Prediction of the Number of New Students at Bangka Belitung University Using Fuzzy Logic Tsukamoto Method

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Abstract The fluctuation in the number of new students each year is a significant challenge for universities in designing admission policies and providing efficient academic facilities. This study aims to predict the number of new students at Bangka Belitung University using the Tsukamoto fuzzy logic method. This method was chosen because of its ability to manage uncertain historical numerical data and produce precise linguistic rule-based estimates. The data analyzed included the number of applicants and students accepted in six faculties during the period 2020–2023. The analysis process involved the stages of fuzzification, fuzzy inference, and defuzzification. The prediction results for 2024 showed a Mean Absolute Percentage Error (MAPE) value of 16.19%, which is included in the "accurate" category according to the Lewis scale. These findings indicate that the Tsukamoto method is effective in producing reliable predictions and can be applied as a tool in strategic decision making, especially in managing capacity and improving the quality of higher education services.

Keywords Fuzzy Logic, Tsukamoto, Prediction, Freshmen, Fuzzification, MAPE

1 Introduction

Education plays an important role in improving the quality of life of the nation's population [1]. Higher education is an institution that carries out the process of continuing formal education at the highest level [2]. Higher education as an educational institution is an institution that plays an important role in producing human resources who have high qualifications and competencies [3]. As an educational institution, higher education must provide adequate facilities to support the needs of students. In achieving this goal, higher education must understand the increase and decrease in the number of students each year so that the facilities provided are considered sufficient to meet the needs of students. Every year, higher education will hold New Student Admissions (PMB). The New Student Admissions System (PMB) is a mechanism for accepting new students in a higher education environment [4]. The number of new students can increase and decrease each year. In this case, the facilities available at a higher education institution also affect the number of new students such as adequate classrooms, supporting facilities such as air conditioning, projectors and the quality of teaching staff or lecturers.

One of the universities in Indonesia is Bangka Belitung University, which is located in the Bangka Belitung Islands province. Every year, Bangka Belitung University accepts thousands of prospective new students from various regions, especially from the Bangka Belitung Islands province. A prediction system is needed to accurately estimate the number of new students to improve educational services and campus facilities. Forecasting is the process of estimating future demand using various forecasting factors, often taken from previous time series data [5]. This prediction is important for decision making related to capacity, budget allocation, procurement of teaching staff, and educational facilities and infrastructure at Bangka Belitung University.

The number of new students at Bangka Belitung University changes every year. This is known from observations made in the form of new student admissions data every year from 2020 to 2023 with details of 2020 data of 1169 new students, then for 2021 there were 1427 new students, then for 2022 there were 2004 new students joining Bangka Belitung University, and finally in 2023 there were 1975 new students joining the extended family of Bangka Belitung University. In this case, the campus takes a policy related to the facilities available to support the needs of students which are increasing every year. Planning the provision of new student needs is an important part so that the learning process runs smoothly [6]. One solution that can be taken

in responding to this is to predict the number of students for the coming year; by making this prediction it can be a picture for universities to provide complete facilities to ensure the smooth running of the lecture process.

Fuzzy logic can be applied to these problems, where fuzzy set theory is used as a mathematical framework in solving uncertainty, ambiguity, or lack of information. Fuzzy logic is widely used in prediction and decision-making systems involving uncertainty and ambiguity [7]. Fuzzy logic is a precise way to map an input space into an output space, having continuous values. Fuzzy is expressed in terms of degrees of membership and degrees of truth [8]. The fuzzy logic inference method can generally be used to determine the production quantity of a product, there are three methods that can be used, namely, the Tsukamoto method, the Mamdani method and the Sugeno method [9]. A fuzzy set is a set that maps each element from the interval 0 to 1. Simply put, a fuzzy set is a set that does not have strict boundaries [10]. Fuzzy logic with the Tsukamoto method can be used in the above problems. The Tsukamoto method is one of the fuzzy logic techniques that is suitable for predicting the number of new students in the coming year. Each result of an IF-THEN-based approach is represented by a fuzzy set with a monotonic membership function. Thus, the output of each operation is given with certainty based on a predetermined alpha (α), which is then determined using the central mean [11]. In this study, to predict 2024, data from the previous 4 years is needed, namely 2020, 2021, 2022, and 2023.

Research related to predicting the number of new students using the fuzzy logic method has been conducted by several previous researchers. One of them is a study by Irfan et al, which compared the Mamdani, Sugeno, and Tsukamoto fuzzy logic methods in predicting the number of new students at the Faculty of Science and Technology UIN Sunan Gunung Djati Bandung. The results of the study showed that the Mamdani method had the smallest error rate, but the Tsukamoto method still provided quite good prediction results with an error value of 39.03%. This study aims to discuss the use of Tsukamoto's fuzzy logic method in predicting the number of new students. This study is expected to help universities in making decisions related to the availability of facilities to support student needs. In this study, researchers used the MAPE method to determine the accuracy of the predictions that have been made.

2 Methodology

This study uses a descriptive quantitative approach that aims to build a prediction system for the number of new students at Bangka Belitung University based on several determining factors. This method was chosen because the Tsukamoto method has the advantage of producing highly numerical and precise output through fuzzy rule-based inference.

2.1 Types and Approaches of Research

This type of research is included in the type of descriptive quantitative research that aims to predict the number of new students at Bangka Belitung University using the Tsukamoto method fuzzy logic approach. This method was chosen because of its ability to handle historical numerical data and transform it into fuzzy rule-based predictions that can be interpreted linguistically.

2.2 Population and Sample

The population in this study includes all data on the number of applicants, graduates and new students at Bangka Belitung University from 2020 to 2023. The data used comes from applicants, graduates and new students from several main faculties of Bangka Belitung University, such as the Faculty of Science and Engineering, Faculty of Economics and Business, Faculty of Social and Political Sciences, Faculty of Law, Faculty of Agriculture, Fisheries and Marine Sciences and the Faculty of Medicine and Health Sciences.

2.3 Data Collection Technique

Data collection in this study was carried out through:

a. Documentation study, namely using data on applicants, graduates and data on the number of new students from the archives of new student admissions (PMB) of Bangka Belitung University from 2020-2023.

b. Informal interviews with PMB managers to gain an understanding of new student admission policies and procedures.

2.4 Tsukamoto Fuzzy Logic

The Tsukamoto method stipulates that each consequence in the IF-THEN rule must be represented in a fuzzy set that has a monotonic membership function, namely a function whose value always increases or decreases regularly. With this approach, the output of the inference process for each rule is determined based on the predicate value (degree of truth) of the premise of the rule.

To obtain the final result, the Weighted Average method is used from all rule outputs. For example, there are two input variables, namely X and Y and one output variable, namely Z. Variable X is grouped into two fuzzy sets, namely A1 and A2 while variable Y is divided into B1 and B2. The output variable Z is divided into two fuzzy sets, namely C1 and C2 where both of these sets must have monotone membership functions so that the inference process can be carried out correctly.

Here are the rules of Tsukamoto Method Logic:

a. IF the number of applicants to college decreases and the number of students who graduate decreases THEN the number of new students decreases.

b. IF the number of applicants to college increases and the number of students who graduate also increases THEN the number of new students increases.

c. IF the number of applicants to college decreases and the number of students who graduate increases THEN the number of new students increases.

d. IF the number of applicants to college increases and the number of students who graduate decreases THEN the number of new students decreases.

2.5 Data Anlysis Technique

a. Fuzzyfication: Ascending and descending linear membership functions are used to transform numerical data including the number of applicants and graduates into linguistic variables such as “low”, “medium”, and “high”. This function forms a membership representation based on the minimum and maximum values in the previous data.

$$\mu_{down}\begin{cases}1; & \text{if } x \le a,\\ \frac{b-x}{b-a}; & \text{if } a \le x \le b\\ 0; & \text{if } x \ge b\end{cases} \tag{1}$$

$$\mu_{increases}\begin{cases}1; & \text{if } x \le b,\\ \frac{x-a}{b-a}; & \text{if } a \le x \le b\\ 0; & \text{if } x \ge a\end{cases} \tag{2}$$

b. Rule Base Implementation: Rule Base Implementation is a fuzzy rule arranged in the form of IF-THEN. For example, if the number of applicants and graduates is high, then the number of new students will increase. The predicate value is obtained from the minimum membership value (α-predicate) of the input variable, and each rule is operated through the logical AND operator.

$$\text{IF } x \text{ is } A \text{ THEN } y \text{ is } B. \tag{3}$$

c. Fuzzy Inference: The monotone fuzzy value of each rule will be generated as an output value (z) which is calculated using the membership function on the output variable (number of new students).

1. d. Defuzzification: The z-scores of each rule are combined with a weighted average:

$$z = \frac{\sum(\alpha_n \times zn)}{\sum \alpha_n} \tag{4}$$

e. Model accuracy test: To measure the accuracy of the model, the Mean Absolute Percentage Error (MAPE) is used:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \times 100\%$$

Description:

- A_i = Actual value (actual number of new students)
- F_i = Predicted value
- n = Number of data.

Interpretation of MAPE values according to the Lewis scale (1982):

- $< 10\%$: Very Accurate
- 10%–20% : Accurate
- 20%–50% : Quite Accurate
- $> 50\%$: Inaccurate.

The steps above can also be understood with the following flow diagram:

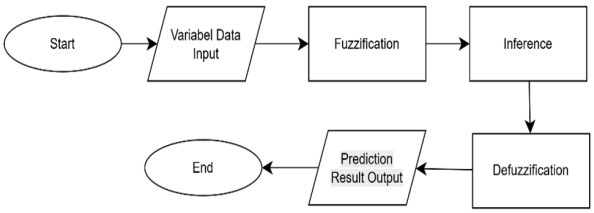

Figure 1. Fuzzy Logic Flowchart

2.6 Research Limitations

This study used 4 years of historical data (2020–2023) to build the Tsukamoto fuzzy logic model. Using at least several years of data helps to form valid membership functions and reliable prediction rules. If fewer data are used (e.g., only 1–2 years), the reliability of the model decreases.

The focus of this study is limited to the use of new student data for the last four years ($2020 - 2023$). This study only looks at two main input variables: the number of interested students and the number of students who graduate. Therefore, the predictions made are only contextual and do not consider additional variables such as capacity, the number of those who fail re-registration, and geographic factors.

3 Results and Discussion

At this stage, data collection is carried out in accordance with the existing problems. From the results of data collection, data is obtained as in the following table.

Next, process the data from data collection. The data in this study is historical data of at least 4 years back in order to obtain accurate results in a prediction using the Tsukamoto method of fuzzy logic, after data collection, then perform calculations using Tsukamoto Fuzzy Logic by applying a logic flowchart and applying a flowchart flow as in Figure 1. At the implementation stage, the researcher starts with calculations and processes data according to the stages of Tsukamoto Fuzzy Logic.

a. Data Input

b. Fuzzyfication
The first calculation stage is fuzzyfication, to produce the output of membership degrees obtained from input data that is in accordance with fuzzy rules, the data used as input data in this calculation process is data in 2023, all data can be seen in table 1 using the firm value procedure. The membership function limit for each variable and the selected fuzzy set serves as the basis for fuzzyfication calculations.

1. Interest Variables
Referring to Table 2, it can be seen that the lowest interest variable is 1401 students while the highest interest variable is 2287 students, thus it can be described in the form of a linear representation curve in Figure 2 below. From Figure 2 above, the membership function for the interested variable can be arranged as follows.

$$\mu_{down} \begin{cases} 1; & \text{if } x \leq 1401, \\ \frac{2287-x}{2287-1401}; & \text{if } 1401 \leq x \leq 2287 \\ 0; & \text{if } x \geq 2287 \end{cases}$$

Table 1. Data on Applicants, Graduates and New Students of UBB 2020-2023

Year	Faculty	Fans	Passed	New Students
2020	Faculty of Science and Engineering	1955	395	331
	Faculty of Agriculture, Fisheries and Marine Sciences	1366	373	308
	Faculty of Economics and Business	1823	287	260
	Faculty of Law	471	143	124
	Faculty of Social and Political Sciences	796	198	146
	Faculty of Medicine and Health Sciences	0	0	0
2021	Faculty of Science and Engineering	1401	500	421
	Faculty of Agriculture, Fisheries and Marine Sciences	1272	401	324
	Faculty of Economics and Business	2461	320	290
	Faculty of Law	842	176	160
	Faculty of Social and Political Sciences	1335	279	232
	Faculty of Medicine and Health Sciences	0	0	0
2022	Faculty of Science and Engineering	1902	729	611
	Faculty of Agriculture, Fisheries and Marine Sciences	1345	427	367
	Faculty of Economics and Business	2552	506	456
	Faculty of Law	931	228	211
	Faculty of Social and Political Sciences	1200	308	260
	Faculty of Medicine and Health Sciences	1191	115	99
2023	Faculty of Science and Engineering	2287	660	563
	Faculty of Agriculture, Fisheries and Marine Sciences	1075	436	355
	Faculty of Economics and Business	2889	587	512
	Faculty of Law	725	227	190
	Faculty of Social and Political Sciences	770	300	246
	Faculty of Medicine and Health Sciences	1191	158	109

Table 2. Faculty of Science and Engineering Student Data 2020-2023

Year	Fans	Passed	New Students
2020	1955	395	331
2021	1401	500	421
2022	1902	729	611
2023	2287	660	563

$$\mu_{increases} \begin{cases} 1; & \text{if } x \leq 2287, \\ \frac{x-1401}{2287-1401}; & \text{if } 1401 \leq x \leq 2287 \\ 0; & \text{if } x \geq 1401 \end{cases}$$

From the membership function above, to find the value of the degree of membership for the descending set is as follows

$$\mu_{fans\ are\ down} = \frac{2287 - 2287}{2287 - 1401} = 0$$

The result of the membership degree value for the interested variable with the descending set is 0. Next, to find the membership degree value for the ascending set is as follows

$$\mu_{interest\ increases} = \frac{2287 - 1401}{2287 - 1401} = 1$$

The result of the membership degree value for the interested variable with the increasing set is 1.

2. Pass Variable
Referring to table 2, it can be seen that the lowest passing variable was 395 students, while the highest passing variable was 729 students, thus it can be described in the form of a linear representation curve in Figure 3 below. From Figure 3 above, the membership function for the graduated variable can be arranged as follows:

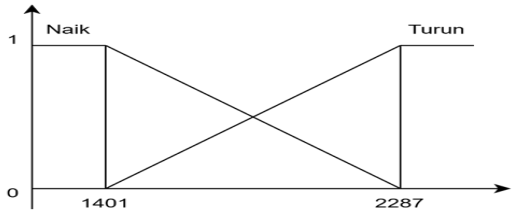

Figure 2. Linear Representation Curve Display Faculty of Science and Engineering Interest Variables

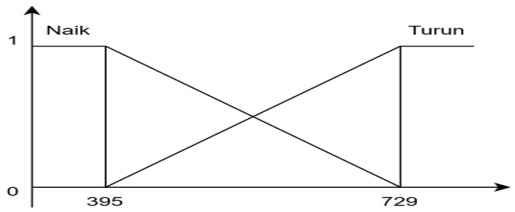

Figure 3. Linear Representation Curve Display Faculty of Science and Engineering Graduate Variable

$$\mu_{down}\begin{cases}1; & \text{if } y \leq 395,\\ \frac{729-y}{729-395}; & \text{if } 395 \leq y \leq 729\\ 0; & \text{if } y \geq 729\end{cases}$$

$$\mu_{increases}\begin{cases}1; & \text{if } y \leq 729,\\ \frac{y-395}{729-395}; & \text{if } 395 \leq y \leq 729\\ 0; & \text{if } y \geq 395\end{cases}$$

From the membership function above, to find the value of the degree of membership of the graduated variable for the descending set is as follows.

$$\mu_{pass\ down} = \frac{729-660}{729-395} = 0.2$$

With the result of the membership degree value for the variable accepted with the descending set is 0.2. Furthermore, to find the membership degree value for the variable accepted with the ascending set is as follows

$$\mu_{pass\ up} = \frac{660-395}{729-395} = 0.8$$

The result of the membership degree value for the accepted variable with the increasing set is 0.8.

3. New Student Variables
Referring to table 3, it can be seen that the lowest number of new students is 331 students, while the highest number of new students is 611 students, so it can be described in the form of a linear representation curve in Figure 4 below From the figure 4, the membership function for the new student variable can be arranged as follows:

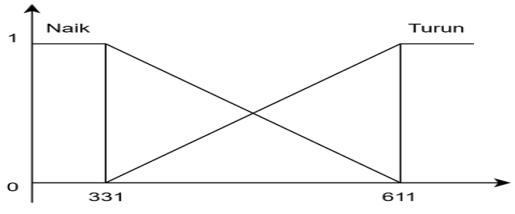

Figure 4. Linear Representation Curve Display Faculty of Science and Engineering Student Variables

$$\mu_{reduce}\begin{cases}1; & \text{if } z \leq 331,\\ \frac{611-z}{611-331}; & \text{if } 331 \leq z \leq 611\\ 0; & \text{if } z \geq 611\end{cases}$$

$$\mu_{increase}\begin{cases}1; & \text{if } z \leq 611,\\ \frac{z-331}{611-331}; & \text{if } 331 \leq z \leq 611\\ 0; & \text{if } z \geq 331\end{cases}$$

c. Rules
The rule below is obtained by combining each existing variable, this rule will produce the predicate alpha value. The search for the predicate alpha value is done using the AND operator, the results of the predicate alpha value will be used to find the z value for each rule.

1. IF Applicants GO DOWN ∩ Graduates GO DOWN, THEN New Students GO DOWN

$$\begin{aligned}\alpha_1 &= MIN\{\mu \text{ peminat turun; lulus turun}\}\\ \alpha_1 &= MIN\{0; 0.2\}\\ \alpha_1 &= 0\end{aligned}$$

To find the z value in rule 1, look at the membership function of the new student variable, REDUCE,

$$Z_1 = 611$$

Since the alpha value of the 1st predicate is 0, the value of $Z_1 = 611$ corresponds to the membership function.

2. IF Applicants GO UP ∩ Passed GO UP, THEN New Students INCREASE

$$\begin{aligned}\alpha_2 &= MIN\{\mu \text{ peminat naik; lulus naik}\}\\ \alpha_2 &= MIN\{1; 0.8\}\\ \alpha_2 &= 0.8\end{aligned}$$

To find the z value in rule 2, look at the membership function of the new student variable INCREASED

$$\begin{aligned}\frac{z_2 - 331}{611 - 331} &= 0.8\\ z_2 - 331 &= 488.8 - 264.8\\ z_2 - 331 &= 224\\ z_2 &= 224 = 331\\ z_2 &= 555\end{aligned}$$

3. IF Interest DOWN ∩ Graduates UP, THEN New Students INCREASE

$$\begin{aligned}\alpha_3 &= MIN\{\mu \text{ peminat turun; lulus naik}\}\\ \alpha_3 &= MIN\{0; 0.8\}\\ \alpha_3 &= 0\end{aligned}$$

To find the z value in rule 3, look at the membership function of the new student variable INCREASED,

$$Z_3 = 331$$

Since the alpha value of the 3rd predicate is 0, the value of $Z_3 = 331$ corresponds to the membership function.

4. IF Applicants GO UP ∩ Graduates GO DOWN, THEN New Students GO DOWN

$$\begin{aligned}\alpha_4 &= MIN\{\mu \text{ peminat naik; lulus turun}\}\\ \alpha_4 &= MIN\{1; 0.2\}\\ \alpha_4 &= 0.2\end{aligned}$$

To find the z value in rule 4, look at the membership function of the new student variable, which is DECREASE.

$$\begin{aligned}\frac{611 - z_4}{611 - 331} &= 0.2\\ 611 - z_4 &= 122.2 - 66.2\\ 611 - z_4 &= 56\\ -z_4 &= 56 - 611\\ z_4 &= 555\end{aligned}$$

d. Defuzzification
After obtaining the z value for each rule in the rule inference process or Tsukamoto rule above, the next step is the defuzzification process with the following process.

$$z = \frac{(0 \times 611) + (0.8 \times 555) + (0 \times 331) + (0.2 \times 555)}{0 + 0.8 + 0 + 0.2}$$
$$= 555$$

So, the estimated number of new students in the faculty of science and engineering in 2024 will increase by an estimated number of 555 students. By carrying out the same process, the prediction of new students in each faculty is calculated with the results of the prediction calculations which can be seen in table 3 as follows. From the table it can be seen

Table 3. Research Instruments

Faculty	Year 2023	2024 Prediction Results	Actual Data 2024
Faculty of Science and Engineering	563	555	610
Faculty of Agriculture, Fisheries and Marine Sciences	355	367	375
Faculty of Economics and Business	512	512	661
Faculty of Law	190	169	302
Faculty of Social and Political Sciences	246	249	238
Faculty of Medicine and Health Sciences	109	109	128

that Tsukamoto fuzzy logic can be used to predict the number of new students. So that Tsukamoto fuzzy logic can be implemented to solve problems similar to this study.

e. Model Accuracy Test
The model accuracy test was conducted to measure how good the prediction model for the number of new students built with fuzzy logic using the Tsukamoto method. In this study, the testing method used was the Mean Absolute Percentage Error (MAPE).

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \times 100\%$$

Table 4. Calculation Results

No	Actual Data	Prediction Results	MAPE
1	610	555	0,090164
2	375	367	0,021333
3	661	512	0,225416
4	302	169	0,440397
5	238	249	0,046218
6	128	109	0,148438
		Total	0,97197

$$MAPE = \frac{1}{6} \times \frac{(0,090164 + 0,021333 + 0,225416 + @0,440397 + 0,046218 + 0,148438)}{6} \times 100\%$$
$$= \frac{0,97197}{6} \times 100\%$$
$$= 16.19944\%$$

In Faculty of Law, the prediction error (MAPE) reached 44%, which falls into the 'quite inaccurate' category. This shows the limitation of the model because only two input variables were used. External factors such as admission quota policy or accreditation status may have influenced the results.

The calculation results show that the MAPE value is 16.1944% which is included in the accurate category. So the Tsukamoto fuzzy logic model in this study is suitable for use in predicting the number of new students at Bangka Belitung University.

4 Conclusions

Based on the results of the analysis using the Tsukamoto fuzzy logic method on historical data on new student admissions (PMB) at Bangka Belitung University from 2020 to 2023, a prediction model for the number of new students was obtained with a fairly good level of accuracy. This is indicated by the Mean Absolute Percentage Error (MAPE) value of 16.19%, which according to the Lewis interpretation scale is included in the ”accurate” category. Although there are differences between the predicted results and actual data in several faculties, the differences are generally not significant. Thus, the Tsukamoto fuzzy logic approach can be considered feasible as a basis for planning capacity and providing more adaptive educational facilities, and has the potential to be a strategic tool in data-based policy making in higher education environments.

Acknowledgements

The author would like to thank Mrs. Baiq Desy Aniska Prayanti, S.Si., M.Sc., as a lecturer in the Fuzzy Logic Course who has provided assistance and support during the research from determining the title to the process of making the journal until completion. The author also thanks all parties who have provided assistance and contributions both directly and indirectly during the implementation of this research.

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