

A STATISTICAL EXPLORATION OF THE EFFECTS OF ADDITIONAL PARAMETERS IN MATHEMATICS

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Abstract

The Bipolar Fuzzy Set is an advancement of the classical fuzzy set, developed to represent situations involving both positive and negative preferences or opinions simultaneously. The bipolar score function plays a vital role in decision-making theory. In this article, a bipolar score function is applied to real-life data to examine the effect of additional parameters in the field of mathematics. Furthermore, a research hypothesis is formulated, and the bipolar score function values are statistically analyzed using SPSS software to determine the impact of these additional parameters in mathematics.

Keywords: Bipolar fuzzy set, score function, Decision making, Statistical Analysis

1. INTRODUCTION

Decision Support Systems are advanced technologies that facilitate decision-making in complex environments by offering structured analysis and data-driven choices [14]. As a result, these systems are becoming crucial in various disciplines, including corporate strategy, health, and well-being. In an attempt to achieve a resolution, several tools and decision-making systems were integrated, but none of them was able to adequately illustrate the complexity of problem. New theories are now being used by researchers as mathematical instruments for decision assistance and decision-making systems. Mathematical and analytical models are used in model management system (MMS) to interpret data and make choices. Mathematical models are instruments for improving decision-making systems because they contain specialized information or principles to help decision-making, such as fuzzy set theory [2], rough set theory [3], and soft set theory [4]. Analytical models (AM) are mathematical representations employed to analyze the data, interpret it, and predict the behavior of the process, or decision-making system. AM uses mathematical formulas, statistical techniques, or algorithms to examine input data and provide output insights, assisting in decision-making, aiding in understanding correlations between variables, and forecasting outcomes using various analytical tools like EXCEL, SPSS, MATLAB, R, and Python.

Bipolar fuzzy set is an extension of fuzzy set which deals with the positive and negative membership values of a case. Various authors extended the Bipolar idea [12] and applied in many fields to handle the bipolarity situation [15],[17],[16] and [18]. Score function plays an important role in the decision making theory. Several researchers have applied fuzzy set theory and the concept of fuzzy numbers to address various social issues and identify effective solutions. For instance, Daniel Neff utilized the fuzzy set approach to assess poverty levels [5], while Thakre et

al. [6] employed fuzzy logic-based multi-criteria analysis to evaluate teacher performance. Revathi Anbalagan and Amudhambigai applied fuzzy mathematics to identify societal concerns affecting farmers [7]. Raj Kumar and T. Pathinathan introduced the Pentagonal Fuzzy Decision-Making technique in their study "Sieving out the Poor" [8]. During the COVID-19 pandemic in Greece, Konstantina Chrysafiadi et al. [9] assessed the effectiveness and acceptance of e-learning among computer science students using fuzzy logic. Similarly, Siva et al. explored fuzzy cognitive mapping to investigate poverty levels in Tamil Nadu during the pandemic. Overall, fuzzy logic evaluation techniques and fuzzy mathematical models have been widely employed by numerous scholars to analyze and address complex social challenges [10], [11].

In this article, Section 2 provides an overview of the definitions and operations related to Bipolar Fuzzy Sets. Section 3 presents the application of the bipolar score function to evaluate the impact of additional parameters in the field of mathematics. Section 4 outlines the proposed algorithm and the hypothesis formulation based on the collected data. In Section 5, the results analyzed using SPSS software are discussed. Finally, Section 6 presents the conclusion and highlights the potential scope for future research.

2. PRELIMINARIES

Bipolar fuzzy sets [12]: Let X be the non-empty fuzzy set. The bipolar fuzzy set $B = \{B^-, B^+\}$ is defined in X . $B^+ \in [0, 1]$ is the satisfaction degree of x in B , $B^- \in [-1, 0]$ is the satisfaction degree of the implicit counter property of x in B .

Operations on Bipolar fuzzy sets[13]: Consider $B_1, B_2 \in BFS$. Zhang defines the following operations.

- i) Disjunction : $B_1 + B_2 = (-\max[b_1^-, b_2^-], \max[b_1^+, b_2^+])$
 $= (-[b_1^- \vee b_2^-], [b_1^+ \vee b_2^+])$
- ii) Parallel conjunction: $B_1.B_2 = (-\min[b_1^-, b_2^-], \min[b_1^+, b_2^+])$
 $= (-[b_1^- \wedge b_2^-], [b_1^+ \wedge b_2^+])$
- iii) Serial conjunction: $B_1 \times B_2 = (-\{[b_1^- \wedge b_2^+] \vee [b_1^+ \wedge b_2^-]\}, \{[b_1^- \wedge b_2^-] \vee [b_1^+ \wedge b_2^+]\})$
- iv) Negation: $\neg B_1 = [-b_1^+, b_1^-]$
- v) Complement: $\neg B_1 = \neg[-1 + b_1^-, 1 - b_1^+]$

Score Function [14]: T. Mahmood et al. defines the score function as $S'(B)$ of $B = (b^-, b^+) \in BFS$ as:

$$S'(B) = b^+ + b^-$$

where $S'(B) \in [-1, 1]$, and if $b^+ = b^- \implies S'(B) = 0$

3. DECISION MAKING USING BIPOLAR SCORE FUNCTION

After the COVID-19 epidemic, mathematics has emerged as an important scientific tool, notably in decision-making, predictive modeling, and statistical analysis. Mathematical modeling helps immensely in forecasting epidemics of diseases, tracking infection rates, and monitoring the effectiveness of measures such as vaccination and isolation period. Significant data sets are examined using machine learning models that rely on mathematical techniques. Experts use AI and machine learning to ensure effective health care, effective therapies, and predicting medical results. The field of mathematics has progressed in generating predictive and optimization algorithms, which are employed to allocate constrained substances like booster shots, and hospital beds.

After COVID-19, the study of mathematics has evolved and enriched with various scientific methodologies. Even Nevertheless, there is a drop in students' decision to pursue a

career in mathematics, and curiosity in Mathematics has declined. It is influenced by several variables, notably the difficulty of learning fundamental ideas via the internet and the absence of live instruction, peer problem solving, and discussion that sustains interest in subjects. This exacerbates the situation and makes the trend towards choosing multidisciplinary, technical disciplines over pure mathematics. Meantime, there is a growing need for medical research and other related fields. The changes in mathematics syllabus with less emphasis on particular topics, make students demotivated and lose interest in continuing mathematics at a higher level, their attention is directed towards skill-based or pragmatic subjects.

Data Collection:

A survey was conducted using an objective and analytically designed questionnaire among college students in the Vellore district to investigate the reasons behind the declining interest in pursuing Mathematics at higher levels of study. The data were collected through a Google Form, which focused on gathering information related to students’ interest in Mathematics, the structure of the Mathematics curriculum, the challenges encountered, and the career prospects in the field. Additionally, information pertaining to students’ interest in other subjects, their respective course structures, and associated career opportunities was also obtained.

The collected data is categorized into four groups based on distinct criteria. Let the set of alternatives be denoted by $C_i = \{c_1, c_2, c_3, c_4\}$, representing four different colleges that offer Mathematics either as an allied or a core subject.

Suppose the set of criteria is given by $\Delta_i = \{\Delta_1 = \text{course structure of the Mathematics subject, } \Delta_2 = \text{level of job opportunities in Mathematics, } \Delta_3 = \text{level of interest in Mathematics, } \Delta_4 = \text{level of interest in other courses}\}$. Let the weight vector associated with C_i be $\omega=(0.25, 0.22, 0.26, 0.27)$.

Step 1: Table 1 gives the Bipolar decision making matrix of the collected data.

Step 2: Table 2 presents the normalized weighted Bipolar decision matrix.

Table 1: *Bipolar Decision Making Matrix*

	Δ_1	Δ_2	Δ_3	Δ_4
c_1	(0.7,-0.4)	(0.5,-0.3)	(0.4,-0.8)	(0.9,-0.6)
c_2	(0.8,-0.2)	(0.7,-0.5)	(0.3,-0.7)	(0.7,-0.3)
c_3	(0.4,-0.5)	(0.8,-0.7)	(0.5,-0.8)	(0.6,-0.4)
c_4	(0.6,-0.7)	(0.9,-0.6)	(0.7,-0.5)	(0.5,-0.2)

Step 3: Table 3 displays the score value, calculated using the definition [3].

Table 2: *Normalized weighted Bipolar Decision Matrix*

	Δ_1	Δ_2	Δ_3	Δ_4
c_1	(0.175,-0.1)	(0.11,-0.066)	(0.104,-0.208)	(0.243,-0.162)
c_2	(0.2,-0.05)	(0.154,-0.11)	(0.078,-0.182)	(0.189,-0.081)
c_3	(0.1,-0.125)	(0.176,-0.154)	(0.13,-0.208)	(0.162,-0.108)
c_4	(0.15,-0.175)	(0.198,-0.132)	(0.182,-0.13)	(0.135,-0.054)

Result: In each category c_i , the score function corresponding to students’ interest in other courses is observed to be higher than that of other evaluated criteria. This suggests that the influence of other courses is notably positive among the student population. Specifically, in categories c_1, c_2 , and c_3 , the interest level in Mathematics is found to be negative, indicating a considerably low level of engagement and enthusiasm for the subject. Moreover, in categories c_3 and c_4 , students

Table 3: Score Value Function

	Δ_1	Δ_2	Δ_3	Δ_4
c_1	0.075	0.044	-0.104	0.086
c_2	0.15	0.044	-0.104	0.108
c_3	-0.025	0.022	-0.078	0.054
c_4	-0.025	0.066	0.052	0.081

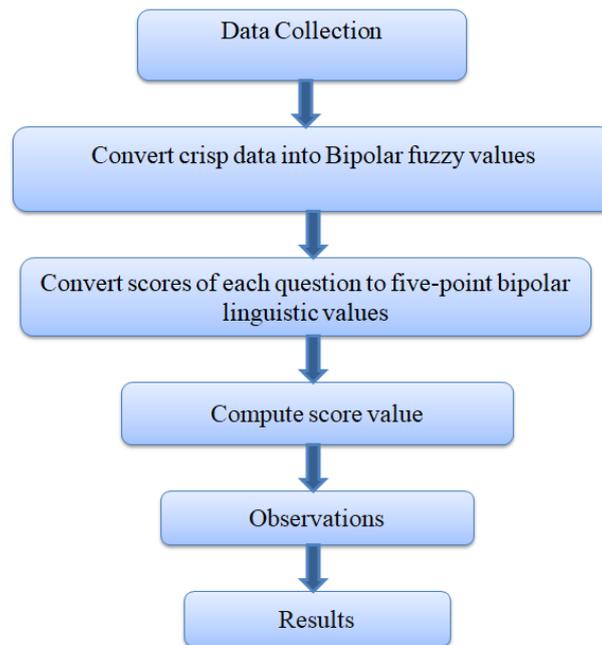


Figure 1: Algorithm

express negative satisfaction with the structure of the course, highlighting potential areas for curriculum review and improvement.

4. A PROPOSED ALGORITHM AND FORMULATION OF HYPOTHESIS

Algorithm:

Figure 1 depicts the flowchart of the proposed algorithm, which incorporates the bipolar score function to quantitatively assess the impact of additional parameters related to the field of Mathematics. The computational and statistical analysis are conducted using SPSS software to ensure methodological accuracy and reliability.

Conceptual Model of the study:

Figure 2 illustrates the conceptual model developed for this study, in which four key variables have been identified: job opportunities in Mathematics (Job), Mathematics course structure (*Course_Struct*), other courses (*Other_Courses*), and decline in Mathematics choice (*Maths_decline*).

The dependent variable refers the decline in Mathematics choice, while the independent variables represents job opportunities in Mathematics, Mathematics course structure, and other courses.

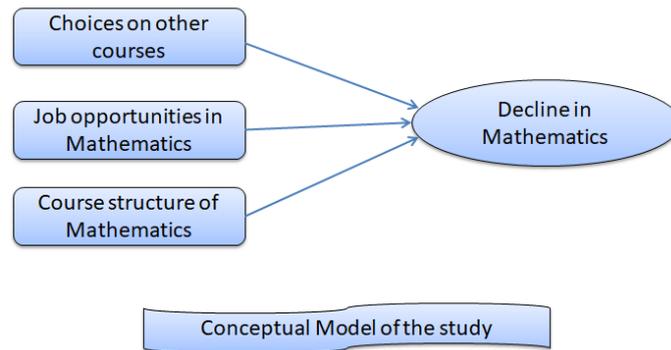


Figure 2: Model of the Study

Model Summary ^b									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.795 ^a	.632	.618	.22605	.632	45.739	3	80 ^a	.000

a. Predictors: (Constant), Course_Struct, Other_Courses, Job
 b. Dependent Variable: Maths_decline

Figure 3: Model Summary

Objective of the analysis:

- To measure the extent to which job opportunities in Mathematics dissuade students from choosing Mathematics for higher studies.
- To evaluate how other applied courses in higher education influence the decision to choose Mathematics.
- To ascertain which aspects of the Mathematics course structure deter students from selecting Mathematics for higher studies.

Research Hypothesis:

The hypothesis are formulated based on the objective:

H01: There is no significant effect of job opportunities in Mathematics that leads to the decline in Mathematics choice.

H02: There is no significant impact of other applied courses that influence the decrease in Mathematics choice.

H03: There is no significant impact of Mathematics course structure that reduces the Mathematics choice.

2. Transformed crisp data into bipolar fuzzy data.
3. Represented the data into 5-point bipolar linguistic value.
4. The score value is computed for all the linguistic values using the definition [3].

5. RESULTS

A multiple regression test is employed to analyze the study. A multiple correlation co-efficient between the predictors and the dependent variable is 0.795, which gives a strong and positive correlation. With an R-Square value of 0.632, the model explains 63.2% of the variation in Decline in Mathematics. The model represents a significant amount of variance (63.2%) in the dependent

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	.169	.050		3.413	.001
Other_Courses	-.265	.062	-.355	-4.306	.000
Job	.378	.077	.408	4.930	.000
Course_Struct	.213	.074	.221	2.888	.005

Figure 4: Significance of the Coefficients

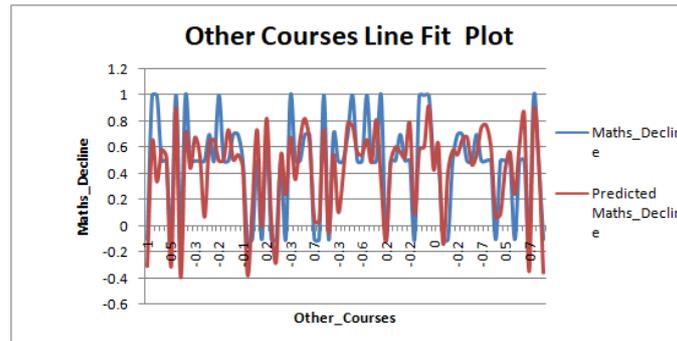


Figure 5: Impact of other courses in the choice of Mathematics

variable, as depicted in Figure 3. The F-value = 45.739 in Table 4, indicates that the model is statistically significant. The statistical significance of the model ($p < 0.001$), implies a strong connection between the predictors and the dependent variable.

Table 4: ANOVA Test

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	7.012	3	2.337	45.739	.000
Residual	4.088	80	0.51	0.2017	
Total	11.100	83			

- Job (Beta = 0.408): Among all the factors, Job has the greatest positive effect on *Maths_decline*, as depicted in Figure 4.
- *Other_Courses* (Beta = -0.355): This indicates that *Other_Courses* has a relatively substantial negative influence on *Maths_decline*, as shown in Figure 5.
- *Course_Struct* (Beta = 0.221): *Course_Struct* significantly and positively affects *Maths_decline* but less strongly.
- The study found that the t-value of 3.413 is a significant predictor, while other courses (t = -4.306) have a strong negative effect on the independent variable. Job opportunities (t = 4.930) have the strongest positive effect on the independent variable, while course structure (t = 2.888) has a positive effect on the dependent variable. These findings suggest that job opportunities play a crucial role in predicting outcomes.

6. DISCUSSION

The regression model is statistically significant, with a large F-statistic (45.739) and a p-value (0.000) confirming its significance as shown in Figure 6. Job (Beta= 0.408) is the most important

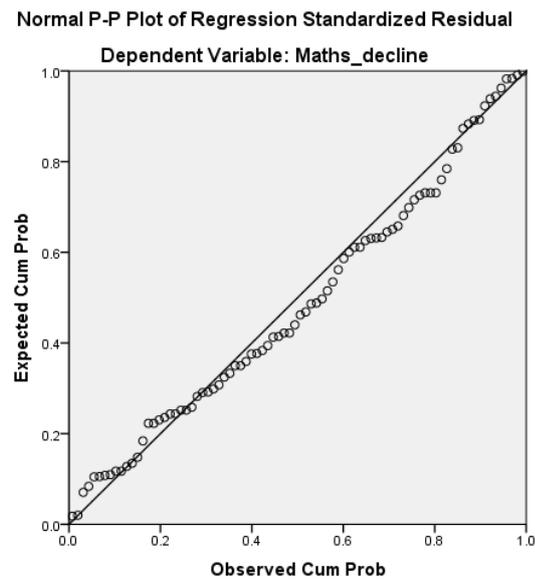


Figure 6: Regression Plot

factor influencing the dependent variable, followed by other courses (Beta= -0.355), which have opposite effects on the dependent variable. All predictors are statistically significant in explaining the decline in Mathematics choice in higher studies.

7. CONCLUSION

In this article, we explore the application of the bipolar score function in mathematics. By formulating a research hypothesis and employing statistical analysis through SPSS, the study demonstrated how additional parameters influence mathematical choices and perceptions. The findings highlight the effectiveness of the bipolar fuzzy framework as a powerful tool in both educational and analytical domains, especially for evaluating complex factors involved in decision-making.

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