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Designing Optimal Routes for Mobile Prenatal Care Clinics Using Neutrosophic Cognitive Maps

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Abstract. This manuscript examines the routing of mobile prenatal clinics in Ecuador, focusing on maternal and infant health in vulnerable, hard-to-reach areas. This assessment is significant because even with new developments geographically expanding access to mobile prenatal clinics, there remain accessibility gaps for vulnerable women located in hard-to-reach, topographic regions where it's uncertain if they truly need services or can assess whether they can travel to a clinic. While previous studies sought to assess the potential for newly mobile units and coverage, few studies have been found to assess new routes through accessibility uncertainty and villages with varying demand for access to clinics based on fluctuating prenatal needs. Therefore, this project will incorporate a novel approach called Neutrosophic Cognitive Maps to determine causal relationships among villages, accessibility challenges through geography, and the prevalence of need through access over time. Results show the strengths and weaknesses of interconnectivity, some females who cannot access a clinic, and other metrics that suggest a new way of assessing routing that is not only more effective but fairer in terms of access. Ultimately, this study contributes to existing literature by providing an avenue for real-life health service routing endeavors amidst uncertainty and practical implications for decentralizing routes over time, providing access to potential prenatal care that could change the course of maternal and infant health in Ecuador.

Keywords: Optimal route design, mobile clinics, prenatal care, Neutrosophic Cognitive Maps, maternal health, access to health, uncertainty, Ecuador, rural areas.

1. Introduction

Optimizing routes for mobile prenatal care clinics in hard-to-reach regions is a crucial challenge for ensuring maternal and child health, especially in countries with geographical disparities such as Ecuador. Timely prenatal care significantly reduces maternal and neonatal mortality rates, a priority objective in global health policies [1]. This study addresses the logistics planning of these clinics, a relevant topic given the direct impact of accessibility on health indicators. The integration of advanced tools to model uncertainty in logistics decision-making reinforces the relevance of this research, aligned with the Sustainable Development Goals [2]. Historically, health systems in rural areas have faced logistical constraints, from poor infrastructure to variability in service demand. In recent decades, the use of mobile clinics has emerged as a viable solution to expand health coverage [3]. However, planning optimal routes remains a challenge, especially in contexts with complex topographies and limited resources. Recent advances in mapping technologies and data analysis have opened up new possibilities to address these difficulties [4].

The central problem lies in the lack of methods that integrate the uncertainty inherent in factors such as fluctuating demand, geographic barriers, and community preferences into route planning for mobile clinics. How can efficient and equitable routes be designed that maximize prenatal care coverage in highly uncertain environments? This question, still unanswered in the literature, guides the present study, which seeks to propose an innovative and adaptable solution. To address this challenge, the study employs Neutrosophic Cognitive Mapping, a methodology that models complex causal relationships under conditions of indeterminacy. This approach allows for the incorporation of heterogeneous data, from geographic information to community perceptions, overcoming the limitations of traditional optimization methods [5]. The research focuses on Ecuador, where regional disparities amplify the need for effective logistics solutions.

The magnitude of the problem is evident: in many rural communities, pregnant women face long journeys to access prenatal care, increasing the risks to their health and that of their babies [6]. The absence of a systematic approach to route optimization exacerbates this situation, reducing the efficiency of available resources. This study aims to fill this gap by offering a tool that combines analytical rigor with practical applicability. Neutrosophic Cognitive Maps stand out for their ability to handle ambiguity in information, a critical aspect in contexts where data is imprecise or incomplete. By modeling factors such as geographic accessibility and demand for services, this methodology identifies patterns that conventional approaches often overlook. The study builds on this advantage to propose routes that are not only efficient but also equitable.

The research question focuses on how to ensure accessible and timely prenatal care in underserved regions. This problem has not only practical but also theoretical implications, contributing to the development of methodologies for decision-making in uncertain environments. The research seeks to answer this question through an interdisciplinary approach that combines logistics, public health, and computational modeling. The objectives of the study are clear: first, to develop a model based on Neutrosophic Cognitive Maps to optimize mobile clinic routes; second, to evaluate the effectiveness of these routes in terms of coverage and equity; and third, to provide practical recommendations for their implementation in public health systems. These objectives, aligned with the research question, guide the development of the article and lay the foundation for a significant contribution to the field of health logistics.

2. Preliminaries.

2.1 Prenatal Care.

Prenatal care is an increasingly essential process involving medical and educational intervention throughout pregnancy to minimize risk, as it ranges from early diagnosis of complications to adjusted healthy lifestyle interpretation intent on mother/fetus well-being. Therefore, there's enough inherent incentive to minimize scheduling challenges since complications can occur at any stage of gestation that require immediate action, and assessments render trained professionals to undertake appropriate measures preventing preterm labor and/or birth defects common to people whether in urban or rural settings. However, where prenatal care becomes the most problematic is in developing nations, for accessibility is the foremost issue compounded by geographical location and socioeconomic standing.

Developed nations have transitioned the years of prenatal care facilitation from simple recommendations with a wellness visit to multiple ultrasounds, blood draws, and mental health counseling throughout a single pregnancy. In recent years, the who has supported woman-centric developments in prenatal care for the past few decades; however, developing nations tend to struggle with implementing such advancements due to lack of resources or personnel who were trained.

A key aspect of prenatal care is its ability to identify specific risks, such as preeclampsia or gestational diabetes, that may go undetected without regular monitoring. Early detection allows for timely interventions, significantly reducing maternal mortality, which remains a global problem with approximately 295,000 cases annually [7]. However, the effectiveness of these interventions depends on the frequency and quality of visits, raising questions about equity in access.

The literature highlights that prenatal care not only benefits physical health but also strengthens women's empowerment by providing them with information about their pregnancy. However, gaps in coverage persist, especially in rural communities where mobile clinics are presented as a viable but insufficiently optimized solution. The lack of efficient routes and uncertainty in demand for services complicate planning, underscoring the need for innovative approaches such as Neutrosophic Cognitive Mapping.

The strength of prenatal care lies in its preventive approach, which combines medical science with humane care. However, its implementation faces criticism for its lack of adaptability to diverse cultural contexts. In the Andean regions of Ecuador, for example, traditional beliefs can influence the acceptance of prenatal care, which requires strategies that integrate interculturality. This limitation highlights the importance of designing interventions that respect local dynamics.

From a logistics perspective, optimizing mobile prenatal care clinics is an area of opportunity. The application of tools such as Neutrosophic Cognitive Mapping allows for modeling complex factors, such as geographic barriers and community preferences, under conditions of uncertainty. This approach surpasses traditional methods by incorporating uncertainty, offering more equitable and efficient routes that maximize coverage in remote areas [8].

However, the implementation of technological solutions must be accompanied by sound public policies. Training health personnel and investing in infrastructure are essential to ensure that mobile clinics not only reach communities but also provide quality services. Evidence suggests that successful programs combine technology with community engagement, which strengthens trust in the health system [9].

One argument in favor of prenatal care is its long-term economic impact. Reducing complications during pregnancy lowers the costs associated with hospitalizations and neonatal treatment. Furthermore, improving maternal health indicators promotes social development, as healthy mothers contribute more actively to the well-being of their families and communities. This preventive approach is, therefore, a strategic investment.

On the other hand, criticisms of prenatal care point to its dependence on robust health systems, which are not always available in low-resource settings. Lack of continuity in consultations and poor coordination between levels of care can reduce its effectiveness. In this sense, Neutrosophic Cognitive Maps offer an advantage by enabling adaptive planning, although their implementation requires technical training and computing resources.

In conclusion, prenatal care is an essential pillar of maternal and child health, but its success depends on overcoming logistical, cultural, and economic barriers. Integrating innovative approaches, such as Neutrosophic Cognitive Mapping, along with inclusive policies can transform the accessibility and equity of these services. This analysis highlights the need for a multidimensional approach that combines technology, community engagement, and political commitment to maximize the impact of prenatal care in challenging contexts.

3. Materials and methods

This section reviews the theoretical foundations necessary for the development of the study.

A. Neutrosophic cognitive maps

Definition 1: ([10, 11, 12]) Let X be a universe of discourse. A *Neutrosophic Set* (NS) is characterized by three membership functions, $u_A(x), r_A(x), v_A(x) : X \rightarrow]_A^-0, 1^+[$, that satisfy the condition $_A^-0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3^+$ for everyone $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ are the truth, indeterminacy, and falsity membership functions of x in A, respectively, and their images are standard or nonstandard subsets of $]_A^-0, 1^+[$.

Definition 2: ([10, 11, 12]) Let X be a universe of discourse. A *Univalued Neutrosophic Set* (SVNS) A over X is a set of the form:

$$A = \{\langle x, u_A(x), r_A(x), v_A(x) \rangle : x \in X\} \quad (1)$$

Where $u_A, r_A, v_A : X \rightarrow [0,1]$, satisfies the condition $0 \leq u_A(x) + r_A(x) + v_A(x) \leq 3$ for everyone $x \in X$. $u_A(x), r_A(x)$ and $v_A(x)$ denote the truthfulness, indeterminacy, and falsity membership functions of x in A, respectively. For convenience, a *Univalent Neutrosophic Number* (NNUN) will be expressed as $A = (a, b, c)$, where$a, b, c \in [0,1]$ and satisfy $0 \leq a + b + c \leq 3$.

Other important definitions are related to graphics.

Definition 3: ([10, 11, 12, 16, 17]) A *neutrosophic graph* is a graph that contains at least one indeterminate edge, which is represented by dotted lines.

Definition 4: ([10, 11, 12, 16, 17]) A *neutrosophic directed graph* is a directed graph that contains at least one indeterminate edge, which is represented by dotted lines.

Definition 5: ([10, 11, 12]) A *Neutrosophic Cognitive Map* (NCM) is a neutrosophic directed graph, whose nodes represent concepts and whose edges represent causal relationships between edges.

Yeah$C_1, C_2, \ldots, C_k$ There are k nodes, each of whichC_i $(i = 1, 2, \ldots, k)$ can be represented by a vector $(x_1, x_2, \ldots, x_k)$where $x_i \in \{0, 1, I\}$. $x_i = 1$ means the nodeC_i is in an activated state, $x_i = 0$ it means that the nodeC_i is in a disabled state and$x_i = I$ means that the nodeC_i is in an indeterminate state, at a specific time or in a specific situation.

YeahC_m andC_n are two nodes of the NCM, one edge directed fromC_m toC_n It is called connection and represents the causality of C_ma C_n. Each node in the NCM is associated with a weight within the set $\{-1, 0, 1, I\}$. Ifα_{mn} denotes the weight of the edge C_mC_n,$\alpha_{mn} \in \{-1, 0, 1, I\}$ So we have the following:

$\alpha_{mn} = 0$YeahC_m does not affect C_n,

$\alpha_{mn} = 1$If there is an increase (decrease) inC_m produces an increase (decrease) in C_n,

$\alpha_{mn} = -1$If there is an increase (decrease) inC_m produces a decrease (increase) in C_n,

$\alpha_{mn} = I$If the effect ofC_m inC_n is indeterminate.

Definition 6: ([10, 11, 12,]) An NCM that has edges with weights in$\{-1, 0, 1, I\}$ It is called *Simple Neutrosophic Cognitive Map.*

Definition 7: ([10, 11, 12,]) If$C_1, C_2, \ldots, C_k$ are the nodes of an NCM. The neutrosophic matrix $N(E)$ is defined as $N(E) = (\alpha_{mn})$, whereα_{mn} denotes the weight of the directed edge C_mC_n, such that $\alpha_{mn} \in \{-1, 0, 1, I\}$. $N(E)$is called *the neutrosophic adjacency matrix* of the NCM.

Definition 8: ([10, 11, 12,]) Let$C_1, C_2, \ldots, C_k$ Let be the nodes of an NCM. Let $A = (a_1, a_2, \ldots, a_k)$, where $a_m \in \{-1, 0, 1, I\}$. A is called *the neutrosophic instantaneous state vector* and represents the on-off-indeterminate state position of the node at a given instant.

$a_m = 0$YeahC_m is disabled (has no effect),

$a_m = 1$YeahC_m is activated (has an effect),

$a_m = I$YeahC_m is indeterminate (its effect cannot be determined).

Definition 9: ([10, 11, 12,]) Let $C_1, C_2, \ldots, C_k$ Let, $\overrightarrow{C_2C_3}$, $\overrightarrow{C_3C_4}$,…, $\overrightarrow{C_mC_n}$be the nodes of an NCM.$\overrightarrow{C_1C_2}$ be the edges of the NCM, then the edges constitute a *directed cycle*.

The NCM is called *cyclic* if it presents a directed cycle. It is called *acyclic* if it does not present a directed cycle.

Definition 10: ([10, 11, 12,]) An NCM with cycles is said to have feedback. When feedback exists in the NCM, it is said to be a *dynamical system*.

Definition 11: ([10, 11, 12,]) Let $\overrightarrow{C_1C_2}$, $\overrightarrow{C_2C_3}$, $\overrightarrow{C_3C_4}$,…,$\overrightarrow{C_{k-1}C_k}$ be a cycle. WhenC_m It is activated and its causality flows along the edges of the cycle and then it is the cause ofC_m In itself, then, the dynamic system circulates. This holds true for each node. $C_m$with $m = 1, 2, \ldots, k$. The equilibrium state of this dynamic system is called the *hidden pattern*.

Definition 12: ([10, 11, 12,]) If the equilibrium state of a dynamical system is a single state, then it is called *a fixed point*.

An example of a fixed point is when a dynamical system starts to be activated by [number] C_l. If the NCM is assumed to settle on [number] $C_l$and [number C_k], i.e. the state remains as [$(1, 0, \ldots, 0, 1)$number], then this neutrosophic state vector is called *a fixed point* .

Definition 13: ([10, 11, 12,]) If the NCM is established with a neutrosophic state vector that repeats in the form:

$A_1 \to A_2 \to \cdots \to A_m \to A_1$, then the equilibrium is called the NCM *limit cycle.*

Method for determining hidden patterns

Leave$C_1, C_2, \ldots, C_k$ Let be the nodes of the feedback NCM. Let E be the associated adjacency matrix. A hidden pattern is found when $C_l$activated and a vector input is used.$A_1 = (1, 0, 0, \ldots, 0)$ It is provided. The data must pass through the neutrosophic matrix $N(E)$, which is obtained by multiplyingA_1 by the matrix $N(E)$.

Leave$A_1 N(E) = (\alpha_1, \alpha_2, \ldots, \alpha_k)$ with the replacement threshold operationα_m for 1 yes$\alpha_m > p$ andα_m for 0 yes$\alpha_m < p$ (p is a suitable positive integer) andα_m is replaced by I if it is not an integer. The resulting concept is updated; vectorC_1 It is included in the updated vector by transforming the first coordinate of the resulting vector into 1.

Yeah$A_1 N(E) \to A_2$ The same procedure is assumed, $A_2 N(E)$considered and repeated until a limit cycle or fixed point is reached.

Definition 14: ([13,14, 15]) A *neutrosophic number* N is defined as a number as follows:

$N = d + I$ (2)

Where d is called the determinate part and i is called the indeterminate part [18, 19].

Giventhat $N_1 = a_1 + b_1 I$ and $N_2 = a_2 + b_2 I$they are two neutrosophic numbers, some operations between them are defined as follows:

$N_1 + N_2 = a_1 + a_1 + (b_1 + b_2)I$ (Addition);

$N_1 - N_2 = a_1 - a_1 + (b_1 - b_2)I$ (Difference),

$N_1 \times N_2 = a_1 a_2 + (a_1 b_2 + b_1 a_2 + b_1 b_2)I$ (Product),

$\frac{N_1}{N_2} = \frac{a_1 + b_1 I}{a_2 + b_2 I} = \frac{a_1}{a_2} + \frac{a_2 b_1 - a_1 b_2}{a_2(a_2 + b_2)} I$ (Division).

4. Results: Study - Application to Mobile Prenatal Care Clinics

For the design of optimal routes for mobile prenatal care clinics, the following critical variables were identified:

- **V_1** : Geographical accessibility of the communities
- **V_2** : Demand for prenatal care services
- **V_3** : Efficiency of the designed routes
- **V_4** : Population coverage achieved
- **V_5** : Available resources (personnel, equipment, fuel)
- **V_6** : Climatic and seasonal barriers
- **V_7** : Travel time between communities
- **V_8** : Equity in the distribution of services

The following scale was used, adapted to facilitate evaluation by public health specialists:

Table 1: Relationship between linguistic and numerical values as measurement scales in the study carried out

Numerical Value	Linguistic Value
3	Highly directly correlated
2	Directly Correlated
1	Little directly correlated
0	Uncorrelated
-1	Slightly inversely correlated
-2	Inversely Correlated

Numerical Value	Linguistic Value
-3	Highly Inversely Correlated
I	Undetermined/Cannot be determined

Three Ecuadorian specialists in public health and health planning, each with at least five years of experience in maternal and child health programs, were consulted. The specialists individually and independently evaluated the causal relationships between the eight defined variables.

Group of experts: $E = \{e_1, e_2, e_3\}$

pair of variables $j, k \in \{1,2,\ldots,8\}, j \neq k$, each e_i $(i = 1,2,3)$ expert $R_{ijk} \in \{-3,-2,-1,0,1,2,3,I\}$. provided his evaluation

Step 1: Normalization of values

- Numerical values R_{ijk} are calculated as $\hat{R}_{ijk} = round\left(\frac{R_{ijk}}{3}\right)$
- I $R_{ijk} = I$, then $\hat{R}_{ijk} = I$

Step 2: Consensus calculation for each pair (j,k)

- If the mode for $\hat{R}_{ijk}$ i=1,2,3 is unimodal: $\bar{R}_{jk} = mode_{i(\hat{R}_{ijk})}$ y $\bar{R}_{kj} = 0$
- If the mode of $\hat{R}_{ijk}$ is not unimodal:
  - If $\hat{R}_{ikj}$ for i=1,2,3 is unimodal and $\bar{R}_{jk} = 0$: $\bar{R}_{kj} = mode_{i(\hat{R}_{ikj})}$
  - If $\hat{R}_{ikj}$ it is not unimodal: $\bar{R}_{jk} = \bar{R}_{kj} = I$

Data collected by expert:

Expert 1 (e_1):

- $R_{112} = 2$ $(V_1 \to V_2)$:Geographic accessibility directly affects demand
- $R_{113} = 3$ $(V_1 \to V_3)$: Accessibility is crucial for route efficiency
- $R_{114} = 3$ $(V_1 \to V_4)$: Accessibility strongly determines coverage
- $R_{115} = -1$ $(V_1 \to V_5)$Greater accessibility may require fewer resources
- $R_{116} = I$ $(V_1 \to V_6)$:Uncertain relationship with climatological barriers
- $R_{117} = -2$ $(V_1 \to V_7)$:Better accessibility reduces travel time
- $R_{118} = 2$ $(V_1 \to V_8)$: Accessibility improves equity

Expert 2 (e_2):

- $R_{122} = 1$ $(V_1 \to V_2)$: Positive but moderate relationship
- $R_{123} = 3$ $(V_1 \to V_3)$:High correlation agreement
- $R_{124} = 2$ $(V_1 \to V_4)$: Important direct relationship
- $R_{125} = 0$ $(V_1 \to V_5)$:He sees no direct relationship
- $R_{126} = I$ $(V_1 \to V_6)$:He also considers the relationship uncertain
- $R_{127} = -3$ $(V_1 \to V_7)$: Very inverse - better access, less time
- $R_{128} = 3$ $(V_1 \to V_8)$: Very important for equity

Expert 3 (e_3):

- $R_{132} = 2$ $(V_1 \to V_2)$:Confirmation of direct relationship
- $R_{133} = 3$ $(V_1 \to V_3)$: Consensus on high correlation
- $R_{134} = 3$ $(V_1 \to V_4)$: Confirmation of high correlation
- $R_{135} = -1$ $(V_1 \to V_5)$: Concordance in slight inverse relationship
- $R_{136} = 0$ $(V_1 \to V_6)$: Not correlated
- $R_{137} = -2$ $(V_1 \to V_7)$: Moderate inverse relationship
- $R_{138} = 2$ $(V_1 \to V_8)$: Important direct relationship

For the relationship $V_1 \to V_2$:

- Expert 1:$R_{112} = 2 \to \hat{R}_{112} = round(2/3) = 1$
- Expert 2: $R_{122} = 1 \to \hat{R}_{122} = round(1/3) = 0$
- Expert 3:$R_{132} = 2 \to \hat{R}_{132} = round(2/3) = 1$
- Fashion:{1,0,1} → It is not unimodal
- We evaluate $V_2 \to V_1$:All experts agree on 0

- Therefore: $\bar{R}_{12} = 0 \, and \, R_{21} = 0$

For the relationship $V_1 \rightarrow V_3$:

- Expert 1:$R_{113} = 3 \rightarrow \bar{R}_{113} = round(3/3) = 1$
- Expert 2: $R_{123} = 3 \rightarrow \bar{R}_{123} = round(3/3) = 1$
- Expert 3:$R_{133} = 3 \rightarrow \bar{R}_{133} = round(3/3) = 1$
- Fashion:{1,1,1} → Unimodal
- Therefore: $R_{13} = 1 \, and \, R_{31} = 0$

Continuing with the same process for all relationships...

After applying the consensus algorithm to all the experts' assessments, the following neutrosophic adjacency matrix was obtained:

Table 2: Adjacency matrix N (E) obtained from the study

Node	V_1	V_2	V_3	V_4	V5	V_6	V_7	V_8
V_1	0	0	1	1	-1	I	-1	1
V_2	1	0	1	1	0	0	0	1
V_3	0	0	0	1	-1	0	-1	1
V_4	0	0	0	0	0	0	0	1
V5	0	1	1	1	0	I	0	0
V_6	I	0	-1	-1	I	0	1	-1
V_7	0	0	0	-1	0	0	0	-1
V_8	0	0	0	0	0	0	0	0

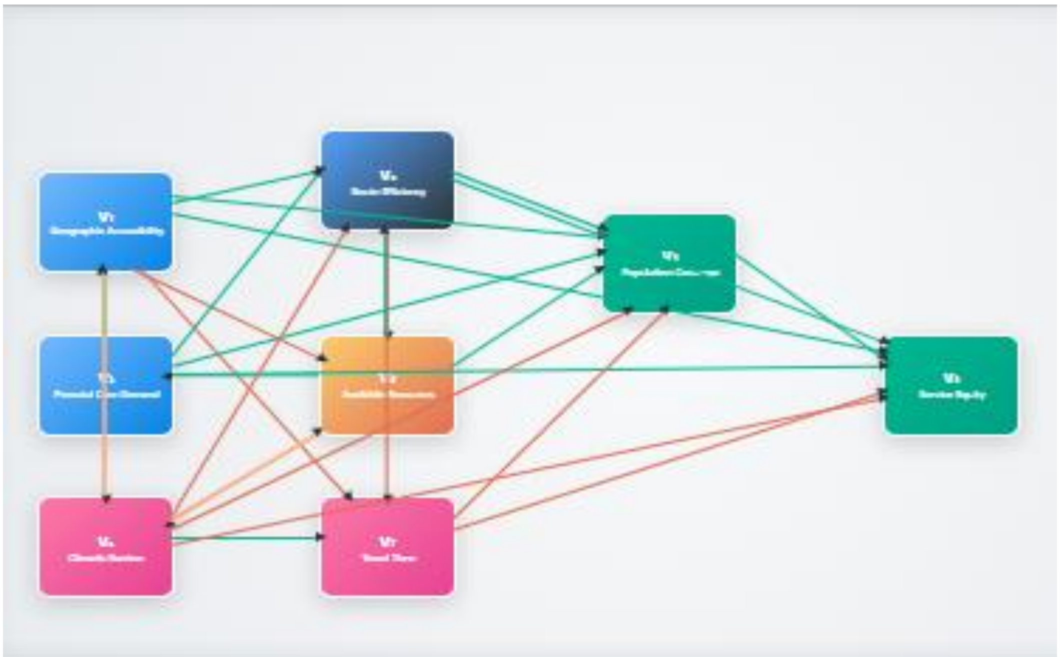

Figure 1: Graphic representation of the Neutrosophic Cognitive Map obtained

The hidden pattern matching algorithm was run for all 2^8-1 = 255 possible initial vectors (excluding the degenerate case where no nodes are active).

Calculation process for each initial vector:

1. It applies $A_1 \cdot N(E) = (\alpha_1, \alpha_2, \dots, \alpha_8)$
2. The threshold operation is performed: $\alpha_m \rightarrow 1\ si\ \alpha_m > 0, \alpha_m \rightarrow 0\ si\ \alpha_m < 0, \alpha_m \rightarrow I$ if it is not an integer
3. The resulting vector is updated
4. It is repeated until convergence is reached (fixed point or limit cycle)

Table 3: Convergence results for all possible initial vectors except the degenerate case

Variable	Convergence towards 0	Convergence towards 1	Convergence towards I
V_1 - Geographical accessibility	51 (0.200000)	102 (0.400000)	102 (0.400000)
V_2 - Demand for services	25 (0.098039)	153 (0.600000)	77 (0.301961)
V_3 - Route efficiency	13 (0.050980)	191 (0.749020)	51 (0.200000)
V_4 - Population coverage	0 (0.000000)	204 (0.800000)	51 (0.200000)
V_5 - Available resources	76 (0.298039)	128 (0.501961)	51 (0.200000)
V_6 - Climatic barriers	102 (0.400000)	51 (0.200000)	102 (0.400000)
V_7 - Travel time	127 (0.498039)	77 (0.301961)	51 (0.200000)
V_8 - Equity in distribution	0 (0.000000)	204 (0.800000)	51 (0.200000)

The convergence results reveal critical patterns for optimal route design:

Variables with High Activation (>75%):

- **V_3 (Route Efficiency):** 74.90% - It is consistently activated, indicating that it is a determining factor
- **V_4 (Population Coverage):** 80.00% - Shows the highest activation stability
- **V_8 (Distribution Equity):** 80.00% - Equally stable, confirming its importance

Variables with Mixed Behavior:

- **V_2 (Service Demand):** 60.00% activation - Moderately stable behavior
- **V_5 (Available Resources):** 50.20% activation - Balanced behavior

Variables with High Uncertainty:

- **V_1 (Geographic accessibility)** : 40% activation, 40% indeterminacy
- **V_6 (Climate barriers)** : 20% activation, 40% indeterminacy
- **V_7 (Travel time)** : 30% on, 50% off

5. Conclusions

The results of this study reveal that population coverage and equity in distribution are the most stable and central objectives in the design of mobile clinic systems, achieving 80% activation. Route efficiency also proved to be a fundamental factor for the system's success, with 74.90% activation. On the other hand, external factors such as climatic barriers and geographical accessibility present high uncertainty, while the management of available resources shows a balanced behavior, being crucial but not decisive in itself.

Based on these findings, it is recommended that public health planners prioritize policies that strengthen coverage and equity. It is essential to optimize route efficiency through the use of geographic information systems (GIS) and to develop adaptive strategies, such as contingency plans, to manage the uncertainty of external factors. Furthermore, an integrated and flexible resource management system must be implemented to respond dynamically to the changing needs of the environment, thus ensuring the continuity and effectiveness of the service.

In conclusion, the Neutrosophic Cognitive Mapping methodology is established as a robust tool for planning health services in contexts of high uncertainty. This approach not only allows for the design of optimal routes for mobile clinics focused on equity and coverage but also incorporates mechanisms for adaptation and continuous monitoring. In this way, the study contributes significantly to the improvement of prenatal care in Ecuador, offering a practical and validated framework for decision-making in the health system.

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