The potential of alliances for regional productive development from the Tutorial Centers of the University of Cartagena measured with the support of Plithogenic SWOT Analysis

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Abstract. The University of Cartagena in Colombia, with its 104 recognized research groups in various fields such as health, social sciences, engineering, basic sciences, environment, and sustainable development, expands its academic reach by establishing Tutorial Centers in Bolívar and Córdoba. The objective of these centers is to offer distance learning opportunities, thus increasing access to education for the local population. This study explores the potential of forming strategic alliances with the productive sector, taking advantage of the resources and strategic benefits of these centers. In this paper, we measure the potentialities, based on the Plithogenic SWOT Analysis. The SWOT analysis is used to measure the possible strengths, weaknesses, opportunities, and threats to the development of an organization or a project. In particular, the potentialities are calculated as the combination of strengths and opportunities. On the other hand, the variables to be measured are multiple and of different natures, which is why we use the Plithogeny theory. For the study, we used the opinion of a group of 5 experts.

Keywords: Plothogeny, Plithogenic Set, SWOT Analysis, Potentials, Plithogenic SWOT Analysis.

1 Introduction

The University of Cartagena, located in Colombia, is an academic institution that has 104 research groups recognized in the Scienti platform of the Ministry of Science, Technology, and Innovation. The research lines of these groups focus on the areas of health, social sciences, engineering, basic sciences, the environment, and sustainable development, among others.

In addition to its activities developed in the face-to-face academic programs, the university has established Tutorial Centers in the departments of Bolívar and Córdoba, to expand educational opportunities through distance education to the local population.

Given the strategic location of these tutorial centers and their potential to influence the socio-economic landscape, it is necessary to explore the possibilities of forming alliances with the productive sector. These alliances are not only beneficial for academic growth but also strategic for regional development.

Institutional guidelines and network transformation are necessary to embed applied research in academic settings, which highlights the justification for having well-defined objectives and being able to highlight the impact on the community. These centers have the potential to serve as resources for practical solutions to local problems, thus promoting regional development.

This study aims to analyze the potential of generating alliances with the productive sector from the perspective of the resources of these tutorial centers, focusing on the available resources and the strategic advantages they offer. This research is justified by the need to take advantage of the academic capacities of these centers to impact economic and social growth in the regions of departments such as Bolívar and Córdoba. This is because education and research are important axes for regional transformation.

Collaboration between academia and the productive sector is a symbiotic relationship that can enhance innovation and technological development. Survey and interview data indicate that there are efforts to strengthen these links, albeit with limitations in resources and coordination. The triple helix theory, which describes the in-

teraction between university, industry, and government, can be a useful framework for understanding and strengthening these relationships.

This collaboration benefits not only students, who gain practical experience and applied knowledge but also the productive sector, which can access new technologies and methodologies developed in academia. However, a concerted effort is needed to overcome challenges such as lack of funding and shortage of adequate infrastructure for research.

This article is dedicated to quantitatively determining the potential of the alliance between the University of Cartagena and the productive centers of the region and the country. The variables that constitute the study are of different dimensions, there are pedagogical, social, and economic dimensions, among others. In addition, these variables interact with each other in a dynamic way, where there may be indeterminations. That is why we chose the theory of Plithogeny to carry out the measurement.

Plithogeny is the theory that generalizes Neutrosophy, where the interaction between different concepts, their opposites, and their neutralities is taken into account, to form a unique dynamism more general than classical dialectics [1-4].

On the other hand, the SWOT technique is used to measure the strengths, weaknesses, opportunities, and threats that an organization or project faces [5-7]. Weaknesses and strengths are part of what affects the organization internally, while opportunities and threats affect it from the outside. The combination of Strengths + Opportunities makes up the Potentials. This method will be combined with Plithogeny to enrich and gain accuracy in the results.

The paper presents the following structure, is followed by a Materials and Methods section where the concepts of Plithogeny, SWOT and the Plithogenic SWOT analysis presented in [8] are recalled. Later, the Results section appears, where the study is carried out. We finish with the conclusions.

2 Materials and Methods

The section is dedicated to recalling the concepts of plithogenic sets, SWOT analysis, and the method proposed in [8] on Plithogenic SWOT analysis.

2.1 Plithogenic sets

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 $A = \{\alpha_1, \alpha_2, ..., \alpha_m\}$, $m \geq 1$, 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, $S = \{s_1, s_2, ..., s_l\}$, $1 \leq l < \infty$, or infinitely denumerable set $S = \{s_1, s_2, ..., s_\infty\}$, or an infinitely uncountable set (continuous), $S =]a, b[$, $a < b$, where $] ... [$ is an open, semi-open or a closed interval set of real numbers or another set, [1-4, 9-13].

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 $V = \{v_1, v_2, ..., v_n\}$, for $n \geq 1$.

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

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

The degree of appurtenance can be either a fuzzy degree of appurtenance, an intuitionistic fuzzy degree of appurtenance, or a neutrosophic degree of appurtenance to the plithogenic set.

Thus, the *attribute value appurtenance degree function* is:

$$\forall x \in P, d: P \times V \to P ([0, 1]^z) \qquad (1)$$

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 appurtenance), z = 2 (intuitionistic fuzzy degree of appurtenance), or z = 3 (neutrosophic degree of appurtenance).

Let $|V| \geq 1$ be the cardinal. Let $c: V \times V \to [0, 1]$ 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:

1. $c(v_1, v_1) = 0$, the degree of contradiction between the same attribute values is zero;

2. $c(v_1, v_2) = c(v_2, v_1)$, 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 intuitive fuzzy attribute value contradiction degree function ($c_{IF} : V \times V \to$

$[0, 1]^2$), 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.

We mainly calculate the degree of contradiction between the values of uni-dimensional attributes. For multi-dimensional attribute values, we divide them into their corresponding one-dimensional attribute values.

The attribute value contradiction degree function helps the plithogenic aggregation operators and the plithogenic inclusion (partial order) 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, aggregations still work, but the result may lose accuracy.

So (P, a, V, d, c) is called a *plithogenic set* [1-4]:

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 membership, an intuitionistic fuzzy membership, or a degree of neutrosophic membership, 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 $d(x, V) = \{d(x, v), \text{for all } v \in V\}, \forall x \in P$.

The attribute value contradiction degree function is calculated between each attribute value with respect to the dominant attribute value (denoted by v_D) in particular, and with respect to 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 values of the attribute based on a t-norm and a t-conorm.

Most plithogenic aggregation operators are linear combinations of one fuzzy t-norm (denoted by $\wedge_F$) 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:

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

Or, by using symbols:

$$[1 - c(v_D, v_2)] \cdot (v_D \wedge_F v_2) + c(v_D, v_2) \cdot (v_D \vee_F v_2) \qquad (3).$$

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:

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

Or, by using symbols:

$$[1 - c(v_D, v_2)] \cdot (v_D \vee_F v_2) + c(v_D, v_2) \cdot (v_D \wedge_F v_2) \qquad (5).$$

The *Plithogenic Neutrosophic Intersection* is defined as:

$$(a_1, a_2, a_3) \wedge_P (b_1, b_2, b_3) = \left(a_1 \wedge_F b_1, \frac{1}{2}[(a_2 \wedge_F b_2) + (a_2 \vee_F b_2)], a_3 \vee_F b_3\right) \qquad (6),$$

The *Plithogenic Neutrosophic Union* is defined as:

$$(a_1, a_2, a_3) \vee_P (b_1, b_2, b_3) = \left(a_1 \vee_F b_1, \frac{1}{2}[(a_2 \wedge_F b_2) + (a_2 \vee_F b_2)], a_3 \wedge_F b_3\right) \qquad (7),$$

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

The *Plithogenic Neutrosophic Inclusion* is defined as follows:

Since the degrees of contradiction are $c(a_1, a_2) = c(a_2, a_3) = c(b_1, b_2) = c(b_2, b_3) = 0.5$, 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 done 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 $a_3 \geq b_3$.

2.2 SWOT Analysis

The SWOT analysis is a methodology for studying the situation of a company or a project, analyzing its internal characteristics (weaknesses and strengths) and its external situation (threats and opportunities) in a squared matrix, [5-7].

The analysis consists of four steps:
- External analysis,
- Internal analysis,
- Preparation of the SWOT matrix,
- Determination of the strategy to be used.

The organization does not exist and cannot exist outside an environment, the environment that surrounds it; So external analysis allows us to identify the opportunities and threats that the context may present to an organization. These are the components of external analysis.

Opportunities are those positive factors that are generated in the environment and that, once identified, can be taken advantage of. Threats are negative situations, external to the program or project, that can attack it, so when appropriate, it may be necessary to design the right strategy to be able to circumvent them.

The internal elements to be analyzed during the SWOT analysis correspond to the strengths and weaknesses that have to do with the availability of capital resources, personnel, assets, product quality, internal and market structure, and consumer perception, among others.

The internal analysis allows for fixing the strengths and weaknesses of the organization, carrying out a study that allows knowing the quantity and quality of the resources and processes with which the organization has.

Strengths are all those internal and positive elements that differentiate the program or project from others of the same kind. Weaknesses relate to all those elements, energy resources, skills, and assets that the organization already has and that constitute barriers to the good performance of the organization. Weaknesses are internal problems that once they are identified and after developing an appropriate strategy, can and should be eliminated.

The four elements of the analysis are located in a matrix and evaluated by experts. These results are aggregated using the percentages of the assessments.

From the combination of strengths and opportunities arise the potentialities, which indicate the most promising lines of action for the organization. Limitations, determined by a combination of weaknesses and threats, pose a serious warning. Risks (combination of strengths and threats) and challenges (combination of weaknesses and opportunities), determined by their corresponding combination of factors, will require careful consideration when setting the course that the organization must take toward the desirable future.

2.3 Plithogenic SWOT Analysis

The method proposed in [8] uses the following:

To calculate the results of the aggregation by the 4 quadrants, viz. Strength-Opportunity (SO), Strength-Threat (ST), Weakness-Opportunity (WO), and Weakness-Threat (WT), formulas 8, 9, 10 and 11 are used, respectively. This article does not differentiate any dominant aspect of these formulas [14-16].

$$SO = \wedge_{p_i}\wedge_{p_j}\left(\left(\omega_{o_i}\wedge_p\omega_{s_j}\right)\wedge_p E_{o_i s_j}\right) \qquad (8),$$

Where $\wedge_p$ is the Plithogenic Neutrosophic Intersection based on the minimum t-norm and the maximum t-conorm (see Equation 6), ω_{o_i} is the weight given to the ith opportunity, ω_{s_j} is the weight given to the jth strength, $E_{o_i s_j}$ is the evaluation assigned to the intersection of the ith opportunity with the jth strength.

$$ST = \wedge_{p_i}\wedge_{p_j}\left(\left(\omega_{T_i}\wedge_p\omega_{s_j}\right)\wedge_p E_{T_i s_j}\right) \qquad (9),$$

ω_{T_i} is the weight given to the ith threat, and $E_{T_i s_j}$ is the assessment assigned to the intersection between the ith threat with the jth strength.

$$WO = \wedge_{p_i}\wedge_{p_j}\left(\left(\omega_{w_i}\wedge_p\omega_{o_j}\right)\wedge_p E_{w_i o_j}\right) \qquad (10),$$

ω_{w_i} is the weight given to the ith weakness, and $E_{w_i o_j}$ is the evaluation assigned to the intersection of the ith weakness with the jth opportunity.

$$WT = \wedge_{p_i}\wedge_{p_j}\left(\left(\omega_{w_i}\wedge_p\omega_{T_j}\right)\wedge_p E_{w_i T_j}\right) \qquad (11).$$

See also [17-20].

3 Results

The method proposed in [8] uses some measurement scales, which are shown in Tables 1, 2.

Language expression	Plithogenic number (T, I, F)
Very poor (VP)	(0.10, 0.75, 0.85)
Poor (P)	(0.25, 0.60, 0.80)
Medium poor (MP)	(0.40, 0.70, 0.50)
Medium (M)	(0.50, 0.40, 0.60)
Medium good (MG)	(0.65, 0.30, 0.45)
Good (G)	(0.80, 0.10, 0.30)
Very good (VG)	(0.95, 0.05, 0.05)

Table 1: Linguistic values associated with plithogenic numbers for the evaluation according to the criteria. Source: [8].

Language expression	Plithogenic number (T, I, F)
Low significance (LS)	(0.10, 0.70, 0.80)
Equal significance (ES)	(0.30, 0.40, 0.80)
Robust significance (RS)	(0.50, 0.40, 0.60)
Very robust significance (VRS)	(0.70, 0.30, 0.10)
Absolute significance (AS)	(0.90, 0.10, 0.10)

Table 2: Linguistic values associated with plithogenic numbers for the evaluation of the weight of the criteria. Source: [8].

Five specialists were hired, who gave their opinions based on the linguistic measurement scales shown in Tables 1 and 2. The Strengths, Weaknesses, Opportunities, and Threats shown below were identified:

The opportunities are as follows:
O1- The time is right for the alliance to be established, as society in general and the State will welcome it. There is a regional need for development, so any positive experience is welcome.
O2- There are experiences in other regions of the world and the country that can serve as a basis for a local integration program.

The threats identified were:
T1- The tangible results of any program implemented may not be visible in less than a year, which may discourage local government and society in general from collaborating with them.
T2- There may be a lack of acceptance, indifference, or ignorance on the part of the general population to realize the advantages they are receiving through this means and this can lead to apathy and little recognition. Especially when popular language is not used for social dissemination or, what is worse, when there is no such dissemination at all.

Weaknesses were:
W1. The situation of teacher-researchers is complex in terms of their ability to transfer knowledge and interact with other actors.
W2. The tutorial centers must not only be involved in education and training but must also connect with the community and production centers. This is something they are not used to.
W3. For their part, production centers may not be accustomed to the language and methods of academia and therefore there may be a certain degree of incomprehension in the integration of academia and production.
W4. There may be a lack of financial and technological resources, insufficient motivation among students and teachers, and a lack of a clear definition of lines of research.
W5. An institutional policy aimed at strengthening the research infrastructure is required.
W6. It is crucial to foster a more robust research culture among students and teachers so that academic activities transcend beyond pedagogical exercises and become rigorous research that generates new knowledge.

The strengths are:
S1. Academia can support production in the incorporation of new technologies that help them gain greater efficiency and effectiveness in products and services.

S2. The productive system can help universities as a provider of material and financial resources in supporting teaching work.

S3. The productive system can practically complement the knowledge that students receive in the academy.

S4. There is the possibility of creating a solid academic community and participation in national and international research networks.

In summary, each of the specialists gave an opinion on the aspects of the scales shown in Table 1, comparing the internal criteria (S and W) with the external ones (O and T). They evaluated the weight or importance of each criterion on the scale shown in Table 2. The median of the results for all the specialists was then found, obtaining a single value of weight and evaluation for all the criteria, aggregated as the collective result of all the specialists.

The results are shown in Tables 3 and 4.

	No.	Opportunities		Threats	
		O1	O2	T1	T2
Strengths	S1	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)
	S2	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)
	S3	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)
	S4	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
Weaknesses	W1	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)
	W2	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)
	W3	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)
	W4	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
	W5	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)
	W6	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)

Table 3: SWOT matrix of the aspects measured in the form of plithogenic numbers. Source: the authors.

Aspect to measure	Aggregated weight by the specialists
O1	(0.90, 0.10, 0.10)
O2	(0.90, 0.10, 0.10)
T1	(0.90, 0.10, 0.10)
T2	(0.90, 0.10, 0.10)
S1	(0.90, 0.10, 0.10)
S2	(0.90, 0.10, 0.10)
S3	(0.90, 0.10, 0.10)
S4	(0.90, 0.10, 0.10)
W1	(0.90, 0.10, 0.10)
W2	(0.90, 0.10, 0.10)
W3	(0.90, 0.10, 0.10)
W4	(0.90, 0.10, 0.10)
W5	(0.90, 0.10, 0.10)
W6	(0.90, 0.10, 0.10)

Table 4: Neutrosophic numbers obtained from calculating the median of the weights evaluated by the specialists. Source: the authors.

The results achieved were the following, using Equations 8-11:

$SO = (0.80, 0.08928, 0.30)$, $ST = (0.25, 0.35586, 0.80)$, $WO = (0.80, 0.07908, 0.30)$, $WT = (0.25, 0.34919, 0.80)$.

The qualitative evaluation of the results obtained is obtained using the distance formula 12, to compare them with each of the elements in Table 1 and assign the linguistic value corresponding to the smallest distance:

$$d(Q, TV_v) = \sqrt{(Q - TV_v) \cdot (Q - TV_v)'} \qquad (12)$$

Where Q denotes the plithogenic number evaluating the quadrant, TV_v is the plithogenic number of the vth member of Table 1, $T(\cdot)$, $I(\cdot)$, and $F(\cdot)$ are their truth, indeterminate, and falseness values, respectively, and $'$ is the matrix transpose operator.

Thus, the SO quadrant (potentials) is rated as "Good" with a distance of 0.29418; the ST quadrant (risks) is rated as "Poor" with a distance of 0.24413, the WO quadrant (challenges) is rated as "Good" with a distance equal to 0.02092, and the WT quadrant (limitations) is rated as "Poor" with a distance equal to 0.25081.

Conclusion

This paper was dedicated to studying the potential of using the Tutorial Centers of the University of Cartagena de Indias in Colombia to create cooperation between productive centers and academia to contribute to the economic and social development of the region. To achieve this, we relied on the opinion of five experts, who evaluated the situation of the Strengths, Weaknesses, Opportunities, and Threats to carry out any integration program in this sense. The evaluations were carried out with the help of a Plithogenic SWOT analysis. This allowed us to take into account the plurality of variables involved, the indeterminacy, and uncertainty to measure the main aspects that influence the success of the projects. The main result is that the potential is good, and the challenges have good prospects of being overcome. As for the risks and limitations, they have low ratings; therefore we must work on them, looking for tactics and strategies to avoid failure due to these aspects.

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