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Article

A mathematical study based on fuzzy inference system for addressing psychosocial issues among students

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Abstract: Psychosocial issues such as stress, anxiety, depression, and social integration challenges are prevalent among students and significantly impact their academic performance and overall well-being. Traditional methods for addressing these issues often fall short due to their reliance on qualitative assessments and generalized interventions. This study proposes a novel approach utilizing a Fuzzy Inference System (FIS) to model and analyze these complex psychosocial dynamics. FIS, grounded in fuzzy set theory, effectively handles the inherent uncertainty and imprecision of human emotions and behaviors. The study outlines the design of an FIS that incorporates key input variables such as stress, anxiety, depression, and social integration, which are fuzzified into linguistic terms like low, medium, and high. By applying a comprehensive set of fuzzy rules derived from expert knowledge and empirical data, the system processes these inputs to generate personalized and actionable insights. The implementation of this FIS in educational settings allows for the continuous monitoring and evaluation of student psychosocial health, enabling early identification and tailored interventions for at-risk students. The study demonstrates that an FIS-based approach provides a structured yet flexible method for addressing psychosocial issues, ultimately enhancing student support mechanisms, and fostering better academic outcomes and well-being.

Keywords: fuzzy logic; psycho-social issues; college students; well-being

1. Introduction

Psychosocial issues among students refer to a range of problems that arise from the interaction between psychological and social factors. These issues can significantly impact students' mental health, behavior, academic performance, and overall well-being (Conley et al., 2013). These issues, often interlinked and multifaceted, can impede students' ability to thrive in academic environments and achieve their full potential. Traditional methods of addressing these problems typically involve qualitative assessments and generalized interventions, which may not adequately account for the unique circumstances and needs of each student.

The psychosocial health issues of college students have become an increasing concern, with a substantial number experiencing psycho-social distress, particularly during and after the COVID-19 pandemic (Elizabeth et al., 2021). Mental and physical health issues can impact motivation, concentration, future career opportunities, and socio-personal interactions (Fajrin et al., 2024). During and after the pandemic, students exhibited maladaptive behaviors, emotional responses, and defensive

reactions. The aim of this review is to collect and synthesize high-quality peer-reviewed literature on the psychosocial issues affecting students. In this process, Bano and Iqbal (2018) identified the psychosocial and emotional problems, as well as the development of psychopathology, among university students. A total of 120 students participated, equally divided between 60 males and 60 females. To gather authentic data, they utilized the "University Student Evaluation of Psychosocial Problems Scale" (USEPP) and the Hopkins Symptoms Checklist (HSCL). Bista et al. (2016) involved 787 adolescent students from 13 schools in Hetauda municipality and conducted a cross-sectional analysis. A set of structured questionnaires, along with the Youth Pediatric Symptom Checklist (Y-PSC), was used to gather data on the psychosocial issues faced by the students. Breda (2017) described the life challenges university students experienced during their first year of study as they transitioned into academia. It highlighted how these challenges, including academic pressure, social adjustment, homesickness, and financial difficulties, impacted their academic performance and well-being at the time. Hemalatha and Hinduja (2022) focused on the psychosocial problems faced by college students, specifically targeting female students as respondents. A total of 60 students participated in the research, and data was collected using a self-prepared questionnaire. The research findings highlighted that students faced various psychosocial challenges and needed motivation. Additionally, it was suggested that changes in the education pattern could help alleviate some of the academic and psychological stress experienced by the students, pointing to the need for systemic improvements to better support their well-being. Jayasree and Ramana (2020) aimed to assess the prevalence of psychosocial problems among female junior college students and focused on identifying common mental health and emotional challenges, such as stress, anxiety, depression, and social adjustment difficulties, experienced by specific group. Katoch et al. (2021) assessed the impact of the COVID-19 pandemic on the psycho-social health of university students. Questionnaires were mailed to undergraduate students of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya (CSKHPKV), Palampur, to gather data on how the pandemic affected their mental and emotional well-being.

1.1. Research objectives

This study aims to:

- Develop a fuzzy inference system to evaluate psychosocial issues among students.
- Identify major psychosocial factors influencing student well-being.
- To construct appropriate membership functions and fuzzy rules based on expert knowledge.
- To evaluate the effectiveness of the proposed model using real or simulated data.
- To compare the proposed fuzzy model with traditional statistical approaches.

1.2. Novel contribution of the study

The novelty of this research lies in the development of a structured fuzzy inference system specifically designed to quantify and analyze psychosocial issues among students using linguistic variables and rule-based reasoning. Unlike

conventional statistical models that rely on precise numerical inputs, the proposed approach incorporates uncertainty and subjective assessments commonly present in psychological evaluation.

This study introduces:

- A multi-criteria fuzzy framework integrating academic stress, social interaction, emotional stability, and behavioral indicators.
- A mathematically formulated rule base derived from expert knowledge in psychology and education.
- A systematic defuzzification process for generating interpretable psychosocial risk scores.

The proposed model provides a flexible, interpretable, and computationally efficient tool that can assist educators and counselors in early detection and intervention.

In recent years, there has been a growing interest in leveraging advanced mathematical and computational techniques to enhance the understanding and management of psychosocial issues. Among these techniques, the Fuzzy Inference System (FIS) stands out due to its ability to handle the ambiguity and complexity inherent in human emotions and behaviors (Famakinwa et al., 2016). Fuzzy logic extends classical binary logic to accommodate the nuanced nature of real-world scenarios, making it particularly suitable for modeling psychosocial phenomena. This paper explores the application of a Fuzzy Inference System to address psychosocial issues among students (Zadeh, 1965). By incorporating various input variables such as stress, anxiety, depression, and social integration, the FIS can generate personalized and actionable insights. These inputs are transformed into fuzzy sets with linguistic terms such as low, medium, and high, enabling the system to process and analyze them through a comprehensive set of fuzzy rules derived from expert knowledge and empirical data (Klir and Yuan, 1995). The primary objective of this study is to develop a robust Fuzzy Inference System framework that can continuously monitor and evaluate the psychosocial health of students, providing early identification and tailored interventions for those at risk. By implementing this system within educational settings, institutions can enhance their support mechanisms, ultimately improving student well-being and academic outcomes (Holt et al., 2014). Some of the common psychosocial issues students face include:

➢ **Stress**

- **Academic pressure:** High expectations, heavy workloads, and pressure to perform well in exams can cause significant stress.
- **Time management:** Balancing academic responsibilities with extracurricular activities and personal life can be challenging.

➢ **Anxiety**

- **Performance anxiety:** Fear of failure or underperforming in academic or extracurricular activities.
- **Social anxiety:** Discomfort or fear in social situations, leading to difficulty in making friends and participating in group activities.

➢ **Depression**

- **Emotional distress:** Persistent sadness, lack of interest in activities once enjoyed, and feelings of hopelessness.
- **Isolation:** Withdrawal from friends and activities, leading to increased feelings of loneliness and depression.

➢ **Social integration**

- **Bullying:** Harassment or bullying by peers can lead to severe psychological and social problems.
- **Peer relationships:** Difficulties in forming and maintaining healthy relationships with peers.

➢ **Behavioral issues**

- **Conduct problems:** Aggressive or disruptive behavior in school.
- **Substance abuse:** Experimentation or dependence on drugs and alcohol as a coping mechanism.

➢ **Self-esteem issues**

- **Body image:** Concerns about physical appearance, often exacerbated by social media.
- **Academic self-efficacy:** Low confidence in academic abilities and fear of not meeting expectations.

➢ **Adjustment problems**

- **Transition phases:** Challenges related to transitioning between different educational stages (e.g., from high school to college).
- **Cultural adjustment:** Difficulties faced by international students or those from diverse cultural backgrounds in adapting to a new environment.

➢ **Family issues**

- **Parental pressure:** Expectations and demands from parents regarding academic success and career choices.
- **Family conflict:** Stress and anxiety stemming from conflicts within the family.

➢ **Mental health disorders**

- **Attention deficit hyperactivity disorder:** Impacts concentration, behavior, and academic performance.
- **Learning disabilities:** Challenges in reading, writing, or mathematics that affect academic progress (Raskind et al., 2019).

2. Impact on students

Psychosocial issues can lead to:

➢ **Poor academic performance:** Inability to concentrate, complete assignments, or perform well in exams.

➢ **Decreased attendance:** Skipping classes or dropping out due to mental health struggles.

- **Health problems:** Physical symptoms such as headaches, fatigue, or gastrointestinal issues stemming from stress and anxiety.
- **Impaired social functioning:** Difficulty in building and maintaining healthy relationships with peers and teachers (Gokhale and Ingole, 2019).

3. Fuzzy logic and psycho-social issues

The application of Fuzzy Inference System (FIS) in addressing psychosocial issues among students has garnered significant attention in recent academic research (Kunst and Gebhardt, 2018). Fuzzy logic, introduced by Zadeh (1965), offers a mathematical framework for dealing with uncertainty and imprecision, which are inherent in human cognitive and emotional processes. In the context of psychosocial issues, FIS can model the complexities of student behaviors and emotions more effectively than traditional binary logic systems. Recent studies have demonstrated the utility of FIS in various educational settings, where it has been employed to evaluate and predict student stress levels, psychological distress, academic performance, and social interactions etc. (Rathore et al., 2024b). For instance, researchers have utilized fuzzy rules and membership functions to assess the psychological well-being of students. These models have shown promise in identifying at-risk students and providing early interventions. Additionally, the adaptability of FIS allows for the continuous refinement of the system as more data becomes available, enhancing its predictive accuracy and reliability. The integration of FIS enriches its capability to address complex psychosocial phenomena (Rathore et al., 2024c). Overall, the use of Fuzzy Inference Systems represents a promising interdisciplinary approach, combining elements of artificial intelligence, psychology, and education to tackle the multifaceted psychosocial issues faced by students today (Rathore et al., 2024b, 2024c).

4. Methodology

This study discusses the design and implementation of a Fuzzy Inference System (FIS) to address psychosocial issues among students. The methodology covers key steps, including:

- **Selection and fuzzification of input variables:** This process involves identifying relevant factors and converting them into fuzzy sets to capture the uncertainties and complexities inherent in psychosocial issues.
- **Construction of fuzzy rules:** A rule-based system is developed to model the relationships between input variables, allowing the FIS to interpret the interactions between different psychosocial factors.
- **Defuzzification process:** The fuzzy outputs are converted into actionable insights that can inform interventions or strategies aimed at improving students' well-being.

The study also highlights the benefits and challenges of using a FIS-based approach in educational contexts, emphasizing how fuzzy logic can be an innovative tool for managing the complex and dynamic nature of psychosocial issues (Latiff et al., 2017). Through this approach, the study aims to showcase the potential of fuzzy logic in providing nuanced, flexible solutions to the challenges faced by students in modern

educational environments (Leeshma and Gladsy, 2019).

4.1. Expert involvement in rule construction

In this study the fuzzy rule base was developed using structured expert input to ensure theoretical consistency and practical relevance of psychosocial indicators. Experts reviewed the questionnaire items to confirm that they appropriately represented major psychosocial constructs such as academic pressure, social and peer pressure, family dynamics and expectations, mental health condition and lifestyle and physical health. Based on questionnaire score ranges, experts defined linguistic categories (e.g., Low, Moderate, High) and determined appropriate threshold values for membership functions. Then the fuzzy IF–THEN rules were constructed based on theoretical relationships between psychosocial variables.

4.2. Model validation

The proposed fuzzy inference system was validated using primary data collected from 300 **s**tudents through a structured questionnaire. For each respondent questionnaire responses were aggregated to compute psychosocial scores (Nsereko et al., 2014). These scores were used as inputs to the fuzzy inference system. The resulting fuzzy output was compared with the overall questionnaire-based classification (Nsereko et al., 2014).

Addressing psychosocial issues among students typically involves multiple components, each requiring judgments often derived from imprecise data. This phase was conducted in several phases, beginning with the data collection stage, where a questionnaire was administered to 300 college students. The responses from this questionnaire formed the dataset, which served as input data and was adjusted according to the system's requirements (Pavithra et al., 2020). To process this data, the study incorporated statistical computations and artificial intelligence methodologies, designed to extract patterns and recognize information from the dataset (Petra and Aziz, 2021). Traditional binary classifications (yes/no) were deemed insufficient to fully capture the complexities of psychosocial issues. Instead, fuzzy logic was employed to handle uncertainty and ambiguity by assigning degrees of membership to various characteristics or factors related to psychosocial problems (Putro, 2016). Fuzzy logic allowed for the use of linguistic variables such as "high," "medium," and "low," offering a more flexible framework to deal with issues that do not fit neatly into predefined categories. This approach proved beneficial in modeling the complexities of psychosocial issues among students (Rajkumar et al., 2015). The research utilized the fuzzy Mamdani process, a well-known fuzzy inference method. **Figure 1** presents the fundamental framework of this process, showing how input data are fuzzified, processed through a rule-based system, and then defuzzified to generate actionable outputs. Through this framework, the methodology demonstrated the potential of fuzzy logic to provide nuanced insights into the psychosocial well-being of students, offering a more comprehensive understanding of their issues compared to traditional methods.

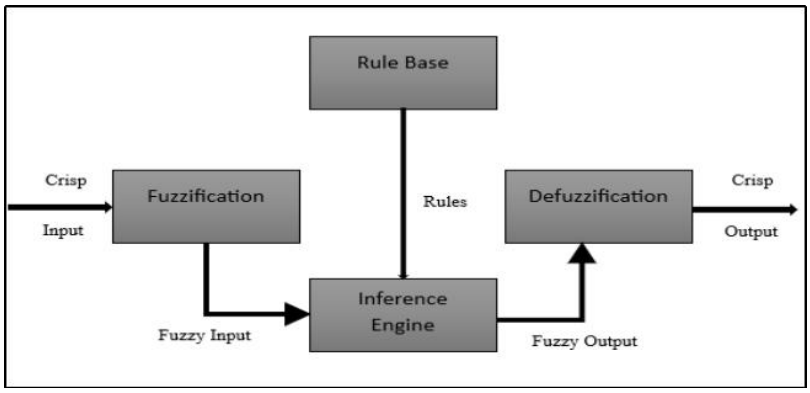

Figure 1. Proposed fuzzy inference system.

Generally, psychosocial issues among students can arise from a variety of factors, often interlinked and spanning personal, academic, social, and environmental domains (Silva et al., 2021). Here are some common factors that contribute to psychosocial issues:

➢ **Academic pressure**

- High expectations for academic performance, often from self, family, or teachers.
- Workload and time management challenges, especially during exams or deadlines.
- Fear of failure or perfectionism, which can lead to stress and anxiety.

➢ **Social and peer pressure**

- Peer comparison and competitiveness can lead to self-esteem issues.
- Social acceptance concerns, including fitting in, social status, or maintaining relationships.
- Bullying and harassment, which can lead to anxiety, depression, and isolation

➢ **Family dynamics and expectations**

- Parental pressure for academic achievement or career choices.
- Family conflicts, separation, or divorce, which can cause emotional stress.
- Financial instability in the family, adding to students' concerns about their future.

➢ **Mental health conditions**

- Anxiety, depression, and mood disorders can be both a cause and result of psychosocial issues.
- Sleep disorders or irregular sleep patterns, which often exacerbate mental health struggles.
- Low self-esteem or self-worth, often stemming from various external pressures.

➢ **Environmental and societal factors**

- Lower socioeconomic status can limit access to resources and add financial strain.
- Access to mental health resources may be limited, leading to untreated or

poorly managed conditions.

- Social media and digital stress, with exposure to idealized lives, online bullying, or time management issues.

➢ **Lifestyle and physical health**

- Poor physical health or chronic illness, which can impact mental and emotional well-being.
- Sedentary lifestyle or lack of exercise, which has been shown to affect mood and energy levels.
- Poor diet and nutrition, impacting concentration, mood, and stress resilience.

➢ **Substance use and risk behaviors**

- Substance abuse such as alcohol, drugs, etc. can lead to or exacerbate existing psychosocial problems.
- Risk behaviors such as impulsive decisions or risky sexual behaviors, may increase as coping mechanisms, complicating psychological well-being.

➢ **Cultural and identity issues**

- Cultural identity conflicts in diverse or international settings can impact students' sense of belonging.
- Gender identity or sexual orientation concerns, which may create stress or a need for acceptance.
- Discrimination or stigmatization due to race, religion, or other identity factors.

Each of these factors, often intertwined, can create complex psychosocial issues among students, impacting their emotional, academic, and social well-being (Shia et al., 2019). Recognizing and addressing these factors can help to create supportive environments and interventions to promote students' holistic health. In examining the psychosocial issues among students, several primary factors have been identified as key influences. The major factors identified as inputs impacting psychosocial well-being include: academic pressure, social and peer pressure, family dynamics and expectations, mental health condition and lifestyle and physical health (Shek and Sun, 2012). In the proposed fuzzy logic system, these factors are treated as input variables, each contributing to the prediction and analysis of the psychosocial issues experienced by students, which serves as the output. These input factors are crucial for constructing an accurate fuzzy model. In the fuzzification process, each factor is divided into three linguistic categories (e.g., "low," "medium," and "high") to capture varying levels of influence on psychosocial outcomes. This classification is displayed in **Table 1** and uses a trapezoidal membership function, which smoothly transitions between categories, accommodating the complexity and imprecision often present in psychosocial data. By leveraging these linguistic labels, the fuzzy model can more effectively interpret and manage the uncertainty and variability in each factor's influence, ultimately providing more nuanced insights into how these issues manifest among students.

Following the fuzzification process, the fuzzy Mamdani inference method is applied to analyze and address psychosocial issues among students. This method is particularly suited for handling the complex and ambiguous nature of psychosocial

issues by allowing for intuitive rule-based reasoning and generating outputs that reflect the combined influence of multiple factors. In this system, linguistic rules are created to model the relationships between inputs and the resulting psychosocial issues. Each rule operates by considering the degree of membership in each input category, and then aggregates the outputs according to predefined fuzzy rules. The proposed fuzzy Mamdani inference system is illustrated in **Figure 2**.

Table 1. Input factors with their linguistic categories.

Input factors	Linguistic categories
Academic pressure	Low, Moderate, High
Social and peer pressure	Low, Moderate, High
Family dynamics and expectations	Low, Moderate, High
Mental health condition	Good, Moderate, Poor
Lifestyle and physical health	Good, Moderate, Poor

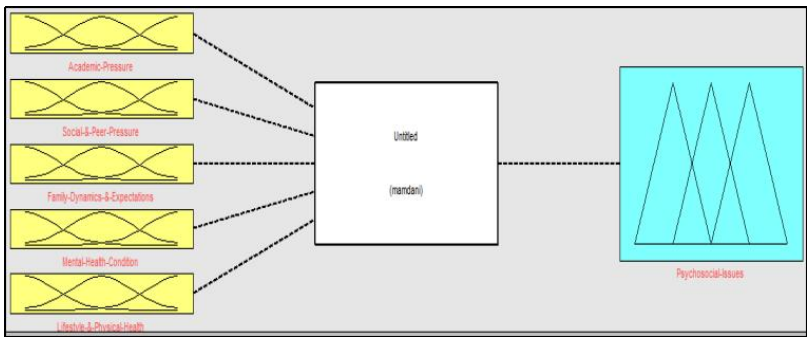

Figure 2. The fuzzy mamdani inference system designed for addressing psychosocial issues among students.

Each input and output variable's membership function are designed using a trapezoidal membership function. **Figures 3–7** show the trapezoidal membership functions plot for each of the five respective input variables. These figures illustrate the distribution of membership values across three linguistic categories for each input variable. **Figure 8** illustrates the membership function for the output variable- psychosocial issues experienced by students. This output variable is similarly represented with a trapezoidal membership function, providing a nuanced categorization that ranges from very low to very high severity of psychosocial issues among students. The trapezoidal membership function equations used for each input and output factor provide a mathematical foundation to categorize the inputs effectively.

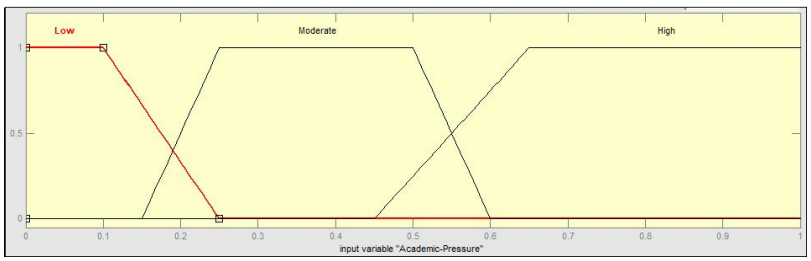

Figure 3. Membership function plots of academic pressure.

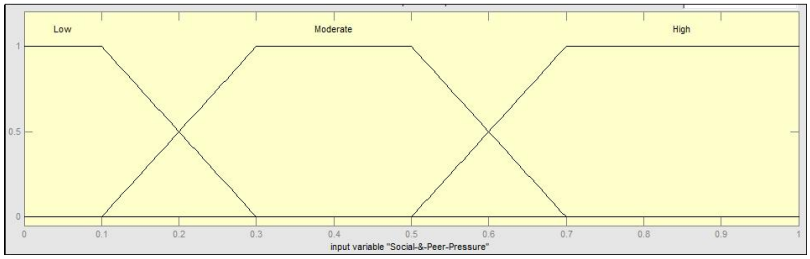

Figure 4. Membership function plots of social & peer pressure.

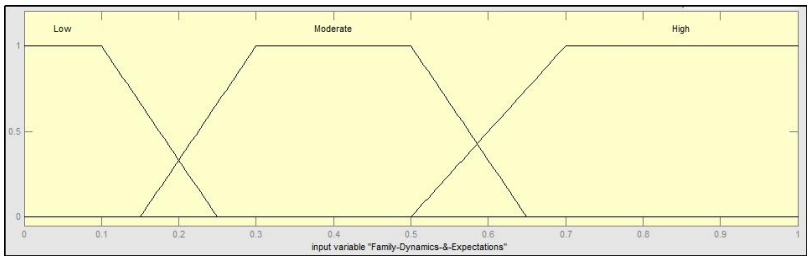

Figure 5. Membership function plots of family dynamics & expectations.

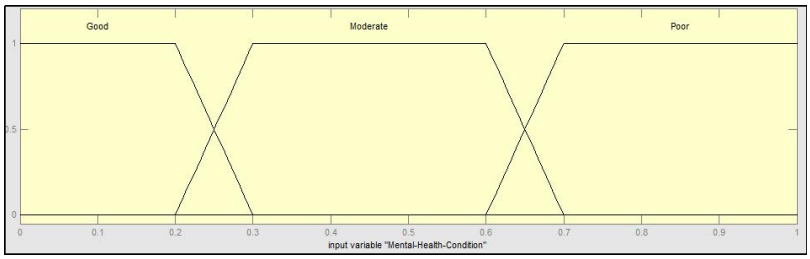

Figure 6. Membership function plots of mental health condition.

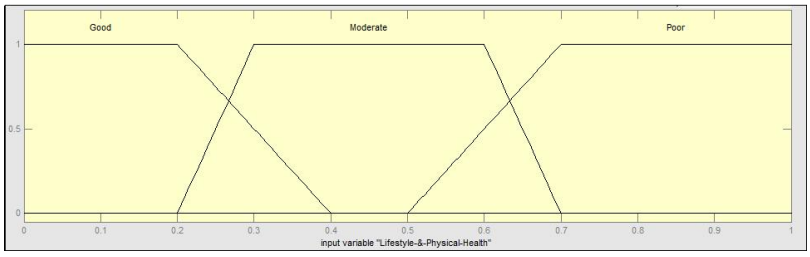

Figure 7. Membership function plots of lifestyle & physical health.

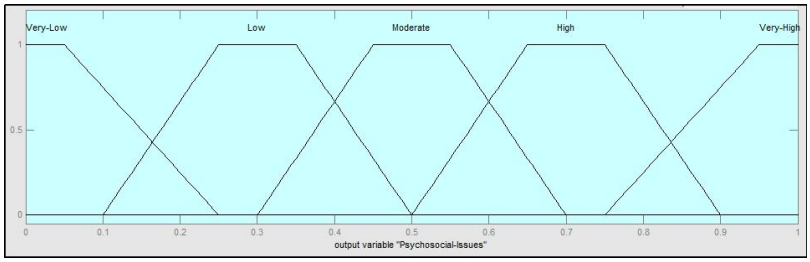

Figure 8. Membership function plots of psychosocial issues.

(1) Academic pressure:

$$\mu_L(\gamma) = \begin{cases} 1 & \gamma \leq 0.10 \\ \dfrac{0.25 - \gamma}{0.25 - 0.10} & 0.10 \leq \gamma \leq 0.25 \end{cases}$$

$$\mu_M(\gamma) = \begin{cases} \frac{\gamma - 0.15}{0.25 - 0.15} & 0.15 \le \gamma \le 0.25 \\ 1 & 0.25 \le \gamma \le 0.50 \\ \frac{0.60 - \gamma}{0.60 - 0.50} & 0.50 \le \gamma \le 0.60 \end{cases} \quad (1)$$

$$\mu_H(\gamma) = \begin{cases} \frac{\gamma - 0.45}{0.65 - 0.45} & 0.45 \le \gamma \le 0.65 \\ 1 & 0.65 \le \gamma \end{cases}$$

(2) Social and peer pressure:

$$\mu_L(\gamma) = \begin{cases} 1 & \gamma \le 0.10 \\ \dfrac{0.30 - \gamma}{0.30 - 0.10} & 0.10 \le \gamma \le 0.30 \end{cases}$$

$$\mu_M(\gamma) = \begin{cases} \frac{\gamma - 0.10}{0.30 - 0.10} & 0.10 \le \gamma \le 0.30 \\ 1 & 0.30 \le \gamma \le 0.50 \\ \frac{0.70 - \gamma}{0.70 - 0.50} & 0.50 \le \gamma \le 0.70 \end{cases} \quad (2)$$

$$\mu_H(\gamma) = \begin{cases} \frac{\gamma - 0.50}{0.70 - 0.50} & 0.50 \le \gamma \le 0.70 \\ 1 & 0.70 \le \gamma \end{cases}$$

(3) Family dynamics & expectations:

$$\mu_L(\gamma) = \begin{cases} 1 & \gamma \le 0.10 \\ \dfrac{0.25 - \gamma}{0.25 - 0.10} & 0.10 \le \gamma \le 0.25 \end{cases}$$

$$\mu_M(\gamma) = \begin{cases} \frac{\gamma - 0.15}{0.30 - 0.15} & 0.15 \le \gamma \le 0.30 \\ 1 & 0.30 \le \gamma \le 0.50 \\ \frac{0.65 - \gamma}{0.65 - 0.50} & 0.50 \le \gamma \le 0.65 \end{cases} \quad (3)$$

$$\mu_H(\gamma) = \begin{cases} \frac{\gamma - 0.50}{0.70 - 0.50} & 0.50 \le \gamma \le 0.70 \\ 1 & 0.70 \le \gamma \end{cases}$$

(4) Mental health condition:

$$\mu_G(\gamma) = \begin{cases} 1 & \gamma \le 0.20 \\ \dfrac{0.30 - \gamma}{0.30 - 0.20} & 0.20 \le \gamma \le 0.30 \end{cases}$$

$$\mu_M(\gamma) = \begin{cases} \frac{\gamma - 0.20}{0.30 - 0.20} & 0.20 \le \gamma \le 0.30 \\ 1 & 0.30 \le \gamma \le 0.50 \\ \frac{0.70 - \gamma}{0.70 - 0.60} & 0.60 \le \gamma \le 0.70 \end{cases} \quad (4)$$

$$\mu_P(\gamma) = \begin{cases} \frac{\gamma - 0.60}{0.70 - 0.60} & 0.60 \le \gamma \le 0.70 \\ 1 & 0.70 \le \gamma \end{cases}$$

(5) Lifestyle & physical health:

$$\mu_G(\gamma) = \begin{cases} 1 & \gamma \leq 0.20 \\ \dfrac{0.40-\gamma}{0.40-0.20} & 0.20 \leq \gamma \leq 0.40 \end{cases}$$

$$\mu_M(\gamma) = \begin{cases} \frac{\gamma-0.20}{0.30-0.20} & 0.20 \leq \gamma \leq 0.30 \\ 1 & 0.30 \leq \gamma \leq 0.60 \\ \frac{0.70-\gamma}{0.70-0.60} & 0.60 \leq \gamma \leq 0.70 \end{cases} \quad (5)$$

$$\mu_P(\gamma) = \begin{cases} \frac{\gamma-0.50}{0.70-0.50} & 0.50 \leq \gamma \leq 0.70 \\ 1 & 0.70 \leq \gamma \end{cases}$$

(6) Psychosocial issues:

$$\mu_{VL}(\gamma) = \begin{cases} 1 & \gamma \leq 0.05 \\ \dfrac{0.25-\gamma}{0.25-0.05} & 0.05 \leq \gamma \leq 0.25 \end{cases}$$

$$\mu_M(L) = \begin{cases} \frac{\gamma-0.10}{0.25-0.10} & 0.10 \leq \gamma \leq 0.25 \\ 1 & 0.25 \leq \gamma \leq 0.35 \\ \frac{0.50-\gamma}{0.50-0.35} & 0.35 \leq \gamma \leq 0.50 \end{cases}$$

$$\mu_M(\gamma) = \begin{cases} \frac{\gamma-0.30}{0.45-0.30} & 0.30 \leq \gamma \leq 0.45 \\ 1 & 0.45 \leq \gamma \leq 0.55 \\ \frac{0.70-\gamma}{0.70-0.55} & 0.55 \leq \gamma \leq 0.70 \end{cases} \quad (6)$$

$$\mu_H(\gamma) = \begin{cases} \frac{\gamma-0.50}{0.65-0.50} & 0.50 \leq \gamma \leq 0.65 \\ 1 & 0.65 \leq \gamma \leq 0.75 \\ \frac{0.90-\gamma}{0.90-0.75} & 0.75 \leq \gamma \leq 0.90 \end{cases}$$

$$\mu_{VH}(\gamma) = \begin{cases} \frac{\gamma-0.75}{0.95-0.75} & 0.75 \leq \gamma \leq 0.95 \\ 1 & 0.95 \leq \gamma \end{cases}$$

After completing the system analysis, the fuzzy rule base is established, consisting of numerous if-then rules. These rules define the relationships between the input variables and the output variable psychosocial issues. Each rule functions as a specific guideline that interprets how combinations of input values influence the output. In this system, a total of 243 rules is constructed, covering all possible scenarios for the five input variables, each of which has three linguistic categories. This comprehensive rule base enables the model to capture a wide range of psychosocial issues. An example rule might be structured as follows: Example Rule: "If academic pressure is high, social and peer pressure is moderate, family dynamics and expectations are low, mental health condition is moderate, and lifestyle and physical health is poor, then psychosocial issues are very high". These rules allow the fuzzy Mamdani inference system to process complex input combinations and produce realistic, nuanced assessments of psychosocial challenges. **Figure 9** presents a selection of these if-then rules, providing a snapshot of how the rule base operates within the system. This illustration highlights the intricate mapping of input conditions to specific outputs, showcasing how each rule contributes to the comprehensive assessment of psychosocial issues among students.

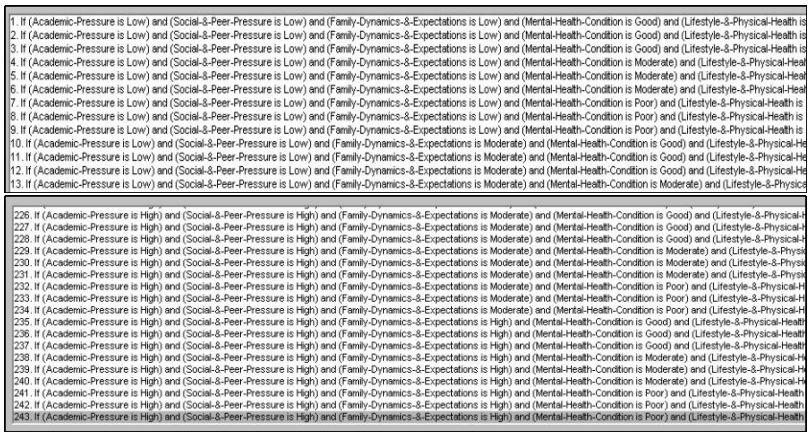

Figure 9. Fuzzy rule bases for addressing psychosocial issues.

Following the establishment of the rule base, the next step is defuzzification using the centroid method. Defuzzification is essential to translate the fuzzy output produced by the rule base into a crisp value that represents the level of psychosocial issues among students in a more actionable form. The centroid method, also known as the center of gravity method, is used here for its accuracy in reflecting the weighted distribution of all possible outcomes. This method calculates the center of the area under the aggregated fuzzy output curve, resulting in a single crisp value. The centroid method is particularly effective in systems like this, where the goal is to capture a balanced, nuanced view of the complex input interactions. This defuzzified output enables the rule viewer to interpret and address psychosocial issues more effectively, providing a clear, quantifiable assessment based on the combination of all input variables. Through this approach, stakeholders can understand the severity of psychosocial issues in practical terms, facilitating more informed interventions and support for college students.

$$\varnothing_{Centroid} = \frac{\sum_{i=0}^{n} \mu\ (\varnothing_i) \,.\, (\varnothing_i)}{\sum_{i=0}^{n} \mu\ (\varnothing_i)} \tag{7}$$

During this procedure, **Figure 10** illustrates the status of a case based on input and output variables. If the input variables- Academic pressure at 83.8% (high), social and peer pressure at 93.6% (high), family dynamics and expectations at 86.1% (high), mental health condition at 21.4% (good), and lifestyle and physical health at 50.8% (moderate) collectively indicate that the student is experiencing a very high level of psychosocial issues, measured at 91.3%.

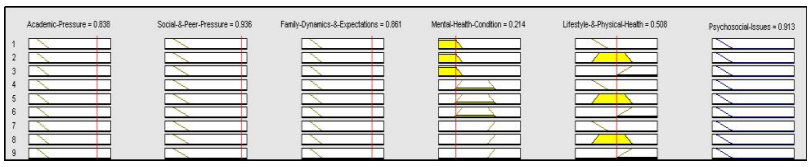

Figure 10. Psychosocial issues analysis with rule viewer.

A three-dimensional representation of two input variables and an output variable can effectively be visualized using a surface viewer. This method provides an intuitive way to understand the relationships between inputs and how they collectively influence the output variable, which, in this case, relates to psychosocial issues among students. These surface viewer representations help in identifying trends, clusters, and potential

thresholds where significant changes in psychosocial issues occur. These 3D plots, insights into how specific factors contribute to student well-being, facilitating targeted interventions and support mechanisms.

The visualizations presented in **Figures 11–20** illustrate various instances of these 3D representations. Each figure likely focuses on different combinations of input variables, showcasing how variations in the inputs correspond to changes in the output variable.

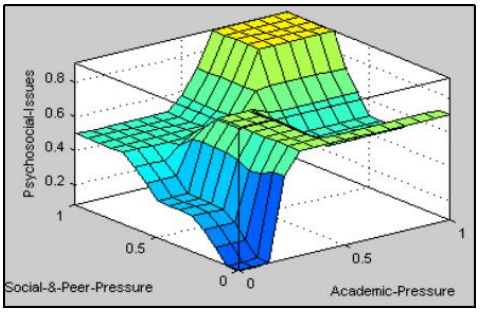

Figure 11. 3D surface view 1.

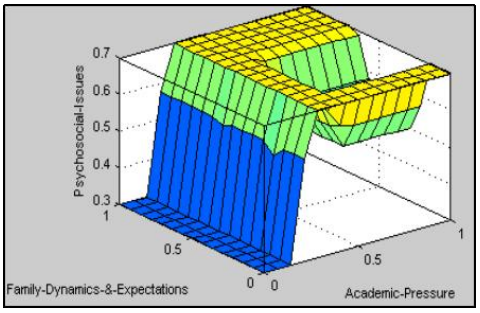

Figure 12. 3D surface view 2.

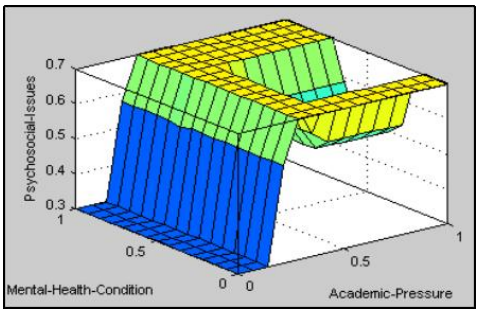

Figure 13. 3D surface view 3.

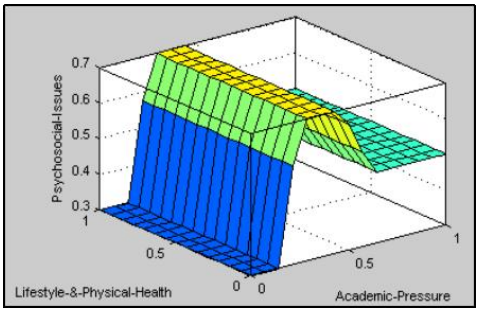

Figure 14. 3D surface view 4.

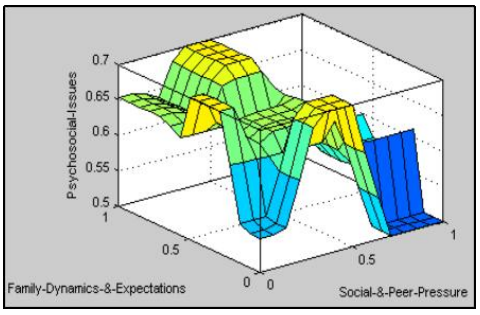

Figure 15. 3D surface view 5.

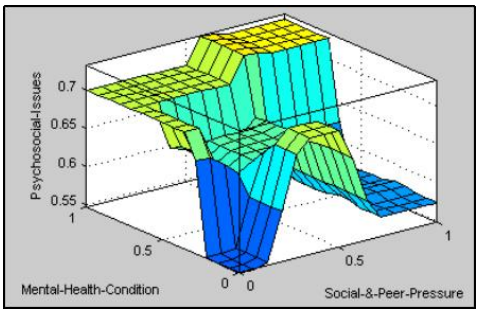

Figure 16. 3D surface view 6.

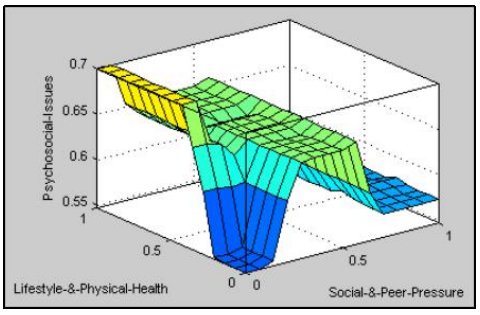

Figure 17. 3D surface view 7.

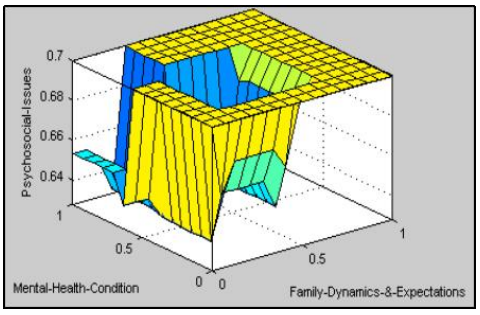

Figure 18. 3D surface view 8.

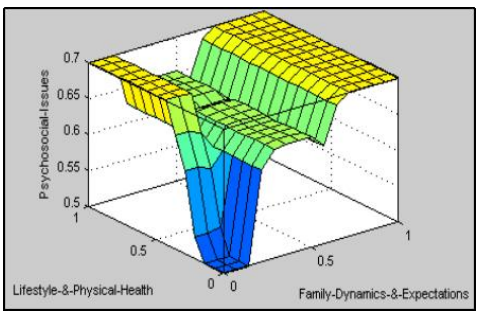

Figure 19. 3D surface view 9.

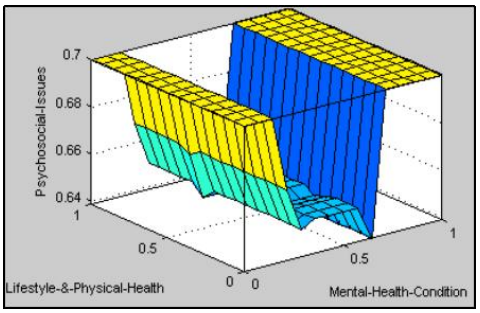

Figure 20. 3D surface view 10.

5. Result

This study involved a comprehensive survey of 600 B.Sc. students from various colleges affiliated with Dr. Bhimrao Ambedkar University, Agra, encompassing both rural and urban areas. The demographic distribution showed that 402 students (67%) were male, and 198 students (33%) were female. The levels of psychosocial issues among the participants were categorized as follows:

- Very low: 54 students (9%).
- Low: 18 students (3%).
- Moderate: 192 students (32%).
- High: 174 students (29%).
- Very high: 162 students (27%).

These results reveal that a significant number of students fall into the moderate, high, and very high categories, emphasizing the urgent need for targeted interventions and support mechanisms. Additionally, the analysis indicates that male students are more susceptible to psychosocial issues than their female counterparts, suggesting a need for further exploration of the causes and factors contributing to these differences. To enhance understanding, a graphical representation of these findings is created, which is as follow (**Figure 21**):

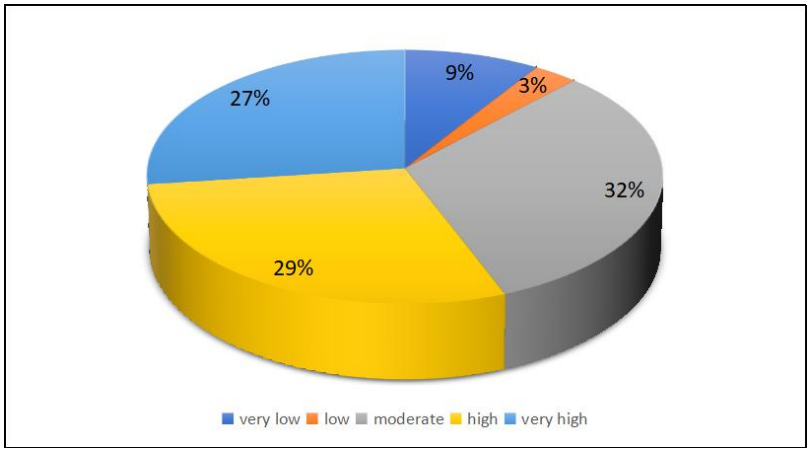

Figure 21. Visual depiction illustrating the percentage of students going through different levels of psychosocial issues.

This graphical representation would serve to effectively communicate the prevalence of psychosocial issues among students and highlight the gender differences observed in the study. By visually depicting the data, stakeholders can better grasp the

scope of the psychosocial issues faced by students, which is essential for developing targeted interventions and support strategies.

6. Limitations of the proposed model

Despite the methodological rigor of the proposed fuzzy inference framework, this study contains several limitations which are given below.

- **Sample and data limitations**
  The study relied on primary questionnaire data collected from students within a specific institution/region. Therefore, the findings may reflect localized psychosocial characteristics and may not fully represent broader student populations. Additionally, self-reported responses may be subject to response bias or social desirability effects.
- **Model structure assumptions**
  In this study the fuzzy inference system was developed using predefined membership functions and expert-derived rule bases.
- **Limited variable scope**
  The model incorporates selected psychosocial indicators. Other potentially relevant factors were not included, which may limit explanatory completeness.
- **Expert dependency**
  The construction of the fuzzy rule base depends on expert knowledge. While consensus was achieved, variations in expert opinion across different institutions or cultural contexts may influence rule formulation.

7. Generalizability of the proposed model

The proposed fuzzy inference framework is mathematically adaptable and can be extended to other educational settings with appropriate recalibration of membership functions and rule bases. However, generalizability depends on the similarity of psychosocial constructs across populations, cultural and institutional contexts, and validation using larger and more diverse datasets. Although the current study focused on specific region, the methodological structure of the fuzzy model is transferable. With reparameterization using local expert input and population-specific data, the framework may be applied to secondary schools, higher education institutions, or other youth populations. Future research involving multi-institutional or cross-cultural datasets would further enhance the external validity of the model (Rathore and Singh, 2024; Rathore et al., 2024a).

8. Conclusion

This study has introduced the concept of a fuzzy logic system and highlighted its potential benefits in addressing psychosocial issues among college students. By utilizing fuzzy logic, the research provides a nuanced understanding of the complexities surrounding psychosocial challenges, offering insights that traditional methods may overlook. The innovative application of the fuzzy logic system illuminates the intricate nature of psychosocial challenges faced by students, allowing for a more

comprehensive analysis of contributing factors. The study emphasizes the importance of careful planning, ethical considerations, and a robust methodology to ensure the validity and practical utility of the findings (Singh et al., 2021). By exploring other prominent factors contributing to psychosocial challenges, educators, parents, and communities can more effectively identify students at risk and implement targeted interventions. Failing to address these issues poses significant risks to both the mental and physical health of students. These risks include: increased likelihood of alcoholism, cigarette smoking, and drug use, heightened risk of depression and greater involvement in violent acts towards themselves and others (Storch et al., 2004). The study underscores the necessity of early intervention strategies, supportive environments, counseling, and positive reinforcement of pro-social behaviors to mitigate the effects of psychosocial issues. The findings derived from the fuzzy logic research can be practically applied to inform colleges and universities about the best strategies for addressing and preventing psychosocial challenges among their students. In conclusion, this study demonstrates that a fuzzy logic system is a valuable tool for understanding and addressing psychosocial issues among college students. It provides practical recommendations that can aid in the development of more effective intervention and prevention strategies, ultimately fostering a healthier academic environment. The insights gained from this study not only enhance our understanding of the challenges faced by students but also pave the way for actionable solutions that can significantly improve their overall well-being (Yelbi et al., 2021).

Challenges and future directions

The application of fuzzy inference system in addressing psychosocial issues presents several promising opportunities, yet it also encounters several challenges that must be addressed to optimize its effectiveness:

- **Extensive data collection**:
  Implementing a FIS requires comprehensive data to accurately capture the nuances of psychosocial issues. Gathering reliable and extensive datasets can be resource-intensive and time-consuming.
- **Need for continuous updates**:
  As psychosocial issues evolve, the FIS must be regularly updated to reflect new findings, changing social dynamics, and emerging challenges. This necessitates a commitment to ongoing research and system maintenance, which can be a logistical challenge.
- **Integration with existing systems**:
  Incorporating FIS into current frameworks for addressing psychosocial issues requires careful integration with existing data management and intervention systems, which may not always be compatible.
- **Interdisciplinary collaboration**:
  Effective application of FIS in psychosocial contexts often requires collaboration across multiple disciplines, including psychology, sociology, education, and computer science. Bridging these fields can present challenges in communication and methodology.

Future directions explore the synergy between fuzzy inference system and machine learning technologies. By leveraging machine learning algorithms, the adaptability and accuracy of fuzzy inference system can be enhanced, allowing for dynamic adjustments based on new data and trends. Establishing standardized protocols for data collection, rule formulation, and system updates can streamline the implementation of FIS and improve the consistency of findings across studies. Creating user-friendly interfaces for stakeholders, including educators and mental health professionals, will facilitate the application of FIS insights in real-world settings, making it easier to implement recommended interventions. Future research should also consider the applicability of FIS across different cultural and demographic groups to ensure that interventions are effective and relevant in varied contexts (Yorguner et al., 2021). Addressing ethical considerations related to data privacy and the potential implications of decisions made based on FIS outputs is crucial. Future work should emphasize the responsible use of data and transparency in the modeling process. By acknowledging these challenges and pursuing these future directions, researchers and practitioners can enhance the utility of FIS in addressing psychosocial issues, ultimately leading to more effective interventions and improved outcomes for students.

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Institutional review board statement: This study was conducted using questionnaire-based surveys among students from rural and urban colleges affiliated with Dr. Bhimrao Ambedkar University, Agra. As the study involved minimal risk and anonymous survey data, formal Institutional Review Board approval was not required as per institutional guidelines.

Informed consent statement: Informed consent was obtained from all participants involved in the study. The anonymity and confidentiality of participants were ensured.

Data availability statement: The data used in this study are available from the corresponding author upon reasonable request.

Conflict of interest: The authors declare no conflict of interest.

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