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Use of Neutrosophic Cognitive Maps for a more complex representation of human perceptions

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Abstract. The research addresses a central problem in the modeling and analysis of human perceptions: the need for tools that capture more richly and accurately the complexity inherent in opinions, especially in contexts of high uncertainty and contradiction. In a scenario where traditional methodologies such as conventional cognitive maps lack the flexibility to represent nuances such as ambiguity or non-linear relationships, a key opportunity arises to explore innovative approaches. This methodological gap raises the question of how to integrate neutrosophic logic into analytical tools to improve the representation and analysis of complex perceptions in diverse environments. The study proposes and validates the use of Neutrosophic Cognitive Maps (NCM) as an advanced methodology that incorporates degrees of truth, falsity, and indeterminacy simultaneously. The results show that NCMs allow for modeling more dynamic and realistic scenarios, overcoming the limitations of traditional techniques. Moreover, its implementation not only contributes to the theory of neutrosophic logic but also presents significant practical applications in solving complex problems, from strategic decision-making to organizational planning. This contribution highlights how NCMs, by fusing mathematical rigor with interpretive flexibility, constitute an essential tool to address contemporary challenges in disciplines such as management, social sciences, and engineering.

Keywords: Neutrosophic Cognitive Maps, perceptual modeling, uncertainty analysis, neutrosophic logic, complex representation, indeterminacy, analytical tools, strategic decision-making.

1. Introduction

Neutrosophic cognitive maps emerge as fundamental tools in the judicial field, especially in the litigation process, due to their unique ability to capture, represent, and analyze the complexity of the mental models of the various actors involved (judges, plaintiffs, defenders, etc.). These maps allow for a richer and more nuanced representation of each actor's perceptions, beliefs and expectations, facilitating a deeper understanding of their positions and motivations. This ability to represent not only binary aspects (true/false) but also uncertainty and degrees of truth and falsity is crucial to addressing the inherently complex and multifaceted nature of legal cases [1] .

The use of neutrosophic cognitive maps contributes significantly to legal certainty. By offering a clear view of the perspectives of all actors, these maps help judges and parties to identify areas of consensus and disagreement, thereby reducing the chances of misunderstandings or misinterpretations of the parties'

intentions or arguments [2] . This clarity and transparency increase the predictability of judicial processes, a cornerstone of legal certainty, by ensuring that decisions are made based on a comprehensive understanding of all the aspects involved.

In terms of procedural fairness, neutrosophic cognitive maps play a crucial role in ensuring that all voices are heard and considered equally [3] . By explicitly visualizing the perceptions and arguments of each actor, these maps promote a more balanced and fair approach to decision-making, avoiding bias towards any one party and ensuring that the process is inclusive and representative of all viewpoints. This fairness is essential to maintaining trust in the justice system and to ensuring that all actors feel that their perspectives have been adequately valued.

The impact of the abandonment order on access to justice can be significantly modulated with neutrosophic cognitive maps. By identifying and understanding the perceived barriers and challenges faced by actors, especially plaintiffs, these maps can help identify proactive solutions to prevent abandonment of the process. Furthermore, by offering a clear representation of actors' mental models, they facilitate the identification of areas in which the justice system may be perceived as inaccessible or unfavorable, thus allowing the implementation of corrective measures that promote greater access to justice for all.

The use of neutrosophic cognitive maps to identify and represent the mental models of different actors in a judicial process is an innovative approach that seeks to capture the complexity of perceptions and attitudes toward abstract concepts such as legal certainty, procedural fairness, and access to justice, especially in the context of the abandonment order. This methodology is based on the neutrosophic theory, which extends classical logic and fuzzy logic by introducing the degree of indeterminacy along with the degrees of truth and falsity.

The steps to implement Neutrosophic Cognitive Maps are described (Figure 1):

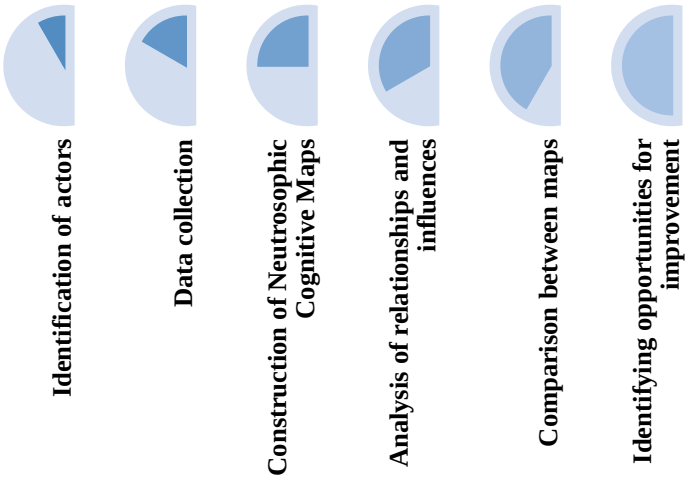

Figure 1: Steps for the implementation of Neutrosophic Cognitive Maps. Source: Elaboration own

1. Start by identifying the key players in the legal process of reporting: judges, complainants (victims), defenders (lawyers for the accused) and prosecutors.

2. Through interviews, questionnaires or workshops, collect data on the perceptions of these actors regarding legal certainty, procedural fairness and the impact of the abandonment order on access to justice.
3. Use the information you have gathered to build a cognitive map for each stakeholder group. Each map should represent key concepts as nodes and perceptions or beliefs about these concepts as links, with labels reflecting the degree of truth, falsity, and indeterminacy of these perceptions.
4. Analyze how these concepts interrelate and influence each other within each map.
5. Compare the neutrosophic cognitive maps of the different actors to identify areas of consensus, conflict or significant indeterminacy. This may reveal, for example, whether judges and complainants have very different mental models regarding the impact of the abandonment order on access to justice.
6. Based on comparative analysis, identify opportunities to improve the perception of legal certainty, procedural fairness and access to justice.

By applying the Neutrosophic Cognitive Maps methodology, it is possible to improve the perception and actions of the different actors involved in the judicial process of the complaint. In turn, this can inform more effective strategies to improve legal certainty and access to justice. The implications of using cognitive maps are described below in (Figure 2).

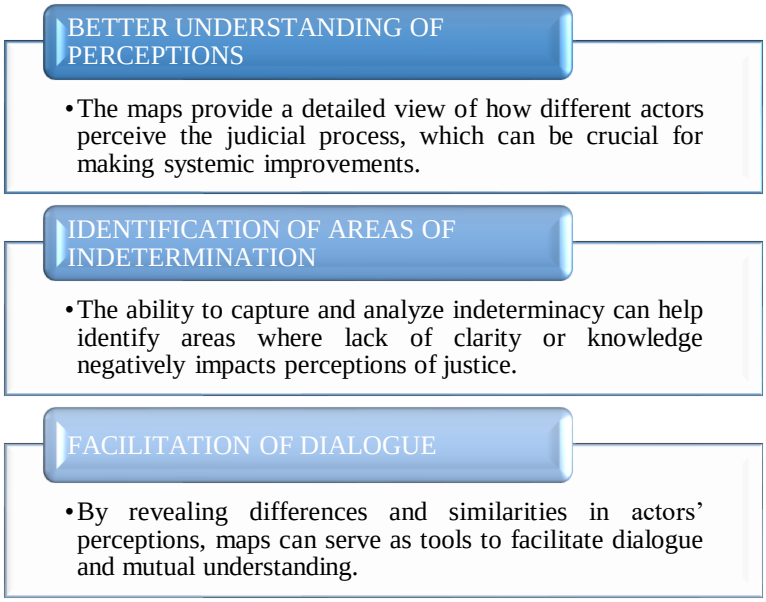

Figure 2: Implications of neutrosophic cognitive maps. Source: Own elaboration.

1.2 Legal framework on abandonment in the judicial process

The Ecuadorian criminal legal framework is aimed at promoting equal access to justice, as stipulated by the National Constituent Assembly [4,12] . It seeks to guarantee due process and safeguard the essential rights of citizens. Within this spectrum, the right of appeal takes on special importance, which empowers the parties involved in judicial disputes to challenge judicial decisions that they consider adverse.

Regarding the relevant Ecuadorian criminal legal provisions on the dismissal order within the framework of the complaint and its respective enforcement procedure, the Comprehensive Organic Criminal Code (COIP) and its subsequent reforms, enacted by the National Assembly in 2014, stand out. These legislations outline the principles and procedures that govern the criminal judicial framework in Ecuador, incorporating specific regulations on the complaint and the dismissal order. Fundamentally, article 647 of the COIP constitutes a cornerstone for understanding the complaint within the Ecuadorian criminal system. It defines and regulates the complaint as a special mechanism for the private exercise of criminal action, through which an individual can file a complaint with the judicial authority after being the victim of a private crime [5] .

The aforementioned article 647 defines the requirements and conditions for filing a claim, including the deadline for filing it and the formalities required. On the other hand, article 651 of the COIP refers directly to the order of withdrawal of the claim, establishing that, at the request of the accused party, the judge may issue the order of withdrawal when the complainant has withdrawn from pursuing the claim for a period of thirty days from the last procedural request. This implies that, in the event of inaction by the complainant to continue with the process within said period, the judge is empowered to declare the withdrawal of the claim, thereby concluding the procedure.

It is imperative to point out that the criminal law does not expressly provide for the possibility of appealing the decision of abandonment in the COIP. This omission is crucial in the context of the right to appeal, since, as it is a conclusive decision that puts an end to the process, it deprives the complainant of the possibility of challenging said determination before higher instances.

The lack of an explicit provision on the appeal of the order of abandonment creates uncertainty about the right of the complainant to appeal, which could violate the guarantee of due process and effective judicial protection. Such a situation could generate legal uncertainty and restrict access to justice for persons involved in a criminal process that culminates in the order of abandonment.

The figure of withdrawal from the claim has significant implications for the right of the complainant to appeal in the Ecuadorian judicial system. It is essential to examine both the advantages and the limitations that this legal provision may entail in terms of effective judicial protection and due process. Withdrawal is interpreted as a mechanism aimed at ensuring the agility and effectiveness of the criminal process, avoiding the indefinite prolongation of cases without substantial progress, which could contribute to the decongestion of the courts and the prompt resolution of other disputes.

However, from the perspective of the right to appeal, the order to abandon raises significant concerns, as it is considered a final decision that puts an end to the process and deprives the complainant of the right to challenge the decision before a higher instance, restricting the exercise of the right of defense and the possibility of a more detailed review of the judicial decision. The absence of a specific avenue of appeal for the order to be abandoned may lead to varied interpretations by the judicial body and generate disparities in the application of the law, affecting the uniformity and predictability of judicial decisions, which, in turn, could negatively affect legal certainty.

The research aims to analyze and improve the understanding of the complexities in the judicial litigation process with neutrosophic cognitive maps. Through this, it is intended to identify and mitigate the barriers faced by the different actors involved in access to justice, legal certainty and procedural fairness. This will be achieved by capturing, representing and analyzing the mental models of these actors regarding key concepts.

2. Related Work .

2.1. Neutrosophic cognitive maps (NCM).

Neutrosophic cognitive maps (NCMs) represent an evolution of conventional cognitive schemes by incorporating neutrosophic principles for the effective management of elements such as uncertainty, ambiguity, and contradiction. Originated by Florentin Smarandache in the late 1990s, neutrosophic cognitive maps extend the foundations of earlier systems such as fuzzy logic, intuitionistic sets, and fuzzy sets, providing a more robust framework for dealing with uncertainty and indeterminacy.

In a fuzzy cognitive map, both causal connections and concepts are characterized not only by binary values (true or false) or degrees of membership (as in fuzzy cognitive maps), but also by degrees of truth, falsity, and indeterminacy. This feature facilitates the modeling of scenarios in which connections between concepts are not fully defined or are inherently uncertain.

Effective application of NCMs requires an interdisciplinary approach spanning disciplines such as psychology, engineering, computer science, and mathematics to adequately simulate the complexity of real systems in uncertain contexts.

By fusing the elements of cognitive maps with the guidelines of neutrosophic theory, NCMs employ a set of mathematical formulations intended to facilitate the modelling and analysis of causal interactions between concepts in situations of uncertainty, ambiguity and contradiction. These formulations, based on neutrosophic logic and operations with neutrosophic sets, seek to quantify how variations of one concept affect others within the map structure.

A neutrosophic set is characterized by the presence of three fundamental parameters assigned to each element: the degree of truth (T), the degree of falsity (F) and the degree of indeterminacy (I), where each of these parameters varies from 0 to 1. The fundamental premises related to neutrosophic set are described in [8], [9] .

A neutrosophic cognitive map is a directed neutrosophic graph, where vertices represent concepts and edges represent causal relationships between vertices [10,13] .

Vertex Representation: If there are k vertices $C_1, C_2, \ldots, C_k$, each can be represented by a vector $(x_1, x_2, \ldots, x_k)$ where $x_i \in \{0, 1, I\}$ according to the state of vertex C_i at a specific time or situation:

- $x_i = 0$: Vertex C_i is in an activated state.
- $x_i = 1$: Vertex C_i is disabled.
- $x_i = I$: The state of vertex C_i is indeterminate.

Connections between vertices: A directed edge from C_m to C_n is called a connection and represents causality from C_m to C_n.

Assigning weights to each vertex: Each vertex in the NCM is associated with a weight within the set { 0 , 1, -1, I}. The edge weight $C_m C_n$, denoted as α_{mn}, indicates the influence of C_m on C_n and can be:

- $\alpha_{mn} = 0$: C_m *has no* effect on C_n.
- $\alpha_{mn} = 1$: An increase (decrease) in C_m produces an increase (decrease) in C_n.
- $\alpha_{mn} = -1$: An increase (decrease) in C_m produces a decrease (increase) in C_n.
- $\alpha_{mn} = I$: The effect of Cm on Cn *is* indeterminate .

If $C_1, C_2, \ldots, C_k$ are the vertices of an NCM. The neutrosophic matrix N(E) is defined as $N(E) = \alpha_{mn}$), where α_{mn} denotes the weight of the directed edge $C_m C_n$, where $\alpha_{mn} \in [0.1]$ [11,14] N(E), is called *the neutrosophic adjacency matrix* of the NCM.

The coding used to identify the nodes resulting from the exchange with the study participants is described below:

N1 - Abandonment Order: Represents the judicial decision that ends the trial process without admitting any appeal, based on the inactivity of the plaintiff.

N2 - Right to Appeal: The legal capacity of plaintiffs to challenge judicial decisions, crucial for effective judicial protection and due process.

N3 – Legal uncertainty: Reflects the uncertainty and limitations in accessing justice generated by the impossibility of appealing the abandonment order.

N4 - International Human Rights Standards: International standards and principles that underline the importance of the right to appeal and to effective judicial protection.

N5 - Implications for plaintiffs: The direct consequences for people who file lawsuits, including their ability to defend their rights and obtain justice.

N6 - Judicial Training and Education: The need to educate judicial operators about regulatory changes and the importance of the right to appeal.

3. Results and discussion

For the development of the research, surveys were conducted separately to professional staff (judges, prosecutors, and lawyers) and non-professional parties (plaintiffs and defendants). Based on the results, the criteria displayed in the following tables and graphs were obtained, according to their degree of importance to them.

Table 1: Adjacency matrix (Group of legal professionals). Source: Prepared by own

	N1	N2	N3	N4	N5	N6
N1	0	0	1	0	0	0
N2	0.8	0.7	0	0	0	0
N3	0.7	1	Yo	0	0	Yo
N4	0.1	1	Yo	0	0	0
N5	0.5	0	0.9	Yo	0	0
N6	0.5	0	0.9	Yo	0	0

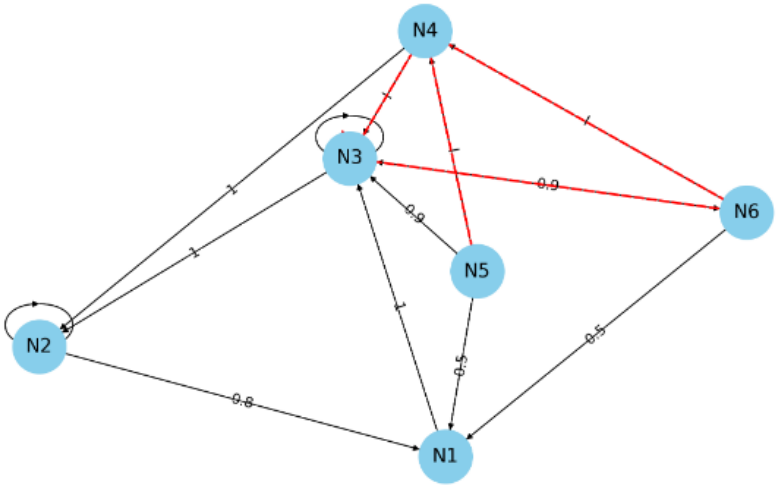

Figure 3: Neutrosophic cognitive map. Source: Own elaboration

Table 2: Centrality analysis (Legal Professionals Group). Source: Prepared by own

Node	$of(v_i)$	$id(v_i)$	$td(v_i)$
N1	1.1	2.6	3.7
N2	1.5	2.7	4.2
N3	1.7+2I	2.8+2I	4.5+4I
N4	1.1+I	0+2I	1.1+3I
N5	1.4+I	0.4	1.8+I
N6	1.4+I	0+me	1.4+2I

This analysis reveals the complex interdependence between the right of appeal, judicial training and international human rights standards in the context of ensuring justice and fairness. It highlights how legal uncertainty emerges as a central problem, influenced by the ability to appeal and the need for judicial training. Neutrosophic values and centrality measures reflect the uncertain and multifaceted nature of these concepts and their impact on the judicial system. [15, 16]

Table 3: Adjacency matrix (Group of non-legal professionals). Source: Own elaboration

	N1	**N2**	**N3**	**N4**	**N5**	**N6**
N1	0.5	0	0	0.4	0.3	0
N2	Yo	0.2	0	0	0	0

	N1	**N2**	**N3**	**N4**	**N5**	**N6**
N3	1	Yo	0	0	0	0.8
N4	0	0.9	Yo	0	0.1	0
N5	0	0.9	Yo	0	0.1	0
N6	0	1	0	0	0.5	Yo

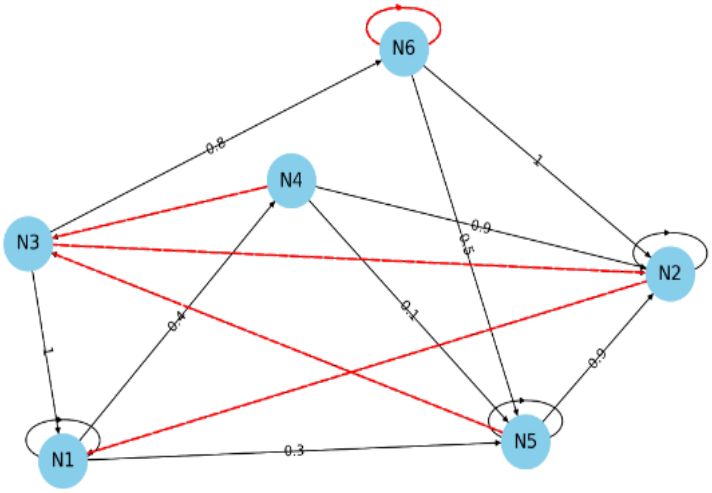

Figure 4: Neutrosophic cognitive map. Source: Own elaboration

Table 4: Centrality analysis (Non-legal professionals group). Source: Prepared by own

Node	***of*(v_1)**	***id*(v_i)**	***td*(v_i)**
N1	1.2	1.5+yo	2.7+yo
N2	0.2+I	3+me	3.2+2I
N3	1.8+I	0+2I	1.8+3I
N4	1+me	0.4	1.4+I
N5	1+me	1,2	2.2+I
N6	1.5+yo	0.8+yo	2.3+2I

The analysis of the neutrosophic cognitive map, in the context of a study involving non-legal professionals, reflects the complex interactions and perceptions about the judicial system and the appeal process. The adjacency matrix and centrality analysis provide both quantitative and qualitative insight into

these relationships, using specific coding for each node, which relates to different aspects of the judicial process and the rights of complainants.

Together, the cognitive map and centrality analysis illustrate the perception of a judicial system that could significantly benefit from greater clarity, training and alignment with international human rights standards to improve access to justice and legal certainty.

The combination of neutrosophic analysis (Figure 5) with centrality data provides a multidimensional view of the impact of certain nodes within both groups: legal professionals and non-legal professionals. This integration allows us to understand how certain topics and concepts are interconnected and how they influence the judicial system from different perspectives.

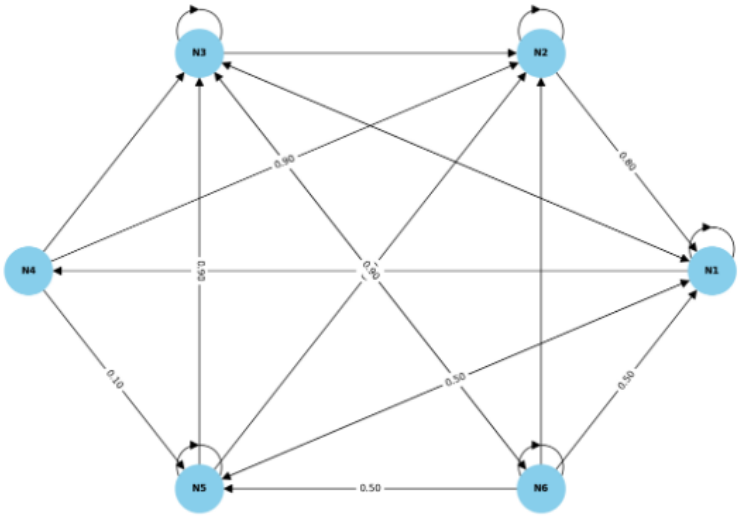

Figure 5: Combined neutrosophic cognitive map. Note: Own elaboration.

The combined neutrosophic cognitive map visualizes the relationships between different nodes, which represent the perspectives of both legal professionals and non-legal subjects. In this map, each node reflects a particular aspect of the judicial system, and the connections between them indicate the interactions and perceptions about their importance and functioning. The weights on the edges show the perceived strength of these connections, and the absence of a specific weight indicates areas of uncertainty or indecision (previously denoted by 'I') [15].

This map integrates the complexity and differences in perception between groups, offering a visual representation that highlights both areas of consensus and areas of uncertainty. It reflects how certain nodes, such as N3, can play a central role in the network, suggesting their importance in the justice system from both perspectives. The visualization facilitates the identification of key points to focus on for improvement, clarity, training and alignment with international human rights standards, in pursuit of fairer and safer access to justice.

Focusing on these areas could therefore significantly help improve people's ability to defend their rights and access justice. It is important to highlight the need to take measures to address these issues both in the training of legal professionals and in raising public awareness.

As a culmination of this research, the strategy for Improving Access to Legal Resources in Ecuador is proposed, which would address the points of convergence detected as a result of the study. It is essential to address the various barriers that citizens face in accessing justice. The implementation of this strategy can be structured in several key phases :

Needs assessment and mapping of existing resources:

- Conduct a national diagnosis to identify the main barriers to access to justice, including geographical, economic, linguistic and cultural barriers.
- Map existing legal resources across the country to identify areas of deficiency and oversaturation, ensuring equitable distribution of new resources.

Development of Online Platforms with Information and Legal Advice:

- Implement a comprehensive digital platform that provides clear and accessible legal information, tutorials and interactive tools to help people understand their rights and legal processes. This platform could also include an online consultation system to provide free basic legal advice.
- Ensure that the platform is accessible on multiple devices, including mobile phones, and is available in multiple languages, including the predominant indigenous languages in Ecuador.

Availability of Specialized Public Defenders:

- Expand the public defense program to include specializations in high-demand and complex areas.
- Implement a system of ongoing training for these lawyers, ensuring that they are up to date with the latest laws and legal practices.

4. Conclusions

This article explored the influence of perceptions of legal certainty and access to justice in the context of complaint processes through the use of Neurosophic Cognitive Maps (NCM). This innovative methodology allowed for a detailed and nuanced representation of the complexity inherent in judicial systems, capturing the various facets of truth, falsehood and indeterminacy that characterise the perceptions and experiences of those involved, both legal professionals and non-professionals.

The research showed that legal uncertainty (N3) constitutes a central axis in the perception of both groups. These findings underline the critical importance of addressing this aspect in order to improve access to justice and strengthen trust in the judicial system. The centrality of these nodes in the neutrosophic cognitive maps reflects not only the perceived relevance of these issues, but also their potential as intervention points for systemic reforms and improvements.

The application of NCMs revealed that the inclusion of degrees of truth, falsity and indeterminacy offers a deeper understanding of the dynamics and perceptions at play, facilitating the identification of priority areas for intervention. This approach allows for a richer and more detailed analysis than traditional methods, opening up new avenues for designing specific, evidence-based strategies to improve the justice system.

In response to these findings, a multifaceted strategy focused on improving access to legal resources in Ecuador was proposed. This strategy, designed to address the barriers identified in the study, includes the implementation of online information and advice platforms, the expansion of the availability of specialized public defenders, and the creation of free legal aid centers. Each of these components is geared toward addressing the specific needs of citizens and strengthening the judicial system from an inclusive and equitable perspective.

Adopting a proactive approach, as suggested in this study, has the potential not only to improve legal certainty and access to justice but also to increase the predictability of judicial proceedings. This, in turn, can contribute to preventing whistleblowers from abandoning proceedings, promoting a more fair, balanced and trustworthy justice system.

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