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

University of New Mexico

Neutrosophic Evaluation of Eligibility Variables in Asylum and Immigration Processes

Edison Joselito Naranjo Luzuriaga[1], Marco Rodrigo Mena Peralta[2], Leonso Torres Torres[3], and Arlen Martín Rabelo [4]

[1]Universidad Regional Autónoma de Los Andes, Ambato. Ecuador. E-mail: ua.edisonnaranjo@uniandes.edu.ec
[2]Universidad Regional Autónoma de Los Andes, Puyo. Ecuador. E-mail: up.marcomena@uniandes.edu.ec
[3]Universidad Regional Autónoma de Los Andes, Santo Domingo. Ecuador. E-mail: us.leonsotorres@uniandes.edu.ec
[4]Exxis, Avda. Aviadores del Chaco N° 1669 c/ San Martin; Edif. Aymac I, 4to. piso, Asunción, Paraguay.
E-mail: arlen.martin@exxis-group.com

Abstract. The objective of this study was to apply neutrosophic logic in the context of the DEMATEL method to evaluate the variables involved in the eligibility of individuals in asylum requests and immigration processes. To achieve this, information acquisition methods were employed to gather the variables necessary for inclusion in the study. An expert panel was engaged to assess these variables, taking into account the inherent indeterminacy and uncertainties associated with decision-making. The study's results highlighted variables such as "Persecution in the country of origin" and "Reasons for the application" as highly influential elements in the eligibility process. This information provided decision-makers with a clearer understanding of which aspects should be prioritized in the evaluation of asylum and immigration requests. The combination of neutrosophic logic and the DEMATEL method proved to be an effective tool in addressing the complexity of this process and provided a more robust framework for decision-making.

Keywords: asylum, immigration, DEMATEL, SVNS, neutrosophy, neutrosophic logic.

1. Introduction

Eligibility for asylum and immigration is a matter of great significance in the context of international migration and human rights. This process involves the assessment of individuals seeking refuge in a foreign country or wishing to establish permanent residence in a new territory. Eligibility determination is based on a set of legal criteria and specific factors that vary according to the laws and regulations of each receiving country.

In the context of immigration, eligibility is based on a series of factors that vary depending on the destination country. These factors may include the existence of close relatives who are already residents or citizens of the country, the applicant's ability to integrate into the host society, as well as their potential economic contribution to the country. Additionally, immigration authorities often evaluate the applicant's criminal background and may deny the application in case of certain crimes or illegal activities.

Often, eligibility for asylum and immigration involves a meticulous assessment of multiple legal and personal factors. Applicants must meet specific criteria set by the receiving country, and decisions are made to protect the individual's rights and the security and stability of the host country. This process is complex and multidimensional, and its nature varies according to the circumstances and laws of each nation. Decision-making in this field is of paramount importance.

One of the most significant challenges in decision-making regarding eligibility for asylum and immigration is the presence of indeterminacies and uncertainty in the evaluation of the criteria. Indeterminacies refer to the lack of clear information or ambiguity in the data provided by the applicants [1]. Uncertainty, on the other hand, is related to the unpredictability of the results and the possible consequences of the decision [2]. These indeterminacies and uncertainties can arise in various aspects, such as the credibility of the applicant's statements, the authenticity of the documentation presented, and the interpretation of the situation in the country of origin.

To address these difficulties, decision-making approaches have been developed to systematically handle indeterminacy and uncertainty. Multi-criteria decision-making methods such as the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) enable decision-makers to weigh and assess different factors and criteria within a structured framework. These methods can accommodate the lack of precise information by allowing the comparison and evaluation of alternatives based on multiple criteria.[3]

However, in reality, decision-makers may express a preference for evaluating attributes using linguistic variables instead of precise values, either due to their partial knowledge of the attributes or due to a lack of information in the problem domain [4]. The tool of fuzzy sets, introduced by Zadeh in 1965, becomes one of the resources employed to mathematically represent such imprecision [5]. However, fuzzy sets are limited to considering the degree of affiliation of not clearly defined parameters or events, without the ability to address the degree of non-affiliation and the imprecision associated with uncertainty parameters.[6]

In an effort to partially address the limitations in defining imprecise parameters, Atanassov in 1986 introduced intuitive fuzzy sets (IFS), characterized by the simultaneous representation of degrees of affiliation and non-affiliation. However, it is important to note that, in the IFS, the sum of the degrees of affiliation and non-affiliation of the unclear parameter does not reach unity, which poses certain restrictions.[7]

To overcome these deficiencies, Smarandache presented the neutrosophic concept in 1999 as an approach to address unspecified or inconsistent information that is commonly found in reality [8]. The notion of a neutrosophic set establishes a general platform that extends the principles of classical sets, the fuzzy sets proposed by Zadeh in 1965, the intuitive fuzzy sets of Atanassov in 1986, and the intuitive interval fuzzy sets proposed by Atanassov and Gargov in 1989. Distinguishing from intuitive and interval fuzzy sets, in the neutrosophic set, indeterminacy is described explicitly. [9]

In the context of decision-making, neutrosophic logic has been used to deal with the uncertainty inherent in evaluating multiple criteria that may be qualitative or quantitative. Criteria can be ambiguous, contradictory, or subject to different interpretations, making accurate decision-making difficult. Neutrosophic logic allows degrees of truth, falsity, and indeterminacy to be assigned to each criterion, which more accurately reflects the uncertain and ambiguous nature of the data.[10]

When neutrosophic logic is applied to multi-criteria decision-making, specific methods that take into account these degrees of membership, non-membership, and indeterminacy can be used to calculate the relative importance of each criterion and the alternatives. Some of these methods may include the AHP, TOPSIS; analytic network process (ANP), and others, as neutrosophic extensions of traditional MCDM techniques [11], [12].

The proposed study aims to apply neutrosophic logic in the context of the DEMATEL method to evaluate the variables involved in the eligibility of individuals in asylum applications and immigration processes. Neutrosophic logic becomes a crucial tool to address the complexity and uncertainty associated with this selection process.

The DEMATEL (Decision-Making Trial and Evaluation Laboratory) method is a technique widely used in multi-criteria decision-making to analyze causal relationships between different factors or criteria. Incorporating neutrosophic logic allows for the representation of degrees of truth, falsehood, and ambiguity in these relationships, which is particularly relevant when it comes to assessing the eligibility of individuals in complex and often ambiguous situations.

In the context of asylum and immigration, the criteria used to evaluate applicants can be vague, contradictory, or imprecise, making it difficult to make fair and objective decisions. Neutrosophic logic allows consideration not only of the uncertainty associated with these criteria but also the possibility that the data is true to some extent and false to some extent, reflecting the complex nature of the information provided by applicants.

Ultimately, this study seeks to contribute to the improvement of decision-making processes in asylum and immigration matters, by more effectively addressing the indeterminacies and uncertainties that often characterize these decisions. This could result in fairer and more objective decisions that balance the rights and needs of applicants with the interests and security of recipient countries.

2 Neutrosophy preliminaries

In the context of a space of points (objects) X, where the generic elements in X are represented as x, the concept of a Neutrosophic Single-Valued Set (SVNS) is introduced. An SVNS A in X is characterized by three membership functions: the truth membership function TA(x), the indeterminacy membership function IA(x), and the falsity membership function FA(x). Therefore, an SVNS A can be represented as A = {x, TA(x), IA(x), FA(x) | x∈X}, where TA(x), IA(x), and FA(x) take values in the interval [0,1] for each point x in X. It is important to note that the sum of TA(x), IA(x), and FA(x) satisfies the condition 0 ≤ TA(x) + IA(x) + FA(x) ≤ 3 [14].

In [13], a neutrosophic number $E_k = (T_k, I_k, F_k)$ is defined to assess the *k-th* decision maker. Then, the weight of the *k-th* decision-maker can be expressed as:

$$\psi_k = \frac{1-\sqrt{[(1-T_k(x))^2+(I_k(x))^2+(F(x))^2]/3}}{\sum_{k=1}^{p}\sqrt{[(1-T_k(x))^2+(I_k(x))^2+(F(x))^2]/3}} \tag{1}$$

Furthermore, to attain a positive outcome, collective decision-making plays a crucial role in any decision-making procedure. Within the group decision-making process, it is imperative to combine the assessments provided by each decision-maker into a comprehensive neutrosophic decision matrix. This task can be accomplished by using the single-value neutrosophic weighted average (SVNWA) aggregation operator as introduced by [14-

20-21-22].

Consider the single-valued neutrosophic decision matrix $D_k = \left(d_{ij(k)}\right)_{mxn}$ representing the evaluations of the *k-th* decision-maker, and let $\psi = (\psi_1 \psi_2, \dots, \psi_p)^T$ be the weight vector of the decision-maker, where each $\psi_k \in [0,1]$, Here, D represents the matrix $D = (d_{ij})_{mxn}$,[14] where:

$$d_{ij} = \langle 1 - \prod_{k=1}^{p}\left(1 - T_{ij}^{(p)}\right)^{\psi_k}, \prod_{k=1}^{p}\left(I_{ij}^{(p)}\right)^{\psi_k}, \prod_{k=1}^{p}\left(F_{ij}^{(p)}\right)^{\psi_k} \rangle \tag{2}$$

Deneutrosophication of an SVNS $\tilde{N}$ can be defined as a process of transforming $\tilde{N}$ into a single crisp output, denoted as $\psi^* \in X$, through the mapping function x $f\colon \tilde{N} \to \psi^*$.When $\tilde{N}$ is a discrete set, the vector of tetrads $\tilde{N} = \{(x \mid T\tilde{N}(x), I\tilde{N}(x), F\tilde{N}(x)) \mid x \in X\}$ simplifies to a single scalar value $\psi^* \in X$ during the deneutrosophication process. This resulting scalar value more effectively represents the overall distribution of the three degrees of membership within the neutrosophic element, namely, $T_{\tilde{N}(x)}, I_{\tilde{N}(x)}$, and $F_{\tilde{N}(x)}$. Hence, the deneutrosophication process can be achieved as follows [17]:

$$\psi^* = 1 - \sqrt{[(1 - T_k(x))^2 + (I_k(x))^2 + (F(x))^2]/3} \tag{3}$$

2.1 SVNS DEMATEL

DEMATEL (Decision Making Trial and Evaluation Laboratory) is a technique developed in 1972 by Fontela and Gabus at the Geneva Research Center of the Battelle Memorial Institute [15]. It is used to analyze the interdependence (relationship or influence) between components, variables, or attributes of a complex system, identify those that are critical, and study their cause-effect relationships, using an impact relationship diagram. DEMATEL is mainly used in complex multi-criteria decision-making processes to analyze the internal relationships between decision criteria.

The steps to apply DEMATEL in its neutrosophic variant are detailed below and can be found in more detail in [16].

Step 1. Identify the influential variables in the eligibility of individuals in asylum applications and immigration processes: Through the application of semi-structured interviews to a representative sample and the generation of ideas through a brainstorming process, a set of relevant factors in the context of eligibility for asylum and immigration is identified. Subsequently, a panel of experts is requested to assess the mutual influence between these factors through paired comparisons using the scoring scale based on linguistic variables, as shown in [13-18-19].

Step 2. Determine the relative importance of the experts in the context of eligibility: The group of experts participating in the evaluation has different levels of experience and knowledge in the field of decision-making related to eligibility for asylum and immigration. As a result, a specific weight is assigned to each expert, which is expressed in terms of linguistic variables and transmitted in the form of neutrosophic numbers (SVNN) for later identification using equation (1).

Step 3. Transform the linguistic evaluations provided by the experts into neutrosophic numbers (SVNN): From the individual evaluation matrices containing crisp values obtained from the experts, individual neutrosophic matrices are constructed for each decision maker. See [13] for further details.

Step 4. Obtain the initial matrix of direct relationships in the form of crisp numbers: To obtain the initial matrix of direct relationships initially presented as crisp numbers, the individual neutrosophic matrices of decision makers are combined, and then they are denoted using equations (2) and (3) respectively. Matrix A shows the initial effects that factor j causes, as well as the initial effects that factor j receives from other factors. The sum of each *i-th* row of matrix A represents the total direct effects that factor *i* transmits to the other factors, and the sum of each *i-j* column of matrix A represents the total direct effects that factor *j* receives from the other factors.

Step 5. Identify the cause-effect relationships between the factors: Based on the aggregate matrix of direct relationships A obtained in step 4, it is possible to calculate the matrix of total relationships T by applying the equations (4 -6), as shown below:

$$D = A * S \tag{4}$$

Where

$$S = \frac{1}{\max\limits_{l \le i \le n} \sum_{j=1}^{n} a_{ij}} \tag{5}$$

And

$$T = D(I - D)^{-1} \tag{6}$$

I: is the identity matrix.

The values t_{ij} of the matrix T reflects the direct and indirect interdependence exerted by the element in row *i* on the element in column *j*. Indirect interdependence is when one element *i* can influence another element *j* through third-party elements in the system. These indirect interdependences arise when the matrix X is raised to successive powers.

Step 6. Obtain the Causal Importance Relationship Diagram. In the stage of obtaining the Causal Importance Relationship Diagram, one should first calculate the vectors R (the sum of the rows of T) and C (the sum of the columns of T). Then, on the horizontal axis of the causal diagram, "Prominence" is defined as the vector R+C. This vector indicates the importance or relevance of each element in the system. The higher the value of R+C, the greater the prominence of the element. A high value of R+C signifies that an element:

- Considerably influences other elements.
- Receives a great influence from other elements.
- It exerts influence and is influenced in a balanced way so that the sum of both concepts is high.

If R+C is low, the element has little "importance" because both types of influence are reduced. On the vertical axis, "Ratio" is defined as the vector R-C. This vector establishes the net influence of each element. If R-C>0, it indicates that the element exerts more influence than it receives. This element would be the "cause" (influential/transmitter) of the influence. If R-C<0, it indicates that the element receives more influence than it emits, so it is considered an "effect" (influenced/receiver). Based on these values, it is possible to create a relationship map (R+C, R-C).[17]

3 Results

Through the application of semi-structured interviews and the brainstorming process, a set of relevant factors in the context of eligibility for asylum and immigration was identified. These factors are considered essential for understanding and evaluating asylum applications and immigration processes. Below is a list of the 10 study variables that emerged as a result of this identification process:

1. Persecution in the country of origin: The presence of political, religious, ethnic, or other types of persecution in the applicant's country of origin is one of the most important factors for asylum eligibility.
2. Integration into the host country: The applicant's ability to integrate into the host country's society, including language proficiency, cultural adaptation, and willingness to contribute to the community.
3. Economic contribution: In some cases, the applicant's ability to contribute economically to the host country, either through employment, investment, or business creation, may be considered.
4. National security: Evaluating potential threats to the host country's national security is an important factor. Authorities must ensure that the applicant does not represent a risk to the country's security.
5. Hosting capacity: The host country's capacity to receive and accommodate new immigrants is a critical factor. This includes considering the availability of resources such as housing, employment, and social services.
6. Relatives in the host country: The existence of close relatives who are already residents or citizens of the host country can be a determining factor in eligibility for immigration.
7. Criminal record: The applicant's criminal record is reviewed, and certain crimes may lead to the denial of asylum or immigration applications.
8. Reasons for application: Specific reasons for seeking asylum or immigration, such as family reunification, pursuit of better economic opportunities, or fleeing natural disasters or conflicts, are also taken into consideration.
9. Health status: The applicant's health status can be a factor, as some medical conditions may require special attention or affect eligibility.
10. Compliance with legal procedures and requirements: The applicant's ability to comply with legal procedures and requirements, such as completing required documentation and following proper procedures, is crucial.

These variables represent key dimensions that influence the eligibility of individuals in asylum applications and immigration processes. The linguistic variable-based scoring scale used by the panel of experts to assess the mutual influence among these factors is a tool that assigns values to influence relationships. This scale is a fundamental component of the evaluation process and is structured into five categories, each with its respective values:

1. "No influence/importance" (0.1, 0.8, 0.9): Indicates that one factor does not exert influence or is not important in relation to another.
2. "Low influence/importance" (0.35, 0.6, 0.7): Denotes a low but significant influence between factors.
3. "Medium influence/importance" (0.5, 0.4, 0.45): Reflects a medium and significant influence level.
4. "High influence/importance" (0.8, 0.2, 0.15): Indicates a high and significant influence.
5. "Very high influence/importance" (0.9, 0.1, 0.1): This represents a very high influence and great importance in the relationship between factors.

The evaluations carried out by the experts are recorded in bidirectional tables using the linguistic values described earlier. These values are subsequently expressed in terms of SVNN (see Table 1) and then transformed using equations 2 and 3 to derive the initial matrix of direct interdependence.

Table 1. Evaluation of the analyzed variables carried out by an expert n. Source: own elaboration.

	V 1	V 2	V 3	V 4	V 5	V 6	V 7	V 8	V 9	V10
V1	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.8; 0.2; 0.15)	(0.9; 0.1; 0.1)	(0.8; 0.2; 0.15)	(0.5; 0.4; 0.45)
V2	(0.8; 0.2; 0.15)	(0.1; 0.8; 0.9)	(0.8; 0.2; 0.15)	(0.8; 0.2; 0.15)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.9; 0.1; 0.1)
V3	(0.1; 0.8; 0.9)	(0.8; 0.2; 0.15)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.8; 0.2; 0.15)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.8; 0.2; 0.15)	(0.9; 0.1; 0.1)
V4	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.8; 0.2; 0.15)	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)
V5	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.8; 0.2; 0.15)	(0.8; 0.2; 0.15)	(0.9; 0.1; 0.1)
V6	(0.5; 0.4; 0.45)	(0.9; 0.1; 0.1)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)
V7	(0.8; 0.2; 0.15)	(0.8; 0.2; 0.15)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)
V8	(0.9; 0.1; 0.1)	(0.1; 0.8; 0.9)	(0.9; 0.1; 0.1)	(0.35; 0.6; 0.7)	(0.8; 0.2; 0.15)	(0.8; 0.2; 0.15)	(0.35; 0.6; 0.7)	(0.1; 0.8; 0.9)	(0.8; 0.2; 0.15)	(0.9; 0.1; 0.1)
V9	(0.35; 0.6; 0.7)	(0.8; 0.2; 0.15)	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.5; 0.4; 0.45)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)	(0.5; 0.4; 0.45)
V 10	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)	(0.8; 0.2; 0.15)	(0.8; 0.2; 0.15)	(0.1; 0.8; 0.9)	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)	(0.35; 0.6; 0.7)	(0.5; 0.4; 0.45)	(0.1; 0.8; 0.9)

Table 2 displays the initial matrix of direct interdependence, providing valuable information about the mutual influence of the variables evaluated in the context of eligibility for asylum and immigration. It is observed that experts 1 and 2 received assessments of "Very High" in terms of importance, indicating that their perceptions and knowledge regarding these variables were considered highly significant in the evaluation process. On the other hand, experts 3 and 4 received assessments of "High" in terms of importance. This implies that, while their opinions are valued, they are not attributed the same level of relevance as experts 1 and 2. These differences in the importance assigned to the experts are due to their specific experience and knowledge in the field of decision-making related to eligibility for asylum and immigration. These findings highlight the importance of considering the weighting of expert opinions when analyzing the interdependence of variables and are essential for making informed decisions in this context.

Table 2. Values associated with the direct relationship matrix of the analyzed variables. Source. own elaboration.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1	0.000	0.761	0.542	0.713	0.239	0.644	0.852	0.885	0.636	0.548
V2	0.767	0.000	0.815	0.767	0.239	0.548	0.239	0.377	0.644	0.873
V3	0.239	0.815	0.000	0.548	0.239	0.815	0.377	0.548	0.815	0.873
V4	0.436	0.644	0.404	0.000	0.377	0.525	0.815	0.533	0.377	0.377
V5	0.239	0.807	0.548	0.636	0.000	0.548	0.644	0.815	0.744	0.841

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V6	0.548	0.873	0.785	0.548	0.239	0.000	0.404	0.764	0.548	0.548
V7	0.815	0.815	0.772	0.548	0.548	0.548	0.000	0.503	0.377	0.548
V8	0.885	0.239	0.850	0.377	0.815	0.772	0.377	0.000	0.815	0.857
V9	0.377	0.713	0.764	0.431	0.548	0.458	0.377	0.548	0.000	0.548
V10	0.377	0.764	0.815	0.815	0.239	0.377	0.377	0.533	0.548	0.000

From the initial matrix of direct interdependence, the next step involves normalization to obtain the normalized initial direct relationship matrix D. This is achieved using equations (4) and (5), which allow for the adjustment of interdependence values among the study variables. Additionally, the total direct relationship matrix T is calculated using equation (6). This process is essential for understanding the cause-and-effect relationships between the variables and evaluating their impact in the context of eligibility. The resulting matrices provide a quantitative representation of interactions between factors and are crucial for making informed decisions in this field.

$$T = D(I-D)^{-1} = \begin{bmatrix} 0.65 & 0.96 & 0.93 & 0.84 & 0.52 & 0.81 & 0.72 & 0.86 & 0.84 & 0.89 \\ 0.69 & 0.77 & 0.88 & 0.77 & 0.47 & 0.72 & 0.57 & 0.71 & 0.77 & 0.85 \\ 0.62 & 0.88 & 0.76 & 0.74 & 0.47 & 0.76 & 0.59 & 0.73 & 0.79 & 0.85 \\ 0.58 & 0.77 & 0.74 & 0.58 & 0.44 & 0.64 & 0.59 & 0.66 & 0.65 & 0.70 \\ 0.68 & 0.96 & 0.93 & 0.82 & 0.48 & 0.79 & 0.68 & 0.84 & 0.85 & 0.93 \\ 0.67 & 0.90 & 0.89 & 0.75 & 0.47 & 0.65 & 0.60 & 0.77 & 0.76 & 0.82 \\ 0.73 & 0.93 & 0.92 & 0.78 & 0.54 & 0.76 & 0.57 & 0.77 & 0.77 & 0.85 \\ 0.79 & 0.92 & 1.00 & 0.81 & 0.61 & 0.85 & 0.67 & 0.75 & 0.89 & 0.96 \\ 0.59 & 0.81 & 0.82 & 0.68 & 0.48 & 0.66 & 0.55 & 0.69 & 0.62 & 0.76 \\ 0.59 & 0.83 & 0.83 & 0.73 & 0.44 & 0.65 & 0.55 & 0.68 & 0.71 & 0.67 \end{bmatrix}$$

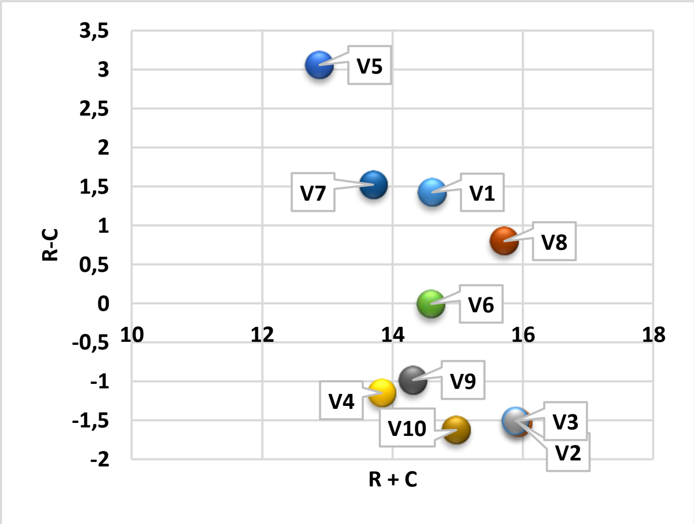
After obtaining the total direct relationship matrix, the next step involves analyzing the direct and indirect effects of the elements identified through the analysis of the prominence and relationship axes for the cause-and-effect group. The results of this analysis are presented in Table 3. These effects are calculated by considering the interaction of factors and their influence on the system, providing crucial information for understanding the dynamics of the studied variables.

Table 3. Level of influence between the variables. Source. own elaboration

Variables	R_i	C_i	$R_i + C_i$	$R_i - C_i$
Persecution in the country of origin	8,016	6,592	14,608	1,424
Integration in the host country	7,199	8,725	15,924	-1,526
Economic contribution	7,186	8,698	15,884	-1,512
National security	6,343	7,493	13,836	-1.15
Hosting capacity	7.97	4.91	12.88	3.06
Relatives in the host country	7.29	7,298	14,588	-0.008
Criminal record	7,612	6,091	13,703	1,521
Reasons for the application	8,255	7,455	15.71	0.8
Health status	6,663	7,648	14,311	-0.985
Compliance with procedures and legal requirements	6,675	8,299	14,974	-1,624

The creation of an influential graph is the final step in applying the DEMATEL model, helping decision-makers identify the most influential variables. In Figure 1, the X-axis contains the values of R + D, and the Y-axis contains the values of R - D. These values are based on Table 3. This graph positions the most influential variables at the highest (upper) level and the least influential factor at the lowest (lower) level.

Figure 1. Causal diagram. Source: own elaboration



The results obtained through the application of the DEMATEL method to assess the mutual influence among variables related to the eligibility of individuals in asylum applications and immigration processes reveal an insightful panorama. Each variable has been evaluated in terms of its relative importance (Ri) and causality (Ci), as well as the sum of both (Ri+Ci) and the difference between them (Ri-Ci).

The variable "Persecution in the country of origin" displays high relative importance (8.016) and significant causality (6.6), resulting in a total score (Ri+Ci) of 14.608. This indicates that persecution in the country of origin exerts a substantial influence on the eligibility of individuals. Furthermore, the difference (Ri-Ci) is positive (1.424), suggesting that this variable has a driving effect in this context.

On the other hand, the variables "Integration in the host country" and "Economic contribution" show similar scores, with a total score (Ri+Ci) of 15.924 and 15.884, respectively. However, both exhibit a negative difference (Ri-Ci), indicating a higher influence received than exerted. This suggests that integration in the host country and economic contribution are factors more influenced by other elements in the system.

The "Hosting capacity" stands out with a high total score (Ri+Ci) of 12.88 and a positive difference (Ri-Ci) of 3.06, implying that this variable exerts a significant influence and is a driving factor in the context of eligibility.

Discussion

The use of the DEMATEL method in conjunction with neutrosophic logic during the research has proven to be of vital importance. This approach provided an effective tool to assess and understand the interdependence and causality relationships among multiple influential factors in the eligibility process for asylum and immigration applications. Through DEMATEL, it became possible to visualize the direct and indirect effects of each factor in the context of a multidimensional and highly complex problem.

Neutrosophic logic, on the other hand, effectively handled and represented the inherent uncertainty and ambiguity in expert assessments in this field. This logic allowed for a more precise description of the levels of influence of each factor, surpassing the limitations of traditional approaches that tend to oversimplify the complexity of factor relationships.

The combination of DEMATEL and neutrosophic logic also proved valuable in identifying and prioritizing the most influential factors in the decision-making process related to eligibility for asylum and immigration. This information was crucial for decision-makers, as it provided them with a deeper and well-founded understanding of which aspects should be considered a priority in the evaluation process.

In retrospect, this research underscores the importance of integrating advanced analytical and logical approaches into decision-making in the field of eligibility for asylum and immigration. The application of the DEMATEL method and neutrosophic logic has demonstrated its effectiveness in addressing multidimensional problems in high-uncertainty contexts, providing a solid foundation for informed and strategic decision-making in a matter of critical importance.

Conclusions

Within the scope of this study, neutrosophic logic was applied to evaluate the variables involved in the eligibility of individuals in asylum and immigration applications. A set of influential variables for the study was identified through the use of semi-structured interviews and brainstorming. Single-valued neutrosophic sets were employed to conduct the corresponding evaluations based on linguistic variables. It was found that factors such as "Persecution in the country of origin" and "Reasons for the application" had a high influence, while factors like "Integration in the host country" and "Economic contribution" had a moderate influence. This provided crucial information for decision-makers, helping them prioritize the most critical aspects of the evaluation process. The results obtained provided a solid foundation for informed and strategic decision-making, contributing to a more efficient and equitable process in the field of eligibility for asylum and immigration. By using neutrosophic logic in combination with the DEMATEL method, a more robust structure and a deeper understanding of the interrelationships between the involved factors were achieved.

References

[1] M. H. Zack, “The role of decision support systems in an indeterminate world,” Decis. Support Syst., vol. 43, no. 4, pp. 1664–1674, 2007, [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0167923606001308.

[2] K. Yao and X. Ji, “Uncertain decision making and its application to portfolio selection problem,” Int. J. Uncertainty, Fuzziness Knowledge-Based Syst., vol. 22, no. 01, pp. 113–123, 2014, [Online]. Available: https://www.worldscientific.com/doi/abs/10.1142/S0218488514500056.

[3] L. A. Ocampo and E. E. Clark, “A framework for capturing uncertainty of group decision-making in the context of the AHP/ANP,” Adv. Ind. Eng. Manag., vol. 3, no. 3, pp. 7–16, 2014, [Online]. Available: https://scce.ac.in/e_journals/mech5.pdf.

[4] F. Herrera and L. Martínez, “A 2-tuple fuzzy linguistic representation model for computing with words,” IEEE Trans. fuzzy Syst., vol. 8, no. 6, pp. 746–752, 2000, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/890332/.

[5] L. Zadeh, G. Klir, and B. Yuan, Conjuntos difusos, lógica difusa y sistemas difusos: artículos seleccionados, Vol. 6. World Scientific, 1996.

[6] F. Smarandache, “Neutrosophic set – A generalization of the intuitionistic fuzzy set,” J. Def. Resour. Manag., vol. 1, no. 1, pp. 107-116., 2010, [Online]. Available: https://www.ceeol.com/search/article-detail?id=266793.

[7] E. Szmidt and J. Kacprzyk, “A new similarity measure for intuitionistic fuzzy sets: straightforward approaches may not work,” in 2007 IEEE International Fuzzy Systems Conference, 2007, pp. 1–6, [Online]. Available: https://ieeexplore.ieee.org/abstract/document/4295414.

[8] F. Smarandache, A unifying field in logics: neutrosophic logic. Neutrosophy, neutrosophic set, neutrosophic probability: neutrosophic logic. Neutrosophy, neutrosophic set, neutrosophic probability. American Research Press, 2005.

[9] H. Wang, F. Smarandache, R. Sunderraman, and Y. Q. Zhang, Interval neutrosophic sets and logic: theory and applications in computing: Theory and applications in computing, vol. 5. Arizona: Hexis, 2005.

[10] K. Mondal and S. Pramanik, “Neutrosophic decision-making model of school choice,” Neutrosophic Sets Syst., vol. 7, pp. 62–68, 2015, [Online]. Available: https://books.google.com/books?hl=es&lr=&id=yKVoCgAAQBAJ&oi=fnd&pg=PA62&dq=neutrosophic+decision+making&ots=-f2y8lOigb&sig=nu7a7vNvfvgxHV_vMo8VXVUaqOo.

[11] M. Junaid, Y. Xue, M. W. Syed, J. Z. Li, and M. Ziaullah, “A neutrosophic ahp and topsis framework for supply chain risk assessment in automotive industry of Pakistan,” Sustainability, vol. 12, no. 1, p. 154, 2019, [Online]. Available: https://doi.org/10.3390/su12010154.

[12] M. Abdel-Baset, V. Chang, A. Gamal, and F. Smarandache, “An integrated neutrosophic ANP and VIKOR method for achieving sustainable supplier selection: A case study in importing field,” Comput. Ind., vol. 106, pp. 94–110, 2019, [Online].

[13] P. Biswas, S. Pramanik, and B. C. Giri, “TOPSIS method for multi-attribute group decision-making under single-valued neutrosophic environment.,” Neural Comput. Appl., vol. 27, no. 3, pp. 727–737, 2016, [Online]. Available: https://link.springer.com/article/10.1007/s00521-015-1891-2.

[14] J. Zou, Y. Deng, Y. Hu, and G. Lin, Measure distance between neutrosophic sets: An evidential approach. Infinite Study, 2018.

[15] J. Gan and L. Luo, “Using DEMATEL and intuitionistic fuzzy sets to identify critical factors influencing the recycling rate of end-of-life vehicles in China.,” Sustainability, vol. 9, no. 10, p. 1873, 2017, [Online]. Available: https://www.mdpi.com/2071-1050/9/10/1873.

[16] A. Awang, A. T. A. Ghani, L. Abdullah, and M. F. Ahmad, “A DEMATEL method with single valued neutrosophic set (SVNS) in identifying the key contribution factors of Setiu Wetland’s coastal erosion,” AIP Conf. Proc., vol. 1974, 2018, doi: 10.1063/1.5041542.

[17] D. Vujanović, V. Momčilović, N. Bojović, and V. Papić, “Evaluation of vehicle fleet maintenance management indicators by application of DEMATEL and ANP,” Expert Syst. Appl., vol. 39, no. 12, pp. 10552–10563, 2012, [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0957417412004228.

[18] Ricardo, J. E., Villalva, M. I. M., Padilla, Z. A. O., & Hurtado, L. A. C. ¨Filosofía de la comunicación, complemento necesario en el aprendizaje de las Ciencias Sociales¨. Magazine de las Ciencias: Revista de Investigación e Innovación, vol 3 núm. 2, pp 39-52, 2018.

[19] de Mora-Litardo, K., & Estupiñan-Ricardo, J. ¨La influencia de la programación neurolingüística en estudiantes universitarios en la República de Ecuador¨. Luz, vol 16 núm 1, pp 104-112, 2017

[20] 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

[21] 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

[22] 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 31, 2023. **Accepted:** December 19, 2023