out, such as The Environmental Management Law; Law for the Prevention and Control of Environmental Pollution; Law that

Protects Biodiversity in Ecuador, Unified Text of Secondary Environmental Legislation (TULSMA), and the Organic Code of the Environment (CODA), among others[8]. The latter (CODA) [9], summarizes and updates a series of environmental principles, and establishes as a means of protection, the insertion of environmental criteria in the planning and ordering of territories [8].

The principles to consider are: Comprehensive Responsibility; Best Available Technology and Best Environmental Practices; Sustainable development; The polluter pays; In dubio pro natura; Access to information, Participation and Justice in Environmental Matters; Caution; Prevention; Comprehensive Reparation and Subsidiarity [9,10]

Considering these principles, and the analysis of the bibliography consulted on environmental policies, laws, and legal regulations in Ecuador [11-16], it is determined that there are no systematized criteria for prioritizing them in current legislation. So, the objective of this research is to determine the priority established in the environmental principles of CODA, to be considered in the teaching of environmental law. For this, the use of the Analytic Hierarchy Process formulated by Tomas Saaty (AHP Saaty) is necessary.

Based on an analysis of studies on this topic [17-20], it was possible to establish that researchers show algorithmically relevant multi-criteria evaluation models, where the AHP Saaty is used together with other heterogeneous methods and decision-making techniques. These methods used are mostly supported by expert judgment. The environment of uncertainty and possible indeterminacies that this social phenomenon entails will be considered. Neutrosophy is the segment of philosophy that studies the beginning, nature, and scope of neutralities. It guarantees that assuming the uncertainty inherent in decision-making, containing the indeterminacies where experts will express their judgments using linguistic and non-numerical knowledge, which is a more natural way for human beings to measure [21-27].

To fulfill the general objective of this research, the following specific objectives are necessary: Select the principles to prioritize using a Pareto Diagram and Prioritize using AHP Saaty in a neutrosophic environment, to be later considered for the teaching of Environmental Law.

2 Materials and Methods

2.1 Pareto diagram

The Pareto Diagram is based on what was described by Vilfredo Federico Pareto in 1896, in the Political Economy Course [28]. One of the main disseminators of this tool was Joseph M Jurán [29], which is based on analyzing a problem, considering the causes of greatest incidence, and aims to determine the 20% of the causes that cause 80% of the problems.[30]

One of its main advantages is that it focuses on the aspects whose improvement will have the bigger impact, optimizing efforts. An optimal view of the relative importance of problems. Preventing some causes from aggravating while trying to solve others of less significance and being able to be analyzed graphically encourages continuing work to improve the process.

Preparing a Pareto Diagram has the following steps: selecting the data, grouping and tabulating them (calculating absolute and cumulative frequency, unitary and cumulative relative frequency), drawing the Pareto diagram, representing the bar graph (by locating all the causes along the coordinates axis, ordered from highest to lowest incidence and placing their corresponding percentages along the ordinates axis), outline the cumulative curve, identify the diagram and analyze it (causes that are up to 80% will be those with the highest incidence.

In the case of this research, experts on the subject of Environmental Law from different Law Schools in the country, and from organizations related to the topic, both in person and virtually, were consulted to determine the priority of the environmental principles of the CODA.

2.2 AHP Saaty Neutrosophic:

The Analytic Hierarchy Process was proposed by Thomas Saaty in 1980 [21]. This technique models the problem that leads to the formation of a hierarchy representative of the associated decision-making scheme [22, 23]. 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 [24],[25,26]. The hierarchy is constructed so that the elements are of the same order of magnitude and can be related to some of the next level. 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 levels. At the lowest level the decision options are understood [27]. The levels of importance or weighting of the criteria are estimated through paired comparisons between them.

For the description of the method, the following definitions must be presented:

Definition 1: ([31, 32, 42,43]) The *Neutrosophic set* N is characterized by three membership functions, which are the truth-membership function T_A, indeterminacy-membership function I_A, and falsehood-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 $^-0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3^+$. Notice 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: ([31,32, 44]) The *Single-Valued Neutrosophic Set* (SVNS) N over U is $A = \{\langle x; T_A(x), I_A(x), F_A(x)\rangle : x \in U\}$, where $T_A: U \to [0, 1]$, $I_A: U \to [0, 1]$, and $F_A: U \to [0, 1]$, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$. The *Single-Valued Neutrosophic Number* (SVNN) is represented by N = (t, I, f), such that $0 \leq t, I, f \leq 1$ and $0 \leq t + I + f \leq 3$.

Definition 3: ([31-34]) the *single-valued trapezoidal neutrosophic number*, $\tilde{a} = \langle (a_1, a_2. a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on $\mathbb{R}$, whose truth, indeterminacy, and falsehood membership functions are defined as follows, respectively:

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

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

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

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

Definition 4: ([31-34]) 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:

Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$

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

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 $a_1, a_2, a_3, a_4 \neq 0$.

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 $a_2 = a_3$, [35-37]. For simplicity, we use the linguistic scale of triangular neutrosophic numbers, see Table 1 and also compare with the scale defined in [38]. The levels of importance or weighting of the criteria are estimated through paired comparisons between them. This comparison is carried out using a scale, as expressed in equation (6) [39].

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

The theory of the AHP technique in a neutrosophic framework can be found in [38]. Thus, the indeterminacy of decision-making by applying neutrosophic AHP, or NAHP for short, can be modeled. Equation 7 contains a generic neutrosophic pair-wise comparison matrix for NAHP.

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

Matrix $\tilde{A}$ must satisfy 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 [38], they are the so-called score and accuracy indexes, respectively, see Equations 7 and 8:

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

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

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

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

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 [40]. The neutrosophic pair-wise comparison matrix of factors, sub-factors, and strategies are as described in Equation 6.

Step 3 Check the consistency of experts' judgments.

If the pair-wise comparison matrix has a transitive relation, ie., $a_{ik} = a_{ij}a_{jk}$ 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 into a deterministic matrix using Equations 9 and 10. To get the score and the accuracy degree of $\tilde{a}_{ji}$ the following equations are used:

$$S(\tilde{a}_{ji}) = {}^{1}\!/_{S(\tilde{a}_{ij})} \quad (9)$$

$$A(\tilde{a}_{ji}) = {}^{1}\!/_{A(\tilde{a}_{ij})} \quad (10)$$

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

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (11)$$

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 the consistency of the evaluations can be determined by the equation:

$$CI = \frac{\lambda_{max} - n}{n-1} \text{ [41]}, \quad (12)$$

where n is the order of the matrix. In addition, the *Consistency Ratio* (CR) is defined by equation:

$$CR = \frac{CI}{RI} \quad (13)$$

RI is given in Table 2.

Table 2: RI associated with every order.

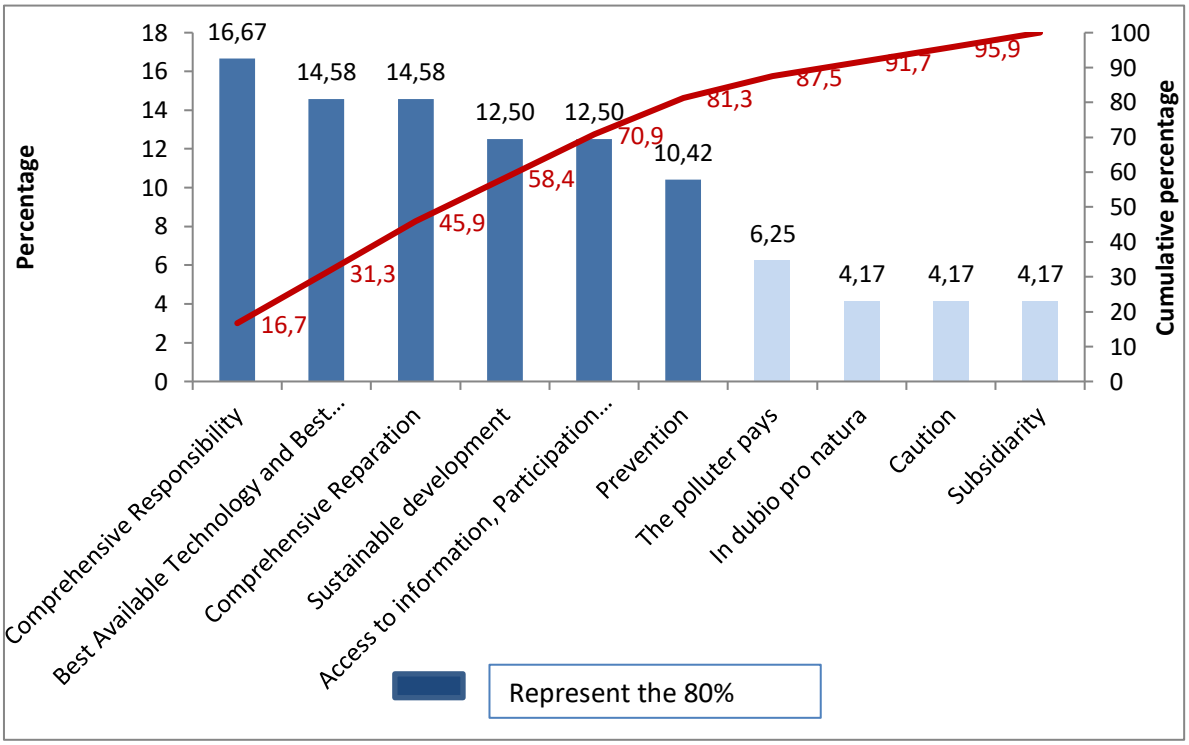
Order (n)	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

If CR≤0.1 It can be considered 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 Results

For the development of the research, the environmental principles that appear in CODA are considered [9-11], and the Pareto Diagram is applied to the criteria of the selected experts.

Figure 1. Pareto diagram for the selection of principles. Source: own elaboration.



Subsequently, the Saaty Neutrosophic AHP is applied to the principles resulting from the analysis of the Pareto Diagram: Comprehensive Responsibility, Best Available Technology and Best Environmental Practices, Comprehensive Reparation, Sustainable Development, Access to information, Participation and Justice in Environmental Matters And Prevention.

Table 3: Paired matrix for Neutrosophic AHP Saaty. Source: own elaboration.

Criteria	Comprehensive Responsibility	Best available technology and best environmental practices	Comprehensive Reparation	Sustainable development	Access to information, participation and justice in environmental matters	Prevention
Comprehensive Responsibility	**⟨(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⟩	⟨(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⟩
Best available technology and best environmental practices	$\frac{1}{\langle(1,1,1);\ 0.50,0.50,0.5}$	**⟨(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⟩
Comprehensive Reparation	$\frac{1}{\langle(1,1,1);\ 0.50,0.50,0.5}$	$\frac{1}{\langle(1,1,1);\ 0.50,0.50,0.50\rangle}$	**⟨(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);

Criteria	Comprehensive Responsibility	Best available technology and best environmental practices	Comprehensive Reparation	Sustainable development	Access to information, participation and justice in environmental matters	Prevention
Sustainable development	1 / ⟨(2,3,4); 0.30,0.75,0.7	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	1 / ⟨(2,3,4); 0.30,0.75,0.7	**⟨(1,1,1); 0.50,0.50, 0.50⟩**	⟨(2,3,4); 0.30,0.75,0.70⟩	0.30,0.75,0.70⟩ ⟨(2,3,4); 0.30,0.75,0.70⟩
Access to information, participation and justice in environmental matters	1 / ⟨(2,3,4); 0.30,0.75,0.7	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	1 / ⟨(2,3,4); 0.30,0.75,0.7	1 / ⟨(2,3,4) 0.30,0.75,0	**⟨(1,1,1); 0.50,0.50,0.50⟩**	⟨(4,5,6); 0.80,0.15,0.20⟩
Prevention	1 / ⟨(2,3,4); 0.30,0.75,0.7	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	1 / ⟨(2,3,4); 0.30,0.75,0.7	1 / ⟨(2,3,4) 0.30,0.75,0	1 / ⟨(4,5,6); 0.80,0.15,0.20⟩	**⟨(1,1,1); 0.50,0.50,0.50⟩**

Table 4: Determination of weights of the principles applying the Neutrosophic AHP method. Source: own elaboration.

Criteria	Comprehensive Responsibility	Best available technology and best environmental practices	Comprehensive Reparation	Sustainable development	Access to information, participation and justice in environmental matters	Prevention	Weight	A x Weight	Approx. Eigenvalues
Comprehensive Responsibility	0.25	0.25	0.25	0.28	0.23	0.17	0.24	1.57	**6.6299**
Best available technology and best environmental practices	0.25	0.25	0.25	0.28	0.23	0.17	0.24	1.57	**6.6299**
Comprehensive Reparation	0.25	0.25	0.25	0.28	0.23	0.17	0.24	1.57	**6.6299**
Sustainable development	0.08	0.08	0.08	0.09	0.23	0.17	0.12	0.85	**6.9448**
Access to information, participation and justice in environmental matters	0.08	0.08	0.08	0.03	0.08	0.28	0.11	0.68	**6.4048**
Prevention	0.08	0.08	0.08	0.03	0.02	0.06	0.06	0.36	**6.1087**

When analyzing the consistency, according to the proposed method, an eigenvalue of 6.558 was obtained, the consistency index, CI=0.11, and the Consistency Ratio RC=0.09, which allows to affirm that the exercise was performed correctly.

In the research, consent among the consulted experts is achieved, by identifying six environmental principles to include in teaching in Law Schools, and that must comply with the evaluation process and the weighting of weights that determines their level of relevance. The search for the best alternatives allowed to identify that the greatest weight falls on Comprehensive Responsibility, Best Available Technology and Best Environmental Practices and Comprehensive Reparation.

The consistency analysis of the paired matrix allows for determining the consistency of the research by presenting a value of 0.09, which is less than 0.10.

Conclusion

- Legal regulations associated with the environment are a key issue for the sustainable development of cities. There should be no territorial development strategies and plans in which respect for the environment is not considered. This allows a better quality of life for people and animals, and the preservation of natural resources, so necessary for the preservation of life on the planet.
- The teaching of Environmental Law must focus on environmental principles. Considering those presented in the CODA, Comprehensive Responsibility, Best Available Technology and Best Environmental Practices and Comprehensive Repair are fundamental. However, although these have higher priority, the rest should not be ignored.
- The synergy established between the Pareto Diagram and the AHP Saaty allowed establishing a hierarchical order for the principles, which should be taught in this way according to experts: Comprehensive Responsibility, Best Available Technology and Best Environmental Practices, Comprehensive Repair, Sustainable Development, Access to information, Participation and Justice in Environmental Matters and Prevention.
- Environmental principles must be disseminated to the entire population, not only among those who work in the Law field. Children, young adults, and the elderly must have a legal and environmental culture that allows them to realize when their environmental rights are violated and know where to go to amend them. Economic, political, social, and sustainable development can only be possible if it is in harmony with the environment, which will allow a better life for Ecuadorian citizens.

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