Neutrosophic Sets and Systems {Special Issue: Neutrosophic Advancements And Their Impact on Research in Latin America}, Vol. 62, 2023

University of New Mexico

A hybrid of ARAS and neutrosophic 2-tuple linguistic model to evaluate gender equitable policies from the perspective of Latin American professor's

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Abstract. This paper aims to introduce a hybrid model between the Additive Ratio Assessment System (ARAS) method and the neutrosophic 2-tuples linguistic model. ARAS is used to make complex decisions by comparing the collected data with optimal values. The neutrosophic 2-tuple linguistic model allows the inclusion of indeterminacy in addition to uncertainty for computation with words. The hybridization of both models allows us to make decision with evaluations based on linguistic scales, which is a natural way of deciding by human beings. This new model is applied to measure the implementation of gender-equitable policies in Latin America. The results of the analysis of public gender equity policies are presented from the perception of university professors from Peru, Colombia, Costa Rica, Argentina, Chile, El Salvador, Mexico, and Ecuador. The discoveries reveal that in all age groups until adulthood, there has always been gender discrimination in various aspects such as health, education, work, family, and mainly socially. Latin American countries have sexist roots, however they also seek to guarantee the implementation of effective public policies for gender equality in all sectors of society.

Keywords: Gender equality, equal opportunities, equal rights, public policies, Additive Ratio Assessment System (ARAS), neutrosophic linguistic 2-tuple model.

1 Introduction

The linguistic 2-tuple method has enjoyed acceptance and popularity within the Soft Computing scientific community [1]. It is a special case of Computing with Words championed by L. Zadeh who promoted calculations with words rather than with numbers [2, 3]. It is known that human beings ordinarily make decisions without the need to perform calculations based on numerical scales. So, linguistic terms also help us to calculate effectively.

The neutrosophic linguistic 2-tuple method has served to generalize the original technique, where a triad of elements is incorporated to determine the truthfulness, indeterminacy, and falsity of a proposition [4-6]. The idea is to achieve greater accuracy at the cost of greater indeterminacy in the evaluations. Both the original fuzzy method and its neutrosophic pair preserve information during processing, due to the concept of "symbolic translation."

Additionally, we use the method known as Additive Ratio Assessment System (ARAS) [7]. This is used to make complex decisions for comparing the assessment with ideal values of the criteria. In this article we apply the method to evaluate the policies of equality gender by Latin American countries, in addition to ordering these aspects in a way that highlights which countries in the region are the ones that need the most attention from the authorities. A contribution of this paper is that it combines the ARAS decision-making method with the neutrosophic linguistic 2-tuples for the first time, to the best of the authors' knowledge. The hybrids of ARAS with other models can be read in [8-14], especially ARAS has been hybridized with fuzzy 2-tuples linguistic model [15, 16-20].

Gender equality is a key issue on the international sustainable development agenda and is recognized as a fundamental human right of people in the social and economic spheres, food, health, housing, education, right to work and equal opportunities. The gender perspective is crucial to identify and challenge discrimination against women and seek equal opportunities and resources for men and women. In addition, the perspective of women's empowerment and the importance of promoting their participation in processes of social change are analyzed. International and regional organizations that have promoted the gender perspective in Latin America stand out. Although progress has been made in public policies that promote gender equality, it is still not enough.

If we analyze this phenomenon by country, El Salvador continues to face challenges such as the lack of acceptance of gender theory in academia and the persistence of gender roles and stereotypes in society. Studies in Colombia examined government policy regarding women and gender equality in the municipality of Chinavita, Boyacá. It was concluded that in recent decades, national governments have done much to improve policies for women.

Continuing with the analysis we find the progress made by academia in Costa Rica in promoting gender equality, but they also recognize the ongoing issues and controversies surrounding these initiatives. They highlight the need to continue efforts to increase gender equality in higher education, particularly in science and technology. The prohibition of *in vitro* fertilization in Costa Rica also draws attention due to the Catholic influence in the country's legislation.

Likewise in Chile, we can see that gender colonialism and public policies cause the imposition of a dominant vision of the masculine over the other. In this specific case we find the discriminatory gender perspective of the mestizo society in Chile on the Native Americans. We consider that this gender colonialism has existed since the relationship between indigenous peoples with European and Chilean societies, which has been expressed specifically through the implementation of public policies since the period after the dictatorship (1990 hereinafter) in the context of government action directed by a neoliberal development model.

In Peru, despite the efforts made by the government and civil society, gender inequalities persist in different areas, including access to education, health, employment, and women's political participation. In this context, it is necessary to evaluate the public policies implemented to promote gender equity and determine their effectiveness in reducing gender gaps in the country.

According to the 2021 World Bank report, Peru has made progress in promoting gender equality in recent years, but there are still significant gaps in access to economic and political opportunities for women. In this context, it is necessary to evaluate the public policies implemented to promote gender equity and determine their effectiveness in reducing gender gaps.

In summary, in this paper, we also analyze the implementation of public policies against gender violence in several Latin American countries, and point out deficiencies in their compliance.

To evaluate the situation of equal opportunities in Latin American countries, we consulted women academics and researchers from universities in this region of the planet. We determined that this is a qualitative rather than a quantitative issue, where a value cannot be established exactly, since discrimination contains many subtle ways of manifesting itself, which is why there is uncertainty and indeterminacy when we have to determine the degree of discrimination within Latin American societies, in addition to the fact that we want to give a general vision of the region, where there are also differences by country. For all these reasons we used measurements based on linguistic scales, and we processed data using the neutrosophic linguistic 2-tuple method. We carry out the rankings using the ARAS method, which also provides a similarity index for each country comparing with ideal values.

This paper consists of a materials and methods section where the basic notions of the neutrosophic linguistic 2-tuple and ARAS methods are recalled. The new model and results section exposes the model we propose here and its application to the case study. We finished the paper with the Conclusions section.

2 Materials and Methods

This section contains the basic notions of the neutrosophic linguistic 2-tuple model in subsection 2.1 and the ARAS decision-making method in subsection 2.2.

2.1. Neutrosophic linguistic 2-tuple model

Definition 1 ([4-6]). Let $S = \{s_0, s_1, \dots, s_g\}$ be a set of linguistic terms and $\beta \epsilon [0, g]$ a value that represents the result of a symbolic operation, then the linguistic 2-tuple that expresses the information equivalent to β is obtained using the following function:

$$\Delta: [0, g] \rightarrow S \times [-0.5, 0.5)$$
$$\Delta(\beta) = (s_i, \alpha) \quad (1)$$

Where s_i is such that $i = \text{round}(\beta)$ and $\alpha = \beta - i, \quad \alpha \in [-0.5, 0.5)$ and "round" is the usual rounding operator, s_i is the index label closest to β and α is the value of the *symbolic translation*.

It should be noted that $\Delta^{-1}: \langle S\rangle \rightarrow [0, g]$ is defined as $\Delta^{-1}(s_i, \alpha) = i + \alpha$. Thus, a *linguistic 2-tuple* $\langle S\rangle$ is identified with its numerical value in $[0, g]$.

Suppose that $S = \{s_0, \dots, s_g\}$ is a *2-Tuple Linguistic Set* (2TLS) with odd cardinality g+1. It is defined for $(s_T, a), (s_I, b), (s_F, c) \in L$ and a, b, c $\in$[0, g], where $(s_T, a), (s_I, b), (s_F, c) \in L$ independently express the degree of truthfulness, indeterminacy, and falsehood by 2TLS. The *2-Tuple Linguistic Neutrosophic Number* (2TLNN) is defined as follows:

$$l_j = \left\{(s_{T_j}, a), (s_{I_j}, b), (s_{F_j}, c)\right\} \quad (2)$$

Where $0 \leq \Delta^{-1}(s_{T_j}, a) \leq g$, $0 \leq \Delta^{-1}(s_{I_j}, b) \leq g$, $0 \leq \Delta^{-1}(s_{F_j}, c) \leq g$, and $0 \leq \Delta^{-1}\left(s_{T_j}, a\right) + \Delta^{-1}\left(s_{I_j}, b\right) + \Delta^{-1}(s_{F_j}, c) \leq 3g$.

The scoring and accuracy functions allow us to rank 2TLNN.

Let $l_1 = \left\{(s_{T_1}, a), (s_{I_1}, b), (s_{F_1}, c)\right\}$ be a 2TLNN in L, the scoring and accuracy functions in l_1 are defined as follows, respectively:

$$S(l_1)=\Delta\left\{\frac{2g+\Delta^{-1}(s_{T_1},a)-\Delta^{-1}(s_{I_1},b)-\Delta^{-1}(s_{F_1},c)}{3}\right\},\ \Delta^{-1}(S(l_1)) \in [0, g] \quad (3)$$

$$H(l_1)=\Delta\left\{\frac{g+\Delta^{-1}(s_{T_1},a)-\Delta^{-1}(s_{F_1},c)}{2}\right\},\ \Delta^{-1}(H(l_1)) \in [0, g] \quad (4)$$

2.2. Notions on Additive Ratio Assessment System (ARAS)

The first step in solving the multi-criteria decision-making problem with the support of the ARAS method is to form the following $m \times n$ matrix with m rows and n columns ([7-18-19]).

$$X = \begin{bmatrix} x_{01} & \cdots & x_{0j} & \cdots & x_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix} i = 1,2, \dots, m; j = 1,2, \dots, n. \quad (5)$$

Where m is the number of alternatives, n is the number of criteria that describe each alternative, x_{ij} represents the evaluation of the i alternative according to the j criterion, whereas x_{0j} is the optimal value of the j criterion.

When x_{0j} is unknown then it is taken as:

$$x_{0j} = max_i\, x_{ij},\ \text{if } max_i\, x_{ij} \ is\ preferable$$
$$x_{0j} = min_i\, x_{ij}^*,\ \text{if } min_i\, x_{ij}^* \ is\ preferable \quad (6)$$

The criteria whose values are maximum are normalized with the following Equation:

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \quad (7)$$

The criteria whose values are minimum are normalized with the following Equations:

$$x_{ij} = \frac{1}{x_{ij}^*}, \bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \quad (8)$$

In the other stage, the weights w_j are defined for the criteria, which satisfy $w_j \in (0,1)$:

$$\sum_{j=1}^{n} w_j = 1 \quad (9)$$

Thus, the following matrix is formed:

$$\hat{X} = \begin{bmatrix} \hat{x}_{01} & \cdots & \hat{x}_{0j} & \cdots & \hat{x}_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{i1} & \cdots & \hat{x}_{ij} & \cdots & \hat{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{m1} & \cdots & \hat{x}_{mj} & \cdots & \hat{x}_{mn} \end{bmatrix} i = 1,2, \dots, m; j = 1,2, \dots, n. \quad (10)$$

This is the matrix whose its elements are normalized by Equation 11:

$$\hat{x}_{ij} = \bar{x}_{ij} w_j; j = 1,2, \dots, n. \quad (11)$$

Later, numerical values are calculated with Equation 12:

$$O_i = \sum_{j=1}^{n} \hat{x}_{ij}; i = 1,2, \dots, m. \quad (12)$$

Where O_i is the value of the optimality function of the i alternative.

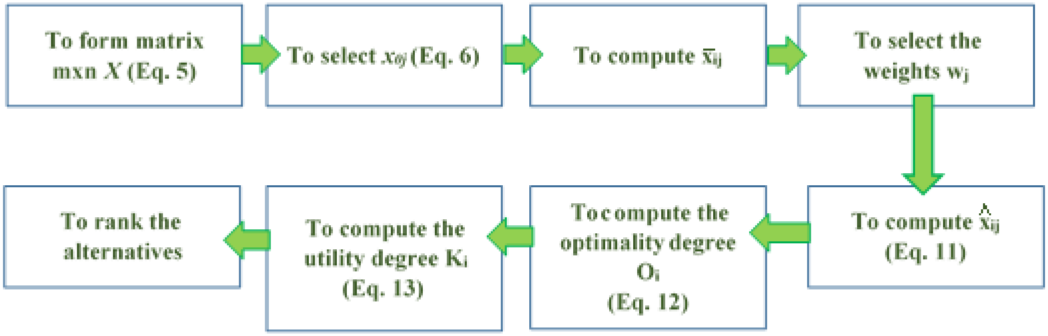
The highest value for O_i is the best and the lowest value is the worst.

The degree of usefulness of the i alternative is obtained by comparing it with the ideal degree O_0, which is calculated with Equation 13:

$$K_i = \frac{O_i}{O_0};\ i = 1,2,\dots,m. \quad (13)$$

Figure 1 contains a diagram of the algorithm to follow in the ARAS method.

Figure 1: Scheme of the ARAS algorithm for multi-criteria decision-making.



3 New Model and Results

This section consists of two subsections, the first one where we present the details of the new model and the second one contains the results of applying the model to the case study of gender parity in Latin America.

3.1. The New Model

This subsection contains the details of the new model that hybridizes neutrosophic linguistic 2-tuple model with the ARAS multicriteria decision-making method. We explain this in the following steps:

1. We start from a set $E = \{e_1, e_2, \dots, e_k\}$ of $k \geq 1$ experts, and $C = \{c_1, c_2, \dots, c_n\}$ of n criteria to measure m feasible alternatives $A = \{a_1, a_2, \dots, a_m\}$, as in the original ARAS method.
   For each criterion there is a linguistic measurement scale consisting of a set $S_i = \{s_1^i, s_2^i, \dots, s_{l_i}^i\}$ with l_i which is an odd number.
2. Each expert e_p evaluates each alternative a_j according to the criterion c_i, giving a triad $\left(s_{jpq_T}^i, s_{jpq_I}^i, s_{jpq_F}^i\right)$ where $s_{jpq_T}^i \in S_i$ means the linguistic evaluation given by the p expert that the alternative meets the given criterion, see that q_T is the index of the linguistic term within the set S_i. In a similar way, $s_{jpq_I}^i$ indicates the linguistic label for indeterminacy and likewise, $s_{jpq_F}^i$ is used for falsehood.
   This includes the evaluation of an ideal alternative a_0 for each of the criteria. The evaluations of this ideal alternative are obtained from experts or either as the maximum of the values given when the maximum is preferable, or the minimum when this is preferable.
3. The triads $\left(s_{jpq_T}^i, s_{jpq_I}^i, s_{jpq_F}^i\right)$ are aggregated for each criterion and each alternative for all experts. To do this, the arithmetic mean is used by all the experts of the given evaluations. In this way values are obtained, see Equation 14:

   $$\left(\bar{s}_{jq_T}^i, \bar{s}_{jq_I}^i, \bar{s}_{jq_F}^i\right) \text{ with } \beta_T = \frac{\sum_{p=1}^k q_T}{k},\ \beta_I = \frac{\sum_{p=1}^k q_I}{k}, \text{ and } \beta_F = \frac{\sum_{p=1}^k q_F}{k} \quad (14)$$

   To simplify the notations, there are $r_j^i = \left(\beta_{T_j}^{\ i}, \beta_{I_j}^{\ i}, \beta_{F_j}^{\ i}\right) \in [0, l_i]^3$ triples of beta values obtained for each of the evaluations for truthfulness, falsity, and indeterminacy, respectively.
   This is how the matrix that appears in Equation 15 is formed.

$$X_\beta = \begin{bmatrix} r_0^1 & \cdots & r_o^j & \cdots & r_0^n \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ r_i^1 & \cdots & r_i^j & \cdots & r_i^n \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ r_m^1 & \cdots & r_m^j & \cdots & r_m^n \end{bmatrix} i = 1,2,\dots,m;\ j = 1,2,\dots,n. \quad (15)$$

4. Now the values of the matrix X_β are normalized as follows:
   The criteria whose ideal values are maximum are normalized with Equation 16.

$$\bar{r}_i^j = \frac{r_i^j}{\sum_{i=0}^m r_i^j} \quad (16)$$

Where $\bar{r}_j^i = \left(\frac{\beta_{T_j^i}}{\sum_{t=0}^m \beta_{T_j^t}}, \frac{\beta_{I_j^i}}{\sum_{t=0}^m \beta_{I_j^t}}, \frac{\beta_{F_j^i}}{\sum_{t=0}^m \beta_{F_j^t}}\right)$.

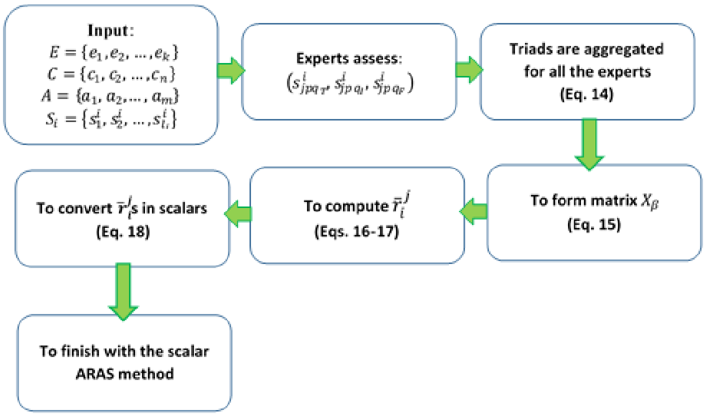
The criteria whose values are minimum are normalized with Equation 17:

$$r_i^j = \frac{1}{r_i^{j*}}, \bar{r}_i^j = \frac{r_i^j}{\sum_{i=0}^m r_i^j} \quad (17)$$

5. To convert $\bar{r}_i^j = (\gamma_T, \gamma_I, \gamma_F) \in [0,1]^3$ into a scalar in $[0,1]$, so we use Equation 18 ([17]).
   $$\lambda(\bar{r}_i^j) = \frac{2+\gamma_T-\gamma_I-\gamma_F}{3} \quad (18)$$
   Let us call $\bar{x}_{ij} = \lambda(\bar{r}_i^j)$.
6. The original ARAS method is applied to the above results, utilizing Equations 7, 9-13 for the values $\bar{x}_{ij}$s.

Figure 2 contains a schematic of the proposed algorithm.

Figure 2: Scheme of the ARAS algorithm hybridized with the neutrosophic linguistic 2-tuple model for multi-criteria decision-making



3.2. The Case Study

A total of 240 female academics from Latin American universities in Peru, Colombia, Costa Rica, Argentina, Chile, El Salvador, Mexico, and Ecuador who have been surveyed online about the implementation of gender parity policies in their countries. 30 academics were selected from each country, especially those whose research topic is related to the study of gender parity.

It was decided to ask them their impressions on the following aspects:

C_1 - **Political participation**: refers to the degree of representation and influence of women in public decision-making spaces. It is measured on the scale $S_1 = \{s_1^1, s_2^1, s_3^1\}$ with s_1^1= "Poor", s_2^1= "More or less", and s_3^1= "Adequate".

C_2 - **Presence of gender violence**: refers to the forms of physical, sexual, psychological or economic violence that women suffer due to their condition of being women. It is measured on a scale $S_2 = \{s_1^2, s_2^2, s_3^2\}$ with s_1^2= "Little or none", s_2^2= "Medium", and s_3^2= "High".

C_3 - **Presence of wage gap**: refers to the difference between the average earnings of men and women for the same job or for equivalent jobs. It is measured on a scale $S_3 = \{s_1^3, s_2^3, s_3^3\}$ with s_1^3= "Little or none", s_2^3= "Medium", and s_3^3= "High".

C_4 - **Labor considerations towards women**: refers to the fact that the particularities of women are taken into account in terms of their work performance beyond salary parity, such as the granting of paid maternity leave for workers with advanced pregnancies or recently given birth; the employment consideration of women with small children, etc. It is measured on a scale $S_4 = \{s_1^4, s_2^4, s_3^4\}$ with s_1^4= "Little or none", s_2^4= "Medium", and s_3^4= "High".

C_5 - **Access to public life**: refers to the access that women have to study, to work in a decent job, and to receive quality care in health centers. It is measured on a scale $S_5 = \{s_1^5, s_2^5, s_3^5\}$ with s_1^5= "Little or none", s_2^5= "Medium", and s_3^5= "High".

The respondents were asked to give their opinion on each of these criteria, according to the scales specified in a triad of linguistic values, the first to express certainty, the second indeterminacy, and the third to mean falsehood. It was explained to them that this way greater accuracy in their answers is guaranteed.

The alternatives to measure are the eight countries mentioned above, which are: a_1 =Peru, a_2 =Colombia, a_3 = Costa Rica, a_4 =Argentina, a_5 =Chile, a_6 =El Salvador, a_7 =Mexico, and a_8 =Ecuador.

Each alternative (country) was evaluated by the women of this country, not by all, which is why Formula 14 was restricted to the corresponding respondents.

a_0 was defined with the following values for the criteria:

(s_3^1, s_3^1, s_1^1), (s_1^2, s_1^2, s_3^2), (s_1^3, s_1^3, s_3^3), (s_3^4, s_3^4, s_1^4), and (s_3^5, s_3^5, s_1^5), where the first two terms are equal because it means that there is no indeterminacy.

Table 1 contains the data requested in Equation 15 about the triads that appear in Equation 14.

Table 1: Matrix of evaluations with the triple betas aggregated for all experts for each country.

Country/Criteria	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**
a_0 = Optimal	(3,3,1)	(1,1,3)	(1,1,3)	(3,3,1)	(3,3,1)
Peru	(2.53, 2.54, 1.21)	(1.42,1.41,2.63)	(1.40,1.42,2.59)	(2.43,2.42,1.52)	(2.62,2.60,1.32)
Colombia	(1.54, 1.49, 1.21)	(1.55,1.49,2.59)	(1.45,1.42,2.58)	(2.44,2.39,1.49)	(2.65,2.63,1.36)
Costa Rica	(2.98, 2.93, 1.07)	(1.03,1.04,2.97)	(1.14,1.13,2.89)	(2.90,2.89,1.02)	(2.98,2.99,1.01)
Argentina	(2.82, 2.79, 1.12)	(1.65,1.62,2.42)	(1.35,1.36,2.66)	(2.89,2.90,1.03)	(2.68,2.62,1.26)
Chile	(2.89, 2.88, 1.09)	(1.05,1.05,2.91)	(1.33,1.33,2.69)	(2.91,2.93,1.01)	(2.77,2.74,1.12)
El Salvador	(2.42, 2.36, 1.23)	(1.89,1.73,2.00)	(1.61,1.65,2.09)	(2.01,2.00,1.80)	(2.23,2.20,1.78)
Mexico	(2.82, 2.76, 1.16)	(1.77,1.78,2.05)	(1.34,1.35,2.60)	(2.78,2.76,1.24)	(2.67,2.64,1.40)
Ecuador	(2.54, 2.50, 1.22)	(1.40,1.37,2.62)	(1.37,1.38,2.61)	(2.46,2.47,1.43)	(2.66,2.63,1.39)

Table 2 contains the normalized values for each criterion, according to Equations 16 and 17.

Table 2: Matrix of evaluations with the normalized triple betas from Table 1.

Country/Criteria	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**
a_0 = Optimal	(0.13,0.13,0.10)	(0.15,0.15,0.09)	(0.15,0.15,0.10)	(0.13,0.13,0.09)	(0.12,0.12,0.09)
Peru	(0.11, 0.11, 0.12)	(0.11,0.10,0.11)	(0.10,0.10,0.11)	(0.10,0.10,0.13)	(0.11,0.11,0.11)
Colombia	(0.07, 0.06, 0.12)	(0.11,0.10,0.11)	(0.10,0.11,0.11)	(0.10,0.10,0.13)	(0.11,0.11,0.12)
Costa Rica	(0.13,0.13,0.10)	(0.15,0.14,0.09)	(0.13,0.13,0.10)	(0.12,0.12,0.09)	(0.12,0.12,0.09)
Argentina	(0.12, 0.12, 0.11)	(0.09,0.09,0.12)	(0.11,0.11,0.11)	(0.12,0.12,0.09)	(0.11,0.11,0.11)
Chile	(0.12, 0.12, 0.11)	(0.14,0.14,0.10)	(0.11,0.11,0.11)	(0.12,0.12,0.09)	(0.11,0.11,0.10)
El Salvador	(0.10, 0.10, 0.12)	(0.08,0.09,0.14)	(0.09,0.09,0.14)	(0.08,0.08,0.16)	(0.09,0.09,0.15)
Mexico	(0.12, 0.12, 0.11)	(0.08,0.08,0.14)	(0.11,0.11,0.11)	(0.12,0.12,0.11)	(0.11, 0.11, 0.12)
Ecuador	(0.11, 0.11, 0.12)	(0.11,0.11,0.11)	(0.11,0.11,0.11)	(0.10,0.10,0.12)	(0.11, 0.11, 0.12)

Table 3 reflects the results of converting the values in Table 2 to scalars after applying Equation 18.

Table 3: Matrix of evaluations with the results of Table 2 converted into numerical values.

Country/Criteria	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**
a_0 = Optimal	0.63333	0.63667	0.63333	0.63667	0.63667
Peru	0.62667	0.63333	0.63000	0.62333	0.63000
Colombia	0.63000	0.63000	0.63000	0.62333	0.62667
Costa Rica	0.63333	0.63333	0.63333	0.63667	0.63667
Argentina	0.63000	0.62667	0.63000	0.63667	0.63000
Chile	0.63000	0.63333	0.63000	0.63667	0.63333
El Salvador	0.62667	0.61667	0.62000	0.61333	0.61667
Mexico	0.63000	0.62000	0.63000	0.63000	0.62667
Ecuador	0.62667	0.63000	0.63000	0.62667	0.62667

Equation 7 is applied to the elements in Table 3 to normalize them. These results are shown in Table 4.

Table 4: Matrix of the normalized elements of Table 3.

Country/Criteria	C_1	C_2	C_3	C_4	C_5
a_0 = Optimal	0.11176	0.11249	0.11176	0.11242	0.11242
Peru	0.11059	0.11190	0.11118	0.11006	0.11124
Colombia	0.11118	0.11131	0.11118	0.11006	0.11065
Costa Rica	0.11176	0.11190	0.11176	0.11242	0.11242
Argentina	0.11118	0.11072	0.11118	0.11242	0.11124
Chile	0.11118	0.11190	0.11118	0.11242	0.11183
The Savior	0.11059	0.10895	0.10941	0.10830	0.10889
Mexico	0.11118	0.10954	0.11118	0.11124	0.11065
Ecuador	0.11059	0.11131	0.11118	0.11065	0.11065

Table 5 contains a summary of the optimality and utility values applying the ARAS crisp method. The weights $w_j = \frac{1}{5}$ were applied.

Table 5: Optimality and utility values of the ARAS crisp method for the results of Table 4.

Country/Criteria	Optimality	Utility	Ranking
a_0 = Optimal	0.11217	1.00000	-
Peru	0.11099	0.98950	4
Colombia	0.11088	0.98846	5
Costa Rica	0.11205	0.99895	1
Argentina	0.11135	0.99265	3
Chile	0.11170	0.99580	2
El Salvador	0.10923	0.97377	8
Mexico	0.11076	0.98740	7
Ecuador	0.11088	0.98846	5

Thus, the country with the greatest parity among those studied is Costa Rica, followed by Chile, and in that order are Argentina, Peru, Colombia and Ecuador in the same position, Mexico, and ending with El Salvador.

Conclusion

This paper was dedicated to introducing a model where the ARAS decision-making method is hybridized with the neutrosophic linguistic 2-tuple model. The new model presents several advantages, such as the possibility of evaluating and calculating with words, which is a natural way for human beings to carry out evaluations in daily life. Additionally, the neutrosophic component allows us to include not only uncertainty but also indeterminacy. As for the ARAS method, it helps make complex decisions and is computationally inexpensive, due to its simplicity and effectiveness.

We successfully tested this new model to determine the degree to which gender parity policies are applied in eight Latin American countries, from the perspective of 240 female academics from universities in these countries. It was concluded that the order in which the countries are, from the one in the best conditions to the one with the worst conditions, is as follows: Costa Rica, Chile, Argentina, Peru, Colombia and Ecuador are in the same position, Mexico, and El Salvador.

References

[1]. Wu, Q., Wu, P., Zhou, L., Chen, H. and Guan, X. (2018). Some new Hamacher aggregation operators under single-valued neutrosophic 2-tuple linguistic environment and their applications to multi-attribute group decision making. Computers & Industrial Engineering, 116, 144-162.

[2]. Zadeh, L. A. (1999). From computing with numbers to computing with words. From manipulation of measurements to manipulation of perceptions. IEEE Transactions on circuits and systems I: fundamental theory and applications, 46, 105-119.

[3]. Zadeh, L. A. (1996). Fuzzy logic computing with words. IEEE transactions on fuzzy systems, 4, 103-111.

[4]. Carvajal, V. M. P., Valverde, M. T. M. and Pután, R. A. (2020). A neutrosophic linguistic model for internal control evaluation to an Ecuadorian Company. Neutrosophic Sets and Systems, 34, 169-176.

[5]. Jaramillo, M. E. N., Ayala, M. A. G., and Flores, D. A. (2020). Evaluating the acceptance level of the papillomavirus vaccine using a neutrosophic linguistic model. Neutrosophic Sets and Systems, 34, 79-85.
[6]. Ruiz, D. V. P., Matute, J. C. A., Arias, E. J. J., Zambrano, L. O. A., Chalacán, L. J. M., Quevedo, Í. M. S., and Paredes, A. R. Z. (2019). Softcomputing in neutrosophic linguistic modeling for the treatment of uncertainty in information retrieval. Neutrosophic Sets and Systems, 26, 69-75.
[7]. Zavadskas, E. K. and Turskis, Z. (2010) A New Additive Ratio Assessment (ARAS) Method in Multicriteria Decision-Making, Technological and economic development of economy: Baltic Journal on Sustainability, 16, 159–172.
[8]. Goswami, S. S., and Behera, D. K. (2021). Solving material handling equipment selection problems in an industry with the help of entropy-integrated COPRAS and ARAS MCDM techniques. Process Integration and Optimization for Sustainability, 5, 947-973.
[9]. Goswami, S. S., Behera, D. K., Afzal, A., Razak Kaladgi, A., Khan, S. A., Rajendran, P. and Asif, M. (2021). Analysis of a robot selection problem using two newly developed hybrid MCDM models of TOPSIS-ARAS and COPRAS-ARAS. Symmetry, 13, 1331.
[10]. Raj Mishra, A., Sisodia, G., Raj Pardasani, K., and Sharma, K. (2020). Multi-criteria IT personnel selection on intuitionistic fuzzy information measures and ARAS methodology. Iranian Journal of Fuzzy Systems, 17, 55-68.
[11]. Rao, S. H., Kalvakolanu, S., and Chakraborty, C. (2021). Integration of ARAS and MOORA MCDM techniques for measuring the performance of private sector banks in India. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 29, 279-295.
[12]. Chen, Z. S., Chin, K. S., and Tsui, K. L. (2019). Constructing the geometric Bonferroni mean from the generalized Bonferroni mean with several extensions to linguistic 2-tuples for decision-making. Applied Soft Computing, 78, 595-613.
[13]. Xiong, G., Cao, Y., Yang, Y. and Chai, Y. (2020). The Approval Evaluation of Agricultural Project Based on the Integration of 2-Tuples and GR. In Proceedings of the Fourteenth International Conference on Management Science and Engineering Management: Volume 1 (pp. 588-600). Springer International Publishing.
[14]. Akram, M., Khan, A., & Ahmad, U. (2023). Extended MULTIMOORA method based on 2-tuple linguistic Pythagorean fuzzy sets for multi-attribute group decision-making. Granular Computing, 8, 311-332.
[15]. Daoud Ben Amor, W., Labella, A., Moalla-Frikha, H. and Martínez López, L. (2022) Pharmaceutical Supply chain Risk Assessment During COVID-19 Epidemic, IFAC PapersOnLine 55-10, 2022, 2203–2208.
[16]. Daoud-Ben-Amor, W., Martínez-López, L. and Frikha, H. M. (2022). A Multigranular Linguistic Additive Ratio Assessment Model in Group Decision Making, International Scholarly and Scientific Research & Innovation, 16, 357-362.
[17]. Hernández, N. B., Chacón, L. J. R., Cruzaty, L. E. V., Zumba, G. R., Chávez, W. O., & Quispe, J. T. (2022). Model Based on Neutrosophic Ontologies for the Study of Entrepreneurship Competence. Neutrosophic Sets and Systems, 51(1), 57.
[18]. Sudeep Dey, & Gautam Chandra Ray. ¨Covering Properties via Neutrosophic b-open Sets¨. Neutrosophic Systems With Applications, vol 9, pp 1–12, 2023. https://doi.org/10.61356/j.nswa.2023.66
[19]. Mohamed, M., & El-Saber , N. ¨Toward Energy Transformation: Intelligent Decision-Making Model Based on Uncertainty Neutrosophic Theory¨. Neutrosophic Systems With Applications, vol 9, pp 13–23, 2023. https://doi.org/10.61356/j.nswa.2023.65
[20]. S.P.Priyadharshini, & F. Nirmala Irudayam. ¨An Analysis of Obesity in School Children during the Pandemic COVID-19 Using Plithogenic Single Valued Fuzzy Sets¨. Neutrosophic Systems With Applications, vol 9, pp 24–28, 2023. https://doi.org/10.61356/j.nswa.2023.51

Received: October 16, 2023. **Accepted:** December 14, 2023