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# A Study on DEMATEL Approach Under Uncertainty Environments

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**ABSTRACT**

A fuzzy set is a mathematical construct that assigns a membership grade to each element within a universe of discourse, representing the degree to which the element belongs to the set. This approach extends classical binary logic by allowing continuous values between 0 and 1, making it a natural framework for handling uncertainties and vague concepts often expressed in natural language. Fuzzy sets are particularly powerful in modelling real-world scenarios where ambiguity and imprecision are inherent, such as in human decision-making, linguistic expressions, and complex systems. This paper introduces a novel application of fuzzy logic by proposing a fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) method. DEMATEL is a well-established technique used to analyse cause-and-effect relationships within complex systems. Still, its traditional form relies on crisp values, which may not adequately capture the inherent uncertainties in real-world data. Our proposed method integrates triangular fuzzy numbers into the DEMATEL framework, enabling the representation and analysis of data with imprecision and vagueness. Specifically, we apply the fuzzy DEMATEL approach to study the cause-and-effect relationships among factors affecting transgender individuals, a population often marginalized and underrepresented in research. By leveraging triangular fuzzy numbers, our method provides a more nuanced and realistic representation of the uncertainties and complexities in the data. This approach not only enhances the accuracy of the analysis but also offers a meaningful way to interpret vague or subjective information, ultimately contributing to more informed decision-making and policy development for transgender communities.

## 1. Introduction

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) method is a robust analytical tool for identifying and analyzing causal relationships among criteria within complex systems. Originating from the Geneva Research Center of the Battelle Memorial Institute, DEMATEL is grounded in digraph theory, enabling the classification of factors into cause-and-effect groups. This method is particularly effective in constructing and analyzing structural models, facilitating the extraction of relationships between intricate criteria. DEMATEL has gained significant traction in

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recent years due to its ability to visually represent and elucidate complex causal structures, aiding decision-making processes.

An empirical study was conducted to demonstrate the applicability of the DEMATEL method. Building on Zadeh's [1] proposition, linguistic assessments were employed instead of numerical values to evaluate criteria, leveraging linguistic variables to address the inherent imprecision in decision-making. This approach aligns with the principles of fuzzy logic, which provides a more nuanced framework for handling uncertainty. The integration of fuzzy logic with DEMATEL, as proposed by Wu *et al.,* [2], has proven effective in segmenting competencies and enhancing decision-making in fuzzy environments. Gabus and Fontela [3] further established DEMATEL as a reliable technique for decision-making, while subsequent studies by Yang and Tzeng [4] and Lin *et al.,* [5] utilized DEMATEL to analyze cause-and-effect relationships among evaluation criteria.

Hosseini and Tarokh [6] advanced the application of DEMATEL by incorporating interval type-2 fuzzy sets to capture the uncertainty associated with linguistic assessments. Similarly, Abbasi *et al.,* [7] employed DEMATEL to identify critical risk factors affecting knowledge networks, such as policy risk, knowledge asset risk, and culture risk. Devadoss and Felix [8] extended the method to handle pairwise criteria expressed as triangular fuzzy numbers, demonstrating its suitability for group decision-making in fuzzy environments. Chen-Yi *et al.,* [9] introduced a fuzzy DEMATEL methodology to model customer choice behavior, while Gharakhani *et al.,* [10] integrated fuzzy AHP with DEMATEL to analyze supplier selection criteria. Kuei-Hu Chang *et al.,* [11] simplified risk evaluation algorithms by combining fuzzy ordered weighted averaging (OWA) with DEMATEL.

Recent advancements have further expanded the scope of DEMATEL and fuzzy logic applications. Vidhya and Saraswathi [12] explored using fuzzy Floyd-Warshall and fuzzy rectangular algorithms for shortest-path problems. Broumi [13] developed an efficient approach for time-dependent shortest-path problems under Fermat Ean neutrosophic environments. Prakash and Appasamy [14] proposed optimal solutions for fully spherical fuzzy linear programming problems, while Saraswathi [15] introduced a fuzzy-trapezoidal DEMATEL approach for decision-making under uncertainty. Dharmaraj and Appasamy [16] applied a modified Gauss elimination technique to separable fuzzy nonlinear programming problems. Vidhya and Saraswathi [17] utilized an A* search algorithm for shortest-path problems under interval-valued Pythagorean fuzzy environments. Saraswathi [18] addressed minimal flow problems and proposed a triangular fuzzy clustering model under uncertainty. Yuvashri and Saraswathi [19] developed a novel multi-objective linear programming model under spherical fuzzy environments, and Karthick *et al.,* [20] applied neutrosophic linear fractional programming with denominator objective restriction. Saraswathi and Nedumaran [21] conducted a comparative study on critical path identification using triangular fuzzy numbers.

The paper is organized as follows: Section one provides an introduction and literature review of DEMATEL. Section two discusses the concept of fuzzy numbers, arithmetic operations, and related results. Section three introduces the fuzzy DEMATEL method and performs calculations based on data collected through a survey among transgender individuals. Section four presents a numerical example to demonstrate the efficiency of the proposed method. Finally, section five offers conclusions and suggestions based on the discussion.

## 2. Preliminaries

*Definition 1*. A fuzzy set $\widetilde{A}$ is a subset of a universe of discourse *X*, which is characterized by a membership function $\widetilde{A}: X \to [0,1]$. The function value $\widetilde{A}(x)$ is called the membership value, which represents the degree of truth that *x* is an element of a fuzzy set $\widetilde{A}$. It is assumed that $\widetilde{A}(x) \in [0,1]$

where $\widetilde{A}(x) = 0$ reveals that *x* belongs completely to $\widetilde{A}$, while indicates that *x* does not belong to the fuzzy set $\widetilde{A}$.

*Definition 2*. A fuzzy set $\widetilde{A}$ defined on the set of real numbers *R* is a fuzzy number if its membership function $\widetilde{A} : R \to [0,1]$ has the following characteristics [22]:

i. $\widetilde{A}$ is convex, that is $\widetilde{A}(\lambda x_1 + (1-\lambda x_2) \geq \min\{\widetilde{A}(x_1), \widetilde{A}(x_2)\}$, for all $x_1, x_2 \in R$ and $\lambda \in [0,1]$.

ii. $\widetilde{A}$ is normal i.e. there exists an $x \in R$ such that $\widetilde{A}(x) = 1$.

iii. $\widetilde{A}$ is piecewise continuous.

*Definition 3*. A fuzzy number $\widetilde{A}$ on *R* is a triangular fuzzy number (TFN) or linear fuzzy number if its membership function $\widetilde{A} : R \to [0,1]$ has the following characteristics [1]:

$$\widetilde{A}(x) = \begin{cases} \dfrac{x - a_1}{a_2 - a_1}, \; for\, a_1 \leq x \leq a_2 \\ \dfrac{a_3 - x}{a_3 - a_2}, \; for\, a_2 \leq x \leq a_3 \\ 0, \qquad elsewhere \end{cases}$$

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

*2.1 Operations on Triangular Fuzzy Numbers*

For arbitrary triangular fuzzy numbers $\tilde{A} = (a_1, a_2, a_3)$, $\tilde{B} = (b_1, b_2, b_3)$, and $* = \{+, -, \times, \div\}$ the arithmetic operations on the triangular fuzzy numbers. For any two triangular fuzzy numbers $\widetilde{A} = (a_1, a_2, a_3)$, and $\widetilde{B} = (b_1, b_2, b_3)$, we ca define the following operations [23]:

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 $(\otimes): k \otimes A = (ka_1, ka_2, ka_3), k \in R, k \geq 0$;
$A \otimes b = (a_1 b, a_2 b, a_3 b), a_1 \geq 0, a_2 \geq 0, a_3 \geq 0$

iv. Division $(\div)$: $(A)^{-1} = (a_1, b_1, c_1)^{-1} \cong \left(\dfrac{1}{c_1}, \dfrac{1}{b_1}, \dfrac{1}{a_1}\right), a_1 > 0, b_1 > 0, c_1 > 0$;
$A \div B \cong \left(\dfrac{a_1}{c_2}, \dfrac{b_1}{b_2}, \dfrac{c_1}{a_2}\right), a_1 \geq 0, a_2 > 0$

*Definition 4.* Linguistic variables are used as variables whose values are not numbers but linguistic terms. The linguistic variables approach usually converts fuzzy data into the Crisp Scales (CFCS) method based on determining the maximum and minimum of the fuzzy range. The total score can be found as a weighted average according to membership functions. Let $A_{ij} = (l_{ij}^n, m_{ij}^n, n_{ij}^n)$ mean the degree of criterion that affects criterion *j* and fuzzy questionnaires *n* where *n*=1,2,3,…,*p*.

*Lemma 1.* Suppose the square matrix $S = [s_{ij}]$ is given, where $0 \leq s_{ij} \leq 1$. Then, the term $M = S + S^2 + ... + S^k$ where $k \to \infty$ can be estimated by $M = S(1-S)^{-1}$.

*Proof*:

$$Me = S + S^2 + \ldots + S^k \Rightarrow S \times Me$$
$$= S^2 + S^3 + \ldots + S^{k+1} \Rightarrow Me - S \times Me$$
$$= Me(1-S) = (S + S^2 + \ldots + S^k) - (S^2 + S^3 + \ldots + S^{k+1}) \Rightarrow S - S^{k+1}$$
$$= S(1-S^k) \Rightarrow Me \times (1-S)$$
$$= S \times (1-S^k) \Rightarrow Me$$
$$= \frac{S \times (1-S^k)}{1-S}$$

where $k \to \infty$ then $S^k \to 0$.

Therefore, $Me = \frac{S}{1-S} = S(1-S)^{-1} = M$.

## 3. Application of the DEMATEL method to analyze the problems of cause and effect of transgender

Transgender people experience some kinds of mental health problems that non-transgender people do. However, the stigma, discrimination, and internal conflict that many transgender people experience may place them at increased risk for certain mental health problems. Discrimination, lack of social support, and inadequate access to care can exacerbate mental health problems in transgender people, while support from peers, family, and helping professionals may act as protective factors. In our study, we consider the following problems faced by transgender people based on our interview and survey:

$C_1$ - Poverty;
$C_2$ - Identity;
$C_3$ - Estrangement from family Harassment;
$C_4$ - Harassment;
$C_5$ - Mental illness (Psychological distress);
$C_6$ - Homelessness;
$C_7$ - Marginalization &social exclusion;
$C_8$ - Discrimination;
$C_9$ - Poor economic condition;
$C_{10}$ - Drug addiction;
$C_{11}$ - Crimes and violence;
$C_{12}$ - Legal Injustice.

### *3.1 The Survey was based on the following Questionnaire*

i. What is your perspective of transgender, and what is your sex preference?
ii. Did the puberty blockers and the hormone treatments help you transition into a more female body?
iii. Do you hate your body? Have you ever regretted who you are?
iv. Do you always remember wanting, thinking, and believing from your earliest possible memories?
v. Are you a girl/boy?
vi. Before transitioning, have you been in relationships with the same sex or opposite sex?
vii. If you have, what were the challenges you've had to come across?
viii. Have you been sexually harassed?

ix. Have you been physically abused?
x. Did you get an education and a job? Are you financially supported?
xi. If you can, will you give birth to a baby? How would you react if your baby grew up as a Tran?
xii. Man, or a Tran's woman?
xiii. What was the most helpful resource you found when learning about your transition?
xiv. What was the hardest thing to adapt?
xv. Are you aware of the organizations that are to help you people? If yes, how effective are they in this country?
xvi. If you have a chance to change your gender, will you?

*3.2 Application of the DEMATEL method*

*Step 1*: Preparation of the assessment data matrix.

Experts prepare sets of pairwise comparisons regarding effects and direction between criteria. Then, the initial data can be obtained as the direct-relation matrix, which is an *n*x*n* matrix *Z* where each element $z_{ij}$ is denoted as the degree to which criterion *i* affects the criterion *j* [24]. In this step, experts use the linguistic variables [25].

*Step 2*: Generating the fuzzy linguistic scale.

The pairwise comparison scale (Table 1) may be designated with five levels, where the scores of 0.07, 0.2, 0.4, 0.6, and 0.8 represent "Very Low influence", "Low influence", "Medium Influence", "High influence", and "Very high influence" respectively.

**Table 1**
The Fuzzy linguistic scale

| Linguistic terms | Influence scores | Triangular fuzzy numbers |
|---|---|---|
| Very Low | 0.07 | (0, 0.07, 0.20) |
| Low | 0.2 | (0, 0.20, 0.40) |
| Medium | 0.4 | (0,20, 0.40, 0.60) |
| High | 0.6 | (0.40, 0.60, 0.80) |
| Very High | 0.8 | (0.6, 0.8, 1) |

*Step 3*: Construction of the initial direct-relation matrix.

The initial direct-relation matrix [25-28] is *n*x*n* matrix obtained by pairwise comparisons in terms of influences and directions between criteria, in which $z_{ij}$ is denoted as the degree to which the criterion *i* affects the criterion *j*, i.e., $Z = [z_{ij}]_{n \times n}$ . The initial direct-relation matrix is generated using triangular fuzzy numbers (0, 0,0.20), (0, 0.20,0.40), (0.20, 0.40, 0.60), (0.40,0.60,0.80), (0.60, 0.80, 1).

*Step 4*: Preparation of the generalized direct-relation matrix.

By using triangular fuzzy numbers, the generalized direct-relation matrix is prepared. In this study, we implemented triangular fuzzy numbers (TFNs) as the most popular ones. TFNs are fuzzy numbers represented with three points.

*Step 5*: Calculating normalized direct-relation matrix.

The normalized direct-relation matrix $S = [s_{ij}]_{n \times n}$; $0 \le s_{ij} \le 1$ is obtained through the following equations in which all diagonal elements are equal to zero [26].

$$K = \frac{1}{\max\limits_{1 \le i \le n} \sum\limits_{j=1}^{n} a_{ij}} i, j = 1, 2, ..., n$$

*Step 6*: Generating the total-relation matrix.

The total relation matrix is defined using the sum of rows and columns within the total-relation matrix, where *I* is denoted as the identity matrix.

$$M = \lim_{k\to\infty}\left(I + S_1 + S_2 + ... + S_k\right) = \left(I - S\right)^{-1} = \left[m_{ij}\right]_{n\times n}$$

*Step 7*: Generating a causal diagram.

The sum of rows and the sum of the columns are separately denoted as vector *D* and vector *R* [27]. Finally, a causal and effect diagram can be acquired by mapping the dataset of *(D+R, D-R),* where the horizontal axis *(D+R)* is made by adding *D* to *R*, and the vertical axis *(D-R)* is made by subtracting R from *D*.

$$M = [m_{ij}], i, j = 1, 2, ..., n$$

$$D = \left[\sum_{j=1}^{n} m_{ij}\right]_{n\times 1} = [t_i]_{n\times 1}$$

$$R = \left[\sum_{i=1}^{n} m_{ij}\right]_{1\times n} = [t_j]_{1\times n}$$

## 4. Numerical example

*Step 1*: Preparation of the assessment data matrix.

This step prepares an *n* × *n* fuzzy matrix for each corresponding expert. The assessment data matrix (Table 2) is generated by using linguistic variables "Very Low" (VL), "Low" (L), "Medium" (M), "Very High" (VH) and "High" (H) [28].

**Table 2**
Assessment data table

| Crit. | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $C_1$ | 0 | VH | H | M | VH | H | VL | H | L | M | L | VL |
| $C_2$ | H | 0 | H | VH | M | VH | L | M | VL | H | M | H |
| $C_3$ | M | VL | 0 | H | VL | VL | VH | L | VL | M | M | VH |
| $C_4$ | VH | H | L | 0 | H | M | VH | H | H | H | VH | VL |
| $C_5$ | H | M | H | VL | 0 | H | VL | L | H | L | H | VH |
| $C_6$ | VH | H | H | VH | H | 0 | VL | M | H | VH | M | H |
| $C_7$ | VL | L | M | VH | H | M | 0 | H | VH | M | H | VH |
| $C_8$ | M | L | VL | H | L | L | H | 0 | L | VH | L | H |
| $C_9$ | VH | L | M | H | VH | H | L | H | 0 | L | VH | H |
| $C_{10}$ | L | VL | L | VH | M | H | L | H | L | 0 | M | VH |
| $C_{11}$ | H | VH | M | VH | H | M | L | H | VH | VL | 0 | H |
| $C_{12}$ | M | H | L | H | VH | M | VL | M | VL | L | VL | 0 |

*Step 2*: Generating the linguistic scale.

For this step, the Linguistic scale table is defined as shown in Table 1.

*Step 3*: Preparation of the initial direct-relation matrix.

Using triangular fuzzy numbers (0,0,0.20), (0,0.20,0.40), (0.20,0.40,0.60), (0.40,0.60,0.80), (0.60,0.80,1) respectively, initial direct-relation matrix is prepared.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ |
|---|---|---|---|---|---|---|
| $C_1$ | 0 | (0.60, 0.80, 1) | (0.40, 0.60, 0.80) | (0,20, 0.40, 0.60) | (0.60, 0.80, 1) | (0.40, 0.60, 0.80) |
| $C_2$ | (0.40, 0.60, 0.80) | 0 | (0.40, 0.60, 0.80) | (0.60, 0.80, 1) | (0,20, 0.40, 0.60) | (0.60, 0.80, 1) |
| $C_3$ | (0,20, 0.40, 0.60) | (0, 0, 0.20) | 0 | (0.40, 0.60, 0.80) | (0, 0, 0.20) | (0, 0, 0.20) |
| . $C_4$ | (0.60, 0.80, 1) | (0.40, 0.60, 0.80) | (0, 0.20, 0.40) | 0 | (0.40, 0.60, 0.80) | (0,20, 0.40, 0.60) |
| $C_5$ | (0.40, 0.60, 0.80) | (0,20, 0.40, 0.60) | (0.40, 0.60, 0.80) | (0, 0, 0.20) | 0 | (0.40, 0.60, 0.80) |
| $C_6$ | (0.60, 0.80, 1) | (0.40, 0.60, 0.80) | (0.40, 0.60, 0.80) | (0.60, 0.80, 1) | (0.40, 0.60, 0.80) | 0 |
| $C_7$ | (0, 0,0.20) | (0, 0.20, 0.40) | (0,20, 0.40, 0.60) | (0.60, 0.80, 1) | (0.40, 0.60, 0.80) | (0,20, 0.40, 0.60) |
| $C_8$ | (0,20, 0.40, 0.60) | (0, 0.20, 0.40) | (0, 0, 0.20) | (0.40, 0.60, 0.80) | (0, 0.20, 0.40) | (0, 0, 0.20) |
| $C_9$ | (0.60, 0.80, 1) | (0, 0.20, 0.40) | (0,20, 0.40, 0.60) | (0.40, 0.60, 0.80) | (0.60, 0.80, 1) | (0.40, 0.60, 0.80) |
| $C_{10}$ | (0, 0.20, 0.40) | (0, 0, 0.20) | (0, 0.20, 0.40) | (0.60, 0.80, 1) | (0,20, 0.40, 0.60) | (0.40, 0.60, 0.80) |
| $C_{11}$ | (0.40, 0.60, 0.80) | (0.60, 0.80, 1) | (0,20, 0.40, 0.60) | (0.40, 0.60, 0.80) | (0.40, 0.60, 0.80) | (0,20, 0.40, 0.60) |
| $C_{12}$ | (0,20, 0.40, 0.60) | (0.40, 0.60, 0.80) | (0, 0.20, 0.40) | (0.40, 0.60, 0.80) | (0.60, 0.80, 1) | (0,20, 0.40, 0.60) |

| | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ |
|---|---|---|---|---|---|---|
| $C_1$ | (0, 0, 0.20) | (0.40, 0.60, 0.80) | (0, 0.20, 0.40) | (0,20, 0.40, 0.60) | (0, 0.20, 0.40) | (0, 0, 0.20) |
| $C_2$ | (0, 0.20, 0.40) | (0,20, 0.40, 0.60) | (0, 0, 0.20) | (0.40, 0.60, 0.80) | (0,20, 0.40, 0.60) | (0.40, 0.60, 0.80) |
| $C_3$ | (0.60, 0.80, 1) | (0, 0.20, 0.40) | (0, 0, 0.20) | (0,20, 0.40, 0.60) | (0,20, 0.40, 0.60) | |
| $C_4$ | (0.60, 0.80, 1) | (0.40, 0.60, 0.80) | (0.40, 0.60, 0.80) | (0, 0.20, 0.40) | (0.60, 0.80, 1) | (0, 0, 0.20) |
| $C_5$ | (0, 0, 0.20) | (0, 0.20, 0.40) | (0.40, 0.60, 0.80) | (0.40, 0.60, 0.80) | (0.40, 0.60, 0.80) | |
| $C_6$ | (0, 0, 0.20) | (0,20, 0.40, 0.60) | (0.40, 0.60, 0.80) | (0.60, 0.80, 1) | (0,20, 0.40, 0.60) | (0.40, 0.60, 0.80) |
| $C_7$ | 0 | (0.40, 0.60, 0.80) | (0.60, 0.80, 1) | (0,20, 0.40, 0.60) | (0.40, 0.60, 0.80) | |
| $C_8$ | (0.40, 0.60, 0.80) | 0 | (0, 0.20, 0.40) | (0.60, 0.80, 1) | (0, 0.20, 0.40) | (0.40, 0.60, 0.80) |
| $C_9$ | (0, 0.20, 0.40) | (0.40, 0.60, 0.80) | 0 | (0, 0.20, 0.40) | (0.60, 0.80, 1) | (0.40, 0.60, 0.80) |
| $C_{10}$ | (0, 0.20, 0.40) | (0.40, 0.60, 0.80) | (0, 0.20, 0.40) | 0 | (0,20, 0.40, 0.60) | |
| $C_{11}$ | (0, 0.20, 0.40) | (0.40, 0.60, 0.80) | (0.60, 0.80, 1) | (0, 0, 0.20) | 0 | (0.40, 0.60, 0.80) |
| $C_{12}$ | (0, 0, 0.20) | (0,20, 0.40, 0.60) | (0, 0, 0.20) | (0, 0.20, 0.40) | (0, 0, 0.20) | 0 |

*Step 4*: Preparation of the Generalized Direct-Relation Matrix.
The generalized direct-relation matrix is presented below.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $C_1$ | 0 | 0.8 | 0.6 | 0.4 | 0.8 | 0.6 | 0.067 | 0.6 | 0.2 | 0.4 | 0.2 | 0.067 |
| $C_2$ | 0.6 | 0 | 0.6 | 0.8 | 0.4 | 0.8 | 0.2 | 0.4 | 0.067 | 0.6 | 0.4 | 0.6 |
| $C_3$ | 0.4 | 0.067 | 0 | 0.6 | 0.067 | 0.067 | 0.8 | 0.2 | 0.067 | 0.4 | 0.4 | 0.8 |
| $C_4$ | 0. | 0.6 | 0.2 | 0 | 0.6 | 0.4 | 0.8 | 0.6 | 0.6 | 0.6 | 0.2 | 0.067 |
| $C_5$ | 0.6 | 0.4 | 0.6 | 0.067 | 0 | 0.6 | 0.067 | 0.2 | 0.6 | 0.2 | 0.6 | 0.8 |
| $C_6$ | 0.8 | 0.6 | 0.6 | 0.8 | 0.6 | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 0.4 | 0.6 |
| $C_7$ | 0.067 | 0.2 | 0.4 | 0.8 | 0.6 | 0.4 | 0 | 0.6 | 0.8 | 0.4 | 0.6 | 0.8 |
| $C_8$ | 0.4 | 0.2 | 0.067 | 0.6 | 0.2 | 0.2 | 0.6 | 0 | 0.2 | 0.8 | 0.2 | 0.6 |
| $C_9$ | 0.8 | 0.2 | 0.4 | 0.6 | 0.8 | 0.6 | 0.2 | 0.6 | 0 | 0.2 | 0.2 | 0.6 |
| $C_{10}$ | 0.2 | 0.067 | 0.2 | 0.8 | 0.4 | 0.6 | 0.2 | 0.6 | 0.2 | 0 | 0.4 | 0.8 |
| $C_{11}$ | 0.6 | 0.8 | 0.4 | 0.6 | 0.6 | 0.4 | 0.067 | 0.6 | 0.8 | 0.067 | 0 | 0.6 |
| $C_{12}$ | 0.4 | 0.6 | 0.2 | 0.6 | 0.8 | 0.4 | 0.067 | 0.4 | 0.067 | 0.2 | 0.067 | 0 |

Step 5: Preparation of the normalization matrix. The normalization matrix is performed as follows.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $C_1$ | 0 | 0.12765 | 0.09574 | 0.06383 | 0.12765 | 0.09574 | 0.0107 | 0.09574 | 0.03191 | 0.06383 | 0.03191 | 0.0107 |
| $C_2$ | 0.09574 | 0 | 0.09574 | 0.12765 | 0.06383 | 0.12765 | 0.03191 | 0.06383 | 0.0107 | 0.09574 | 0.06383 | 0.09574 |
| $C_3$ | 0.06383 | 0.0107 | 0 | 0.09574 | 0.0107 | 0.0107 | 0.12765 | 0.03191 | 0.0107 | 0.06383 | 0.06383 | 0.12765 |
| $C_4$ | 0.12765 | 0.09574 | 0.03191 | 0 | 0.09574 | 0.06383 | 0.12765 | 0.09574 | 0.09574 | 0.09574 | 0.03191 | 0.0107 |
| $C_5$ | 0.09574 | 0.06383 | 0.09574 | 0.0107 | 0 | 0.09574 | 0.0107 | 0.03191 | 0.09574 | 0.03191 | 0.09574 | 0.12765 |
| $C_6$ | 0.12765 | 0.6 | 0.09574 | 0.12765 | 0.09574 | 0 | 0.03191 | 0.06383 | 0.09574 | 0.12765 | 0.06383 | 0.09574 |
| $C_7$ | 0.0107 | 0.03191 | 0.06383 | 0.12765 | 0.09574 | 0.06383 | 0 | 0.09574 | 0.12765 | 0.06383 | 0.09574 | 0.12765 |
| $C_8$ | 0.06383 | 0.03191 | 0.0107 | 0.09574 | 0.03191 | 0.03191 | 0.09574 | 0 | 0.03191 | 0.12765 | 0.03191 | 0.09574 |
| $C_9$ | 0.12765 | 0.03191 | 0.06383 | 0.09574 | 0.12765 | 0.09574 | 0.03191 | 0.09574 | 0 | 0.03191 | 0.03191 | 0.09574 |
| $C_{10}$ | 0.03191 | 0.0107 | 0.03191 | 0.12765 | 0.06383 | 0.09574 | 0.03191 | 0.09574 | 0.03191 | 0 | 0.06383 | 0.12765 |
| $C_{11}$ | 0.09574 | 0.12765 | 0.06383 | 0.09574 | 0.09574 | 0.06383 | 0.0107 | 0.09574 | 0.12765 | 0.0107 | 0 | 0.09574 |
| $C_{12}$ | 0.06383 | 0.09574 | 0.03191 | 0.09574 | 0.12765 | 0.06383 | 0.0107 | 0.06383 | 0.0107 | 0.03191 | 0.0107 | 0 |

*Step 6*: Computation of the total direct relation matrix. The total relation matrix is determined as follows:

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ | $C_{11}$ | $C_{12}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $C_1$ | 0.111537 | 0.203362 | 0.173188 | 0.180675 | 0.219503 | 0.185661 | 0.077085 | 0.180814 | 0.106097 | 0.155507 | 0.12219 | 0.131505 |
| $C_2$ | 0.21459 | 0.106875 | 0.180962 | 0.257574 | 0.186753 | 0.225353 | 0.106546 | 0.17184 | 0.101866 | 0.196015 | 0.16218 | 0.215899 |
| $C_3$ | 0.141013 | 0.086878 | 0.060411 | 0.190179 | 0.107882 | 0.087854 | 0.172665 | 0.115192 | 0.080604 | 0.129312 | 0.133691 | 0.208076 |
| $C_4$ | 0.255442 | 0.204726 | 0.139162 | 0.158036 | 0.233811 | 0.18833 | 0.194618 | 0.218892 | 0.198065 | 0.201931 | 0.23756 | 0.16361 |
| $C_5$ | 0.200754 | 0.154873 | 0.173204 | 0.133398 | 0.114452 | 0.184064 | 0.067952 | 0.125972 | 0.161281 | 0.115288 | 0.173351 | 0.229787 |
| $C_6$ | 0.261163 | 0.206894 | 0.194305 | 0.272508 | 0.234036 | 0.128725 | 0.09507 | 0.188032 | 0.185506 | 0.232493 | 0.179007 | 0.233341 |
| $C_7$ | 0.147441 | 0.138587 | 0.15137 | 0.259473 | 0.224824 | 0.172662 | 0.077555 | 0.206135 | 0.216297 | 0.161856 | 0.202019 | 0.253948 |
| $C_8$ | 0.254005 | 0.10709 | 0.076421 | 0.196266 | 0.130995 | 0.115838 | 0.143086 | 0.088984 | 0.100996 | 0.194423 | 0.110289 | 0.185777 |
| $C_9$ | 0.13754 | 0.150221 | 0.161409 | 0.229289 | 0.25497 | 0.204916 | 0.104761 | 0.206219 | 0.099794 | 0.137606 | 0.225501 | 0.223498 |
| $C_{10}$ | 0.225487 | 0.101798 | 0.102676 | 0.230483 | 0.167944 | 0.176549 | 0.092679 | 0.181477 | 0.108942 | 0.08687 | 0.14512 | 0.220878 |
| $C_{11}$ | 0.152361 | 0.227322 | 0.159892 | 0.230642 | 0.223885 | 0.178413 | 0.105581 | 0.203918 | 0.207696 | 0.119984 | 0.110029 | 0.221228 |
| $C_{12}$ | 0.06383 | 0.164247 | 0.100551 | 0.182016 | 0.205146 | 0.141741 | 0.061903 | 0.135508 | 0.074529 | 0.108022 | 0.086449 | 0.090672 |

*Step 7*: Generating the causal diagram. In this step, the sum of rows and the columns are separately denoted as vector *D* and vector *R* (Table 3).

**Table 3**
The degree of central role (D+R) and (D-R)

| Crit. | *D* | *R* | *D+R* | *D-R* | Rank |
|---|---|---|---|---|---|
| $C_1$ | 1.847124 | 2.249138 | 4.096262 | -0.40201 | 9 |
| $C_2$ | 2.126153 | 1.852873 | 3.979026 | 0.27328 | 5 |
| $C_3$ | 1.513748 | 1.673551 | 3.187299 | -0.1598 | 8 |
| $C_4$ | 2.394183 | 2.520239 | 4.914422 | -0.12606 | 7 |
| $C_5$ | 1.834376 | 2.304201 | 4.138577 | -0.46983 | 11 |
| $C_6$ | 2.41108 | 1.990097 | 4.401177 | 0.420983 | 3 |
| $C_7$ | 2.212167 | 1.299501 | 3.511668 | 0.912666 | 1 |
| $C_8$ | 1.59797 | 2.022983 | 3.620953 | -0.42501 | 10 |
| $C_9$ | 2.252189 | 1.641673 | 3.893862 | 0.610516 | 2 |
| $C_{10}$ | 1.752956 | 1.839307 | 3.592263 | -0.08635 | 6 |
| $C_{11}$ | 2.214077 | 1.887386 | 4.101463 | 0.326691 | 4 |
| $C_{12}$ | 1.503145 | 2.378219 | 3.881364 | -0.87507 | 12 |

Based on the values shown in Table 2, we can generate the causal diagram in Figure 1.

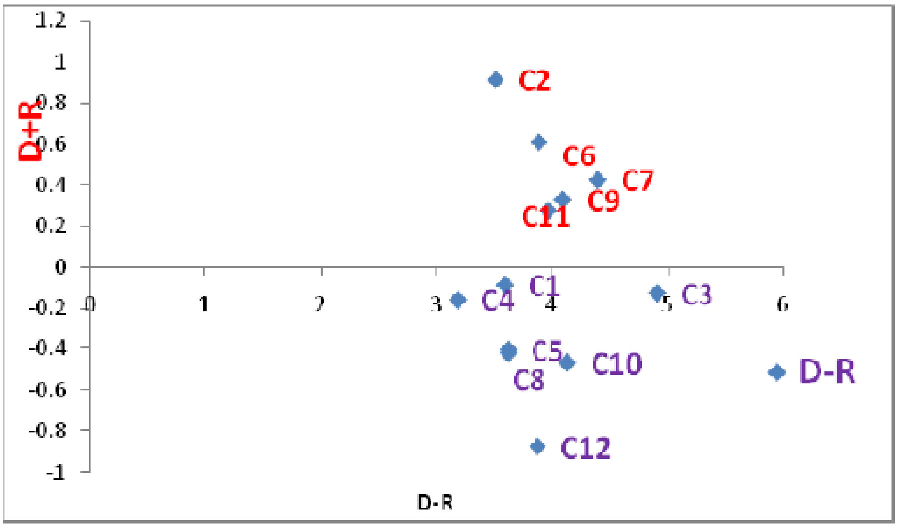


**Fig. 1.** Casual diagram

In Figure 1, D+R is the cause group, and D-R is the effective group.

## 5. Discussion and conclusion

Figure 1 shows that the evaluation criteria were visually divided into the cause group, including the categories $C_2, C_6, C_7, C_9, C_{11}$ and the effect group, which are factors responsible for effective groups of transgender people. It is clear that transgender facing a lot of problems, from the simplest personal relations to the most general social ignorance of the society. Table 3 also reveals the ranking of the fuzzy DEMATEL method attributes $C_7 > C_9 > C_6 > C_{11} > C_2 > C_{10} > C_4 > C_3 > C_1 > C_8 > C_5 > C_{12}$.

The findings presented in Table 3 highlight the multifaceted challenges faced by transgender individuals in their daily lives. A significant factor underpinning these challenges, as identified in this study, is the role of hormonal disorders, which contribute to both physiological and psychological difficulties. If these underlying hormonal issues are not adequately addressed, the well-being and progress of the transgender community will remain hindered. It is imperative to recognize that transgender individuals are entitled to the same fundamental rights as others, including freedom of expression, access to education, healthcare, and public services, and opportunities for employment and political participation. Governments and policymakers must take proactive measures to ensure the implementation of inclusive policies, such as job reservations, educational support, and counseling services, to promote the social and economic integration of transgender individuals. Furthermore, societal acceptance and respect for their dignity must be prioritized to eliminate discrimination and barriers to full social participation.

This study has several limitations that should be acknowledged. First, the research primarily focuses on hormonal disorders as a contributing factor to the challenges faced by transgender individuals, which may overlook other significant social, cultural, and economic determinants. Second, the data used for analysis was limited to specific regions or populations, potentially reducing the generalizability of the findings to broader contexts. Third, the study relied on secondary data and calculations, which may not fully capture the lived experiences and nuanced perspectives of transgender individuals. Future studies should incorporate longitudinal designs and qualitative methods to provide a more comprehensive understanding of these issues.

Future research should explore the intersectionality of factors affecting transgender individuals, including socioeconomic status, cultural norms, and legal frameworks, to develop a more holistic understanding of their challenges. Investigations into the long-term effects of hormonal therapies and their accessibility in different regions could provide valuable insights into improving healthcare outcomes for this population. Additionally, studies focusing on the effectiveness of policy interventions, such as job reservations and educational programs, are needed to evaluate their impact on the social and economic empowerment of transgender individuals. Collaborative research involving transgender communities, healthcare providers, and policymakers is essential to ensure that future initiatives are inclusive, evidence-based, and responsive to the needs of this marginalized group. Finally, exploring global best practices and comparative studies across countries could offer innovative solutions for advancing transgender rights and well-being worldwide.

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**Conflicts of Interest**
The authors declare no conflicts of interest.

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