A neutrosophic model for the evaluation of the formative development of investigative competences

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Abstract. This paper presents a multicriteria method, solved by means of a method which is based on the ideal distance using neutrosophic numbers, which is convenient to evaluate the development of the investigative competencies of graduates in the UNIANDES Ibarra Law School, their competences and functions, for which we used theoretical samples that address the follow-up programs for higher education graduates, the analysis of their competencies and their impact on labor markets. The descriptive field research with a quantitative approach was applied. The sample covered a total of 122 Law professionals. The results obtained showed a similarity in the decisions obtained in practice.

Keywords: Law School graduates follow-up, competencies, multi-criteria selection, neutrosophic numbers.

1 Introduction

This investigation is the result of conducting an evaluation of the research competencies at the Regional Autonomous University of the Andes (UNIANDES), Ecuador, in the specificity of Law degree, and then, to extend its scope to the Ecuadorian and Latin American universities of this century applying TOPSIS [1] as a modern multicriteria decision method for a finite number of alternatives [2]. The selected alternative will have the farthest distance to the ideal negative solution and the shortest distance to the ideal positive solution [3]. During three years of hard work, theoretical inquiry, systematic interpretations and on-site actions, it is demonstrated the need to recognize formative research as a latent need to prepare professionals in their future skills.

The first history of monitoring higher education graduates began in the mid-19th century. Likewise, during the Second World War, in developed countries, the need to assess the competences of higher education graduates and its impact on labor markets was raised. During the second half of the 20th century, with the emergence of communication systems, the production and the administration, the relations between the countries and consequently their working interchanges were transformed (National University of Colombia, 2011).

From that moment, the repercussion of the graduate's performance in the business field became a topic of special interest, that's why the analysis in this regard began to be systematized and the universities had to take the forefront to investigate the research competitiveness of their graduates.

The current trend for the evaluation of multiple criteria requires a new science called Neutrosophy, which is the branch of philosophy that studies the origin, nature and scope of neutralities created by Professor Florentin Smarandache with multiple applications in the field of decision making [4].

Other authors introduce linguistic terms to be able to mathematically evaluate the assessment process when applying neutrosophic science [4, 5], which facilitates decision-making since it allows to know in detail the factors involved in it.

With regard to Ecuador, the review of educational quality required the implementation of mechanisms that would allow the activities, tasks, performance, positions, roles, and functions that graduates carry out to be followed up, also gave room for institutional self-evaluation. It worth mentioning that the University of Loja (UNL) is the one that officially began graduate studies in 2005 [6].

But it is the Organic Law of Higher Education [7], along with the Council of Evaluation, Accreditation and Quality Assurance of Higher Education (CEAACES), which allow the Regional Autonomous University of the Andes (UNIANDES) to have a graduates follow-up program, which allows them to maintain relationships with them through a Web page [8] where there is the possibility of accessing services, registering, finding employment options and accessing a portfolio of companies. This is complemented by an Annual Meeting of Graduates that summons graduates from each Extension to exchange experiences, where they can participate in conferences on innovative topics, plenary sessions and discussions at working groups. In addition, this interaction facilitates the collection of data on aspects related to job performance and inquires about the updating needs of graduates, among others.

UNIANDES Ibarra Extension, has the intentions to implement a reproducible method, even extensive to the rest of the training centers so that it can make an assessment of the competence of students under the precepts of Neutrosophy as a science, just like it is applied by Chakraborty [9] as an approach to current problems.

2 Materials and methods

In this paper, we propose a recommendation model based on the ideal distance using the single value neutrosophic number (SVN), specifically the TOPSIS method, but weighting will not use AHP (Analytical Hierarchy Process) but rather we will be using the aggregation operator WA (Weighted Average).

Decision making has historically been approached by multiple disciplines, from the classic ones such as philosophy, statistics, mathematics and economics, to more recent ones such as Artificial Intelligence. The theories and models developed point to rational support for complex decision making [10]. They include typical activities such as [11, 12], mathematical theory developed to deal with indeterminacy and complex decision making, such as:

• Defining the problem

• Identifying alternatives

• Evaluation criteria

• Selection of experts

• Evaluation of alternatives

• Order and selection of alternatives

• Decision.

Figure 2.1. Process for solving a decision-making problem [10].

In this paper, the highlighted activities will be addressed (Model, Collect information, assess alternatives)

Additionally, in order to obtain the expert evaluations in the evaluation models, the use of Single Value Neutrosophic Numbers (SVN) is proposed [13, 14].

Let X be a universe of discourse, a SVNS A over X, is an object with the following form.

$$A = \{\langle x, u_A(x), r_A(x), v_A(x)\rangle : x \in X\}d \tag{2.1}$$

$Where\ u_A(x): X \to [0,1],\ r_A(x): X \to [0,1]\ y\ v_A(x): X \to [0,1]$
$with\ 0 \leq u_A(x) + r_A(x) + v_A(x): \leq 3\ for\ all\ x \in X$

For convenience, the SVN number will be expressed as A = (a, b, c), where a, *b*, *c* ∈ [0,1], and a + b + c ≤ 3 to determine the degree of association of membership and non-membership of the decision *a* over the proposal *x*

The method to be followed is then to collect the information from the entire set of decisions *Aj* of the discussion universe (data collected from the surveys, normalize their values), choose the best positive ideal vector B*i* by the experts, and then calculate the distances that the separates S*i*.

$$s_i = \left(\frac{1}{3}\sum_{j=1}^{n}\left\{\left(|a_{ij}-a_j^*|\right)^2+\left(|b_{ij}-b_j^*|\right)^2+\left(|c_{ij}-c_j^*|\right)^2\right\}\right)^{\frac{1}{2}}$$
$$(i = 1,2, \dots, m) \qquad (2.2)$$

In this document, linguistic variables are represented using single value neutrosophic numbers (SVN) to develop a decision support framework for evaluating the formative development of investigative skills.

As aggregation operators we will use a type of mathematical function to merge the information. These operators combine *n* values in a domain *D* and return a value in that same domain as treated by Torra and Narukawa [15].

The weighted average (WA) is one of the most mentioned aggregation operators in the literature. An operator WA has an associated vector of weights V, with V*i* ∈ [0, 1] sum Vi = 1 having the following form:

$$WA(a_1, .., a_n) = \sum_1^n v_i a_i \qquad (2.3)$$

Where *Vi* represents the importance/relevance of the data source *ai*

Table 1
There is no source in the current document: *Linguistic terms used*

Linguistic term	ACRONYMS	SVN numbers
Extremely Good	(EG)	(1,0,0)
Very Very Good	(VVG)	(0.9, 0.1, 0.1)
Very Goog	(VG)	(0.8,0,15,0.20)
Good	(G)	(0.70,0.25,0.30)
Moderately Good	(MDG)	(0.60,0.35,0.40)
Medium	(M)	(0.50,0.50,0.50)
Moderately Bad mala	(MDB)	(0.40,0.65,0.60)
Bad	(B)	(0.30,0.75,0.70)
Very Bad	(VB)	(0.20,0.85,0.80)
Very Very Bad	(VVB)	(0.10,0.90,0.90)
Extremely Bad	(EB)	(0,1,1)

The results of the distances calculation allow us to sort the students according to the achievement of the competences.

The collection of the information is represented in the utility vector [16] and is expressed as follows:

$$P_j = \{p_{j1}, p_{j2}, \dots, p_{jk}\} \qquad (2.4)$$

Therefore the decisions for the evaluation of the formative development of investigative competences are provided by means of this valuation vector and the decision vij for each criterion Ci of each group of student Ej is expressed by means of the SVN number.

3 RESULTS AND DISCUSION

The objective of this phase was to evaluate the formative development of the competences at UNANDES Ibarra Law School, addressing the graduates' follow-up program. The sample covered a total of 122 Law professionals and the questionnaire was used as an instrument.

3.1 TOPSIS, Technique of Preference Sorted by Similarity to an Ideal Solution

TOPSIS technique has a totally intuitive approach, and is based on the fact that each of the alternatives can be represented in a Euclidean space, which also happens with the attributes that we're evaluating. The technique seeks to select an alternative that is as close as possible to a positive ideal alternative, but as far as possible from an alternative called negative ideal according to Chen [17]. The first one is integrated with the best nominal values that the attributes have, while the second is formed with the worst nominal values that are found in the attributes. Let be the alternatives $Ai,\ i = 1, 2, \ldots m$, the criteria $Cj,\ j = 1, 2, \ldots n$, the weights of the criteria wj and a decision matrix with $x\ ij\ = U\ j\ (A\ i\ ), \forall i, j$.. Where U is the utility function of the decision maker, operating on the basis that all the criteria are to be maximized/minimized according to whether profits or costs are being considered, respectively.

It is suggested that the direct method to carry out the multicriteria evaluation consists of choosing the alternative that has the shortest distance to the ideal alternative, in this way the chosen alternative would be very similar to the ideal solution, according to Srinivasan and Shocker [18]. Another way of choosing the alternative would be selecting the one that is furthest from the anti-ideal solution, according to Zeleny [19]. And this is the one that was used in the determination of the evaluation of the investigative competences of the students. TOPSIS is a technique that considers the distance to the ideal alternative and the distance to the anti-ideal alternative.

3.2 Identification of Alternatives:

In this phase the evaluation framework of the alternatives is made up by the experts' criteria evaluating three alternatives by neutrosophic methods based on the information aggregation model shown in Table 2

Table 2. *Alternatives for evaluating the formative development of competences*

ID	Acronym	Description	Questions
1	OMT	Occupational Market Trends	4
2	OD	Occupational Demand (employability)	5
3	TF	Training and Feedback	1

Table 1. Alternatives for the evaluation of the formative development of competences

Each of these variables (OMT, OD, TF), called alternatives, have the statistical results of the 10 questions of the survey as values, and these will be weighted with the percentage of the students who answered. The following table shows the data taken from the population of 122 students graduated from UNANDES Ibarra.

Table 3, Survey results, each row adds up to 122

Acronyms	Question	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
OMT	1	60	61	1	0	0
	2	82	40	0	0	0
	3	61	44	17	0	0
	4	111	11	0	0	0
OD	5	104	11	7	0	0
	6	33	11	67	11	0
	7	17	78	5	11	11
	8	22	61	11	28	0
	9	66	39	17	0	0
TF	10	17	33	39	17	16

Possible values go from 0 no response, up to 122 the maximum number of the population, these data are normalized in values from 0 to 1 for the total population to match the numbers of the linguistic terms of the SVN so that we can plot them in the same curved surface of the triangular SVN number.

Linguistic term	Acronym	SVN numbers
Extremely good	(EG)	(1,0,0)
Very very good	(VVG)	(0.9, 0.1, 0.1)
Very good	(VG)	(0.8,0,15,0.20)
Good	(G)	(0.70,0.25,0.30)
Moderately good	(MDG)	(0.60,0.35,0.40)
Medium	(M)	(0.50,0.50,0.50)
Moderately bad	(MDB)	(0.40,0.65,0.60)
Bad	(B)	(0.30,0.75,0.70)
Very bad	(VB)	(0.20,0.85,0.80)
Very very bad	(VVB)	(0.10,0.90,0.90)
Extremely bad	(EB)	(0,1,1)

Table 3. Language terms used

3.4 Collection of information:

The collection of information is carried out automatically without the intervention of specialists, since knowing the value of each sample in percent of the population (0 and 1), it is easy to determine in linguistic terms for each of the three alternatives (OMT, OD, TF), since the region in the space occupied by the SNV neutrosophic number is known.

Figure 1, Decision surface for SNV terms (prepared by the author)

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In [84]: from mpl_toolkits.mplot3d import Axes3D

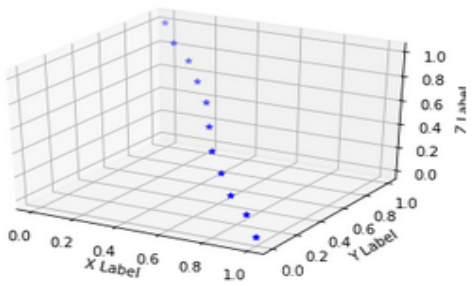
         fig = plt.figure()
         ax = fig.add_subplot(111, projection='3d')

         x =[1,0.9,0.8,0.7,0.6,0.5,0.4,0.3,0.2,0.1,0]
         y =[0,0.1,0.15,0.25,0.35,0.50,0.65,0.75,0.85,0.90,1]
         z =[0,0.1,0.20,0.30,0.40,0.50,0.60,0.70,0.80,0.90,1]

         ax.scatter(x, y, z, c='b', marker='*')

         ax.set_xlabel('X Label')
         ax.set_ylabel('Y Label')
         ax.set_zlabel('Z Label')

         plt.show()
```



Decision makers' opinions are added using the SVNWA aggregation operator, the result is shown in table 4

Table 4, Collection of information

Acronym	Question	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
OMT	1	MDB	M	EB	EB	EB
	2	MDG	B	EB	EB	EB
	3	M	B	VVB	EB	EB
	4	VVG	VVG	EB	EB	EB
OD	5	VG	VVG	EB	EB	EB
	6	VB	VVG	M	VVB	EB
	7	VVB	MDG	EB	VVB	VVB
	8	VVB	M	EB	VB	EB
	9	M	B	VVB	EB	EB
TF	10	VVB	VB	B	VVB	VVB

3.4 Evaluation of Alternatives

From this information and with equation (3.1), (3.2) the ideal alternative for each student sample is selected.

$$A^{+} = \{(\max_{i=1}^{n}|j \in I^{+}|), (\min_{i=1}^{n}|j \in I^{-}|)\} = [v_1^{+}, v_2^{+}, \ldots, v_n^{+}] \quad (3.1)$$

$$A^{-} = \{(\min_{i=1}^{n}|j \in I^{+}|), (\max_{i=1}^{n}|j \in I^{-}|)\} = [v_1^{-}, v_2^{-}, \ldots, v_n^{-}] \quad (3.2)$$

The ideal alternative for expert judgment is:
A+ = (VVG, VVG, VVG, VG, MDG)
The alternatives are evaluated according to the Euclidean distance of all the vectors of set A. To order it, it was compared with the distance to the ideal vector A +. If the alternative Ai is closer than the measured distance A +. Then the calculated distance (closest Ai) is the best alternative, thus allowing establishing an order of priorities between them.

3.5 Selection of Alternatives

The distance of each alternative to the positive ideal solution, d^{+}, and to the negative ideal solution, d^{-}, is given by (3.3) and (3.4) respectively:

$$d_i^{+} = \sqrt{\Sigma_{j=1}^{m}\left(v_{ij} - v_j^{+}\right)},\ i = 1, \ldots, n \quad (3.3)$$

$$d_i^{-} = \sqrt{\Sigma_{j=1}^{m}\left(v_{ij} - v_j^{-}\right)},\ i = 1, \ldots, n \quad (3.4)$$

The relative proximity to the positive ideal solution will be calculated using expression (3.5): which is known as the coefficient of similarity C_i^{+} for each alternative.

$$C_i^{+} = \frac{d_i^{-}}{d_i^{+} + d_i^{-}} \quad i = 1, 2, \ldots m \quad (3.5)$$

For the selection of the alternatives, the anti-ideal distance will be taken, starting with the one that is closest to the ideal solution (greater relative proximity).

Table 5, Calculation of distances.

Acronym	Question	Distance
OMT	1	0,73200
	2	1,00040
	3	0,74420
	4	1,35420
OD	5	1,26880
	6	0,40260
	7	0,20740
	8	0,26840
	9	0,80520
TF	10	0,20740

The results of the calculation of the distances in Table 5 allow us to sort what the competition alternatives should be according to the evaluations carried out on the students in their competitive achievements.

To carry out the evaluation of the formative development of investigative competences at UNIANDES Ibarra, we sorted the alternatives using the Euclidean distance between single-valued SVN neutrosophic numbers applying equation (2.1).

4 Conclusions

The evaluation of the variables: occupational market trends (OMT), occupational demand (OD) and Training and Feedback (TF), was validated from the calculation of the distances, obtaining the following results:

In accordance with the applied method, it indicates that areas such as Law (TMO 4 ----- 1,35420) will be a safe source of employment for Ecuadorians. It also evaluates that Law graduates should enroll in master's degree programs (DO 5 ----- 1,26880), thirdly, it evaluates the training received in the UNIANDES Law Shcool as Very Good (TMO 2 ----- 1,00040), fourthly, continuity of work is guaranteed.

One of the weakest points that the results show is that UNIANDES university graduates are not prepared to practice as a Manager or Executives (DO 7 ----- 0.20740)

To these results, we may add the reality, by saying that the majority of Law graduates entered the labor market in less than a year, once the degree was completed. They also suggest that given the quality of UNIANDES they would be willing to continue postgraduate studies under their auspices, as well as request training in very specific areas, this shows the importance for this group of updating knowledge in their field of specialization.

Another significant finding is that most of the interviewees affirmed that they had been in the last job for years, an indication that they have job stability and have correctly responded to job requirements in a world of strong competition and continuous evolution of knowledge.

Finally, it is essential that the information obtained from monitoring graduates becomes a support for the public academic offer, so this procedure must be integrated into the university culture so that it is carried out with rigorous criteria of formality, regulation and mandatory compliance.

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Received: October 1st, 2019 Accepted: January 17th, 2020