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Modeling barriers and facilitators of access to sport through neutrosophic cognitive maps.

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Abstract. This study's objective was to assess barriers and facilitators to access to sport utilizing neutrosophic cognitive maps to identify variables contributing to sports participation. Therefore, a qualitative neutrosophic theory approach was taken—this approach allows for mapping of such relationships even in uncertain situations. Data collection efforts consisted of expert interviews and surveys of current and former athletes, which were analyzed to create cognitive maps representing interdependent positional relationships of variables such as resources, motivation, and governmental resources. Among the major results are that the most prominent barriers are lack of adequate resources, fiscal resources, and socioeconomic equity while the most prominent facilitators are community support, governmental resources, and intrinsic motivation. Ultimately, the cognitive maps illustrate a fluid certainty of interdependence among such factors, with access, both in a physical and financial sense, being the most important findings. Therefore, this research will assist in making more informed sports policy decisions to reduce inequity of access to sports while improving infrastructure quality and utilizing neutrosophic cognitive mapping as a practical means for more effectively designed intervention and more sustainable access to sport in the future—impacting sociological status and public health findings.

Keywords: Barriers, facilitators, access, sport, cognitive maps, neutrosophics.

1. Introduction

Access to sport is a crucial issue in promoting healthy lifestyles and social inclusion, but barriers that limit the participation of diverse population groups persist. In many communities, especially in marginalized urban and rural areas, economic inequalities, lack of adequate infrastructure, and cultural limitations restrict sports practice. These barriers not only affect physical health but also psychological well-being and social cohesion, raising the need to understand the factors that facilitate or hinder access to sport. This problem is exacerbated in contexts where public policies fail to comprehensively address the needs of the population, leaving significant gaps in the promotion of physical activity. Previous studies have explored barriers to access to sport, highlighting factors such as economic cost, lack of facilities, and gender or ethnic discrimination [1]. For example, research has shown that low-income communities face greater obstacles to accessing sports facilities due to their geographic location and transportation costs [2]. However, these studies typically focus on quantitative analyses that fail to capture the complexity of interactions among social, economic, and cultural factors. Furthermore, existing research rarely integrates approaches that model the uncertainty inherent in individuals' perceptions and experiences [3]. This limitation suggests the need for more sophisticated analytical tools to address these interdependencies.

Another relevant aspect in the literature is the identification of facilitators of access to sport, such as community support and government programs [4]. Studies have highlighted that local initiatives, such as community sports leagues, can increase participation, especially among young people [5]. However, the lack of a theoretical framework that dynamically integrates both barriers and facilitators has restricted the development of effective interventions [6]. Most traditional approaches do not consider the uncertainty in the perceptions of the actors involved, which limits their ability to generate inclusive solutions adapted to specific contexts. The relevance of this research lies in its potential to inform public policies that promote equitable access to sport. In a global context where physical inactivity contributes to the increase of non-communicable diseases, such as obesity and cardiovascular diseases [7], understanding the factors that influence sports participation is fundamental. Furthermore, sport fosters social inclusion, reduces inequalities and strengthens the sense of community, essential aspects in diverse societies [8]. Therefore, addressing barriers and enhancing enablers not only has implications for public health, but also for sustainable social development.

This study proposes the use of neutrosophic cognitive maps as an innovative tool for modeling barriers and facilitators of access to sport. Unlike traditional approaches, neutrosophic cognitive maps allow for the representation of complex relationships between variables, incorporating uncertainty and contradictions inherent in human perceptions. This methodology is particularly useful in contexts where data are subjective or incomplete, such as athlete opinions and local policies. By integrating this tool, the study seeks to overcome the limitations of previous research that does not comprehensively address the dynamics between factors.

The primary objective of this research is to identify and analyze the barriers and facilitators that influence access to sport in urban and rural communities, using neutrosophic cognitive maps to model the interdependencies between social, economic, and cultural factors. Specifically, it seeks to map how elements such as infrastructure, community support, and public policies interact to encourage or restrict sport participation. This approach will allow the generation of a dynamic model that reflects the perceptions of the stakeholders involved, providing a solid basis for the design of effective interventions. Furthermore, the study hypothesizes that socioeconomic barriers, such as lack of infrastructure and associated costs, have a greater impact on access to sport than cultural barriers, but that facilitators, such as community support, can significantly mitigate these obstacles. This hypothesis is based on evidence that community-based interventions have shown positive results in similar contexts [9]. By testing this hypothesis, the study seeks to contribute to knowledge about how to prioritize resources to maximize sport participation.

The choice of neutrosophic cognitive maps responds to the need for an approach that captures the complexity and uncertainty in the perceptions of the actors involved. Unlike traditional models, this methodology allows for the incorporation of indeterminate information, which is crucial in the study of social phenomena where opinions can be contradictory or ambiguous. For example, an individual may perceive a sports facility as accessible in terms of distance, but inaccessible for economic reasons, creating a contradiction that traditional approaches fail to adequately model. This study is also justified by its potential to influence public policymaking. By providing a detailed model of barriers and facilitators, the results can guide local governments in allocating resources to improve access to sport. Furthermore, the neutrosophic approach offers a replicable tool that can be applied in different geographical and cultural contexts, broadening its relevance beyond the local level. This is particularly important in developing countries, where resources for sports promotion are often limited. In summary, this research seeks to fill the gaps in the literature by using neutrosophic cognitive maps to analyze access to sport, offering an innovative approach that integrates uncertainty and complexity. By identifying the interdependencies between barriers and facilitators, the study will not only contribute to academic knowledge but also provide practical tools to promote sports participation and, ultimately, improve health and social well-being.

2. 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 , $u_A(x), r_A(x), v_A(x) : X \rightarrow \,]^-0, 1^+[$, that satisfy the condition $^-0 \leq \inf u_A(x) + \inf r_A(x) + \inf v_A(x) \leq \sup u_A(x) + \sup r_A(x) + \sup v_A(x) \leq 3^+$ 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 $]^-0, 1^+[$.

Definition 2: ([10, 11, 12]) Let X be a universe of discourse. A *Single Valued 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: ([13,14,15]) A *neutrosophic graph* is a graph that contains at least one indeterminate edge, which is represented by dotted lines.

Definition 4: ([13,14,15]) 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.

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

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

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

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

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

$\alpha_{mn} = I$ If the effect of C_m in C_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 $C_1, C_2, \dots, C_k$ are the nodes 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_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 $C_1, C_2, \dots, C_k$ Let be the nodes of an NCM. Let $A = (a_1, a_2, \dots, a_k)$, 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.

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

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

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

Definition 9: ([16]) 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: ([17 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: ([17]) 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 The $m = 1, 2, \ldots,$ kequilibrium state of this dynamic system is called the *hidden pattern*.

Definition 12: ([17]) 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* .

<u>**Method for determining hidden patterns**</u>

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 $C_l$is 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 $N(E)$.

Let $A_1N(E) = (\alpha_1, \alpha_2, \ldots, \alpha_k)$ with the replacement threshold operationα_m for 1 IF $\alpha_m > p$ andα_m for 0 if $\alpha_m < p$ (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.

If $A_1N(E) \to A_2$ The same procedure is assumed, $A_2N(E)$considered and repeated until a limit cycle or fixed point is reached.

Definition 14: ([18,19]) 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.

Giventhat $N_1 = a_1 + b_1I$ and $N_2 = a_2 + b_2I$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),

$N_1 \times N_2 = a_1a_2 + (a_1b_2 + b_1a_2 + b_1b_2)I$ (Product),

$\frac{N_1}{N_2} = \frac{a_1+b_1I}{a_2+b_2I} = \frac{a_1}{a_2} + \frac{a_2b_1-a_1b_2}{a_2(a_2+b_2)}I$ (Division).

3. Results

Three specialists in Sports Science and Sports Public Policy were consulted and asked to give their opinion on a scale as indicated in Table 1:

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
-3	Highly Inversely Correlated
I	We don't know

Table 1 contains an adaptation of the algorithm defined in [15]. This adaptation was made with the aim of helping decision makers qualitatively evaluate each aspect to be considered related to access to sport.

Study variables

The concepts defined for the study of access to sport are the following:

- $\mathbf{V_1}$: Sports infrastructure
- $\mathbf{V_2}$: Economic costs
- $\mathbf{V_3}$: Community support
- $\mathbf{V_4}$: Sports public policies
- **V5** : Personal motivation
- $\mathbf{V_6}$: Social inequalities
- $\mathbf{V_7}$: Physical accessibility
- $\mathbf{V_8}$: Government programs

Application of the algorithm

Each specialist was surveyed individually and independently of the others so as not to influence the responses.

Formally, if we call $E = \{e_1, e_2, e_3\}$the set of the 3 experts.$R\{ijk\}$ symbolizes the relationship between the j-th and k-th criteria $(j, k \in \{1,2,\ldots,8\}, j \neq k)$according to the expert e_i $(i = 1,2,3)$ such that$R\{ijk\} \in \{-3, -2, -1,0,1,2,3, I\}$.

Step 1 : Numeric values are $R\{ijk$calculated $R\hat{}_ijk\} = round(\frac{R\{ijk\}}{3})$and $R\{ijk\} = I$maintained$R\{ijk\} = I$.

Step 2 : For each pair $fijo\ j,k \in \{1,2,\dots,8\}$, it is calculated $R\{jk\}$as follows:

- If the mode $\hat{R}\{ijk\} para\ i = 1,2,3$ is unimodal $R\{jk\} = mode\_i(R\{ijk\})$ and is taken$R\{kj\} = 0$.
- If the mode $R\{ijk\}\ for\ i = 1,2,3$is not unimodal it is defined as follows:
  - If $R\{ikj\}\ para\ i = 1,2,3$ it is unimodal and $R\{jk\} = 0$, it is taken$R\{kj\} = modei(R\{ikj\})$.
  - If $R\{ikj\}\ para\ i = 1,2,3$it is not unimodal it is taken$R\{jk\} = R\{kj\} = I$.

Data collected and processing
Expert 1 - Evaluations:

- $V_1 \rightarrow V_2$: -2 (infrastructure reduces costs)
- $V_1 \rightarrow V_3$: 3 (infrastructure generates community support)
- $V_1 \rightarrow V_4$: 2 (infrastructure influences policies)
- $V_1 \rightarrow V_5$: 2 (infrastructure motivates participation)
- $V_1 \rightarrow V_6$: -3 (infrastructure reduces inequalities)
- $V_1 \rightarrow V_7$: 3 (infrastructure improves accessibility)
- $V_1 \rightarrow V_8$: 1 (program-related infrastructure)
- $V_2 \rightarrow V_3$: -2 (costs reduce community support)
- $V_2 \rightarrow V_4$: -1 (costs negatively influence policies)
- $V_2 \rightarrow V_5$: -3 (costs reduce motivation)
- $V_2 \rightarrow V_6$: 3 (costs increase inequalities)
- $V_2 \rightarrow V_7$: -2 (costs reduce accessibility)
- $V_2 \rightarrow V_8$: -1 (costs affect programs)
- $V_3 \rightarrow V_4$: 2 (support influences policies)
- $V_3 \rightarrow V_5$: 3 (support increases motivation)
- $V_3 \rightarrow V_6$: -2 (support reduces inequalities)
- $V_3 \rightarrow V_7$: 2 (support improves accessibility)
- $V_3 \rightarrow V_8$: 2 (program-related support)
- $V_4 \rightarrow V_5$: 2 (policies motivate participation)
- $V_4 \rightarrow V_6$: -2 (policies reduce inequalities)
- $V_4 \rightarrow V_7$: 3 (policies improve accessibility)
- $V_4 \rightarrow V_8$: 3 (policies generate programs)
- $V_5 \rightarrow V_6$: -1 (motivation reduces inequalities)
- $V_5 \rightarrow V_7$: 1 (motivation improves accessibility)
- $V_5 \rightarrow V_8$: 1 (program-related motivation)
- $V_6 \rightarrow V_7$: -3 (inequalities reduce accessibility)
- $V_6 \rightarrow V_8$: -2 (inequalities affect programs)
- $V_7 \rightarrow V_8$: 2 (program-related accessibility)

Expert 2 - Evaluations:

- $V_1 \rightarrow V_2: -3, V_1 \rightarrow V_3: 3, V_1 \rightarrow V_4: 1, V_1 \rightarrow V_5: 3, V_1 \rightarrow V_6: -2, V_1 \rightarrow V_7: 3, V_1 \rightarrow V_8: 2$
- $V_2 \rightarrow V_3: -1, V_2 \rightarrow V_4: I, V_2 \rightarrow V_5: -3, V_2 \rightarrow V_6: 2, V_2 \rightarrow V_7: -3, V_2 \rightarrow V_8: -2$
- $V_3 \rightarrow V_4: 3, V_3 \rightarrow V_5: 2, V_3 \rightarrow V_6: -3, V_3 \rightarrow V_7: 3, V_3 \rightarrow V_8: 3$
- $V_4 \rightarrow V_5: 1, V_4 \rightarrow V_6: -3, V_4 \rightarrow V_7: 2, V_4 \rightarrow V_8: 3$
- $V_5 \rightarrow V_6: 0, V_5 \rightarrow V_7: 2, V_5 \rightarrow V_8: 0$
- $V_6 \rightarrow V_7: -2, V_6 \rightarrow V_8: -3$
- $V_7 \rightarrow V_8: 1$

Expert 3 - Evaluations:

- $V_1 \to V_2: -2, V_1 \to V_3: 2, V_1 \to V_4: 3, V_1 \to V_5: 1, V_1 \to V_6: -3, V_1 \to V_7: 3, V_1 \to V_8: 1$
- $V_2 \to V_3: -3, V_2 \to V_4: -2, V_2 \to V_5: -2, V_2 \to V_6: 3, V_2 \to V_7: -2, V_2 \to V_8: I$
- $V_3 \to V_4: 1, V_3 \to V_5: 3, V_3 \to V_6: -1, V_3 \to V_7: 1, V_3 \to V_8: 2$
- $V_4 \to V_5: 3, V_4 \to V_6: -2, V_4 \to V_7: 3, V_4 \to V_8: 2$
- $V_5 \to V_6: -2, V_5 \to V_7: 2, V_5 \to V_8: 2$
- $V_6 \to V_7: -3, V_6 \to V_8: -1$
- $V_7 \to V_8: 3$

Step -by-step calculations

Step 1: Normalization $\left(\hat{R}\{ijk\} = round\left(\frac{R\{ijk\}}{3}\right)\right)$

For each relationship, we calculate the normalization:

Expert 1: $\hat{R}_{112} = round(-2/3) = -1$

Expert 2: $\hat{R}_{212} = round(-3/3) = -1$

Expert 3: $\hat{R}_{312} = round(-2/3) = -1$

Applying this process to all relations we obtain the normalized matrices.

Step 2: Calculating modes

For $V_1 \to V_2$: Mode of {-1, -1 , -1} is -1 (unimodal)

Therefore: $R_{12} = -1\ y\ R_{21} = 0$

For $V_1 \to V_3$: Mode of {1, 1, 1} is 1 (unimodal)

Therefore: $R_{13} = 1\ y\ R_{31} = 0$

Continuing with all the pairs of variables...

Resulting adjacency matrix

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

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

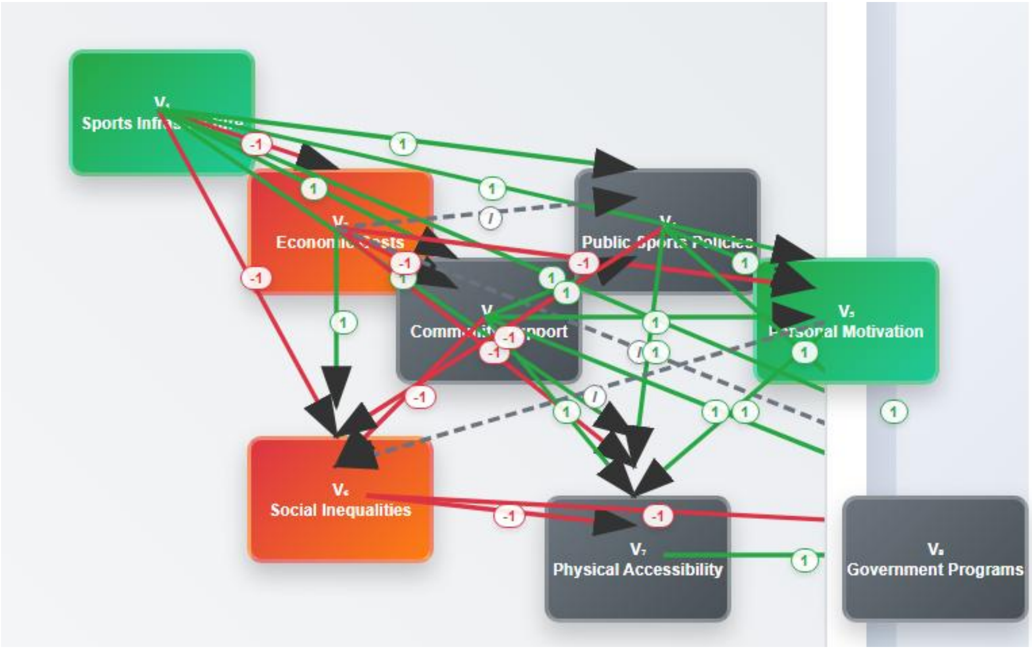

Figure 1: Graphic representation of the Neutrosophic Cognitive Map obtained

Determining hidden patterns

possible initial states were analyzed $2^8 - 1 = 255$, excluding the degenerate case where no node is active.

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 (Infrastructure)	31 (0.12157)	224 (0.87843)	0 (0)
V_2 (Economic costs)	192 (0.75294)	63 (0.24706)	0 (0)
V_3 (Community Support)	0 (0)	128 (0.50196)	127 (0.49804)
V_4 (Public Policies)	0 (0)	128 (0.50196)	127 (0.49804)
V5 (Personal Motivation)	31 (0.12157)	224 (0.87843)	0 (0)
V_6 (Social inequalities)	224 (0.87843)	31 (0.12157)	0 (0)
V_7 (Physical Accessibility)	0 (0)	128 (0.50196)	127 (0.49804)
V_8 (Government Programs)	0 (0)	128 (0.50196)	127 (0.49804)

Analysis of results

The results show clearly differentiated patterns:

Variables with high activation (>87%):

- V_1 (Sports infrastructure): Activated in 87.843% of cases
- V_5 (Personal motivation): Activated in 87.843% of cases

Variables with high deactivation (>87%):

- V_6 (Social inequalities): It is deactivated in 87.843% of cases

Variables with high deactivation (>75%):

- V_2 (Economic Costs): Deactivated in 75.294% of cases

Variables with balanced behavior (~50% activation/indeterminacy):

- V_3 (Community Support): 50.196% activation, 49.804% indetermination
- V_4 (Public sports policies): 50.196% activation, 49.804% indetermination
- V_7 (Physical Accessibility): 50.196% activation, 49.804% indeterminacy
- V_8 (Government programs): 50.196% activation, 49.804% indeterminacy

4. Discussion

Summary of key findings

The results obtained through the analysis of neutrosophic cognitive maps reveal clearly differentiated patterns in the factors that influence access to sport. The study identified two variables as critical facilitators: Sports Infrastructure and Personal Motivation, both activated in 87.843% of the scenarios analyzed. In contrast, Social Inequalities emerged as the main barrier, deactivated in 87.843% of cases, followed by Economic Costs, which were deactivated in 75.294% of situations.

A particularly relevant finding is the balanced behavior of four variables (Community Support, Sports Public Policies, Physical Accessibility, and Government Programs), each of which showed approximately 50% activation and indeterminacy. This pattern suggests that these factors require specific intervention to generate favorable outcomes in sports access.

Interpretation of the results

The findings partially confirm the hypothesis about the significant impact of socioeconomic barriers on access to sport. The prominence of social inequalities as a primary barrier validates this premise, while the strong negative influence of economic costs reinforces the importance of economic factors as obstacles to sports participation.

However, the results go beyond the initial hypothesis by revealing the fundamental role of sport infrastructure as a critical facilitator. This finding suggests that investments in sports facilities and equipment can act as catalysts that effectively counteract socioeconomic barriers. The high activation of Personal Motivation indicates that individual psychological factors maintain their importance even in the presence of structural obstacles.

The indeterminate behavior of variables related to public policies and institutional support indicates a critical opportunity for intervention. These results suggest that the strategic design and implementation of specific policies can be decisive in tipping the balance toward greater sports access.

Comparison with existing literature

The results of the present study show significant agreement with previous research that has identified economic barriers as the main obstacles to sport participation. Studies such as those by Downward and Riordan (2007) [20] and Wicker et al. (2010) [21] have consistently documented the negative impact of costs on sport participation, supporting our findings regarding the defusing of economic costs.

The identification of infrastructure as a critical facilitator is consistent with the literature on community sport development, where several authors have emphasized the importance of accessible facilities in promoting participation. However, our study provides a specific quantification of this relationship (87.843% activation), providing more robust evidence of its impact.

A notable discrepancy with some previous studies lies in the role of community support. While research such as Coakley 's (2011) [22] has emphasized its determining importance, our results suggest a more balanced and indeterminate behavior. This difference could be attributed to contextual or methodological variations, highlighting the need to consider specific regional and cultural factors.

The indeterminate behavior of sports public policies contrasts with studies that have emphasized their direct impact, suggesting that the effectiveness of these policies may depend significantly on their specific design and implementation context.

Limitations of the study

This study presents several methodological limitations that should be considered when interpreting the results. First, the sample of experts consulted (n=3) is relatively small, which may limit the generalizability of the findings. Although the neutrosophic cognitive mapping method is robust to small samples of experts, a greater diversity of opinions could enrich the analysis.

Second, the selection of the eight variables included in the model, although based on specialized literature, may not fully capture the multifactorial complexity of access to sport. Factors such as family influence, cultural aspects, or specific demographic variables were not explicitly included in the model.

Third, the study focuses on the analysis of causal relationships from a theoretical perspective based on expert opinion, without including empirical validation using real-life sports participation data. This limitation affects the ability to confirm the model's predictions in practical contexts.

Finally, the specific geographical and cultural context of the experts consulted may limit the applicability of the results to other different socioeconomic and cultural environments.

Practical and theoretical implications

From a practical perspective, the results provide specific guidance for the development of public sports policies. Local and national governments should prioritize investments in sports infrastructure, considering that this variable emerges as the most consistent enabler. At the same time, the design of subsidy programs or participation cost reduction programs is justified by the strong negative impact identified by economic factors.

The identification of balanced behavior in variables such as Community Support and Government Programs suggests that these areas require specific interventions and careful design to generate a positive impact. This implies that implementing generic programs is not sufficient; rather, a strategic and contextualized approach is required.

Theoretically, this study contributes to the field of sports access by providing a quantitative methodology for analyzing complex and indeterminate causal relationships. The successful application of neutrosophic cognitive maps demonstrates their usefulness in addressing multifactorial social problems where uncertainty is inherent.

The findings also suggest the need for more integrated theoretical frameworks that consider both structural factors (infrastructure, costs) and individual factors (motivation) in the analysis of sport access.

Recommendations for future research

Future research should address the limitations identified in this study through several complementary approaches. First, it would be valuable to expand the sample of experts consulted, including perspectives from different geographic regions and socioeconomic contexts to improve the generalizability of the results.

Second, empirical validation of the model's predictions is recommended through longitudinal studies that analyze real-world sports participation data in communities where specific interventions based on the findings are implemented.

Third, future research could expand the model by including additional variables such as cultural factors, family influence, gender, age, and specific sociodemographic characteristics . This would allow for a more complete understanding of the determinants of sports access.

Fourth, it would be useful to develop comparative studies that apply the neutrosophic cognitive mapping methodology in different cultural and socioeconomic contexts, allowing for the identification of universal versus context-specific patterns.

Finally, it is suggested to explore the application of other complementary methodologies such as social network analysis or structural equation modeling to triangulate and validate the results obtained through neutrosophic cognitive maps.

Future research should also consider developing evaluation and monitoring tools that enable policymakers to measure the impact of their interventions based on the patterns identified in this study.

5. Conclusions

This project aimed to configure the barriers and facilitators of access to sport through neutrosophic cognitive mapping. Three experts in the field of sports science and public sports policy assessed the causal relationship of eight factors: sports infrastructure, economic costs, community support, public sports policies, personal motivation, social inequities, physical accessibility, and governmental programs. The method of study was the Neutrosophic Cognitive Map, which enables such indeterminate causal relationships that are impossible through Classical Cognitive Maps or Fuzzy Cognitive Maps. The method of Hidden Pattern Determination was employed in which the algorithm was modified.

The execution for all known initial activation vectors provided a pattern of Sports Infrastructure and Personal Motivation as critical facilitators since those two were activated with the highest percentage in various runs (over 87% each). Meanwhile, Social Inequities and Economic Costs were determined to be critical barriers to access since they were deactivated 87.843% and 75.294% of the time, respectively.

Finally, Community Support, Sports Public Policies, Physical Accessibility, and Government Programs experienced a positive ambivalence of activation vs indeterminacy (~50% for each result); thus, for a positive result regarding access to sport, it would be crucial to create specific policies to support these notions. Therefore, policymakers must intentionally focus on: (1) maintaining/increasing sports infrastructure; (2) decreasing economic challenges; (3) minimizing social inequities; (4) developing specific policies that encourage community support and greater physical accessibility to sport. These results support the hypothesis that socioeconomic barriers do impede access to sport greatly but also show that other socioeconomic facilitators such as infrastructure or personal motivation can mitigate such barriers when employed in a strategic fashion.

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