Using Fusion Data Analysis and Compensatory Fuzzy Logic to Analyze the Socioeconomic Impact of Venezuelan Migration

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Abstract

The surge of Venezuelan migration has left indelible marks on various regions, notably within Babahoyo Canton, presenting both challenges and opportunities for local communities. This study delves into the socio-economic impacts of Venezuelan migration on Babahoyo throughout 2023, employing a sophisticated blend of compensatory fuzzy logic and information fusion techniques. These methodologies offer a nuanced exploration of the migration's effects, capturing the complex interplay between local perceptions, labor market fluctuations, and broader economic dynamics. The findings underscore the critical need for comprehensive integration strategies that not only facilitate the socio-cultural adaptation of migrants but also leverage local public policies to mitigate adverse impacts while maximizing potential benefits. Ultimately, this research aims to illuminate pathways for informed decision-making and policy development, ensuring that responses to Venezuelan migration in Babahoyo are both effective and empathetic, thus fostering a more integrated and resilient community.

Keywords: compensatory fuzzy logic; Venezuelan migration; information fusion; geometric mean

1. Introduction

Venezuelan migration to Babahoyo, Ecuador, significantly marked the year 2023, driven mainly by Venezuela's economic crisis and attracted by the opportunities in Ecuador, particularly in the province of Los Ríos. This situation has generated a steady flow of migrants to the region, noted for its underemployment opportunities and relatively low housing costs. The integration of these migrants in Babahoyo has impacted both economic and social dynamics, presenting both positive aspects and challenges in terms of coexistence and sustainable development. Understanding how this migration impacts social cohesion, cultural identity, and the community's perception of migrants is crucial for fostering effective dialogue and cooperation among all stakeholders involved[1].

The Venezuelan migration phenomenon in Babahoyo an nearby cantons has not only enriched cultural diversity and the coexistence of identities but also presented significant challenges such as competition in the labor market, access to basic services, and the local community's perception of migrants[2]. The situation in 2022 marks a crucial moment to understand how migration shapes the canton's social, economic, and cultural life, highlighting the importance of international cooperation and hospitality policies. Migration has brought profound changes to intercultural coexistence, sociocultural

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adaptation, and the local economy, emphasizing the need for a detailed analysis of these impacts to formulate integration strategies, the sociocultural adaptation of migrants, and local public policies aimed at promoting harmonious coexistence and sustainable development in Babahoyo[3].

In the intricate domain of public policy formulation and implementation, especially concerning the analysis of social impacts stemming from migration phenomena, the challenge often lies in navigating through the uncertainty and complexity inherent in such dynamic systems. This complexity is further amplified when addressing the Venezuelan migration into Babahoyo in 2022, a scenario characterized not only by its immediate socioeconomic repercussions but also by the profound uncertainties surrounding migrants' integration and its long-term effects on the local community. To effectively address these uncertainties, innovative methodologies such as fuzzy logic techniques and information fusion are indispensable [4].

Fuzzy logic techniques, with their unique ability to manage and interpret the uncertainties inherent in human perceptions and evaluations, offer a promising approach to analyzing the social impact of Venezuelan migration. Unlike traditional binary logic that restricts outcomes to either true or false, fuzzy logic accommodates degrees of truth, allowing for a more nuanced understanding of the complex and often subjective social dynamics at play [5,6]. By applying these techniques, policymakers and researchers can better grasp the multifaceted and sometimes intangible aspects of social integration, such as cultural assimilation, public sentiment towards migrants, and the migrants' sense of belonging within their new community [7].

Furthermore, the employment of information fusion is critical in synthesizing disparate data types—ranging from quantitative statistics on employment, housing, and public services to qualitative insights from community surveys, interviews, and case studies. This integration enables a more holistic view of the socio-economic implications of Venezuelan migration to Babahoyo, capturing both the tangible and intangible dimensions of its impact. Through information fusion, the complexity and diversity of data sources are harnessed to construct a comprehensive picture, facilitating informed decision-making that encompasses the full spectrum of factors influencing the migrant and host community dynamics.

The application of compensatory fuzzy logic and information fusion in analyzing the social impact of Venezuelan migration in Babahoyo in 2023 represents a forward-thinking approach to policy analysis. It acknowledges the inherent uncertainties and complexities of migration phenomena and seeks to transcend traditional analytical limitations by embracing the subtleties of human perception and the richness of diverse data sources. This methodology not only enhances our understanding of the current socio-economic landscape but also equips policymakers with the insights needed to foster harmonious coexistence and sustainable development in the face of ongoing migration challenges.

3. Compensatory Fuzzy Logic (CFL)

Compensatory Fuzzy Logic (CFL) is a variant of fuzzy logic that aims to be more flexible and adaptable than traditional fuzzy logic systems [. Unlike standard fuzzy logic, which relies strictly on Boolean logic principles (true or false), compensatory fuzzy logic allows for intermediate values to reflect the complexity and nuances of real-world situations [9]. In general terms, it can be stated that this is a novel multivalent system that diverges from traditional axioms to achieve semantically superior behavior compared to classical systems. According to the literature reviewed, several key precepts are highlighted, which are listed below [10]:

- In decision-making processes, the use of complex predicates is essential. The resulting truth values of these complex predicates should be responsive to variations in the truth values of the underlying basic predicates. Predicates act as functions from a universe X to the interval [0,1], with the operations of conjunction, disjunction, negation, and implication defined in such a way that Boolean Logic is achieved within its domain.

- This approach steps away from adhering to the traditional properties associated with conjunction and disjunction, rendering Compensatory Fuzzy Logic (CFL) particularly responsive to nuances.

- CFL is characterized by its adaptability and tolerance for ambiguity, facilitating the representation of natural language expressions. This enhances the ability to use full sentences

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over mere linguistic variables, capitalizing on the expert knowledge within the framework of Knowledge Engineering. It aligns with mathematical disciplines that support decision-making through the adoption of human language, which includes interrogative, imperative, and declarative sentences, often embodying a certain level of truth. CFL specifically targets the representation of vagueness and uncertainty.

The technique employs mathematical operators designed to effectively merge intangible factors evaluated by experts. It integrates categorical truthfulness scales [11] and quantitative data, assigning truth values via predicates suitably defined on this basis (refer to Table 1).

Table 1: Overview of Mathematical Operators in Compensatory Fuzzy Logic Predicate Analysis.

Operators	**Predicate logic**
Conjunction	$(and), c, \wedge$
Disjunction	$(or), d, \vee$
Strict fuzzy order	(o)
Negation	(not)

They go from [0,1] n to [0,1], or from [0,1] 2 to [0,1] and n from [0,1]. Which satisfies the following axioms:

i. $min\{x_1, x_2, \cdots, x_n\} \leq d(x_1, x_2, \cdots, x_n) \leq max\{x_1, x_2, \cdots, x_n\}$ (Compensation Property).

ii. $d(x_1, x_2, \cdots, x_n) = d(x_1, x_2, \cdots, x_n)$ (Commutativity or Symmetry Property).

iii. If $x_1 = y_1, x_2 = y_2, \cdots, x_i - 1 = y_i - 1, x_i + 1 = y_i + 1, \cdots, x_n = y_n$, such that none is zero, and $x_i > y_1$, then $d(x_1, x_2, \cdots, x_n) > d(y_1, y_2, \cdots, y_n)$ (Strict Growth Property)

iv. If $x_i = 1$ for some i, then $d(x_1, x_2, \cdots, x_n) = 1$ (Veto Property)

v. $c(x_1, x_2, \cdots, x_n) = d(x_1, x_2, \cdots, x_n) = x$ (Idempotence Property).

According to[12], the use of sigmoidal membership functions is recommended for increasing or decreasing functions, for modeling vagueness(Figure 1) in the CFL framework . The sigmoid function has the form:

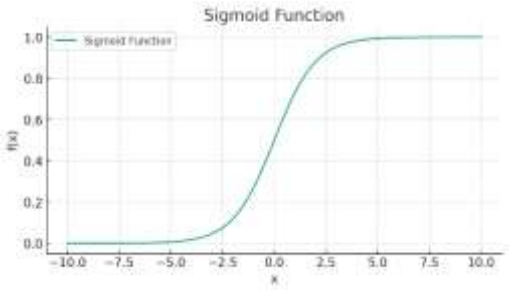

Figure 1: Sigmoid Function

This function is increasing and maps any real number to a value between 0 and 1, making it ideal for modeling concepts that gradually increase or decrease, such as vagueness in fuzzy logic systems:

$$f(x) = \frac{1}{(1 + e^{-x})}$$

This mapping function categorizes the sigmoid output (Table 2) —values ≤ 0.05 as "False" and > 0.85 as "True," with intermediate values indicating varying degrees of truth—bridging the gap between numerical data and linguistic interpretation. This methodology not only incorporates fuzzy logic into our analysis but also enriches the data interpretation, making the findings accessible and meaningful within the context of our study

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2. Proposed Method

The study adopted a mixed-methodology [13] approach that combined quantitative and qualitative research to thoroughly understand the impact of Venezuelan migration in Babahoyo Canton during the year 2023. This approach allowed for comprehensive data collection by capturing both individual and collective perspectives and applying a descriptive and exploratory research design.

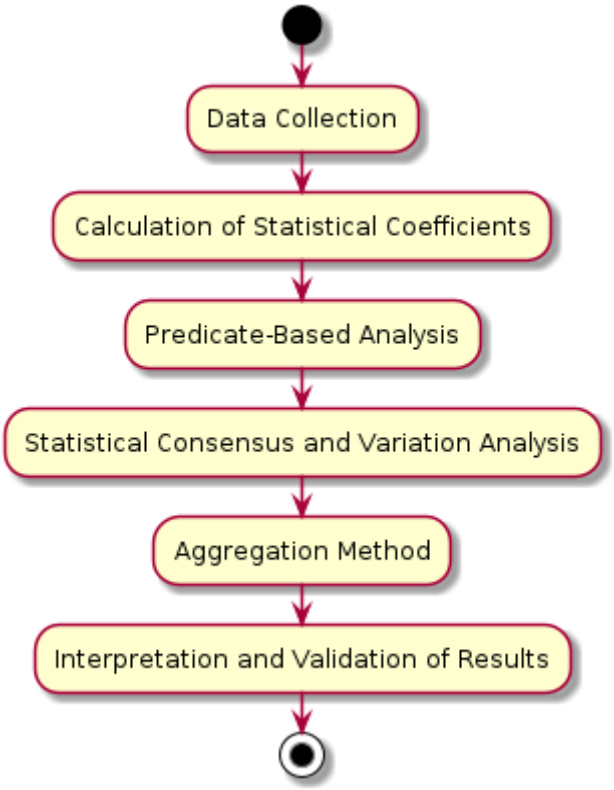

Figura 1: Proposed model

The primary data collection technique was interviews, used to obtain detailed insights from migrants, police officers, and lawyers. Methods such as compensatory fuzzy logic and information fusion were employed to achieve a more comprehensive and nuanced understanding of the socio-economic implications. From local perception to effects on the labor market and economic dynamics, each aspect is addressed comprehensively[14].

The participating population included eight individuals, comprising Venezuelans, lawyers, and police officers. The Venezuelans arrived in Ecuador in search of employment and to escape the difficulties in their country. Interviews revealed that all of them arrived after the approval of the Constituent Assembly in May 2017 in Venezuela.

In our study, the Predicate-Based Analysis of Migration Impacts method is employed to dissect and understand the intricate effects of Venezuelan migration on Babahoyo Canton in 2022. This approach utilizes a set of carefully defined simple and compound predicates—logical statements that describe specific conditions or scenarios—to capture the nuanced aspects of migration, such as integration pace, service coverage, and economic impacts. Simple predicates like the pace of migrant integration and service availability are synthesized into compound predicates, which then form a comprehensive model of migration dynamics. By evaluating these predicates through expert analysis, the methodology provides a structured framework to quantify and categorize the multifaceted social implications of migration. This approach not only facilitates a deeper understanding of the migration phenomenon but also enhances the precision and clarity of our analysis, making it a pivotal component of our research methodology.

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Calculation of Statistical Coefficients[15, 16]

The coefficient of concordance (Cc) is used to determine the degree of consensus among the experts regarding the topic. For this purpose, equation 1 is used.

$$Cc = (1 - \frac{Vn}{Vt}) * 100 \quad (1)$$

Where:

Vn: Number of experts against the predominant criterion.

Vt: Total number of experts.

It is empirically considered that if $Cc \geq 75\%$ then the agreement is acceptable. The components that obtain values of $Cc < 75\%$ are eliminated due to low agreement or little consensus among the experts.

The coefficient of variation (Cv) of the predicates is calculated using equation 2 by applying statistical decision criteria according to the following parameters:

- If $Cv \geq 0.20$, take the modal value (the rating given by the experts that is most repeated in the analyzed range).
- If $Cv < 0.20$, take the value of the arithmetic mean (average rating of the experts).

$$Cv = \frac{S}{X_{med}} \quad (2)$$

where,

S: Standard deviation of data

X_{med}: Average of data

Additionally, we introduce the Statistical Consensus and Variation Analysis, a methodological step that quantifies the degree of expert consensus and the variability in their assessments using statistical coefficients. These methodologies are pivotal in ensuring a rigorous, structured analysis, allowing us to draw nuanced insights into the social implications of migration with a high degree of reliability and accuracy.

In our methodology, to determine the final expert-aligned truth values for assessing the social impact of Venezuelan migration, we apply the Geometric Mean Based Compensatory Logic (GBCFL). This logic framework utilizes a set of operators for conjunction, disjunction, negation, and order, which are mathematically defined as follows [17]:

The GBCFL conjunction is mathematically expressed as:

$$c(x_1, x_2, \dots, x_n) = \left(\left(x_1^{\frac{1}{n}} * x_2^{\frac{1}{n}} * \dots * x_n^{\frac{1}{n}}\right)^n\right)$$

For disjunction, the GBCFL uses the dual of the conjunction:

$$d(x_1, x_2, \dots, x_n) = 1 - \left(\left((1 - x_1)^{\frac{1}{n}} * (1 - x_2)^{\frac{1}{n}} * \dots * (1 - x_n)^{\frac{1}{n}}\right)^n\right)$$

Negation is defined as the complement to 1:

$$n(x) = 1 - x$$

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And the strict order is given by:

$$o(x,y) = 0.5 * ((c(x) - c(y)) + 1)$$

These GBCFL operators are integral to our approach, enabling the nuanced amalgamation of individual expert opinions into a coherent collective assessment. By using these operators, we can effectively synthesize the complex data derived from expert evaluations into a singular, decisive metric that captures the essence of the migration impact.

Following the aggregation of data through our chosen methods, we interpret the statistical outputs and predicate analyses to draw insights into the social effects of Venezuelan migration in Babahoyo Canton. Validation is also key in this stage, where we may cross-reference our results with external data, or apply other validation techniques to ensure the robustness and credibility of our conclusions. This not only provides us with a solid foundation to support our findings but also ensures that our conclusions are reliable and can withstand critical scrutiny.

A. Results.

The evaluation of the impact of Venezuelan migration on labor supply and demand in Babahoyo Canton from a fuzzy perspective involves considering the diversity of perceptions and the nature of social phenomena. Below, an assessment is presented in terms of true or false (see Table 3).

Table 3: Impact of Venezuelan migration on labor supply and demand.

No.	Points	Positive Perception (True)	Negative Perception (False)
1	Labor supply	Venezuelan migration has increased the availability of the workforce by providing a broader labor supply in specific sectors such as agriculture and other low-skilled jobs.	The increased labor supply could create competition and potentially affect wages and working conditions for the local population.
2	Labor demand	The influx of migrants can stimulate labor demand by generating new economic opportunities, especially in sectors like commerce and services.	The additional demand for services may strain resources and public services, posing challenges to meet the needs of the population.
3	Labor market adaptation	The cultural diversity of the migrant population can bring unique skills and experiences, enriching the labor market and fostering creativity and innovation.	Adaptation may require adjustments in labor and social policies to ensure equal opportunities and prevent conflicts.
4	Impact on Labor Stability	The variety of skills and labor profiles can contribute to economic stability and resilience against changes in the labor environment.	The concentration of migrants in certain sectors could create imbalances, affecting labor stability in specific areas.

Overall, the results presented offer a detailed understanding of Venezuelan migration in Babahoyo. They highlight aspects such as motivations for migration, perceptions of discrimination, migrant adaptation, and expert opinions. Next, information fusion and compensatory fuzzy logic are introduced as essential tools for addressing the inherent uncertainty in perceptions and assessments in complex migration contexts.

Interview with Venezuelan Migrants:

- Migration Causes: 62% of Venezuelans migrated primarily for economic reasons, followed by 25% for insecurity, and 13% for political reasons.

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- Choice of Babahoyo: 62% preferred Babahoyo because of the currency, 25% for job opportunities, and 13% based on friends' recommendations.
- Labor Discrimination: 50% perceived discrimination, with 38% experiencing it regularly and 12% not perceiving it.
- Adaptation in Babahoyo: 50% found their stay very difficult, 25% perceived it as difficult, and 25% considered it regular.

Interview with lawyers specializing in labor law:

- Obstacles in accessing services for migrants: 60% of those interviewed indicated that migrants faced obstacles.
- Lack of attention to the problem: 80% indicated that not enough attention has been paid to this problem.

Interview with police officers:

- Intensification of patrols to prevent crime: 80% mentioned that patrols have been intensified.
- Intensification of patrols to prevent conflicts: 60% stated that patrols have been intensified.

Expert criteria:

- Criteria from experts in labor and civil law and police officers were used to validate the proposal.
- The proposal obtained high consistency, with an average of 8.2 on the evaluation scale.

Groups of experts for modeling: 5 groups of 11 (total 55):

i. Group of legal experts
ii. Group of migration experts
iii. Group of experts from public universities
iv. Group of legal aid experts
v. Group of psychologists

Based on the previous information, it is decided to evaluate each predicate by the experts regarding Venezuelan migration, Babahoyo Canton, and its social implications for the year 2022. The results are modeled in the predicate tree and their expressions as shown below:

Simple Predicates:

- R(x): "x is a situation where the integration pace of migrants is normal."
- C(x): "x is a situation with adequate coverage of services for migrants."
- I(x): "x is a situation where the interaction between migrants and locals is positive."
- M(x): "x is a situation with a solid labor market."
- E(x): "x is a situation where the economic impact of migration is well understood."

Compound predicates:

- GI(x): "x is a situation with competitive Integration Management."
- MM(x): "x is a mixture of a solid Labor Market and good Migrant Integration."
- GA(x): "x is a situation where Service Management and Migrant Adaptation are good."

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- GM(x): "x is a situation where the impact of migration is managed efficiently."

Expressions:

- $GI(x) = R(x) \wedge C(x) \wedge I(x)$
- $MM(x) = M(x) \wedge I(x)$
- $GA(x) = E(x) \wedge R(x)$
- $GM(x) = GI(x) \wedge MM(x) \wedge GA(x)$

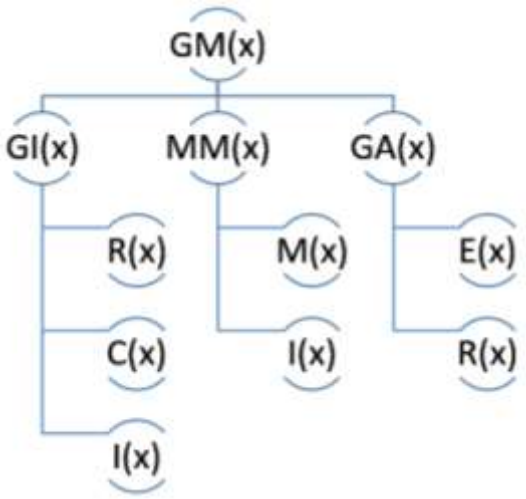

Figure 3: Predicate tree.

After obtaining the results from the consulted experts, the results were tabulated, and the coefficient of variation (Cv) was calculated (see Tables 4 and 5). To determine the final value according to the experts, k Geometric Mean Based Compensatory Logic (GBCFL) is used. Additionally, the calculation of $Cc = 0.845 > 0.5$ was performed, therefore determining that the modeling of the exercise is acceptable.

Table 4: Calculation of truth values for simple predicates.

Simple predicates	Mode	Mean	S	Cv	Truth value
R(x):	0.3	0.333	0.207	0.620	0.300
C(x)	0.4	0.283	0.172	0.608	0.400
I(x)	0.7	0.633	0.175	0.277	0.700
M(x)	0.2	0.450	0.339	0.754	0.200
E(x)	0.7	0.583	0.160	0.275	0.700

Table 5: Calculation of truth values for compound predicates.

Compound predicates	Truth value
GI(x)	0.438
MM(x)	0.374
GA(x)	0.374
GM(x)	**0.394.**

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The following compound predicates were evaluated in terms of their truth values in a specific context, each representing different aspects of management and adaptation in situations involving migration and the labor market. Below are the predicates with their respective truth values:

GI(x): "x is a situation with competitive Integration Management."

Truth Value: 0.438
Interpretation: This value indicates a moderate presence of competitive integration management in the evaluated situation.
MM(x): "x is a mixture of a solid Labor Market and good Migrant Integration."

Truth Value: 0.374
Interpretation: This value suggests a relatively low presence of a solid labor market mix and good migrant integration.
GA(x): "x is a situation where Service Management and Migrant Adaptation are good."
Truth Value: 0.374
Interpretation: Similar to MM(x), this value indicates a relatively low presence of good service management and migrant adaptation.
GM(x): "x is a situation where the impact of migration is managed efficiently."
Truth Value: 0.394
Interpretation: This value signals moderate efficiency in managing the impact of migration in the evaluated situation.

Discussion.

In this study, we embarked on an analytical journey to understand the dynamics of migration management, labor market integration, and migrant adaptation through the lens of compound predicate evaluation. The utilization of truth values to evaluate the effectiveness of these integrated management strategies sheds light on the nuanced complexities inherent in managing migration's multifaceted impact.

The core of our discussion revolves around the role of information fusion, made possible through the rigorous evaluation of compound predicates[18]. This approach allowed us to synthesize disparate data points into coherent insights, reflecting the real-world interplay between competitive integration management, labor market conditions, and migrant adaptation strategies.

The evaluation of the compound predicates GI(x), MM(x), GA(x), and GM(x) reveals a tapestry of interrelated factors that are critical to the successful management of migration and its socioeconomic implications. Notably, the moderate truth values associated with GI(x) and GM(x) highlight a level of effectiveness in managing competitive integration and the impact of migration. However, the relatively lower truth values for MM(x) and GA(x) signal areas where improvements are necessary, specifically in enhancing labor market integration and fostering better migrant adaptation[19].

The fusion of information through predicate evaluation emerges not just as a methodological choice but as a strategic imperative. It enables stakeholders to dissect and understand the complexities of migration management in a structured manner. By integrating diverse aspects of migration into a unified analytical framework, this approach facilitates a comprehensive assessment of strengths and areas for improvement.

Furthermore, the nuanced understanding gained through this fusion of information empowers policymakers, practitioners, and researchers to tailor interventions more effectively. It highlights the importance of a balanced approach that addresses not only the economic aspects of migration, such as labor market integration, but also the social dimensions, including migrant adaptation and community integration[20].

6. Conclusion

The socio-economic impact of Venezuelan migration in Babahoyo underscores the urgent need for comprehensive strategies that address both immediate and long-term challenges. The utilization of information fusion and compensatory fuzzy logic has emerged as pivotal in understanding the diverse impacts of migration, providing a critical foundation for policy-making and development of targeted intervention programs. The emphasis on collaborative efforts among government, academia, and civil society is crucial for fostering sustainable development and harmonious coexistence in the community.

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Addressing the misalignment between local and national legal frameworks is essential for effective migration management, highlighting the necessity for enhanced coordination to bridge regulatory gaps. Future directions include adopting novel fuzzy logic operators to refine integration strategies and exploring adaptive models to keep pace with the evolving dynamics of migration. A holistic approach that includes economic, labor, and sociocultural adaptation components, supported by policies promoting intercultural coexistence, is vital for the successful integration of Venezuelan migrants in Babahoyo, requiring ongoing commitment from all stakeholders.

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