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A Decision-Making Approach of Fuzzy Cognitive Maps Using Triangular Fuzzy Numbers under Uncertainty

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Abstract

Mathematics is effective in everyday life and every period of human civilization. Advancements in science and technology still depend on Mathematics. No branch of knowledge is untouched by mathematics-economics, defence, space science, and recent nanotechnology. Mathematical logic has been used to analyze and solve problems in science and technology and fields such as political, social, economic, and psychological problems. A fuzzy set can be defined mathematically by assigning a value representing its grade of membership in the fuzzy set to each possible individual in the universe of discourse. This paper aims for an interlinking approach of Fuzzy Cognitive Maps (FCM) to find the problems faced by Transgenders using triangular fuzzy numbers. Section one begins with an introduction, some basic definitions, and previous research for FCM and triangular fuzzy numbers. Section two provides the Mathematical formulation and arithmetic operation of FCM of triangular fuzzy numbers. Section three illustrates the ranking analysis of problems faced by Transgenders using FCM using triangular fuzzy numbers and performs the calculations using the collected data among the Transgenders. Section four describes the Conclusion and some suggestions based on our study.

Keywords: Unsupervised transgender, Fuzzy sets, Fuzzy cognitive maps, Combined fuzzy cognitive maps, Hidden patterns, Triangular fuzzy numbers, Decision making and optimization.

1 | Introduction

This chapter begins with an introduction that briefly describes the scope of transgenders and Triangular Fuzzy Cognitive Maps (TrFCM).

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2 | Basics of Triangular Fuzzy Cognitive Maps (TRFCM)

This chapter begins with an introduction that briefly describes the scope of Transgenders and Triangular fuzzy Cognitive Maps.

2.1 | Introduction of Transgenders

Transgenders is an umbrella term for persons whose gender identity, gender expression, or behaviour does not conform to that typically associated with the sex to which they were assigned at birth. Gender identity refers to a person's internal sense of being male or female. Gender expression refers to how a person communicates gender identity to others through behaviour, clothing, hairstyles, voice or body characteristics, etc. Transgender is in between categories of gender. They possess attributes of male and female. They are called transgender, multi-transgender, third-gender, etc. However, this third gender is not accepted by society anywhere in the world. It is due to different activities such as behaviour, talking, hairstyle, dressing, etc. Parents, colleagues, friends, and society should have equal rights in all activities. Gender identity refers to an internal feeling of being male or female gender expression. Transgender is a term used to describe people whose gender identity (sense of them as male or female) or gender expression differs from that usually associated with their birth sex. Many transgender people live part-time or full-time as members of the other gender. Broadly speaking, anyone whose identity, appearance, 18 or behaviour falls outside of conventional gender norms can be described as transgender. However, not everyone whose appearance or behaviour is gender-atypical will identify as a transgender person.

2.2 | Fuzzy Cognitive Maps

The fuzzy set provides us with a meaningful and powerful representation of the measurement of uncertainty with a meaningful representation of vague concepts expressed in natural language. Because every crisp set is fuzzy but not conversely. The mathematical embedding of conventional set theory into fuzzy sets is as natural as embedding real numbers into the complex plane. Thus, the idea of fuzziness is one of enrichment, not of replacement.

A Fuzzy graph is a convenient way of representing information involving relationships between objects. The objects are represented by vertices and relations by edges. When there is vagueness in the description of the objects or their relationships or both, it is natural that we need to design a Fuzzy Graph Model. Applications of fuzzy relations are widespread and important, especially in clustering analysis, neural networks, computer networks, pattern recognition, decision making and expert systems. In each of these, the basic mathematical structure is that of a fuzzy graph.

The membership function of the Triangular Fuzzy number = (a,b,c) is given by, where $a \leq b \leq c$. FCMs can successfully represent knowledge and human experience, introducing concepts to represent the essential elements and the cause-and-effect relationships among the concepts to model the behaviour of any system. It is a very convenient, simple and powerful tool, which is used in numerous fields such as social, economic, medical, etc., illustrated by Vasantha Kandasamy [1] in her book, "Application of Fuzzy Models in Social Sciences [2], [3]. FCM works on unsupervised data. It is a simple and effective tool to analyze social, economic, and political problems. FCM are fuzzy signed digraphs with feedback. The sign (+ or -) of FCM edges indicates a causal increase or decrease. A number in $[-1, 1]$ indicates the fuzzy degree of causality. FCMs learn by modifying their causal connections in sign and magnitude, which are structurally analogous to how neural networks learn. FCM nodes represent variable phenomena or fuzzy sets. An FCM node nonlinearly transforms weighted summed inputs into numerical output, again in analogy to a model neuron. Unlike expert systems, which are feed-forward search trees, FCMs are nonlinear dynamical systems. FCM resonant states are limit cycles or time-varying patterns. An FCM limit cycle or hidden pattern is an FCM inference. Experts construct FCMs by drawing causal pictures or digraphs. The corresponding connection matrices are used for inference. By additively combining augmented connection matrices, any number of FCMs can be naturally combined into a single knowledge network. FCMs can successfully represent knowledge and human experience, introduced concepts to represent the essential elements and the cause and effect relationships among the concepts to model the behaviour of any system.

Usually, in FCM, we analyze the number of states ON-OFF position. For this dissertation, Triangular Fuzzy Cognitive Maps (TFCM) gives the weight of the attributes and the ranking of the attributes. The membership function of the Triangular Fuzzy number = (a,b,c) is given by, where a≤b≤c.

TrFCM are more applicable when the data in the first place is an unsupervised one. The TrFCM works based on the opinions of three experts. TrFCM models the world as a collection of classes and causal relations between classes. It is a different process from FCM. Usually, the FCM only gives the ON-OFF position. However, this triangular fuzzy cognitive map is more precise, and it ranks the causes of the problem by using the weightage of the attribute. It is the main advantage of the new TrFCM.

Applications of FCM in Various Fields

Modelling-knowledge representation, decision making, enterprise resource management, socio-economic systems, engineering & technology management, adaptation and learning, classification tasks, robots and control, political and social fields, military planning, production systems, prediction capabilities, ecology and environmental.

The FCM models play an important role in finding the ranking with triangular fuzzy numbers. Several authors, such as Vidhya et al. [4], studied the fuzzy Floyd Warshall and fuzzy rectangular algorithms to find the shortest path. Broumi et al. [5] made an Efficient Approach for Solving the Time-Dependent Shortest Path Problem under the Fermatean Neutrosophic Environmen Vidhya et al. [6] proposed a Novel Method for Finding the Shortest Path With Two Objectives Under Trapezoidal Intuitionistic Fuzzy Arc Costs. Prakash et al. [7] presented an Optimal solution for a fully Spherical Fuzzy Linear Programming Problem. Saraswathi [2] developed a fuzzy-trapezoidal DEMATEL approach for solving uncertainty decision-making problems. Dharmaraj et al. [3] applied a Modified Gauss Elimination Technique for Separable Fuzzy Nonlinear Programming Problems.

Vidhya et al. [8] investigated the A* search algorithm for the shortest path under an interval-valued Pythagorean fuzzy environment. Saraswathi and Mahalakshmi [9] solved a new approach for solving the minimal flow, which was the shortest. The route, Maximal Flow And The Critical Path Using Network. Appasamy Saraswathi [10] used a Triangular Fuzzy Clustering Model Under Uncertainty. Yuvashri et al. [11] studied A Novel Approach for a Multi-objective Linear Programming Model Under a Spherical Fuzzy Environment and Its Application. Karthick et al. [12] used a Neutrosophic Linear Fractional Programming Problem using the Denominator Objective Restriction Method—Dynamics of Continuous.

Anand and Devadoss [13], Gani and Assarudeen [14], Chen and Chen [15], etc., have studied the TrFCM and their applications in real-world problems. The TrFCM was introduced by Anand and Devadoss [13] and analyzed the causes of divorce in families. Gani and Assarudeen [14] investigated triangular fuzzy numbers for Solving Fuzzy Linear Programming Problems. Chen and Chen [15] contributed a new method for fuzzy risk analysis based on ranking generalized trapezoidal fuzzy numbers. The proposed method considers the centroid points and the standard deviations of generalized trapezoidal fuzzy numbers for ranking generalized trapezoidal fuzzy numbers using Fuzzy risk analysis based on the ranking of generalized trapezoidal fuzzy numbers. Saraswathi and Nedumaran [16] developed a comparative study to find the critical path using triangular fuzzy numbers.

2.3 | Basic Notions of TrFCM

Definition 1. When the TrFCM nodes are fuzzy sets, they are called fuzzy triangular nodes.

Definition 2. TrFCMs with edge weights or causalities from the set {-1, 0, 1} are called simple TrFCMs.

Definition 3. A TrFCM is a directed graph with concepts like policies, events, etc., as nodes and causalities as edges; it represents causal relationships between concepts.

Definition 4. Consider the nodes/concepts are $TrC_1, TrC_2 \ldots\ldots TrC_n$ of the TrFCM. Suppose the directed graph is drawn using edge weight $Tre_{ij} \in \{-1, 0, 1\}$. The triangular matrix M be defined by Tr(M) = Tre_{ij} where Tre_{ij} is the triangular weight of the directed edge Trc_iTrc_j.Triangular Matrix (Tr(M) is called the adjacency matrix of TrFCM, also known as the connection matrix of the TrFCM.

It is important to note that all matrices associated with a TrFCM are always square matrices with diagonal entries as zero.

Definition 5. Let $TrC_1, TrC_2, \ldots, TrC_n$ be the nodes of an TrFCM. A = $(a_1, a_2, \ldots, a_n)$ where $Tre_{ij} \in \{-1, 0, 1\}$. A is called the instantaneous state vector and denotes the node's on-off position at an instant.

$$\text{Instantaneous vector} = \begin{cases} Tr^{a_i} = 1 \text{Maximum(weight)}, \\ Tr^{a_i} = 0 \text{ Otherwise.} \end{cases}$$

Definition 6. Let $TrC_1, TrC_2, \ldots\ldots\ldots, TrC_n$ be the triangular nodes of and TrFCM. Let $\overrightarrow{{}_{Tr}C_1\,{}_{Tr}C_2}, \overrightarrow{{}_{Tr}C_2\,{}_{Tr}C_3}, \overrightarrow{{}_{Tr}C_3\,{}_{Tr}C_4}, \overrightarrow{{}_{Tr}C_i\,{}_{Tr}C_j}$ be the edges of the TrFCM (i≠j). ATrFCM is said to be cyclic if it possesses a directed cycle. A TrFCM is said to be acyclic if it does not possess any directed cycle.

Definition 7. A TrFCM is said to be cyclic and is said to have feedback.

Definition 8. When there is feedback in a TrFCM, i.e., when the causal relations flow through a cycle in a revolutionary way, the TrFCM is called a dynamical system.

Definition 9. Let $\overrightarrow{{}_{Tr}C_1\,{}_{Tr}C_2}, \overrightarrow{{}_{Tr}C_2\,{}_{Tr}C_3}, \overrightarrow{{}_{Tr}C_3\,{}_{Tr}C_4}, \ldots, \overrightarrow{{}_{Tr}C_{n-1}\,{}_{Tr}C_n}$ be a cycle. When TrCi is switched ON and if the causality flows through the triangular edges of a cycle and if it again causes ci, we say that the dynamical system goes round and round. This is true for any triangular node Trci for i =1,2,…,n. The equilibrium state for this dynamical system is called the hidden pattern.

Definition 10. If the equilibrium state of a dynamical system is a unique state vector, then it is called a fixed point. Consider a TrFCM with TrC_1, TrC2,…, and TrC_n as nodes.

For example, let us start the dynamic system by switching on TrC_1.

Let us assume that the TrFCM settles down with TrC1 and TrCn is ON, i.e., in the state, the vector remains as (1, 0, 0,……0) is called fixed point.

Definition 11. If the TrFCM settles down with a state vector repeating in the form $A_1 \to A_2 \to \ldots \to A_i \to A_1$, then this equilibrium is called a limit cycle.

Definition 12. A triangular fuzzy number $\tilde{A} = (a_1, a_2, a_3)$ is said to be non-negative iff $a_1 \geq 0$.

Definition 13. A fuzzy set $\tilde{A}$ defined on X is called a normal fuzzy set if there exists at least one x∈ X such that $\mu_{\tilde{A}}(x) = 1$.

Definition 14. Given a fuzzy set $\tilde{A}$ defined on 'X' and any α ∈[0,1] the α–cut is denoted by $\tilde{A}$ (α) and is defined as,

$$\tilde{A}(\alpha) = \{x, \mu(x) \geq \alpha, \alpha \in [0,1]\}.$$

Definition 15. Arithmetic in triangle fuzzy numbers.

Let's say ã is represented by $\langle \bar{x}_a, l_a, r_a \rangle$ and $\tilde{b}$ is represented by $\langle \bar{x}_b, l_b, r_b \rangle$ both being triangular fuzzy numbers. Additionally, x belongs to the set of real numbers. The addition, subtraction, and multiplication operations of fuzzy numbers are defined as follows in the real number set.

$$\tilde{a} + \tilde{b} = \langle \bar{x}_a + \bar{x}_b, l_a + l_b, r_a + r_b \rangle,$$

$$\tilde{a} - \tilde{b} = \langle \bar{x}_a - \bar{x}_b, l_a - l_b, r_a - r_b \rangle,$$

$$x\tilde{a} = \begin{cases} \langle x\bar{x}_a, xl_a, xr_a \rangle, & x \geq 0, \\ \langle x\bar{x}_a, -xl_a, -xr_a \rangle, & x < 0. \end{cases}$$

Linguistic values of Triangular Fuzzy Numbers

Table 1. The linguistic values.

Very Low	(0, 0, 0.25)
Low	(0, 0.25, 0.50)
Medium	(0.25, 0.50, 0.75)
High	(0.50, 0.75, 1)
Very High	(0.75, 1, 1)

2.4|Previous Research

The New TrFCM models play an important role in finding the ranking with triangular fuzzy numbers. Several authors, such as Anand and Devadoss [13], Gani and Assarudeen [14], Chen and Chen [15] and Vidhya et al. [4], have studied the TrFCM and their applications in real-world problems.

FCM works on unsupervised data. It is a simple and effective tool to analyze social, economic, and political problems. The idea of a fuzzy set was introduced by Zadeh [17] in 1965. Decision-making in a fuzzy environment is focused as an emerging area of research associated with decision sciences. Kosko [18] introduced FCM as fuzzy graph structures to represent causal reasoning. FCMs model the world as a collection of classes and casual relations between classes. Their fuzziness allows hazy degrees of causality between hazy causal concepts; each node in FCM represents a concept. Each (Ci, Cj) is directed as well as weighted and represents a causal link between concepts, showing how concept Ci causes concept Cj [2],[5]. Axelrod proposed cognitive maps as a formal tool for decision-making. He used the matrix representation of the directed graph to represent and study social scientific knowledge. His FCM is signed digraphs. Nodes are variable concepts, and edges are causal connections [7].

Vasantha Kandasamy [1] constructed the Fuzzy Relational Models and FCM and have effectively used the Fuzzy Models in analyzing the problems of displaced persons, school drop-outs, AIDs patients, Dalits, Rag pickers, PWDs, etc [3].

The TrFCM, introduced by Anand and Devadoss [13], analyzed the causes of divorce thought in families [8]. Using the model, Gani and Assarudeen [14] used triangular fuzzy numbers to solve fuzzy linear programming problems [9]. Saraswathi developed an Induced Trapezoidal TrFCM with four linguistic scales and applied them to highlight the problems of the old aged [10]. Chen and Chen [15] developed a new method for fuzzy risk analysis based on ranking generalized trapezoidal fuzzy numbers. The proposed method considers the centroid points and the standard deviations of generalized trapezoidal fuzzy numbers for ranking [11]. Esther Jerlin et al. studied the problems of Deprived Rural persons with Disabilities using trapezoidal FCM [12]. Rajkumar et al. studied Miracles through the Holy Bible using TrFCM [17]. Vidhya et al. [4] presented TrFCM to study the Causes of Child Trafficking using indeterministic TrFCMs [18]. Tapan Kumar Roy et al. proposed an arithmetic Operation and its applications using a Generalized Trapezoidal Fuzzy Number [19].

3|Mathematical Formulation of Triangular Fuzzy Number

Definition 16. If X is a universal set and $x \in X$, then a fuzzy set $\widetilde{A}$ defined as, $\widetilde{A} = \{(x, \mu_{\widetilde{A}}(x)), x \in X\}$, Where $\mu_{\widetilde{A}}$ = membership function.

Definition 17. A fuzzy set $\tilde{A}$ is called a fuzzy number if its membership function $\tilde{A}: R \rightarrow [0,1]$ satisfies the following conditions:

I. $\tilde{A}$ is convex

II. $\tilde{A}$ is normal

III. $\tilde{A}$ is piecewise continuous.

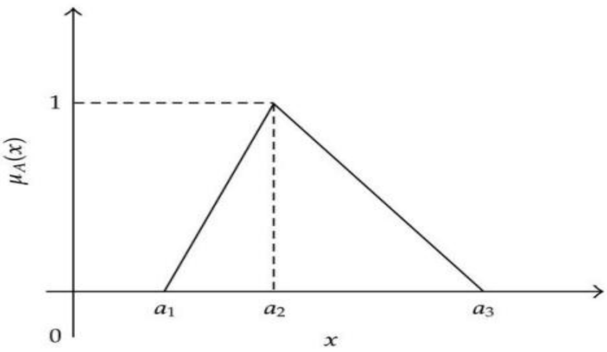

Fig. 1. Graphical representation of TFN.

Definition 18. A fuzzy number $\tilde{A}$ on R is said to be a triangular fuzzy number if its membership function $\tilde{A}: R \rightarrow [0, 1]$ has the following characteristics:

$$\tilde{A}(x) = \begin{cases} \dfrac{x - a_1}{a_2 - a_1}, a_1 \leq x \leq a_2, \\ \dfrac{a_3 - x}{a_3 - a_2}, a_2 < x \leq a_3, \\ 0, \quad \text{otherwise.} \end{cases}$$

We denote this triangular fuzzy number $\tilde{A} = (a_1, a_2, a_3)$.

We use F(R) to denote the set of all triangular fuzzy numbers.

Definition 19. A fuzzy set $\tilde{A}$ is defined by $\tilde{A} = \{(x, \mu A(x)): x \in A, \mu A(x) \in [0,1]\}$, In the pair (x, μ A(x)), the first element x belong to the classical set A, the second element μ A(x), belong to the interval [0, 1], called Membership function.

Definition 20. A fuzzy set $\tilde{A}$ on R must possess at least the following properties to qualify as a fuzzy number

I. $\tilde{A}$ must be a normal fuzzy set.

II. $\tilde{A}$ must be a closed interval for every α [0,1].

Definition 21. Positive triangular fuzzy number.

A positive triangular fuzzy number $\tilde{A}$ is denoted as $\tilde{A} = (a_1, a_2, a_3)$ where all ai's> 0 for all i=1, 2, 3.

Definition 22. Negative triangular fuzzy number.

A negative triangular fuzzy number $\tilde{A}$ is denoted as $\tilde{A} = (a_1, a_2, a_3)$ where all ai's< 0 for all i=1, 2, 3.

Definition 23. Equal Triangular fuzzy number.

Let $\tilde{A} = (a_1, a_2, a_3)$ and $\tilde{B} = (b_1, b_2, b_3)$ be two triangular fuzzy numbers. If $\tilde{A}$ is identically equal to $\tilde{B}$ if and only if $a_1 = b_1$, $a_2 = b_2$ and $a_3 = b_3$.

Arithmetic Operation of Triangular Fuzzy Number

For arbitrary triangular fuzzy numbers $\widetilde{A} = (a_1, a_2, a_3)$ and $\widetilde{B} = (B_1, B_2, B_3)$ andand $* = \{+, -, \times, \div\}$, the arithmetic operations on the triangular fuzzy numbers are defined by

$$\tilde{A} * \tilde{B} = \{a_i * b_j / a_i \in \tilde{A}, b_j \in \tilde{B}\}.$$

In particular, for any two triangular fuzzy numbers $\widetilde{A} = (a_1, a_2, a_3)$ and $\widetilde{B} = (B_1, B_2, B_3)$, we define.

I. Addition (+): $A + B = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$.

II. Subtraction (-): $A - B = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$.

III. Multiplication ($\otimes$):

$$k \otimes A = (ka_1, ka_2, ka_3), k \in R, k \geq 0,$$

$$k \otimes b = (a_1 b, a_2 b, a_3 b), a_1 \geq 0, a_2 \geq 0, a_3 \geq 0.$$

IV. Division

$$(A)^{-1} = (a_1, b_1, c_1)^{-1} \cong \left(\frac{1}{c_1}, \frac{1}{b_1}, \frac{1}{a_1}\right), a_1 > 0, b_1 > 0, c_1 > 0,$$

$$A \emptyset B \cong \left(\frac{a_1}{c_2}, \frac{b_1}{b_2}, \frac{c_1}{a_2}\right), a_1 \geq 0, a_2 > 0.$$

4 | A Ranking Analysis of Problems Faced by Transgenders Using Fuzzy TrFCM Method

The data pertaining to the problems of Transgenders was collected from the three main stakeholders viz, Transgenders, their parents and leaders of NGOs who have been working for their cause. A structural questionnaire was prepared and administered among 50 Transgenders, 20 parents and 5 NGO leaders. Their problems were identified through focus group discussions among the Transgenders. We have also identified the problems, followed by desk work and literacy survey problems. Through these methods, we have identified the following 10 attributes.

4.1 | The Following 10 Concepts are Taken Based on Survey, Interview and Focus Group Discussion

TrC_1-Lack of financial support.

TrC_2 -Deprived of fundamental rights.

TrC_3 -Lack of Sex Reassignment (SRS) Surgery.

TrC_4 -No ID Proof.

TrC_5 -Lack of relations.

TrC_6 -Lack of joining schools and colleges.

TrC_7-Lack of medical facilities.

TrC_8 -Lack of employment opportunities.

TrC_9 -Lack of shelter.

TrC_{10}-No share in the property.

4.2 | Algorithm for TrFCM

Step 1. Prepare a n×n connection matrix.

Step 2. Prepare the weightage matrix related to the Connection matrix of Tr(M).

Step 3. Prepare the average matrix Tr(M) using linguistics values for the triangular fuzzy numbers.

Step 4. Prepare the maximum weightage of the matrix Tr(M) using the average matrix.

Step 5. Find the limit cycle.

I. Let TrC_1, TrC_2…….. TrC_{10} be the nodes of a TrFCM. Here, Tr(M) be an adjacency matrix.

II. Consider the instantaneous state vector as $A_1 = (1,0,0, \dots ,0)$ for A_1TrM is switched ON.

III. Let A_iTr(M)=a_1,a_2….a_n will get a Triangular vector.

IV. Adding the corresponding concepts of the three expert's opinions, we call it the sum of A_iTr(M).

V. The threshold operation is denoted by (→). A_1Tr(M) Max (weight).

VI. Suppose A_1Tr(M) Max (weight)=A_2 then consider A_2Tr(M) weight is the ON attribute Triangular vector.

VII. Find A_2Tr(M).

VIII. The threshold operation is denoted by (→). ie., A_2Tr(M)Max(weight). That is by replacing a_i by 2 if a_i is the maximum weight of the Triangular node.

IX. This procedure is repeated till we get a limit cycle or a fixed point.

Step 6. Obtain the total weightage and find the rank of the TrFCM.

4.3 | Methods of Determination of the Hidden Pattern of TrFCM

Step 1. In this step, prepare a (n×n) fuzzy matrix called the Connection matrix Tr(M) by using linguistic variables Very Low (VL), Low (L), Medium (M), Very High (VH) and High (H) respectively.

Tr(M) =

	T_rC_1	$_{Tr}C_2$	$_{Tr}C_3$	$_{Tr}C_4$	$_{Tr}C_5$	$_{Tr}C_6$	$_{Tr}C_7$	$_{Tr}C_8$	$_{Tr}C_9$	$_rC_{10}$
$_{Tr}C_1$	O	H	VH	L	H	VL	L	H	M	L
$_{Tr}C_2$	M	O	H	VH	L	H	M	H	H	L
$_{Tr}C_3$	H	L	O	L	VL	H	VH	M	L	VL
$_{Tr}C_4$	H	VH	L	O	M	H	H	H	L	M
$_{Tr}C_5$	M	VL	L	VL	O	H	L	M	VH	VL
$_{Tr}C_6$	H	M	L	M	L	O	VL	M	H	VH
$_{Tr}C_7$	M	H	VH	M	VL	L	O	VL	M	H
$_{Tr}C_8$	L	H	VL	M	VL	H	M	O	H	VH
$_{Tr}C_9$	H	L	VL	H	M	VL	L	L	O	VH
$_{Tr}C_{10}$	L	H	VL	H	M	H	L	VL	VH	O

.

Step 2. The following matrix is the Weithtage Matrix related to the Connection matrix Tr(M). By using Triangular Fuzzy Numbers (0, 0, 0.25) (0, 0.25, 0.50), (0.25,0.5, 0.75), (0.5, 0.75,1), (0.75, 1, 1) respectively prepare Weithtage of the Matrix.

PC_1	0	(0.5,0.75,1)	(0.75,1,1)	(0,0.25,0.5)	(0.5,0.75,1)	(0,0,0.25)	(0,0.25,0.5)	(0,0.5,0.75)	(0.25,0.5,0.75)	(0,0.25,0.5)
PC_2	(0.25,0.5,0.75)	0	(0.5,0.75,1)	(0.75,1,1)	(0,0.25,0.5)	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.25,0.5,0.75)	(0,0.25,0.5)
PC_3	(0.5,0.75,1)	(0,0.25,0.5)	0	(0,0,0.25)	(0.5,0.75,1)	(0.5,0.75,1)	(0.75,1,1)	(0.25,0.5,0.75)	(0,0.25,0.5)	(0,0,0.25)
PC_4	(0.5,0.75,1)	(0.75,1,1)	(0,0,0.25)	0	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0,0.25,0.5)	(0.25,0.5,0.75)
PC_5	(0.25,0.5,0.75)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	0	(0.5,0.75,1)	(0,0.25,0.5)	(0.25,0.5,0.75)	(0.75,1,1)	(0,0,0.25)
PC_6	(0.5,0.75,1)	(0.25,0.5,0.75)	(0,0,0.25)	(0.25,0.5,0.75)	(0,0.25,0.5)	0	(0,0,0.25)	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.75,1,1)
PC_7	(0.25,0.5,0.75)	(0.5,0.75,1)	(0.75,1,1)	(0.25,0.5,0.75)	(0,0,0.25)	(0,0.25,0.5)	0	(0,0,0.25)	(0.25,0.5,0.75)	(0.5,0.75,1)
PC_8	(0,0.25,0.5)	(0.5,0.75,1)	(0,0,0.25)	(0.25,0.5,0.75)	(0,0,0.25)	(0.5,0.75,1)	(0.25,0.5,0.75)	0	(0.5,0.75,1)	(0.75,1,1)
PC_9	(0.5,0.75,1)	(0,0.25,0.5)	(0,0,0.25)	(0.5,0.75,1)	(0.25,0.5,0.75)	(0,0,0.25)	(0,0.25,0.5)	(0,0.25,0.5)	0	(0.75,1,1)
PC_{10}	(0,0.25,0.5)	(0.5,0.75,1)	(0,0,0.25)	(0.5,0.75,1)	(0.25,0.5,0.75)	(0.5,0.75,1)	(0,0.25,0.5)	(0,0,0.25)	(0.75,1,1)	0

Step 3. In this step, we obtain average matrix Tr(M) using linguistics values for the triangular fuzzy numbers (0, 0, 0.25) (0, 0.25, 0.50), (0.25, 0.5, 0.75), (0.5, 0.75,1), (0.75, 1, 1).

$$\begin{array}{c} PC_1 \\ PC_2 \\ PC_3 \\ PC_4 \\ PC_5 \\ PC_6 \\ PC_7 \\ PC_8 \\ PC_9 \\ PC_{10} \end{array}\begin{bmatrix} 0 & (0.75) & (0.9167) & (0.25) & (0.75) & (0.0833) & (0.25) & (0.75) & (0.5) & (0.25) \\ (0.5) & 0 & (0.75) & (0.9167) & (0.25) & (0.75) & (0.5) & (0.75) & (0.75) & (0.25) \\ (0.75) & (0.25) & 0 & (0.25) & (0.0833) & (0.75) & (0.9167) & (0.5) & (0.25) & (0.0833) \\ (0.75) & (0.9167) & (0.25) & 0 & (0.5) & (0.75) & (0.75) & (0.75) & (0.25) & (0.5) \\ (0.5) & (0.0833) & (0.25) & (0.25) & 0 & (0.75) & (0.25) & (0.5) & (0.9167) & (0.0833) \\ (0.75) & (0.5) & (0.25) & (0.0833) & (0.25) & 0 & (0.0833) & (0.5) & (0.75) & (0.9167) \\ (0.5) & (0.75) & (0.9167) & (0.5) & (0.0833) & (0.25) & 0 & (0.0833) & (0.5) & (0.75) \\ (0.25) & (0.75) & (0.0833) & (0.5) & (0.0833) & (0.75) & (0.5) & 0 & (0.75) & (0.9167) \\ (0.75) & (0.25) & (0.0833) & (0.75) & (0.5) & (0.0833) & (0.25) & (0.25) & 0 & (0.9167) \\ (0.25) & (0.75) & (0.0833) & (0.75) & (0.5) & (0.75) & (0.25) & (0.0833) & (0.9167) & 0 \end{bmatrix}.$$

Step 4. Prepare the Maximum weightage of the Matrix Tr(M) using the average matrix.

$$\begin{array}{c} PC_1 \\ PC_2 \\ PC_3 \\ PC_4 \\ PC_5 \\ PC_6 \\ PC_7 \\ PC_8 \\ PC_9 \\ PC_{10} \end{array}\begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}.$$

Step 5. Find the limit cycle.

Case 1: Let the lack of provide the financial support is ON state i.e., TrC_1 is ON state and other nodes in the OFF state.

Let $A^{(1)} = (1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0)$,

$A^{(1)}Tr(M)_{weight} = \{0,(0.5,0.75,1),(0.75,1,1),(0,0.25,0.5),(0.5,0.75,1),(0,0,0.25),(0,0.25,0.5),(0,0.5,0.75),(0.25,0.5,0.75),(0,0.25,0.5)\}$,

$A^{(1)}Tr(M)_{average} = \{0,0.75,0.9167,0.25,0.75,0.0833,0.25,0.4167,0.5,0.25\}$,

$A_1^{(1)}Tr(M)_{Max.weight} = (0\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0) = A_1^{(1)}$,

$A_1^{(1)}Tr(M)_{weight} = \{(0.5,0.75,1),(0,0.25,0.5),(0,0.25,0.5),(0,0.25,0.5),(0.5,0.75,1),(0.75,1,1),$

$(0.25,0.5,0.75),(0,0.25,0.5),(0,0,0.25)\}$,

$A^{(1)}Tr(M)_{average} = (0.75,0.25,0,0.25,0.0833,0.75,0.9167,0.50,0.25,0.0833)$,

$A^{(1)}Tr(M)_{Max.weight} = (0,0,0,0,0,0,1,0,0,0) = A_2^{(1)}$,

$A_2^{(1)}TrM_{(weight)} = \{(0.25,0.5,0.75),(0.5,0.75,1),(0.75,1,1),(0.25,0.5,0.75),(0,0,0.25),(0,0.25,0.5),$
$0,(0,0,0.25),(0.25,0.5,0.75),(0.5,0.75,1)\}$

$A_2^{(1)}Tr(M)_{(average)} = \{0.5,0.75,0.9167,0.5,0.0933,0.25,0,0.0333,0.5,0.75\}$,

$A_2^{(1)}Tr(M)_{(Max.weight)} = (0\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0) = A_3^{(1)}$,

$\therefore A_3^{(1)} = A_1^{(1)}$,

Case 2: Let the deprived of fundamental rights is ON state.

TrC_2 is ON state and other nodes in the OFF state.

Let $A^{(2)} = (0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0)$,

$$A^{(2)}TrM_{(weight)} = \{(0.25,0.5,0.75),0,(0.75,1,1),(0.75,1,1),(0,0.25,0.5),(0.5,0.75,1),(0.25,0.5,0.75),(0.5,0.75,1),(0.25,0.5,0.75),(0,0.25,0.5)\}$$

$$A^{(2)}TrM_{(average)} = \{0.5,0,0.75,0.9167,0.25,0.75,0.5,0.75,0.75,0.25\}$$

$$A^{(2)}TrM_{(Max.weight)} = (0\ 0\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0) = A_1^{(2)}$$

$$A_1^{(2)}TrM_{(weight)} = \{(0.5,0.75,1),(0.75,1,1),(0,0,0.25),0,(0.25,0.5,0.75),(0.5,0.75,1),(0.5,0.75,1),(0.5,0.75,1),(0,0.25,0.5),(0.25,0.5,0.75)\}$$

$$A_1^{(2)}TrM_{(average)} = \{0.75,0.9167,0.25,0,0.5,0.75,0.75,0.75,0.25,0.5\}$$

$$A_1^{(2)}TrM_{(Max.weight)} = (0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0) = A_2^{(2)}$$

$$A_2^{(2)}TrM_{(weight)} = \{(0.25,0.5,0.75),0,(0.75,1,1),(0.75,1,1),(0,0.25,0.5),(0.5,0.75,1),(0.25,0.5,0.75),(0.5,0.75,1),(0.25,0.5,0.75),(0,0.25,0.5)\}$$

$$A_2^{(2)}TrM_{(average)} = \{0.5,0,0.75,0.9167,0.25,0.75,0.5,0.75,0.75,0.25\}$$

$$A_2^{(2)}TrM_{(Max.weight)} = (0\ 0\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0) = A_3^{(2)}$$

$$\therefore A_1^{(2)} = A_3^{(2)}$$

Case 3: Let the lack of SRS services for free in public hospitals in various parts of India be ON state.

TrC_3 is ON state and other nodes in the OFF state.

Let $A^{(3)} = (0\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0)$,

$$A^{(3)}TrM_{(weight)} = \{(0.5,0.75,1),(0,0.25,0.5),0,(0,0,0.25),(0.5,0.75,1),(0.5,0.75,1),(0.75,1,1),(0.25,0.5,0.75),(0,0.25,0.5),(0,0,0.25)\}$$

$$A_1^{(3)}TrM_{(\text{average})} = \{0.75,0.25,0,0.25,0.0833,0.75,0.9167,0.5,0.25,0.0833\}$$

$$A_1^{(3)}TrM_{(Max.weight)} = (0\ 0\ 0\ 0\ 0\ 0\ 1\ 0\ 0\ 0) = A_1^{(3)}$$

$$A_1^{(3)}TrM_{(weight)} = \{(0.25,0.5,0.75),(0.5,0.75,1),(0.75,1,1),(0.25,0.5,0.75),(0,0,0.25),(0,0.25,0.5),0,(0,0,0.25),(0.25,0.5,0.75),(0.5,0.75,1)\}$$

$$A_1^{(3)}TrM_{(\text{average})} = \{0.5,0.75,0.9167,0.5,0.0833,0.25,0,0.0833,0.5,0.75\}$$

$$A_1^{(3)}TrM_{(Max.weight)} = (0\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0) = A_2^{(3)}$$

$$A_2^{(3)}TrM_{(weight)} = \{(0.5,0.75,1),(0,0.25,0.5),0,(0,0,0.25),(0.5,0.75,1),(0.5,0.75,1),(0.75,1,1),(0.25,0.5,0.75),(0,0.25,0.5),(0,0,0.25)\}$$

$$A_2^{(3)}TrM_{(\text{average})} = \{0.75,0.25,0,0.25,0.0833,0.75,0.9167,0.5,0.25,0.0833\}$$

$$A_2^{(3)}TrM_{(Max.weight)} = (0\ 0\ 0\ 0\ 0\ 0\ 1\ 0\ 0\ 0) = A_3^{(3)}$$

$$\therefore A_3^{(3)} = A_1^{(3)}$$

Do the process for all 10 cases

Table 2. Weightage of the Attributes.

Attributes	$_{Tr}C_1$	$_{Tr}C_2$	$_{Tr}C_3$	$_{Tr}C_4$	$_{Tr}C_5$	$_{Tr}C_6$	$_{Tr}C_7$	$_{Tr}C_8$	$_{Tr}C_9$	$_{Tr}C_{10}$
(1 0 0 0 0 0 0 0 0 0)	0.5	0.75	0.9167	0.5	0.0833	0.25	0	0.0833	0.5	0.75
(0 1 0 0 0 0 0 0 0 0)	0.5	0	0.75	0.9167	0.25	0.75	0.5	0.75	0.75	0.25
(0 0 1 0 0 0 0 0 0 0)	0.75	0.25	0	0.25	0.0833	0.75	0.9167	0.5	0.25	0.0833
(0 0 0 1 0 0 0 0 0 0)	0.75	0.9167	0.25	0	0.5	0.75	0.75	0.75	0.25	0.0833
(0 0 0 0 1 0 0 0 0 0)	0.25	0.75	0.0833	0.75	0.5	0.75	0.25	0.0833	0.9167	0
(0 0 0 0 0 1 0 0 0 0)	0.75	0.25	0.0833	0.75	0.5	0.0833	0.25	0.25	0	0.9167
(0 0 0 0 0 0 1 0 0 0)	0.5	0.75	0.9167	0.5	0.0833	0.25	0	0.0833	0.5	0.75
(0 0 0 0 0 0 0 1 0 0)	0.75	0.25	0.0833	0.75	0.5	0.0833	0.25	0.25	0	0.9167
(0 0 0 0 0 0 0 0 1 0)	0.75	0.25	0.0833	0.75	0.5	0.0833	0.25	0.25	0	0.9167
(0 0 0 0 0 0 0 0 0 1)	0.75	0.25	0.0833	0.75	0.5	0.0833	0.25	0.25	0	0.9167
Total weight	6.25	4.4167	3.2499	5.9167	3.4999	3.8332	3.4167	3.2499	3.1667	5.5834
Total average weight	0.625	0.44167	0.32499	0.59167	0.34999	0.38332	0.34167	0.32499	0.31667	0.55834

5 | Results

From the above calculations, we come to an understanding that the categories TrC_1 Lack of providing financial support>TrC_4 No proof of ID and address>TrC_{10} No share in property>TrC_2Deprived of fundamental rights>TrC_6-Lack of admission to school and colleges>TrC_5-Lack of relations> TrC_7-Lack of medical facilities>TrC_3-Lack of SRS services for free in public hospitals in various parts of India > TrC_8-Lack of employment opportunities>TrC_9-Lack of shelter>TrC_{10}-No share in property.

From the above table, using a new fuzzy model TrFCM we get the ranking for the major problems of Transgender as follows;

RANK 1-Lack of provide financial support(0.625), RANK 2-Deprived in fundamental rights (0.59167), RANK 3-No share in property (0.55834), RANK -4 Deprived of fundamental rights (0.44167), RANK 5-Lack of joining to school and colleges (0.38332), RANK 6-Lack of shelter (0.34999), RANK 7-Lack of medical facilities (0.34167), RANK 8-Lack of Sex Reassignment Surgery (SRS)(0.32999), RANK 9-Lack of employment opportunities (0.32319) and RANK 10-No share in property (0.31667) as shown in the below pie-chart.

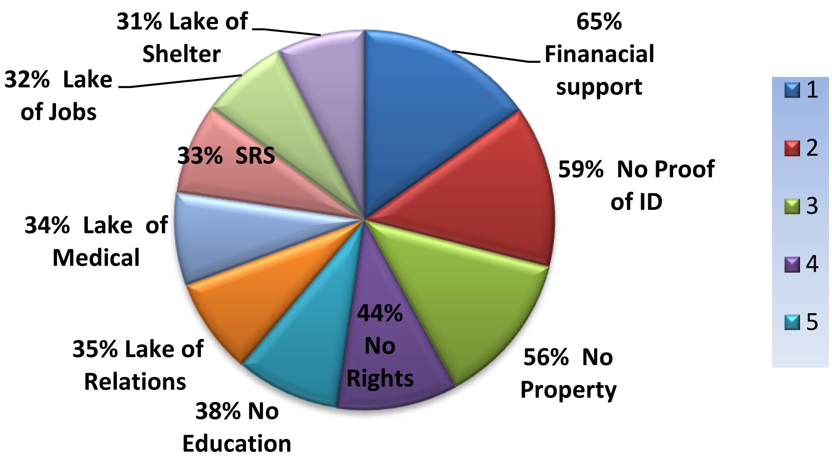

Fig. 2. Pie-chart for ranking of TrFCM.

6 | Conclusion Based on TrFCM

In the study, we find that 63% of the Transgenders lack of financial support, 59% expressed that they do not have ID and address proof; 55% expressed that they do not have a share in the property; 44% expressed that they are deprived of fundamental of rights, 38% of the Transgenders expressed that they not admitted in schools and colleges; 35% expressed that they have lack relations; 34% expressed that they medical facilities; 33% expressed that they free SRS services (SRS–Sex Reassignments Surgery), 32% percent expressed that they lack employment opportunities and 31% expressed that they suffer due to lack of shelter. Thus, the intensity of the issues is quantified, and solutions are sought accordingly.

6.1 | Suggestions Based on TrFCM

There should be research studies worldwide that bring to light their problems, their rights as humans so that the community accepts them as any other person by providing all the rehabilitation measures in the field of health, awareness, education, nutrition, safe sex, shelter, family life and employment. The government can also reserve seats for the representatives of the Transgenders and persons with disability as we have a representation for the minority Anglo-Indian Community in the state Parliament.

Author Contributions

Appasamy Saraswathi conceptualized the study, developed the methodology, and wrote the introduction. Seyed Ahmad Edalatpanah contributed to the mathematical formulation and data analysis. Sanaz Hami Hassan Kiyadeh performed calculations, analyzed data from the transgender population, and reviewed the manuscript. All authors contributed to reviewing and editing the final paper.

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Data Availability

The data used in this study can be made available upon reasonable request from the corresponding author.

Conflicts of Interest

The authors declare no conflicts of interest in relation to this study.

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