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REVIEW ON APPLICATION OF FUZZY MATRICES- ATD MATRIX, RTD MATRIX AND CETD MATRIX IN VARIOUS FIELDS

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Abstract : This review of the literature investigates the use of several fuzzy matrices in a variety of domains, such as Initial row data matrix (IRDM), Average time dependent matrix (ATD), Refined time dependent matrix (RTD), and Combined effective time dependent matrix (CETD). This paper studies how these matrices have been employed to model uncertainty and inaccuracy in decision-making processes, pattern recognition, and data analysis. This review seeks to give a thorough overview of the state of knowledge in the field of fuzzy matrix applications by integrating previous research and identifying possible directions for further study.

IndexTerms **- Fuzzy matrix, ATD matrix, IRDM matrix, CETD matrix, RTD matrix.**

I. INTRODUCTION

A fuzzy matrix is a type of matrix in which the elements reflect the degrees of certainty or relationship values, usually within the range [0,1]. In contrast to traditional matrices that comprise accurate numerical values. Fuzzy matrices deal with uncertainty, ambiguity, and inaccuracy, making them practical in several fields such as network analysis, artificial intelligence, and decision-making.

Fuzzy Matrix: Let A = $[a_{11} \cdots a_{1m} \vdots \ddots \vdots a_{n1} \cdots a_{nm}]$ is called fuzzy matrix if and only if $a_{ij} \in [0, 1]$ for $1 \leq i \leq n$ & $1 \leq j \leq m$.

Four categories of fuzzy matrices are distinguished as follows:

Initial Raw Data matrix (IRDM): Raw data itself is an initial raw data matrix. The Initial Row Data Matrix (IRDM) signifies the raw data obtained from a system prior to any change or processing.

Average Time Dependent Matrix (ATD): Average Time Dependent Data (ATD) matrix has been enhanced from Initial Row Data Matrix A = $[a_{ij}]$ by dividing each entry of the raw data matrix by the time period. We have to calculate the average (μj) and Standard Deviation (σj) of every column in the ATD matrix. This matrix is helpful for systems where interactions change dynamically because it shows the average influence or effect of various components across the time.

Refined Time Dependent Matrix (RTD): Using the average μ_j, the Standard Deviation σ_j of the each j^{th} column we chose a parameter α in [0, 1], the Refined Time Dependent Matrix is defined by the following formula:

- If $a_{ij} \leq (\mu_j - \alpha \times \sigma_j)$ then $e_{ij} = -1$

Else

- If $a_{ij} \in (\mu_j - \alpha \times \sigma_j, \mu_j + \alpha \times \sigma_j)$ then $e_{ij} = 0$

  Else
- If $a_{ij} \geq (\mu_j + \alpha \times \sigma_j)$ then $e_{ij} = 1$

We redefine the ATD matrix into the Refined Time Dependent Matrix for here the entries belong to the set {-1, 0, 1}. In order to get rid of outliers, irregularities, or sudden shifts in the data, the time-dependent values are refined.

Combined Effective Time Dependent matrix (CETD): Combine the RTD matrices for the various α ∈ [0, 1], so that we get the Combined Effective Time Dependent Data (CETD) matrix.

The row sum is obtained for CETD matrix and conclusions are derived based on the row sums. It brings together average trends and fine-tuned tweaks to give a thorough picture of time-dependent relationships.

Here is an example from IRDM that illustrates how ATD, RTD, and CETD can be identified in relation to age groups and symptoms associated with cardiovascular problems.

TABLE I SYMPTOM DISTRIBUTION ACROSS DIFFERENT AGE GROUPS

Age Group (Years)	Symptoms						
	S1	S2	S3	S4	S5	S6	S7
20-30	23	18	24	16	29	15	11
31-43	35	38	37	36	17	29	10
44-65	2	24	21	22	11	20	5

IRDM = [23 18 24 16 29 15 11 35 38 37 36 17 29 10 22 24 21 22 11 20 5 $]_{3\times7}$

Every element of the first row is divided by 11, second row is divided by 13 and third row is divided by 22. It is a length of the class interval of the above TABLE I.

ATDM = [2.09 1.63 2.18 1.45 2.63 1.36 001 2.69 2.92 2.84 2.76 1.30 2.23 0.76 001 1.09 0.95 001 0.50 0.90 0.22 $]_{3\times7}$

Now for this matrix the Average of 1st column is $\mu_j = \frac{2.09+2.69+1}{3} = \frac{5.78}{3} = 1.92$

$$Standard\ Deviation\ (SD) = \sqrt{\frac{\sum_{i=1}^{3}(X-\underline{x})^2}{n-1}} = \sqrt{\frac{(2.09-1.92)^2+2.69-1.92)^2+(1-1.92)^2}{3-1}} = 0.85$$

The Average and Standard Deviation of the above ATD matrix will be calculated as

Average	1.9	1.9	2	1.7	1.5	1.5	2
SD	0.9	0.9	1	0.9	1.1	0.7	1.7

RTD matrix for $\alpha = 0.15$

- For First column we check this condition, If $a_{ij} \leq \mu_j - \alpha \cdot \sigma_j$ then $a_{ij} = -1$
- Else if $a_{ij} \geq \mu_j + \alpha \cdot \sigma_j$ then $a_{ij} = 1$
- Else if $a_{ij} \in \{\mu_j - \alpha \cdot \sigma_j, \mu_j + \alpha \cdot \sigma_j\}$ then $a_{ij} = 0$
- $a_{ij} as\ \{\mu_j + (\alpha \cdot \sigma_j)\} = \{1.92 - (0.15 \cdot 0.85)\} = 1.79$

RTDM ($\alpha = 0.15$) : Row Sum

$$\begin{bmatrix} 1 & -1 & 1 & -1 & 1 & 0 & -1 \\ 1 & 1 & 1 & 1 & 0 & 1 & -1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix} \quad \begin{Bmatrix} 0 \\ 4 \\ -7 \end{Bmatrix}$$

RTDM ($\alpha = 0.35$) : Row Sum

$$\begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 0 & -1 \\ 1 & 1 & 1 & 1 & 0 & 1 & -1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix} \quad \begin{Bmatrix} 2 \\ 4 \\ -7 \end{Bmatrix}$$

RTDM ($\alpha = 0.55$) : Row Sum

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 1 & -1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix} \quad \begin{Bmatrix} 1 \\ 4 \\ -7 \end{Bmatrix}$$

RTDM ($\alpha = 0.75$) : Row Sum

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix} \quad \begin{Bmatrix} 1 \\ 5 \\ -7 \end{Bmatrix}$$

The CETD matrix and the row sum matrix are given here:

$$\begin{bmatrix} 2 & -1 & 2 & -1 & 1 & 0 & -2 \\ 4 & 4 & 4 & 4 & 0 & 4 & -3 \\ -4 & -4 & -4 & -4 & -4 & -4 & -4 \end{bmatrix} \qquad \begin{Bmatrix} 1 \\ 17 \\ -28 \end{Bmatrix}$$

We observe that from the CETD matrix are the maximum age for getting cardio vascular problem is 31-43 and the highest peak of this cardio vascular problem is 17.

In many different fields, fuzzy matrices are widely used to handle vagueness and imprecise data. They assist in ranking options and assessing many factors while making decisions in domains such as business, healthcare, and policy formation. They help with sentiment analysis, pattern recognition, and neural network training in AI and machine learning. In image processing, they improve edge identification and lower noise, while in medicine, they are used for illness diagnosis and patient risk assessment. Additionally, they are essential to control systems and robotics, allowing adaptive decision-making for self-navigating vehicles. They help with ecological assessments and system reliability analysis in engineering and environmental sciences, and they enable risk assessment and stock market analysis in finance. The significance of fuzzy matrices in managing uncertainty and streamlining decision-making procedures is illustrated by these several applications [1,2].

II. Research Gap

There are many uses for fuzzy matrix theory in many different domains, but its application in agriculture is still not completely explored. Given that India is primarily an agricultural nation, attention must be paid to this area in order to assist our farmers. As a result, my research will center on the use of fuzzy matrix theory in agriculture, specifically the identification of leaf diseases in cotton plants.

III. LITERATURE REVIEW

Gauhati University researchers Anamika Dutta et al. use the Combined Effective Time Dependent (CETD) matrix method to discover conservative regions in the secondary structure of rice nucleotide sequences. 24 rice accession numbers from the NCBI record were used in the study, and they were randomly selected into six groups using a lottery approach. For determining the most conservative regions, the researchers used the Combined effective time dependent (CETD) matrix and concentrated on six secondary structure elements: Helix Residue, Beta Sheet Residue, Beta Turn Residue, Helix Region, Beta Sheet Region, and Beta Turn Region. Three α values (0.1, 0.15, and 0.3) were used to create an Initial Raw Data matrix, then Average time dependent (ATD) and Refined time dependent (RTD) matrices. By merging them, the combined effective time dependent (CETD) matrix was created, which made it possible to identify the rice genomes' conservative regions. The unique application of the combined effective time dependent (CETD) matrix, which is commonly used in traffic flow analysis, to biological data, demonstrating its potential in bioinformatics, is a significant finding of the study. By lowering sample bias, the lottery approach of random grouping increases robustness and improves the dependability of genomic study findings. [3].

Dr. A. Kalaichelvi et al. used fuzzy matrices in their study on the difficulties experienced by coffee growers in Kodai Hills, India. She standardizes the main problems affecting coffee growers, with an emphasis on various landholding groups. Using fuzzy sets and matrices to quantitatively assess ambiguous circumstances, this study highlights India's ranking as the sixth-largest producer of coffee, with three southern states accounting for the majority of production. After speaking with 100 farmers from three villages, the researchers recognized ten main issues, containing labor shortages, pest assaults, monsoon failures, high costs, and fluctuating pricing. Fuzzy matrices, such as Initial row data, Average time dependent (ATD), Refined time dependent (RTD) and combined effective time dependent (CETD) Matrices, were used to analyze the data. The study's primary contribution is the Combined Effect Time Dependent Data Matrix (CETD Matrix), which evaluated the cumulative effects of these problems on various land holding groups. According to the analysis, the most impacted cultivators owned between 10 and 12 acres of land. To prioritize interventions for this vulnerable group in Kodai Hills, policymakers and agricultural support institutions must take this understanding into consideration [4].

A fuzzy matrix approach was used to identify the age group of college students most affected by stress. Iftikhar Husain and his colleague Aleem Ali from Glocal University, Saharanpur's examine stress data gathered via questionnaires from 150 students in Delhi and the National Capital Region (NCR), India. The Initial Raw Data Matrix, Average time dependent (ATD) Matrix, Refined Time dependent (RTD) Matrix, and Combined effective time dependent (CETD) Matrix used in the methodology. Stress factors were determined to be nine observable qualities (OA1 to OA9), including financial support, academic stress, social pressures, substance use, career worries, mentorship challenges, parenting care, and health-related issues. According to the results,

students between the ages of 26 and 29 and 30 and 33 experience the highest levels of stress, regardless of the α value (0.25, 0.45, 0.65, 0.85). On the other hand, stress levels are lower among older students (34–37) and younger students (18–21, 22–25). This study provides a quantitative view of stress components and emphasizes the usefulness of fuzzy matrices in the analysis of intricate psychological problems. To effectively support stressed students, the comprehensive approach recommends focused interventions [5].

R. Kokila from Seethalakshmi Ramaswami College, Trichy, India, used fuzzy matrix techniques to investigate the prevalence of subject-specific information-gathering attitudes among college students. The study investigates student behavior by use of the matrix theory created by W.B. Vasantha and V. Indira (1998). Initial Raw Matrix, Average time dependent (ATD) Matrix, Refined Time dependent (RTD) Matrix, and Combined effective time dependent (CETD) Matrix are the four types of matrices used in this process. Based on information gathered from Arts and Science students' verbal questionnaires, four frequencies of knowledge-gathering behaviors were identified: daily, weekly, alternate days, and infrequently. A 4x2 initial raw matrix was created, converted to an Average time dependent (ATD) matrix, and refined time dependent (RTD) matrices with α values of 0.25, 0.50, and 0.75 were produced as part of the analytic process. The refined time dependent RTD matrices were then combined to create a combined effective time dependent (CETD) matrix. The results indicate that for $\alpha = 0.25$, students in the arts collect data on different days, whereas for $\alpha = 0.50$ and 0.75, both students in the arts and science show comparable trends. According to the study's findings, the majority of students, regardless of discipline, collect subject-specific data every other day, which provides information for improving learning methodologies and student engagement [6].

Hindustan University researchers M. Clement Joe Anand and M. Latha Maheswari examined males in Chennai who suffered from cardiovascular disease using the Combined Effective Time Dependent Matrix Approach. Fuzzy matrix theory is used in the study to determine which age groups of men in Chennai, India are most affected by cardiovascular disease. The study analyzes data from 100 men in different age groups using mathematical models that include Average time dependent (ATD) matrices, refined time dependent (RTD) matrices, and (CETD) matrices. The following major risk factors are analyzed: sedentary lifestyle, high blood pressure, diabetes, smoking, abnormal cholesterol, and abdominal obesity. Two sets of 4x6 and 7x6 matrices are used in the analysis, and the data is processed using initial raw data matrices, Average time dependent (ATD) matrices, and refined time dependent (RTD) matrices with varying α values (0.1, 0.3, 0.5, and 0.7). The final combined effective time dependent (CETD) matrix, which is displayed both graphically and tabularly, shows cumulative effects. Two peak age groups for cardiovascular disease are identified by the findings: those aged 46–53 and those aged 66–75. Men with higher levels of education who work in industry, IT, or education are also more vulnerable to unhealthy eating patterns and work-related stress. The study ends with preventive suggestions that include regular exercise, stress management, and health responsibility. New insights into cardiovascular disease trends are provided by this creative application of fuzzy matrix theory [7].

Traffic flow at Chennai, India's Velachery Vijaya Nagar Signal was analyzed by G. Kuppuswami, R. Sujatha, and B. Vasantha Kandasamy using the Combined Effective Time Dependent Data (CETD) Matrix technique. By using fuzzy matrix theory to manage data uncertainty and examine traffic patterns, this study seeks to determine peak and non-peak traffic times. The initial raw data matrix, Average time dependent (ATD) matrix, refined time dependent (RTD) matrix, and Combined Effective Time Dependent (CETD) matrix were created from the data on different vehicle kinds that were passing through the signal at different times. By examining the row sums of the combined effective time dependent (CETD) matrix, traffic flow patterns were identified; high traffic flow was denoted by positive values, while low flow was denoted by negative values. Combined effective time dependent (CETD) matrices and graphs are presented for each of the seven consecutive days that the study spans. According to the results, traffic peaks between 7 to 9 AM, with a morning high occurring between 9 to 1 PM. Between 1 to 3 PM, traffic drops, then increases again between 3 to 5 PM, and it peaks in the evening between 5 to 9 PM. Effective handling of data uncertainty is made possible by the application of fuzzy matrix theory, and non-experts can understand the results from the graphical representations. This strategy can be used in various places for efficient traffic management and provides insightful information for traffic regulation [8].

Hindustan University researchers A. Saraswathi and colleagues used the combined effective time dependent (CETD) matrix to examine the difficulties faced by housemaids in Chennai, India. It introduces fuzzy mathematics and key concepts like fuzzy sets, Average time dependent (ATD) matrix, and refined time dependent (RTD) matrix to frame the research. One hundred housemaids completed linguistic questionnaires that were used to gather data. Ten parents and five leaders of non-governmental organizations identified seven key issues: sexual abuse, wage discrimination, long hours of low-paying job, unemployment, ignorance, and illiteracy. Using a 5x7 matrix, housemaids were categorized into five age groups: 20–25, 26–30, 31–40, 41–55, and 56–60 years. Using several α values (0.01, 0.02, 0.04, 0.05), the Initial Raw Data, Average time

dependent (ATD), Refined time dependent (RTD), and Combined Effective Time Dependent (CETD) matrices were created as part of the Combined effective time dependent (CETD) matrix approach. The results show that housemaids between the ages of 20 and 25 are the most impacted, exhibiting all of the difficulties that have been documented, including psychological concerns. This age group is more vulnerable since they are more conscious of their future. Additionally, the report draws attention to the extent of female migration worldwide and the absence of laws protecting housemaids. To improve the conditions of housemaids, the researchers call for greater government support, fair treatment, and social acceptability [9].

Dr. B. Amudhambigai and K. Sugapriya conducted a study to examine the consequences of demonetization in India by Use of fuzzy matrix models, Fuzzy logic and matrix operations are used in this study to evaluate the effects of demonetization on various age groups. Three key fuzzy matrix models were used: Combined effective time dependent (CETD) Matrix, Average time dependent (ATD) Matrix, and Refined time dependent (RTD) Matrix. Six age groups (ages 21 to 80) provided data on the ten consequences of demonetization (E1 to E10) and the four objectives (O1 to O4). The data was then analyzed using these models to examine perceptions. By using fuzzy logic to a socioeconomic problem, the study takes a novel technique that provides a quantitative view of subjective beliefs. The results show that those between the ages of 31 and 60 were most affected by demonetization. Although there were obstacles, it was generally acknowledged that demonetization would eventually lessen corruption. The researchers recommend actions like avoiding depositing funds in the accounts of impoverished relatives or turning black money into gold in light of these revelations. This creative fusion of social science and fuzzy mathematics reveals a fresh approach to assessing public opinion on governmental policy. [10].

A. Victor Devadoss and co-worker used the combined effective time dependent (CETD) matrix technique to investigate personality traits with focusing on determining the peak age of rage in Chennai,

The study looks at five personality factors: openness, conscientiousness, extraversion, agreeableness, and negative emotion, which are each divided into six facets. This psychological study uses fuzzy matrix theory, which was first created in 1998 for transportation analysis. Initial Raw Data Matrix, Average time dependent (ATD) Matrix, refined time dependent (RTD) Matrix, and Combined effective time dependent (CETD) Matrix were the four types of matrices used to collect and evaluate data from 200 people in Chennai. Each personality factor's beginning, peak, and declining ages were determined by the analysis. The results show that all five dimensions peak at about 27 years of age. Openness and agreeableness develop at 14, extraversion at 15, conscientiousness at 20, and negative emotions at 18. Gender differences in personality development are negligible. Importantly, the study reveals that individuals are most likely to experience rage when they reach their peak personality phase, which occurs between the ages of 26 and 28.

This study provides useful insights into the relationship between personality development and emotional responses among the Chennai population. [11].

A. Victor Devadoss and M. Clement Joe Anand of Loyola College in Chennai used the Combined effective time dependent (CETD) Matrix, based on the OCEAN model—Openness, Conscientiousness, Extraversion, Agreeableness, and Negative Emotion—to investigate the personality dimensions of Chennai women. Here Each element is separated into six parts, with an emphasis on determining the optimal age for experiencing various personality traits, particularly negative emotions such as rage. Researchers gathered data from 100 women of all ages and examined it using matrix theory, which included the Initial Raw Data Matrix, Average time dependent (ATD) Matrix, Refined time dependent (RTD) Matrix, and Combined effective time dependent (CETD) Matrix. Tables and graphs were used to display the findings. The main conclusions show that while negative emotions appear around age 18, openness and agreeableness start to develop around age 14.Most personality traits peak between the ages of 26 and 28. Interestingly, Negative Emotions have two peak periods: 21-28 and 40-47 years. This study provides insightful information about Chennai women's psychological development. It identifies important age groups for emotional concerns and proposes tailored therapies for anger control and support structures to successfully handle personality-related issues. The novel application of the combined effective time dependent (CETD) matrix offers a fresh perspective on personality analysis. [12].

Anjan Mukherjee and Abhik Mukherjee used fuzzy matrix theory to investigate the impact of COVID-19 in Tripura, India, with an emphasis on finding the most affected age groups. The study employs fuzzy sets and matrix theory to address uncertainty in medical data. Data was gathered from 120 COVID-19 patients in Tripura and divided into four age groups: those aged 36–45, 46–55, 56–65, and 66–75. The methodology elaborates transforming raw data into Average time dependent (ATD) Matrix, Refined time dependent (RTD) Matrix and Combined effective time dependent (CETD) Matrix. After finding the means and standard deviations of signs for each age group, fuzzy matrices with α values of 0.25, 0.40, 0.75, and 0.90 were applied to provide visual representations. According to the final combined effective time dependent (CETD) matrix

analysis, COVID-19 had the major effect on people aged 56-65 years. In areas where old statistics might not be sufficient, this work determines the creative application of fuzzy matrix theory in epidemiology, providing a deeper knowledge of illness impact. It emphasizes the critical role of age in COVID-19 risk assessment, with potential implications for public health strategies and pandemic resource allocation [13].

Rahul Deshmukh analyzed the marketing issues faced by Alphonso mango producers in the Konkan region of Maharashtra, India by use of fuzzy matrix model. The study area was Sindhudurg and Ratnagiri districts which are well-known for growing mangos. The objective is to classify cultivators according to the quantity of trees impacted and identify important marketing concerns.100 respondents' data were analyzed and classified as small, marginal, or significant farmers. Price fluctuation, a lack of market awareness, limited money, and transportation issues were among the twelve marketing obstacles identified. He divided the respondents into ten categories according to the number of trees they owned (1-50 to 451-500 trees). For the process he required to build a Time Dependent Matrix, which was then turned into an Average time dependent (ATD) matrix. The data was improved using statistical measurements such as mean and standard deviation to create an Refined time dependent (RTD) matrix and a Combined effective time dependent (CETD) matrix. As per the study mango producers with 200-300 plants have the most significant marketing challenges. This research provides a comprehensive knowledge of marketing issues across various mango growing scales, highlighting the creative application of fuzzy logic and matrix theory in agricultural economics [14].

Mr. M. Suresh and Ms. J. Greeda used the combined effective time dependent (CETD) Matrix Model to analyze women's harassment in villages. This study provided a novel approach to understanding time-dependent data through the use of matrix theory and graphical representation. The subject of the study are four categories of harassment: cyber, sexual orientation, psychological, and job harassment. By use of 7x4 matrix the study finds which age group is most impacted by harassment. The raw data is first transformed into an Initial Raw Data (IRD) matrix and subsequently into an Average time dependent (ATD) matrix as the part of process. They used Mean and standard deviation computations to refine into a refined time dependent (RTD) matrix, and refined time dependent (RTD) matrices with varying alpha values are then combined to create a combined effective time dependent (CETD) matrix. The peak age groups for harassment identified by the help of row sums of the combined effective time dependent (CETD) matrix. The study finds that the harassment begins as early as 14, with the maximum occurrence between ages 21–27. This study encourages individual empowerment by reassuring self-respect and prioritizes primary prevention through education and awareness, particularly in schools. It advocates for comprehensive solutions incorporating international organizations, communities, and individuals to transform cultural norms towards women's respect and empowerment, addressing the underlying causes of harassment [15].

Manit Malhotra used fuzzy matrix analysis to determine which age groups were most affected by swine flu in India. It is divided into four parts. Part 1 presents a description of the 2009 swine flu outbreak, which resulted in approximately 3,000 deaths, with high-risk populations including the elderly, small children, and pregnant women. The document also includes statistics on cases and deaths, with Rajasthan, Gujarat, and Delhi being the most affected areas. Part 2 outlines the methodology, involving the creation of Raw Time Dependent (RTD) and Combined Effective Time Dependent (CETD) matrices. Researchers collected 100 swine flu case records, analyzing eight major symptoms using fuzzy matrix techniques. The process included transforming raw data into an Average Time Dependent (ATD) matrix, then refining it into an RTD matrix using mean and standard deviation calculations. Part 3 employs a 3x8 matrix (age groups 20–30, 31–43, and 44–65 years) and eight symptoms to determine the peak age group affected. The Combined Effective Time Dependent (CETD) matrix was the result of calculations with various parameters (β = 0.25, 0.5, 0.75), and the results were displayed both graphically and in a matrix. The study finds that swine flu affects people starting at age 28 and peaking at 42. This study demonstrates the effectiveness of fuzzy matrix analysis in epidemiological investigations for extracting useful insights from complex data [16].

V. Jayapriya and S. Akila Devi used fuzzy matrix models to investigate solar energy production in various Indian states by use of Refined time dependent (RTD), Average time dependent (ATD), and Combined effective time dependent (CETD) matrices. The authors present a systematic process that begins with collecting raw data, converting the data in to an Average time dependent (ATD) matrix, computing the mean and standard deviation and turning it into a refined time dependent (RTD) matrix finally then producing a combined effective time dependent (CETD) matrix. Data on solar energy from nine Indian states during a five-year period (2017–2021) was subjected to this procedure. As per the data, solar electricity generation is highest in Rajasthan and Tamil Nadu, while it is lowest in Punjab, Maharashtra, Delhi, and West Bengal. The authors provide suggestion to enhancing solar panel production in these underperforming states to boost India's solar energy production. This novel study applies complicated fuzzy matrix techniques to a real-world challenge, providing a unique method for understanding and comparing solar energy statistics across areas

and timeframes. This study approach can be applied to other renewable energy industries or resource management domains, giving useful information for policymakers and researchers. The study underlines the necessity of state-wise analysis to boost solar energy output in India, which will guide targeted development initiatives in the renewable energy industry. [17].

Kamalpreet Kaur Toor and Jiwanjot Kaur Toor used the Combined Effect Time Dependent Matrix to determine the peak age group of school dropouts in Punjab, India. The study, conducted in Ludhiana's Jodhewal slum, focused on 112 school-dropped youngsters between the ages of 6 and 14. To determine which age group is most likely to drop out is the purpose of study and investigate the underlying causes. Data was collected by surveys on sociodemographic characteristics and dropout causes as part of the approach. Initial Raw Data Matrix, Average time dependent (ATD) Matrix, refined time dependent (RTD) Matrix, and Combined effective time dependent (CETD) Matrix were the four steps in the combined effective time dependent (CETD) matrix process. As per the results children between the ages of 9 and 11 are the most at risk of dropping out and its contributing factors are: Parental illiteracy, lack of support, poverty, migration, household duties, and early engagement in revenue-generating activities. The most important dropout stage is the transition from primary to upper primary school, which coincides with physical growth and parental expectations of manual labor as per the study. The need for a comprehensive approach to addressing school dropouts, with an emphasis on retention, quality education, support networks are the highlights of the study. The Combined effective time dependent (CETD) matrix is a unique method for examining dropout trends and providing insights into age-related issues [18].

Iftikhar, Musheer Ahmad, and Anwar Shahzad Siddiqui investigated smoking habits using fuzzy matrix approaches. The goal of the study are finding the peak age group for smoking initiation and the variables affecting this behavior. By use of four types of matrices—Initial Raw Data, Average time dependent (ATD), Refined time dependent (RTD) and Combined effective time dependent (CETD). The study examines data gathered through linguistic questionnaires. 100 people in four age groups—16–20, 21–25, 26–30, and 31–35 years old—were surveyed for the study, which focused on nine elements that influence smoking initiation: peer pressure, parental influence, stress release, media impact, and self-medication. The results showed that smoking peaks between the ages of 22 and 28 and that stress, false information, self-medication, and advertising are major contributing factors. Additionally, the study found that smoking initiation significantly decreased after age 31. This novel study applies fuzzy matrix theory to social difficulties, providing a mathematical method for comprehending intricate behaviors. In future this strategy gives insights that could assist policymakers in developing targeted interventions to lower smoking rates, and its approach can be applied to other public health challenges [19].

Hanyin Zhang et al. investigated the use of CETD matrices to maintain the invariance of peak points in non-symmetrical graphs. When different α-levels are chosen at random during the creation of refined time dependent (RTD) matrices, the authors address the problem of inconsistent peak points. The approach suggested in the study selects α-levels from a homogeneous division of the interval (0,1]. In order to ensure that the peak point or points in the combined effective time dependent (CETD) matrix stay invariant, independent of the α-levels selected, the crucial need is to choose no more than one α-level from each partition cell. For the purpose of precisely identifying age groups or classes with peak values, this consistency is essential. The authors provide examples to support their approach, such as examinations of personality traits and crime statistics for various age groups. Results show that the proposed condition maintains consistent peak points, unlike the variability seen with arbitrary α-level selections. This research provides a unique look into the possibilities for broader applications in domains such as military personnel management, agriculture, and logistics. In order to improve the method's accuracy and practicality, the authors also propose future directions, such as creating algorithms that generate refined time dependent (RTD) matrices with elements that are only in the range [0,1]. [20].

IV. CONCLUSION

This review offers a number of investigations that use fuzzy matrix methods, specifically the Combined Effect Time Dependent (CETD) matrix, to examine a range of problems in diverse fields. Rice genome analysis, issues faced by housemaids and coffee growers, stress in higher education, college students' attitudes toward information gathering, cardiovascular disease in men, traffic flow patterns, the effects of demonetization and COVID-19, personality traits, marketing challenges for mango growers, harassment of women, swine flu outbreaks, solar energy production, school dropouts, and smoking habits are just a few of the topics covered in the studies. The standard process uses fuzzy logic and matrix operations to convert raw data into Initial raw data, Average time dependent (ATD), Refined time dependent (RTD) and Combined effective time dependent

(CETD) matrices. Peak age groups or classes impacted by the problem under investigation can be found using the combined effective time dependent (CETD) matrix, which is created by mixing refined time dependent (RTD) matrices with various α values. The creative application of fuzzy matrix theory to a variety of domains, providing a quantitative viewpoint on intricate problems, is one of the key discoveries. One of the most important findings is the innovative use of fuzzy matrix theory in several fields, which offers a quantitative perspective on complex issues. By suggesting a technique for reliable α-level selection, the study also highlights how crucial it is to guarantee the invariance of peak points in non-symmetrical graphs produced from combined effective time dependent (CETD) matrices. For precise identification of age groups or classes with peak values across multiple domains, this consistency is essential.

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