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Neutrosophic Evaluation of Legal Strategies for Decision-making in a Digital Context

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Abstract. The present study focused on the protection of intellectual property rights in the digital era. A methodology incorporating neutrosophy was applied to evaluate and compare different proposed legal alternatives. The inherent complexity of legal issues, characterized by ambiguous facts and diverse perspectives, underscored the relevance of neutrosophy in this field. The ELECTRE I method was adapted to a neutrosophic structure by incorporating bipolar neutrosophic numbers to manage uncertainty and ambiguity in decision-making. The final results revealed a strong preference for the "Legal Education and Training" alternative due to its cost and time effectiveness. The study provided a solid foundation for informed decision-making in the realm of intellectual property protection in the digital era, supported by the use of neutrosophic theory and the ability to handle indeterminacies inherent in decision-making.

Keywords: legal strategies, intellectual property, neutrosophic evaluation, ELECTRE I.

1. Introduction

In the digital era, the protection of intellectual property rights has become a challenge of great complexity and a multifaceted nature. This phenomenon arises from the global interconnectedness provided by the internet, which has radically transformed the creation, distribution, and utilization of intellectual content. The term "intellectual property" encompasses a broad range of assets, including copyrights, patents, trademarks, and trade secrets, all of which have experienced profound influence and, often, have been threatened by digitization and globalization.

The digital environment has introduced new dimensions to challenges related to intellectual property. The ease of copying and distributing digital content has led to practices of massive infringement, from online piracy to the unauthorized dissemination of intellectual property. Additionally, national borders have become blurred online, complicating the enforcement of intellectual property laws and regulations in a global context. The convergence of technology and digital connectivity has also generated tensions between the interests of rights holders and the need for open access to information and innovation.

This complex challenge manifests in the necessity to adopt effective strategies for protecting intellectual property in the digital environment. Companies and organizations are compelled to consider a range of factors, from content protection technologies to legal measures, strategic alliances, and user education strategies.

Decision-making in this domain has become a critical process involving the consideration of multiple complex and variable factors [1]. Strategic decisions in this field require not only the management of legal and technical aspects but also the evaluation of risks and opportunities inherent in a constantly evolving digital environment. In this regard, the application of neutrosophy as a method becomes fundamental to dealing with the uncertainty and indeterminacies that often surround these decisions [2].

Neutrosophy, introduced by the philosopher and mathematician Florentin Smarandache in the late 20th century, has become a valuable tool for addressing uncertainty and ambiguity in decision-making across various fields, including science [3], business [4], and industry. This theory is based on the idea that truth, falsehood, and indeterminacy can coexist in a statement or proposition, reflecting the inherent complexity of many decision-making situations.

In essence, neutrosophy recognizes that real-world decisions often involve incomplete, ambiguous, or contradictory information. This contrasts with more traditional approaches that assume statements are either entirely true or entirely false [5]. Additionally, it introduces an element of indeterminacy, where the truth or falsehood of a statement may vary based on different perspectives, contexts, or degrees of knowledge.

The applicability of neutrosophy in decision-making is evident in various fields. In science, for example, experimental research often faces contradictory results or incomplete data. Neutrosophy enables scientists to consider indeterminacy in their findings and make informed decisions even when absolute truth is challenging to determine [6].

In the business field, strategic decision-making is especially prone to uncertainty [7]. Neutrosophy has enhanced companies' ability to consider diverse scenarios and assess the possibilities of success or failure, which is fundamental in a highly competitive and ever-changing business environment [8], [9].

In the industry, neutrosophy has found applications in risk management and project planning. Industry leaders can consider indeterminacy in timelines, costs, and resources, allowing them to make more realistic and adaptive decisions [10-17].

From another perspective, the inherent complexity of numerous legal issues, often characterized by ambiguous facts and divergent approaches, emphasizes the relevance of neutrosophy in this field [11-18]. Consequently, the main purpose of this study is to apply neutrosophic methodology to analyze and contrast various proposed legal alternatives for safeguarding intellectual property in the context of the digital era.

To accomplish this task, an adaptation of the ELECTRE I method is proposed, which extends to a neutrosophic structure through the incorporation of bipolar neutrosophic numbers [12]. This approach is chosen to manage the uncertainty and ambiguity present in evaluating legal alternatives in the field of intellectual property in the digital era more precisely and effectively. The use of bipolar neutrosophic numbers allows for the consideration of diverse perspectives and degrees of indeterminacy in decision-making [13-16], which is essential for addressing complex situations in the field of law, specifically in the protection of intellectual property in constantly evolving digital environments. This methodological approach provides a solid foundation for evaluating proposed legal alternatives and determining which stands out as the most effective in the short term with the least possible cost.

2. Bipolar Neutrosophic Sets

Definition 1. Let X be a space of points (objects) with generic elements in X represented by x. A single-valued neutrosophic set (SVNS) A on X is characterized by a truth membership function $T_A(x)$, an indeterminacy membership function $I_A(x)$, and a falsity membership function $F_A(x)$. Therefore, an SVNS A can be represented as $A = \{x, T_{A(x)}, I_{A(x)}, F_{A(x)x} \in X\}$, where $T_{A(x)}, I_{A(x)}, F_{A(x)} \in [0,1]$ for each point x in X. In this way, the sum of satisfies the condition $0 \leq T_{A(x)} + I_{A(x)} + F_{A(x)} \leq 3$. [14]

Definition 2. A bipolar neutrosophic set A in X is defined as an object of the form

$$\tilde{A} = \{x, \langle T_A^+(x), I_A^+(x), F_{\tilde{A}}^+(x), T_{\tilde{A}}^-(x), I_{\tilde{A}}^-(x), F_{\tilde{A}}^-(x)\rangle | x \in X\}, \quad (1)$$

Where $T_A^+(x), I_A^+(x), F_{\tilde{A}}^+(x): X \to [0,1]$ and $T_{\tilde{A}}^-(x), I_{\tilde{A}}^-(x), F_A^-(x): X \to [-1,0]$

2.2 ELECTRE I method with bipolar neutrosophic numbers

Given the existence of a set $S = \{S_1, S_2, \cdots, S_m\}$ of m selection alternatives, as well as a set $T = \{T_1, T_2, \cdots, T_n\}$ of n attributes or evaluation criteria. Likewise, $W = [w_{1w_2} \cdots w_n]^T$ is the vector of weights associated with the evaluation criteria, where $0 \leq wj \leq 1$ and $\sum j = 1_{nwj} = 1$. Assuming that the decision-maker gives the rating value of each alternative □□, (□=1,2,⋯,□) with respect to the attributes □□, (□=1,2,⋯,□) in the form of Bipolar Neutrosophic Sets (BNSs), the steps of the ELECTRE I method can be completed as described below:

Step 1. Each alternative is evaluated based on multiple criteria. The evaluation of each alternative with respect to each criterion is presented using (BNSs). Each entry $k_{ij} =< T_{ij}^+, I_{ij}^+, F_{ij}^+, T_{ij}^-, I_{ij}^-, F_{ij}^- >$ is characterized by $T_{ij}^+, I_{ij}^+, F_{ij}^+$, which represent the degree of membership of positive truth, indeterminacy, and falsity, respectively. Likewise, $T_{ij}^-, I_{ij}^-, F_{ij}^-$ reflect the degree of membership of negative truth, indeterminacy, and falsity, respectively. These values satisfy the constraints $T_{ij}^+, I_{ij}^+, F_{ij}^+ \in [0,1]$, $T_{ij}^-, I_{ij}^-, F_{ij}^- \in [-1,0]$, and $0 \leq T_{ij}^+, I_{ij}^+, F_{ij}^+, T_{ij}^-, I_{ij}^-, F_{ij}^- \leq 6$, where □=1,2,3,…,□ and □=1,2,3,…,□.

Step 2. When the weights of the criteria are not equally distributed and their value is unknown to the decision maker, we resort to the deviation maximization method to calculate the unspecified weights of the criteria. Consequently, the weight of the attribute □□ is calculated as follows:

$$w_j = \sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}| \Big/ \sqrt{\sum_{j=1}^{n} \left(\sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}|\right)^2}, \quad (2)$$

And the normalized weight of the attribute$Tj$is established as described by equation (3):

$$w_j^* = \sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}| \Big/ \sum_{j=1}^{n} \left(\sum_{i=1}^{m} \sum_{l=1}^{m} |k_{ij} - k_{lj}|\right). \quad (3)$$

Step 3. The weighted neutrosophic bipolar cumulative decision matrix is calculated by multiplying the attribute weights to an aggregate decision matrix as follows: $K * W = [k_{ij}^{w_j}]_{m \times n}$ where

$$k_{ij}^{w_j} =< T_{ij}^{w_j+}, I_{ij}^{w_j+}, F_{ij}^{w_j+}, T_{ij}^{w_j-}, I_{ij}^{w_j-}, F_{ij}^{w_j-} > =< 1-(1-T_{ij}^{+})^{w_j}, (I_{ij}^{+})^{w_j}, (F_{ij}^{+})^{w_j}, -(-T_{ij}^{-})^{w_j}, -(-I_{ij}^{-})^{w_j}, -(1-(1-(-F_{ij}^{-}))^{w_j}) >$$

Step 4. Bipolar neutrosophic concordance sets E_{xy} and bipolar neutrosophic discordance sets F_{xy} are defined as follows:

$$E_{xy} = \{1 \leq j \leq n | \rho_{xj} \geq \rho_{yj}\}, x \neq y, x, y = 1,2,\cdots,m,$$
$$F_{xy} = \{1 \leq j \leq n | \rho_{xj} \leq \rho_{yj}\}, x \neq y, x, y = 1,2,\cdots,m, \quad (4)$$

Where $\rho_{ij} = T_{ij}^{+} + I_{ij}^{+} + F_{ij}^{+} + T_{ij}^{-} + I_{ij}^{-} + F_{ij}^{-}, i = 1,2,\cdots,m, j = 1,2,\cdots,n$

Step 5. Construct the bipolar neutrosophic concordance matrix E, where bipolar agreement indices $e_{xy}'s$ are calculated using equation (5)

$$e_{xy} = \sum_{j \in E_{xy}} w_j \quad (5)$$

Step 6. Construct the bipolar neutrosophic discordance matrix F, where the bipolar discordance indices $f_{xy}'s$ are calculated by equation (6):

$$f_{xy} = \frac{\max\limits_{j \in F_{xy}} \sqrt{\frac{1}{6n}\begin{Bmatrix}(T_{xj}^{w_j+}-T_{yj}^{w_j+})^2+(I_{xj}^{w_j+}-I_{yj}^{w_j+})^2+(F_{xj}^{w_j+}-F_{yj}^{w_j+})^2+\\(T_{xj}^{w_j-}-T_{yj}^{w_j-})^2+(I_{xj}^{w_j-}-I_{yj}^{w_j-})^2+(F_{xj}^{w_j-}-F_{yj}^{w_j-})^2\end{Bmatrix}}}{\max\limits_{j} \sqrt{\frac{1}{6n}\begin{Bmatrix}(T_{xj}^{w_j+}-T_{yj}^{w_j+})^2+(I_{xj}^{w_j+}-I_{yj}^{w_j+})^2+(F_{xj}^{w_j+}-F_{yj}^{w_j+})^2+\\(T_{xj}^{w_j-}-T_{yj}^{w_j-})^2+(I_{xj}^{w_j-}-I_{yj}^{w_j-})^2+(F_{xj}^{w_j-}-F_{yj}^{w_j-})^2\end{Bmatrix}}} \quad (6)$$

Step 7. Calculations of the levels of agreement and disagreement are made to rank the alternatives. The bipolar neutrosophic agreement level $\hat{e}$ is established as the average of the bipolar neutrosophic agreement indices as shown:

$$\hat{e} = \frac{1}{m(m-1)} \sum_{\substack{x=1, \\ x \neq y}}^{m} \sum_{\substack{y=1, \\ y \neq x}}^{m} e_{xy} \quad (7)$$

Analogously, the bipolar neutrosophic discordance level $\hat{f}$ is defined as the average value of the bipolar neutrosophic discordance indices, as follows:

$$\hat{f} = \frac{1}{m(m-1)} \sum_{\substack{x=1, \\ x \neq y}}^{m} \sum_{\substack{y=1, \\ y \neq x}}^{m} f_{xy} \quad (8)$$

Step 8. The bipolar neutrosophic concordance dominance matrix ϕ as a function of $\hat{e}$, and the bipolar neutrosophic discordance dominance matrix ψ, as a function of $\hat{f}$, where the values of ϕ_{xy} and ψ_{xy} are defined below:

$$\phi_{xy} = \begin{cases} 1, & \text{if} e_{xy} \geq \hat{e}, \\ 0, & \text{if} e_{xy} < \hat{e}. \end{cases} \quad (9)$$

$$\psi_{xy} = \begin{cases} 1, & \text{if} f_{xy} \leq \hat{f}, \\ 0, & \text{if} f_{xy} > \hat{f}. \end{cases} \quad (10)$$

Step 9. Therefore, the bipolar neutrosophic aggregate dominance matrix π is evaluated by multiplying the corresponding entries of the matrices ϕ and ψ. Where $\pi_{xy} = \phi_{xy}\psi_{xy}$.

Step 10. Finally, the alternatives are ranked according to the π_{xy} surpassing values. That is, for each pair of alternatives S_x and S_y, there is an arrow from S_x to S_y if and only if π_{xy}= 1. As a result, we have three possible cases:

(a) There is a single arrow pointing from S_x to S_y.

(b) There are two possible arrows between S_x and S_y.

(c) There is no arrow between S_x and S_y.

For case a), S_x preferred. In the second case, S_x and S_y are indifferent, while S_x and S_y are incomparable in case c).

3 Application for determining strategic alternatives

In the current digital environment, the protection of intellectual property rights has become essential and challenging for many companies and organizations. In this context, a company named Legal Shield Innovations is at a crossroads as it seeks to identify the most effective and cost-efficient strategy to protect its intellectual property rights in the digital era. In this case, the company aims to evaluate and compare four strategic alternatives within the legal framework to determine which one is the most effective according to its objectives for intellectual property protection in the digital context. To do so, the company must choose from the following alternatives:

1. Rights and Trademarks Registration (RTR): The company explores the possibility of registering its intellectual property rights and trademarks more comprehensively and effectively to strengthen its legal position.
2. Direct Legal Actions (DLA): Considers the option of taking direct legal actions against intellectual property infringers by filing lawsuits and seeking compensation.
3. Collaboration with Compliance Agencies (CCA): The company considers collaborating with compliance agencies and government authorities to strengthen the enforcement of intellectual property infringements.
4. Education and Legal Training (ELT): The entity aims to implement education and legal training programs for its employees and collaborators, strengthening their legal defense capabilities.

For the evaluation of these alternatives, a set of high-importance criteria has been proposed for the company's management. These criteria include:

T1: Cost of implementing the measure - Evaluate the direct cost of implementing each measure, including investments in technology, human resources, and training.

T2: Short-term impact - Evaluate the short-term legal effectiveness of each alternative in protecting the company's intellectual property rights in the initial months of implementation.

T3: User experience - Assesses how each measure affects the user experience in terms of accessibility, ease of use, and the quality of available content.

T4: Long-term legal effectiveness - Evaluate the sustainability and long-term effectiveness of each alternative in protecting the company's intellectual property rights, considering possible changes in legislation.

The obtained alternatives were assessed by experts considering the selected criteria. Table 1 shows the decision matrix of bipolar numbers obtained for this purpose.

Table 1. Bipolar Number Decision Matrix

	T1	T2	T3	T4
S1	(0.4, 0.2, 0.5, -0.6, -0.4, -0.4)	(0.5, 0.3, 0.3, -0.7, -0.2, -0.4)	(0.2, 0.7, 0.5, -0.4, -0.4, -0.3)	(0.4, 0.6, 0.5, -0.3, -0.7, -0.4)
S2	(0.3, 0.6, 0.1, -0.5, -0.7, -0.5)	(0.3, 0.6, 0.1, -0.5, -0.3, -0.7)	(0.4, 0.2, 0.5, -0.6, -0.3, -0.1)	(0.2, 0.7, 0.2, -0.5, -0.3, -0.2)
S3	(0.3, 0.5, 0.2, -0.4, -0.3, -0.7)	(0.4, 0.5, 0.2, -0.3, -0.8, -0.5)	(0.8, 0.5, 0.7, -0.3, -0.4, -0.3)	(0.4, 0.7, 0.6, -0.5, -0.5, -0.4)
S4	(0.5, 0.5, 0.3, -0.2, -0.1, -0.3)	(0.7, 0.4, 0.6, -0.1, -0.3, -0.4)	(0.6, 0.3, 0.6, -0.1, -0.4, -0.2)	(0.8, 0.3, 0.2, -0.1, -0.3, -0.1)

In the present case study, the weight vector for the evaluation criteria is considered as follows: w = (0.3, 0.25, 0.2, 0.25). These weights assigned to the criteria, in combination with the initial decision matrix, allow the calculation of the normalized matrix. The normalized matrix is calculated by multiplying the values in the decision matrix by the weights assigned to each evaluation criterion, as shown in (4). See Table 2.

Table 2. Normalized decision matrix

	T1	T2	T3	T4
S1	(0.142, 0.617, 0.812, -0.858, -0.76, -0.142)	(0.159, 0.74, 0.74, -0.915, -0.669, -0.12)	(0.044, 0.931, 0.871, -0.833, -0.833, -0.069)	(0.12, 0.88, 0.841, -0.74, -0.915, -0.12)
S2	(0.101, 0.858, 0.501, -0.812, -0.899, -0.188)	(0.085, 0.88, 0.562, -0.841, -0.74, -0.26)	(0.097, 0.725, 0.871, -0.903, -0.786, -0.021)	(0.054, 0.915, 0.669, -0.841, -0.74, -0.054)
S3	(0.101, 0.812, 0.617, -0.76, -0.697, -0.303)	(0.12, 0.841, 0.669, -0.74, -0.946, -0.159)	(0.275, 0.871, 0.931, -0.786, -0.833, -0.069)	(0.12, 0.915, 0.88, -0.841, -0.841, -0.12)
S4	(0.188, 0.812, 0.697, -0.617, -0.501, -0.101)	(0.26, 0.795, 0.88, -0.562, -0.74, -0.12)	(0.167, 0.786, 0.903, -0.631, -0.833, -0.044)	(0.331, 0.74, 0.669, -0.562, -0.74, -0.026)

From this information, bipolar neutrosophic concordance sets and bipolar neutrosophic discordance sets, as shown in Tables 3 and 4.

Table 3. Bipolar neutrosophic concordance sets.

E_{xy}	1	2	3	4
E_{1y}	-	{1, 2, 3, 4}	{0}	{0}
E_{2y}	{0}	-	{0}	{0}
E_{3y}	{3,4}	{1, 2, 4}	-	{3}
E_{4y}	{1, 2, 3, 4}	{1, 2, 3, 4}	{1, 2, 4}	-

Table 4. Bipolar neutrosophic discordance sets.

F_{xy}	1	2	3	4
F_{1y}	-	{0}	{1, 2, 3, 4}	{1, 2, 3, 4}
F_{2y}	{1, 2, 3, 4}	-	{1, 2, 3, 4}	{4}
F_{3y}	{1,2}	{3}	-	{1, 2, 4}
F_{4y}	{0}	{0}	{3}	-

Based on the collected data and applying equations 6 and 7, the next step is the calculation and obtaining of the neutrosophic concordance matrix E and the neutrosophic discordance matrix F. These matrices will provide a quantitative representation of the concordance and discordance relationships among the evaluated alternatives, facilitating the decision-making process.

$$E = \begin{bmatrix} - & 1.000 & 0.000 & 0.000 \\ 0.000 & - & 0.000 & 0.000 \\ 0.450 & 0.800 & - & 0.220 \\ 1.000 & 1.000 & 0.800 & - \end{bmatrix}$$

$$F = \begin{bmatrix} - & 0.000 & 1.000 & 1.000 \\ 1.000 & - & 1.000 & 0.8589 \\ 1.000 & 0.9854 & - & 1.000 \\ 0.000 & 0.000 & 0.4524 & - \end{bmatrix}$$

With this information, calculations of the levels of concordance and discordance are performed to rank the alternatives. The bipolar neutrosophic concordance level $\hat{e}$ is calculated as 0.4375, while the bipolar neutrosophic discordance level $\hat{f}$ is obtained as 0.6914. Following this approach, by applying equations 10 and 11, the bipolar neutrosophic concordance dominance matrix ϕ and the bipolar neutrosophic discordance dominance matrix ψ are obtained. These matrices will provide essential information for classifying the alternatives and determining which of the proposed strategies is the most effective based on the previously established criteria.

$$\phi = \begin{bmatrix} - & 1 & 0 & 0 \\ 0 & - & 0 & 0 \\ 1 & 1 & - & 0 \\ 1 & 1 & 1 & - \end{bmatrix}$$

$$\psi = \begin{bmatrix} - & 1 & 0 & 0 \\ 0 & - & 0 & 0 \\ 0 & 0 & - & 0 \\ 1 & 1 & 1 & - \end{bmatrix}$$

Based on the alternatives evaluation methodology and using the resulting dominance matrix, the preference and dominance relationships between the proposed strategies for the protection of intellectual property in the digital age have been determined. The resulting matrix is presented below:

$$\pi = \begin{bmatrix} - & 1 & 0 & 0 \\ 0 & - & 0 & 0 \\ 0 & 0 & - & 0 \\ 1 & 1 & 1 & - \end{bmatrix}$$

Considering the results, it can be observed that there are preference and non-preference relationships among the proposed strategic alternatives. A single arrow going from S_1 to S_2 has been identified, indicating that S_1 is preferred to S_2. Additionally, three possible arrows from S_4 to S_1, S_2, and S_3 have been recorded, indicating the superiority of alternative S_4 over the other alternatives. These results suggest a strong supremacy of alternative S_4

"Education and Legal Training" over the other strategic alternatives. Furthermore, it has been found that alternative S_1 "Rights and Trademarks Registration" is also considered desirable in the context of the study. These findings indicate that, in retrospect, strategies S_4 and S_1 are preferred based on the defined criteria and objectives of the study. The preference for S_4 could be related to its effectiveness in terms of cost and time, making it an attractive option for protecting intellectual property rights in the digital era. On the other hand, the S_1 strategy, focusing on rights and trademark registration, is also considered a desirable option, possibly due to its effectiveness in legal and compliance terms.

Conclusions

Throughout this study, a methodology incorporating neutrosophy was applied to analyze and compare various proposed legal alternatives in the context of intellectual property protection in the digital era. The adaptation and application of the ELECTRE I method to a neutrosophic structure by incorporating bipolar neutrosophic numbers allowed for managing the inherent uncertainty and ambiguity in decision-making in the field of intellectual property law in the digital era. The results indicated a strong preference for the "Education and Legal Training" alternative over others, possibly due to its effectiveness in terms of costs and time. These findings provided a solid foundation for informed decision-making in the field of intellectual property protection in the digital era. The study offered robust support for the use of neutrosophic logic in evaluating and selecting effective and cost-efficient strategies across various fields of science and technology.

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