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Selection of Investment Projects in a Plithogenic Environment

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Abstract. Nowadays, the economic crisis affecting the countries makes more important the selection process of investment projects. Such is the case of Ecuador where the Multi-annual Public Investment Plan 2017-2021 establishes indicative amounts of public investment that are projected to be executed annually to achieve each of the nine strategic objectives of the National Development Plan that pay tribute to the Sustainable Development Goals of the UN. This plan has certain weaknesses that may not allow an effective and efficient choice at the same time. Which entails a scenario of uncertainty for the Ecuadorian investment process. So we dare to say that a classic selection of investment projects is not suitable. Therefore, there is a need for a decision-making support tool that allows the most effective and optimal selection of the projects of greater importance and scope based on multiple, specifically defined criteria. Thus, the main objective of this research is to develop a selection process for investment projects based on multicriteria decision methods in a plithogenic environment. If an adequate method is determined for the selection of an investment project in an environment of uncertainty based on Plithogeny, it will be possible to provide an effective tool that optimizes the decision-making process. For this, the plithogenic versions of the AHP and TOPSIS methods will be adopted.

Keywords: uncertainty, investment projects, selection, Plithogeny, evaluation, decision making

1 Introduction

Decision-makers often face problems of choosing alternatives with complicated, intangible, and conflicting criteria. To choose the best alternative, they generally rely on multicriteria decision-making methods where priorities of contradictory tangible and intangible criteria are managed based on experts to define and assess potential courses of action. Decision-making consists of the choice by one or more individuals of the best alternative among a set of possible solutions. A traditional approach suggests the existence of a certain group of restrictions generated by resource limitations, where the value of the decision variables that satisfy these restrictions constitutes what is called the feasible or achievable set that may or may not be finite [1].

Usually, to determine the best alternative, a criterion function is defined that adequately reflects the preferences or desires of each of the decision-makers which requires a process [2]. The first step is dedicated to the search for specific technical information and the second step to the preferential judgments of the group of decision-makers. Which is usually optimized by mathematical techniques [1]. This process acquires great connotation on the subject of investments, where resources are used to achieve benefits or profits, which constitutes its main objective for the formation of fixed social capital, technical capital, and technical staff [3].

It is well known that to invest people must have financial, material, and human resources, so the decision to execute them or not imposes a challenge of conscience [2]. Investments increase through interest, dividends, shares, appreciation of assets (increase in value) when you have savings, the portion and duration of those savings must be visualized, before deciding to invest and define where to use those resources [3]. Therefore, it is said that carrying out investments implies the acceptance of risks that must be analyzed, hence the importance of using strategic projection tools and techniques.[2]. So that they deal with the current situation in the market, social inequality, environmental problems, and the global economic crisis that is on the rise, as well as the appearance of Covid-19, has paralyzed the economy on the planet [2].

There are several types of investment [3]:

1. In the financial or capital field
2. In the real estate, business, or production and project field.
3. In the field of personal education and, in projection, education for when people have sons and daughters and provisions for retirement.
4. In goods that increase in value over time

However, regardless of the type of investment involved, it needs to be previously evaluated, since implementing a project without this step could generate a significant loss of resources, which could even lead to bankruptcy due to debt or financial inability to sustain it with own resources [4-6]. Therefore, the decision-making process, in general, adopts the following flow of activities, where it can be seen that the investment idea is materialized in an investment project.

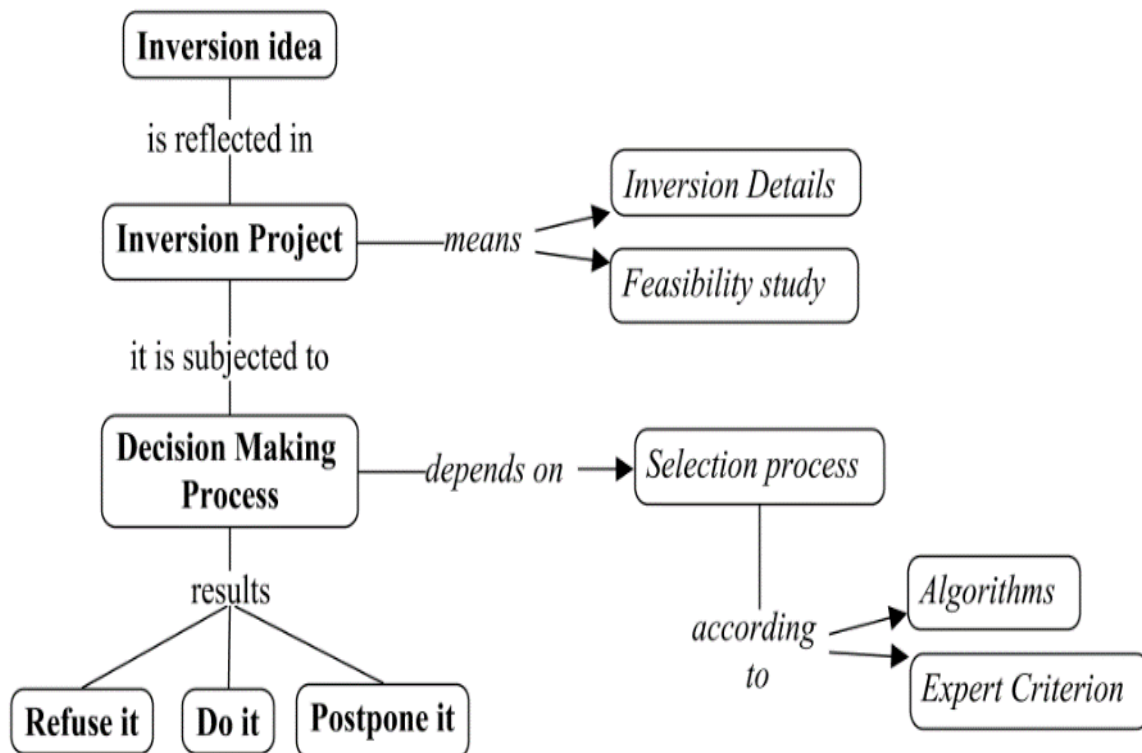


Figure 1. Concept map of the decision-making process for investment projects. Source: Own elaboration (CmapTools software output).

Investment projects are nothing more than documents that include everything related to the execution of the investment idea. The details must be presented in a systemic, qualitative, and quantitative way that allows evaluating investment feasibility from all dimensions. It includes all the elements that allow qualitative and quantitative judging of the advantages and disadvantages of allocating resources to a specific initiative. From the content capable of being exposed, the decision-making capacity is developed, and alternative scenarios are designed to complement the decision-makers opinion when evaluating the investment. The correct design of this document depends on the skills of the person who will execute it and the characteristics of the investment.

On the side of the person who prepares this investment project, it is said that he must have preparation in the techniques of investment projects to collect, create, and systematically analyze a set of economic antecedents that allow judging by experts or algorithms its feasibility for the start-up just as people must design projects with ethical criteria so that the studies base their feasibility in practice always considering the perspective from the project design and evaluation process to develop decision-making capacity and design alternative scenarios. All this so that the investment project resulting from their work can translate responsibility when assuming a project development contract.

On the document side, it is said that this study should determine all the elements that make it possible to evaluate exhaustively:

- The market feasibility to place the product or service that would be developed in the project based on the analysis of the sub-markets and the commercial strategy and the investments and expenses involved. A

- strategy in pessimistic environments, where the life cycle of a project is contemplated: idea, pre-investment, investment, and a study of supply and demand (consumer, market, competition)
- The capacity and location of the investment project, as well as the investments and related costs. The financial viability of the project is based on projected financial statements with a financial-economic study where its source of financing (modalities, types) is exposed. As well as costs and expenses: analysis of the cost of capital, determination of the project income budget, expenditure budget, breakeven point.
 - Execute an organizational and legal study of the investment project and determine the corresponding investments and expenses Basic engineering (Technical study, description of the project and its purposes, Dimensioning and location, technological alternatives, Description of the production process, Determination of the project equipment, and machinery), as well as its structure and schedule and impact.



Figure 2. Aspects for the development of investment projects.

According to those above, the idea of an investment project can lead to three possible scenarios after evaluation through the selection process [4]:

- Do the project: The economic, social, environmental, legal, and market feasibility is confirmed, that is, the project is viable, profitable, so it is decided to do it within the planned deadlines.
- Do not do it: Situations are observed where there is infeasibility for the project (it may be its non-profitability, non-compliance with regulations, due to its negative impact on the environment, or the reluctance of the community).
- Postpone it: It is observed that the project meets the conditions to carry it out, however, it is not pertinent to execute it within the planned period (it may be due to the economic, social, political environment, among others). The project is good, but for contingency reasons, it is better to postpone it for a while until the conditions are feasible for its development.

At present, the economic crisis that affects the countries makes even more important this process of selecting the investment projects to be carried out. Mainly due to the need to allocate human, material, financial resources, even time, in an feasible investment that provides a positive impact on society [2]. That is why the Republic of Ecuador has implemented a Multi-annual Public Investment Plan 2017-2021, which is part of the National Development Plan "A whole lifetime" for the medium term [7]. The 2017-2021 Multi-annual Public Investment Plan establishes indicative amounts of public investment that are projected to be executed annually to achieve each of the nine strategic objectives of the National Development Plan that contribute to the UN Sustainable Development Goals [7, 8] and the criteria for prioritizing investment projects are established:

- Poverty reduction
- Closing territorial gaps
- Employment generation
- Generation of complementarity with private initiatives
- Increase in systemic productivity that contributes to the strengthening of non-traditional exports
- The intensity in national inputs: majority use of raw material of national production, without encouraging increased imports

This plan has certain weaknesses since the Investment Plan does not include a list of projects, nor the costing of individual projects, it only considers indicative estimates of investment amounts added by a strategic axis of the National Development Plan. Similarly, it does not detail the localization of public investment nor does it include product and/or results in indicators. Just as it does not include a list of projects in order of priority and/or prioritization criteria. What does not allow an effective and efficient choice at the same time.

A situation that, along with the current shortage where the resources of this plan must be consciously allocated according to the economic crisis caused by the Covid-19 pandemic in the country, is a problem to analyze. This turns into an unprecedented scenario for the Ecuadorian investment process, which provokes an environment of uncertainty. As a result, it can be said that a classic selection of investment projects is not convenient, which denotes the need to have a decision-making support tool to make the most effective and optimal selection of projects of greater importance and scope based on multiple, specifically defined criteria. Thus, the following problem is proposed:

Multi-criteria decision methods are used to assess decision alternatives in a context with different conflicting objectives and an uncertain environment. The use of these methods allows both objective and subjective knowledge, defined in terms of quantitative and qualitative variables, to be integrated into decision-making [1]. As a complement to these methods, neutrosophic logic is used in its plithogenic version that studies the origin, nature, and scope of neutralities, environments of uncertainty, and their interactions. This part, Plithogeny, advocates for the connections and unification of theories and ideas in varied fields of science [9]. Plithogeny is the genesis or origin, creation, formation, development, and evolution of new entities from dynamics and mergers of multiple contradictory and/or neutral and/or non-contradictory previous entities. Plithogeny advocates for the connections and unification of theories and ideas in varied fields of science. The "Knowledge" is taken as "Entities" in various fields, such as social sciences, technical sciences, theories of arts and letters [10-12].

Which is convenient according to the environment in which the problem is developed. Therefore, it leads to establishing as the main objective of this research: the development of a selection process for investment projects based on multicriteria decision methods in a plithogenic environment. The hypothesis supports this that if an adequate method is determined for the selection of an investment project in an environment of uncertainty based on Plithogeny, it will be possible to provide an effective tool that optimizes the decision-making process. To achieve this objective, the following activities must be carried out:

1. Establish a case study for the selection of a multicriteria method for expert-based decision making
2. Create an algorithm merging the chosen multicriteria method with the plithogenic sets to guarantee the effective choice of a selection project according to the 2017-2021 Multi-annual Public Investment Plan.

2. Case study

2.1 Decision-making process

Decision-making is the study of the identification and choice of alternatives based on the values and preferences of the decision-maker. Making a decision implies that there are alternatives to consider and it is convenient to choose the one that best suits the goals, objectives, desires, values, and all this in a short time according to the characteristics of the decision-maker [1].

2.2 Multi-criteria decision methods

According to [2, 13] multicriteria methods are especially used to make decisions in the face of problems made up of intangible aspects. These methods do not consider the possibility of finding an optimal solution to a problem, but based on preferences and predefined objectives, the central problem of multicriteria methods consists of selecting the best alternatives, accepting alternatives that seem "good" and reject those that seem "bad" and generate a ranking of the alternatives (from the best to the "worst"). When the objective functions take an infinite number of different values that lead to an infinite number of possible alternatives of the problem, it is called Multiobjective Decision, while those problems in which the decision alternatives are finite are called Discrete Multicriteria Decision problems [13]. Discrete Multicriteria Decision problems are the most common in reality and are used to carry out an evaluation and decision regarding problems that, by nature, admit a finite number of solution alternatives, and is going through [13]:

- A stable, generally finite set of alternatives
- A family of evaluation criteria that allow evaluating the alternatives
- A decision matrix that summarizes the evaluation of each alternative
- A methodology or model of aggregation of preferences in a global synthesis
- A decision-making process

There is a great heterogeneity of the methods, so it is advisable to determine a priori before executing the exercise, which of these are appropriate for the fulfillment of the main objective raised at the beginning of the investigation. A bibliographic analysis is then applied through the UCINET software where the presence of these methods in similar investigations was studied. The results are shown below [2, 13-29]:

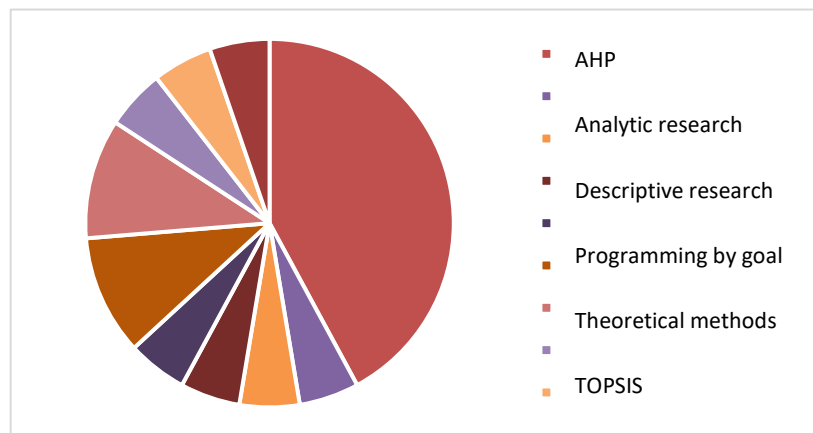


Figure 3. Bibliometric analysis on the multicriteria methods used for the selection and prioritization of investment projects.

As we can see, the Analytic Hierarchy Process (AHP) is the multicriteria decision method with the highest level of presence within the bibliographic references analyzed. Being rated by [15] as a mixed and complex method, which reaffirms the need for application in this case since the variables to be handled: selection criteria, are subjective and qualitative. It is then decided to develop the project selection method based on the AHP. Which taking into account the uncertain environment discussed will be executed in its plithogenic extension for the convenience of the analysis provided by the latter.

3. Methods

After studying the case, it is convenient to define the methods used for this research.

- Analysis and synthesis: to establish the case study and the elaboration of the conclusions.
- Method of Abstraction: for the elaboration of the investigation procedure.
- Hypothetical - Deductive: for the formulation of hypotheses.
- Scientific Observation Method: for the diagnosis of the problem and in the design of the investigation.
- Interviews and questionnaires: to obtain information for the execution of specific objectives.
- Document review
- Brainstorming
- Bibliometric analysis: for the analysis of the consulted bibliography.

3.1 Basic notions of Neutrosophy and Plithogeny

[12, 30-46] Let U be a universe of discourse, and P a non-empty set of elements, $P \subseteq U$. Let A be a non-empty set of *uni-dimensional* attributes $A = \{\alpha_1, \alpha_2, \dots, \alpha_m\}$, $m \geq 1$, and $\alpha \in A$ is a given attribute whose spectrum of all the possible values (or states) is the non-empty set S , where S can be a set of finite discrete, $S = \{s_1, s_2, \dots, s_l\}$, $1 \leq l < \infty$, or infinitely numerable set $S = \{s_1, s_2, \dots, s_\infty\}$, or an infinitely uncountable set (continuous), $S =]a, b[$, $a < b$, where $] \dots [$ is any open, semi-open, or a closed interval set of real numbers or another set.

Let V be a non-empty subset of S , where V is the range of all attribute values needed by experts for the application. Each element $x \in P$ is characterized by the values of all attributes in $V = \{v_1, v_2, \dots, v_n\}$, for $n \geq 1$.

In the set of attribute values, V in general, there is a dominant attribute value determined by experts in its application. Calling an attribute value *dominant* means that it is the most important attribute value that experts are interested in.

Each attribute value $v \in V$ has a corresponding *degree of membership* $d(x, v)$ of the element x , to the set P , concerning some given criteria.

The degree of membership can be a fuzzy degree of membership, a fuzzy intuitionist degree of membership, or a neutrosophic degree of membership to the plithogenic set.

Therefore, the membership degree function of the attribute value is:

$$\forall x \in P, d: P \times V \rightarrow \mathcal{P}([0, 1]^z), \quad (1)$$

Such that $d(x, v)$ is a subset of $[0, 1]^z$, where $\mathcal{P}([0, 1]^z)$ is the power set of $[0, 1]^z$, where $z = 1$ (fuzzy degree of membership), $z = 2$ (intuitionistic fuzzy degree of membership), or $z = 3$ (neutrosophic degree of membership).

Let $|V| \geq 1$ be the cardinality. Let $c: V \times V \rightarrow [0, 1]$ be the *attribute value contradiction degree function* between any two attribute values v_1 and v_2 , denoted by $c(v_1, v_2)$, and satisfying the following axioms:

$$c(v_1, v_1) = 0, \text{ the degree of contradiction between the same attribute values is zero;}$$

$c(v_1, v_2) = c(v_2, v_1)$, commutativity.

We can define a fuzzy attribute value contradiction degree function (c as before, we denote by c_F to distinguish it from the following two), an intuitionistic fuzzy attribute value contradiction degree function ($c_{IF} : V \times V \rightarrow [0, 1]^2$), or more generally, a neutrosophic attribute value contradiction degree function ($c_N : V \times V \rightarrow [0, 1]^3$), the latter one can be used to increase the complexity of the calculation, but also to increase the accuracy.

The degree of contradiction between the values of the one-dimensional attributes is mainly calculated. For multidimensional attribute values, we can divide them into their corresponding one-dimensional attribute values.

The attribute value contradiction degree function helps the plithogenic aggregation and plithogenic inclusion (partial order) operators to obtain a more accurate result.

The attribute value contradiction degree function is designed in each field where a plithogenic set is used according to the application to be solved. If ignored, the aggregations still work, but the result may lose precision.

So, (P, a, V, d, c) is called a plithogenic set

1. Where "P" is a set, "a" is an attribute (multi-dimensional in general), "V" is the range of values of the attribute, "d" is the degree of appurtenance of the attribute value of each element x to the set P for some given criteria ($x \in P$), and "d" means " d_F " or " d_{IF} " or " d_N ", when it is a degree of fuzzy appurtenance, an intuitionistic fuzzy appurtenance, or a degree of neutrosophic appurtenance, respectively, of an element x to the plithogenic set P;
2. "c" means " c_F " or " c_{IF} " or " c_N ", when it is a fuzzy attribute value contradiction degree function, intuitionistic fuzzy attribute value contradiction degree function, or neutrosophic attribute value contradiction degree function, respectively.

Functions $d(\cdot, \cdot)$ and $c(\cdot, \cdot)$ are defined according to the applications that experts need to solve.

Then, the following notation is used:

$x(d(x, V))$, where $d(x, V) = \{d(x, v), \text{ for every } v \in V\}, \forall x \in P$

The attribute value contradiction degree function is calculated between each attribute value concerning the dominant attribute value (denoted by v_D) in particular, and for other attribute values as well.

The attribute value contradiction degree function c evaluated between the values of two attributes is used in the definition of plithogenic aggregation operators (intersection (AND), union (OR), implication (\Rightarrow), equivalence (\Leftrightarrow), inclusion (partial order), and other plithogenic aggregation operators that combine two or more degrees of attribute values based on a t-norm and a t-conorm.

Most plithogenic aggregation operators are linear combinations of one fuzzy t-norm (denoted by Λ_F) with one fuzzy t-conorm (denoted by \vee_F), but nonlinear combinations can also be constructed.

If the t-norm is applied over the dominant attribute value denoted by v_D , and the contradiction between v_D and v_2 is $c(v_D, v_2)$, then v_2 is applied over the attribute value as follows:

$$[1 - c(v_D, v_2)] \cdot t_{\text{norm}}(v_D, v_2) + c(v_D, v_2) \cdot t_{\text{conorm}}(v_D, v_2), \tag{2}$$

Or, by using symbols:

$$[1 - c(v_D, v_2)] \cdot (v_D \Lambda_F v_2) + c(v_D, v_2) \cdot (v_D \vee_F v_2), \tag{3}$$

Similarly, if the t-conorm is applied on the dominant attribute value denoted by v_D , and the contradiction between v_D and v_2 is $c(v_D, v_2)$, then on the attribute value v_2 it is applied:

$$[1 - c(v_D, v_2)] \cdot t_{\text{conorm}}(v_D, v_2) + c(v_D, v_2) \cdot t_{\text{norm}}(v_D, v_2), \tag{4}$$

Or, by using symbols:

$$[1 - c(v_D, v_2)] \cdot (v_D \vee_F v_2) + c(v_D, v_2) \cdot (v_D \Lambda_F v_2), \tag{5}$$

The plithogenic neutrosophic intersection is defined as:

$$(a_1, a_2, a_3) \Lambda_P (b_1, b_2, b_3) = (a_1 \Lambda_F b_1, \frac{1}{2} [(a_2 \Lambda_F b_2) + (a_2 \vee_F b_2)], a_3 \vee_F b_3), \tag{6}$$

The plithogenic neutrosophic junction is defined as:

$$(a_1, a_2, a_3) \vee_P (b_1, b_2, b_3) = (a_1 \vee_F b_1, \frac{1}{2} [(a_2 \Lambda_F b_2) + (a_2 \vee_F b_2)], a_3 \Lambda_F b_3), \tag{7}$$

In other words, concerning what applies to membership, the opposite applies to non-membership, while in indeterminacy the average between them applies.

Plithogenic neutrosophic inclusion is defined as follows:

Since the degrees of contradiction is $c(a_1, a_2) = c(a_2, a_3) = c(b_1, b_2) = c(b_2, b_3) = 0.5$, it applies $a_2 \geq [1 - c(a_1, a_2)]b_2$ or $a_2 \geq (1 - 0.5)b_2$ or $a_2 \geq 0.5b_2$, while $c(a_1, a_3) = c(b_1, b_3) = 1$.

Having $a_1 \leq b_1$ the opposite is fulfilled for $a_3 \geq b_3$, hence $(a_1, a_2, a_3) \leq_p (b_1, b_2, b_3)$ if and only if $a_1 \leq b_1, a_2 \geq 0.5b_2$, and $a_3 \geq b_3$.

3.2 AHP and TOPSIS method in its plithogenic version

AHP: Hierarchical Analysis Process (AHP) [1, 2, 13, 14, 16, 18, 19, 21, 47-56]

a) Make a pairwise plithogenic comparison matrix as defined in equation 7 according to the linguistic terms.

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & \tilde{1} \end{bmatrix} \tag{8}$$

Where the condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$ established for the investment operator is satisfied:

Language expression	Plithogenic number
Low significance	(0.10, 0.70, 0.80)
Equal importance	(0.30, 0.40, 0.80)
Robust importance	(0.50, 0.40, 0.60)
Very robust significance	(0.70, 0.30, 0.10)
Absolute significance	(0.90, 0.10, 0.10)

Table 1. Saaty scale translated to a plithogenic triangular scale

If more than one expert makes the evaluation, then w_1, w_2, \dots, w_n are replaced by $\bar{w}_1, \bar{w}_2, \dots, \bar{w}_n, w'_1, w'_2, \dots, w'_n, \bar{w}'_1, \bar{w}'_2, \dots$, which are their corresponding weighted geometric mean values, see Eq. 1. and Eq. 2. The weights obtained are not necessarily expressed in normal form, therefore, we have the option of calculating equivalent normalized weights or, such that $\bar{w}'_n \sum_{i=1}^n w'_i = 1$ or $\sum_{i=1}^n \bar{w}'_i = 1$.

- a) For each line of the pairwise comparison matrix, determine a weighted sum based on the sum of the product of each cell by the priority of each alternative or corresponding criterion. For each line, divide its weighted sum by the priority of its corresponding alternative or criterion.
- b) Determine the mean λ_{max} of the result of the previous stage
- c) Calculate the consistency index (CI) for each alternative or criterion

$$CI = \frac{\lambda_{max} - m}{m - 1} \tag{9}$$

Where m is the number of alternatives

- d) Determine the Random Index (RI)

Number of alternatives for decision n	Random index	Number of alternatives for decision n	Random index
3	0.58	7	1.32
4	0.9	8	1.41
5	1.12	10	1.49
6	1.24		

Table 2. Random index for the calculation of the consistency coefficient

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

Linguistic term	SVNN
Very Important (MI)	(0.9, 0.1, 0.1)

Important (I)	(0.75, 0.25, 0.20)
Media (M)	(0.50,0.50,0.50)
Not Important (NI)	(0.35, 0.75, 0.80)
Very Not Important (MNI)	(0.10,0.90,0.90)

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

a) Construction of the plithogenic decision matrix
 Each d_{ij} 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. In this way, a matrix $D = (d_{ij})$ is obtained ij , where each d_{ij} is: $(i = 1,2, \dots, m; j = 1,2, \dots, n). (u_{ij}^t, r_{ij}^t, v_{ij}^t)$

b) Normalize the decision matrix
 Suppose that the weight of each criterion is given by $W = (w_1, w_2, \dots, w_n)$, where w_j denotes the relative importance of the criterion w_j . If it is the evaluation of criterion w_j by the t -th expert. Then Equation 10 is used to add those with the weights. The construction of the normalized matrix will be as follows: $w_j^t = (a_j^t, b_j^t, c_j^t) w_j^t$

$$w_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^n f_{ij}^2}} \tag{10}$$

Where: w_{ij} is the normalized value for the qualification of alternative i against criterion j and f_{ij} is the indicator of each alternative i against each indicator j .

c) Construction of the plithogenic decision matrix of the weighted average of unique values concerning the criteria.

$$D^* = D * W, \text{ where } d_{ij}^* = w_j * d_{ij} = (a_{ij}, b_{ij}, c_{ij}) \tag{11}$$

d) Determine the ideal positive and negative solutions.

$$s^+ = (x_1^+, x_2^+, \dots, x_{j+1}^+) \text{ it implies, } s_1^+ = \left(\frac{1}{3} \sum_{j=1}^n \left\{ (a_{ij} - a_j^+)^2 + (b_{ij} - b_j^+)^2 + (c_{ij} - c_j^+)^2 \right\} \right)^{\frac{1}{2}} \tag{12}$$

$$s^- = (x_1^-, x_2^-, \dots, x_{j+1}^-) \text{ namely, } s_1^- = \left(\frac{1}{3} \sum_{j=1}^n \left\{ (a_{ij} - a_j^-)^2 + (b_{ij} - b_j^-)^2 + (c_{ij} - c_j^-)^2 \right\} \right)^{\frac{1}{2}} \tag{13}$$

e) To calculate the Relative Proximity Index (Ri), it is done as follows. The proximity coefficient of each alternative is calculated concerning the positive and negative ideal solutions.

$$Ri(A^k, A^i) = \frac{s^-}{s^- + s^+} \tag{14}$$

f) The alternatives are ordered from highest to lowest, under the condition that Ri is the optimal solution. →

For the conversion of plithogenic numbers into sharp, the following equation will be continued:

$$S([T, I, F]) = \frac{2+T-I-F}{3}, \tag{15}$$

3.3 Algorithm developed for the selection of investment projects in a plithogenic environment

Objective: to offer an efficient choice of investment projects that pay tribute to the National Multi-year Investment Plan by prioritizing them. This level of prioritization will be obtained through the following processes:

Establishment of criteria and sub-criteria for project evaluation:

- Selection of criteria: according to questionnaires, documentary review, and bibliometric analysis.
- Apply the plithogenic AHP technique to determine the level of importance (weights) between subcriteria (single)
- Apply the plithogenic AHP technique to determine the level of importance (weights) between criteria (single)
- Multiply the matrices of each of the sub-criteria by one of the criterion to which it belongs to determine an overall level of importance (weights).

Evaluation of investment projects: First, decision maker must declare the criteria and their respective weights (results of the previous step), the alternatives (number of projects to be selected through the evaluation = and the experts to participate. Then execute the plithogenic TOPSIS analysis and expose the ranking of the evaluated projects to carry out selection.

4 Application of the model

The criteria are the relevant dimensions that significantly affect the objectives and express those involved in decision-making [13]. According to the bibliometric analysis performed [2, 13-23]. In section 2.2 of this document, it was observed that there is a tendency to evaluate projects based on the following criteria and aspects:

Criteria	Sub-criteria
Socio-environmental	Objective 3- Good health: Guarantee a healthy life and promote well-being for all of all ages. Objective 6- Clean water and sanitation: Guarantee the availability of water and its sustainable management and sanitation for all. Goal 7- Affordable and sustainable energy: Guarantee access to affordable, safe, sustainable, and modern energy for all. Objective 12- Responsible consumption and production: Guarantee sustainable consumption and production patterns. Goal 13- Climate Action: Adopt urgent measures to combat climate change and its effects. Impact on quality of life (poverty, health, employment, education, etc.) The number of people who benefited
Economic-Financial	Economic-financial indicators (Net Social Value, Internal Rate of Return, Cost/Benefit, Investment Payback Period, among others) Budget Financing sources
Technicians	Equipment-Technology Execution time Necessary resources (human, material) Location (micro and macro location) Project Type
Market study	Position before the competition Commercial benefits (prestige, brand consolidation, innovation) Customer satisfaction

Table 4. Criteria and subcriteria for the selection of investment projects

According to the above, the degree of cardinality is calculated: $7 \times 3 \times 5 \times 3 = 315$

The AHP method will be applied for each of the criteria set forth. The result of the process is shown below:

Criteria	Socio-environmental	Economic-Financial	Technicians	Market study	Weights
Socio-environmental	Equal importance	Absolute significance	Absolute significance	Absolute significance	0.18
Economic-Financial	$\frac{1}{(0,90; 0,10; 0,10)}$	Equal importance	Very robust significance	Very robust significance	0.19
Technicians	$\frac{1}{(0,90; 0,10; 0,10)}$	$\frac{1}{(0,70; 0,30; 0,10)}$	Equal importance	Absolute significance	0.15
Market study	$\frac{1}{(0,90; 0,10; 0,10)}$	$\frac{1}{(0,70; 0,30; 0,10)}$	$\frac{1}{(0,90; 0,10; 0,10)}$	Equal importance	0.15

Table 5. Application of the AHP to the criteria

In the same way, the weights were calculated for each of the sub-criteria, the final results of the process are shown

below:

Partner-environmental	WEIGHT	Economic-Financial	WEIGHT	Technicians	WEIGHT	Market study	WEIGHT
Objective 3	0.10	Economic-financial indicators	0.12	Equipment-Technology	0.12	Position before the competition	0.16
Goal 6	0.15	Budget	0.19	Execution time	0.16	Business benefits	0.17
Goal 7	0.15	Financing sources	0.19	Resources	0.14	Customer satisfaction	0.18
Goal 12	0.15			Location	0.19		
Quality of life impact	0.21			Project Type	0.22		
Goal 13	0.20						
Benefited	0.21						

Table 6. Results of the application of the AHP technique in the sub-criteria

To confirm the validity of the procedure in each of the binary comparisons, its consistency was analyzed, obtaining the following values respectively: (0.07; 0.09; 0.08; 0.065; 0.059) < 0.10, therefore it is accepted.

Then we proceed to the multiplication of matrices between the criteria and sub-criteria and then to the weighting of them to obtain the global input weights to the TOPSIS technique that will be used for the evaluation and selection of investment projects.

Not.	Sub-criteria	Weights
1	Objective 3- Good health: Guarantee a healthy life and promote well-being for all of all ages.	0.036642444
2	Objective 6- Clean water and sanitation: Guarantee water availability and its sustainable management and sanitation for all.	0.05411483
3	Goal 7- Affordable and sustainable energy: Guarantee access to affordable, safe, sustainable, and modern energy for all.	0.051868009
4	Objective 12- Responsible consumption and production: Guarantee sustainable consumption and production patterns.	0.053992697
5	Goal 13- Climate Action: Adopt urgent measures to combat climate change and its effects.	0.070404688
6	Impact on quality of life (poverty, health, employment, education, etc.)	0.072981582
7	Number of people benefited	0.075290383
8	Economic-financial indicators (Net Social Value, Internal Rate of Return, Cost / Benefit, Investment Payback Period, among others)	0.043197325
9	Budget	0.071653038
10	Financing sources	0.068875919
11	Equipment-Technology	0.035920985
12	Execution time	0.05050696
13	Necessary resources (human, material)	0.043482424
14	Location (micro and macro location)	0.057575976

15	Project Type	0.06803746
16	Position before the competition	0.045358783
17	Commercial benefits (prestige, brand consolidation, innovation)	0.048425688
18	Customer satisfaction	0.051670808

Table 7. Result of the calculation of the overall weighted weights for each sub-criterion for the evaluation of the projects

To better illustrate the method, we proceed to take as an example four projects called A, B, C, and D. Then, to start the application of the plithogenic TOPSIS, the variables are declared:

- Criteria: 18
- Alternatives: 4
- Experts: 10

Weighted Criteria	Weights	Alternatives to evaluate			
		Project A	Project B	Project C	Project D
Objective 3	0.036642444	(0.10,0.90,0.90)	(0,9; 0,1; 0,1)	(0,75, 0,25, 0,20)	(0.50,0.50,0.50)
Objective 6	0.05411483	(0,35; 0,75; 0,80)	(0,9; 0,1; 0,1)	(0.50,0.50,0.50)	(0.50,0.50,0.50)
Objective 7	0.051868009	(0.10,0.90,0.90)	(0,75, 0,25, 0,20)	(0,75, 0,25, 0,20)	(0,75, 0,25, 0,20)
Objective 12	0.053992697	(0,35; 0,75; 0,80)	(0,75, 0,25, 0,20)	(0.50,0.50,0.50)	(0,75, 0,25, 0,20)
Impact on Quality of life	0.070404688	(0,35; 0,75; 0,80)	(0,9; 0,1; 0,1)	(0,75, 0,25, 0,20)	(0.50,0.50,0.50)
Objective 13	0.072981582	(0.10,0.90,0.90)	(0,75, 0,25, 0,20)	(0.50,0.50,0.50)	(0,75, 0,25, 0,20)
Benefitted	0.075290383	(0.10,0.90,0.90)	(0,9; 0,1; 0,1)	(0.50,0.50,0.50)	(0.50,0.50,0.50)
Economic-financial indicators	0.043197325	(0.10,0.90,0.90)	(0,75, 0,25, 0,20)	(0.50,0.50,0.50)	(0.10,0.90,0.90)
Budget	0.071653038	(0.10,0.90,0.90)	(0,75, 0,25, 0,20)	(0.50,0.50,0.50)	(0.10,0.90,0.90)
Funding sources	0.068875919	(0.50,0.50,0.50)	(0,9; 0,1; 0,1)	(0.50,0.50,0.50)	(0.10,0.90,0.90)
Equipment-technology	0.035920985	(0.50,0.50,0.50)	(0,75, 0,25, 0,20)	(0,75, 0,25, 0,20)	(0,75, 0,25, 0,20)
Execution time	0.05050696	(0.50,0.50,0.50)	(0,9; 0,1; 0,1)	(0,75, 0,25, 0,20)	(0,75, 0,25, 0,20)
Resources	0.043482424	(0,35; 0,75; 0,80)	(0,9; 0,1; 0,1)	(0.50,0.50,0.50)	(0.50,0.50,0.50)
Localization	0.057575976	(0.10,0.90,0.90)	(0,75, 0,25, 0,20)	(0.50,0.50,0.50)	(0,9; 0,1; 0,1)
Type of project	0.06803746	(0,35; 0,75; 0,80)	(0,9; 0,1; 0,1)	(0.50,0.50,0.50)	(0.10,0.90,0.90)
Position in front of competence	0.045358783	(0,35; 0,75; 0,80)	(0,9; 0,1; 0,1)	(0.50,0.50,0.50)	(0.50,0.50,0.50)

Business benefits	0.048425688	(0.10,0.90,0.90)	(0,9; 0,1; 0,1)	(0.50,0.50,0.50)	(0.50,0.50,0.50)
Client satisfaction	0.051670808	(0.10,0.90,0.90)	(0,9; 0,1; 0,1)	(0.50,0.50,0.50)	(0.50,0.50,0.50)

Table 8. Step 1. Experts' assessment (median)

Weighted criteria	SIP	SIN
Objective 3	0.025576794	0.005683732
Objective 6	0.040591761	0.016236704
Objective 7	0.029606243	0.007791117
Objective 12	0.03312247	0.015689591
Impact on Quality of life	0.04766518	0.019066072
Objective 13	0.047603727	0.012527296
Benefitted	0.05831968	0.012959929
Economic-financial indicators	0.034460629	0.009068587
Budget	0.05716115	0.015042408
Funding sources	0.053351058	0.011855791
Equipment-Technology	0.019387525	0.012754951
Execution time	0.030541282	0.016967379
Resources	0.032616348	0.013046539
Localization	0.040007334	0.008890519
Type of project	0.055221561	0.012271458
Position in front or competence	0.034023813	0.013609525
Business benefits	0.037510376	0.008335639
Client satisfaction	0.040024036	0.00889423

Table 9. Steps 2-6 of the TOPSIS

TOPSIS	Proj A	Proj B	Proj C	Proj D
s+	0.031446823	0	0.01853756	0.02132344
s-	0	0.03144682	0.0168575	0.01060924
Ri	0	1	0.47626692	0.33223761
Level of prioritization and ranking of the projects selection	4	1	2	3

Conclusion

At present, the economic crisis affecting the countries makes the selection process of investment projects to be carried out more critical. Such is the case of Ecuador, where the Multi-annual Public Investment Plan 2017-2021 establishes indicative amounts of public investment that are projected to be executed annually to achieve each of the nine strategic objectives of the National Development Plan that pay tribute to the Sustainable Development Goals of the UN. However, this plan has certain weaknesses that may not allow an effective and efficient choice at the same time. Which entails a scenario of uncertainty for the Ecuadorian investment process. It can be said that the objective of this research was met by responding to the problem, developing a three-step model for the selection of investment projects in a plithogenic environment using discrete multicriteria decision methods. From its application we may conclude that:

1. In the case of comparison of criteria, for experts, it is more important to choose a project that shows favorable economic-financial indicators and in turn, is compatible with the Socio-environmental indicators that contribute to the implementation of the Sustainable Development Goals.
2. In the case of the separate analysis, it is evident that the experts consulted give greater importance to the budget, financing sources, client satisfaction, location, type of project, impact on quality of life and the number of people benefited.
3. During the TOPSIS, as an example, it was confirmed that, in a weighted way, the experts give greater importance to the impact quality of life, the fulfillment of objective 13 of Sustainable Development "Climate Action" which means adopting urgent measures to fight climate change and its effects, the

number of people benefited and the budget.

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