

Electric Motorcycle Damage Detection System Using Tsukamoto's Fuzzy Inference System

Wahyu Setyo Nugroho¹, Indah Susilawati²

^{1,2}Informatics, Faculty Information Technology
wahyu120897@gmail.com

Revised: March 20, 2025; Accepted: May, 04, 2025

Abstract

With the development of technology today, there are more and more users of electric motorcycles because electric motorcycles are a cheap, affordable and environmentally friendly means of transportation. The number of electric motorcycle users is not proportional to the level of understanding of the damage and the symptoms of the damage. To overcome this, this research creates a system that can help detect damage to electric motorcycles based on the answers to symptoms experienced by customers at the Bogi Power workshop. With this system the repair process becomes fast and efficient. This study uses 21 questions with answer choices (Yes, Sometimes, No) which are assigned a value to determine the weight. In order to make the right decisions in this research, the Tsukamoto Fuzzy Inference System method is used with the rules that have been used then look for the zscore and conclusions about the damage to the electric motorcycle.

Keywords: Electric Motorcycle, Fuzzy Inference System Tsukamoto

1. Introduction

Electric motorcycles are a means of transportation that is currently widely used by several groups of people. Provide information to consumers when buying a used motorbike, there are input criteria that must be considered, including complete documents, engine condition, body condition and price [1]. A system is needed on the vehicle that has a function to avoid collisions between motor vehicles and objects in front of them. By using distance and speed detection between motor vehicles and objects in front of them, ultrasonic sensors will be used as distance parameters, hall effect to measure the speed of motor vehicles. Determination of the output value will be processed using the fuzzy logic method which is processed using a microcontroller [2]. The growth of electric motorcycles is very rapid in line with the level of need and the community's economy for cheap, affordable and environmentally friendly means of transportation. Damage to automatic motorbikes is one of the problems that users often face, so it is not uncommon for users to immediately take the vehicle to a repair shop [3]. Through this system, users can monitor the performance of 3-phase motors accurately and take necessary actions in case of disturbances or abnormal conditions. This system also allows optimization of energy use by adjusting the motor speed according to application needs [4]. Detecting damage to electrical components of automatic injection motorbikes is a system to make it easier for motorbike owners to detect damage to their motorbikes, so that owners can find out early about damage to their motorbikes and can take initial action before being followed up by mechanics [5].

However, the more electric motorcycle users there are, not many people understand the damage they experience and how to overcome it, in terms of business, there are still not many who open electric bicycle service or repair shops to repair electric motorcycles. By implementing Fuzzy Inference System with Mamdani method for detecting electrical damage on motorcycles, it can simplify the process of detecting electrical damage on motorcycles [6]. With a damage detection system on this electric motor, it can help to detect damage to the electric motor, so that it can make it easier to handle damage to the electric motor. The problem encountered with motorbikes is because motorbikes have complicated engine components and the time to predict the level of damage to the motorbike takes a long time [7]. The development of environmentally friendly vehicle technology has encouraged the increasing use of electric motorbikes as an alternative transportation that is energy efficient and has low emissions. Fuzzy Logic Application: The use of fuzzy logic in controlling solar panels for DC motors can increase the efficiency of energy use. Fuzzy logic allows the system to adjust the power generated by the solar panels adaptively according to environmental conditions and the needs of the DC motor [8]. However, electric motorbikes still have the potential to experience various types of damage, both in the electrical system, motor, battery,

and other electronic components. This damage can cause decreased performance or even vehicle failure if not immediately identified and handled. The Sugeno fuzzy logic method acts as a water pump speed controller based on the speed of water discharge entering the reservoir, then the total water and speed of water flow entering the reservoir will be displayed on the LCD display [9].

In practice, the process of diagnosing electric motorbike damage still depends heavily on the expertise of technicians or user experience. This is a challenge in itself because not all symptoms of damage have a definite pattern, and often involve information that is uncertain or vague. Therefore, a system is needed that can help the diagnosis process quickly and accurately even with incomplete or vague data. One approach that can be used to overcome this problem is a Fuzzy Inference System (FIS)-based system. The fuzzy method can accommodate uncertainty and imitate the way humans make decisions based on experience. In particular, the Tsukamoto method in FIS provides results in the form of crisp values that are suitable for diagnostic systems. By combining a number of symptoms inputted by the user, this system can determine the level of damage logically and systematically. The application of the Fuzzy Inference System method Mamdani through a process that begins with Fuzzification Input load settings and sensor load input then performs inference consisting of implication functions with the min method and composition between rules with the max method which ends with the centroid method defuzzification process can help optimize the 3-phase induction motor speed control system so that the motor speed can be constant even though it gets a variable load from 0.5 Nm to 1.75 Nm with a load optimization level of 75% from previous research [10].

In addition, a web called NAMI will be created to monitor the state of the sea. The web aims to make it easier for the public to participate in seeing the latest marine conditions. NAMI is developed on a web service with the Laravel 8 framework, while data processing uses the Fuzzy Tsukamoto Algorithm [11]. The expert system can diagnose washing machine damage and is able to provide convenience for washing machine users to be able to know early about the symptoms of washing machine damage so that they can handle washing machine damage more quickly and precisely [12]. IoT enables real-time data collection from various sensors installed in the field, enabling smarter and more timely decisions. However, to optimize management of rice fields, a method is needed that is able to manage sensor data well, and the Tsukamoto fuzzy method is one method that is able to provide this solution [13]. This method was chosen because it can handle data uncertainty in clinical symptoms. To determine the diagnosis results, the system consists of five main stages, namely collecting data on symptoms and disease characteristics, data fuzzification, rule formation (rule base), fuzzy inference process, and defuzzification [14]. In fuzzy logic there is a Fuzzy Inference System (FIS) and the method used is the Tsukamoto method. The Tsukamoto method has 3 important stages, namely: 1. Fuzzification to determine variables, sets, and domain values, 2. Inference for the process of forming rules and Min implication functions, and 3. Defuzzification using the weighted average method [15]. This study uses the Tsukamoto Fuzzy Inference System (FIS) method with 3 input variables, namely income, collateral, and the character of the prospective borrower. The output variable in this study is the feasibility in the form of a percentage of the Tsukamoto FIS calculation results [16].

Therefore, this study aims to design and implement an electric motorcycle damage detection system using the Tsukamoto method of Fuzzy Inference System, as a solution to support an efficient, flexible, and reliable damage diagnosis process.

2. Method

This study uses the Tsukamoto fuzzy method which forms a rules-based or rule base in the form of "cause and effect" or "if-then". The calculation steps in using the Fuzzy method are as follows:

1. The first step in calculating the Tsukamoto Fuzzy method is to create a fuzzy rule.
2. The next step is to calculate the degree of membership according to the rules that have been made. After the membership value of each fuzzy rule is known, the alpha value of the predicate can be determined by using fuzzy set operations. The linear function is down, namely the fuzzy set starts from the value of the region with the highest degree of membership on the left side, then moves down to the domain value that has a lower degree of membership.

The set in each variable is calculated based on the answer to the selected damage question. With the provisions of the answer choices YES (Value 60-100), the value Sometimes (30-70), and the answer no (0-40). Furthermore, the inference calculation process and finally the defuzzification process with the z-score calculation. The following is a picture of a fuzzy set in the damage detection system on an electric motorbike which can be seen in Figure 1.

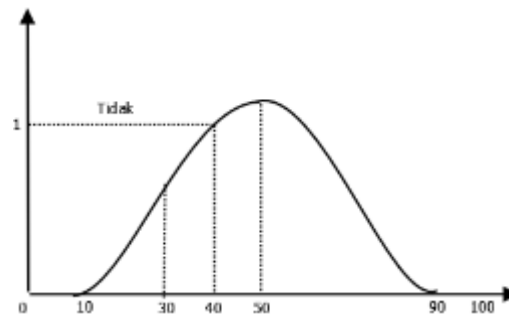


Figure 1. Curva Beta

$$Yes = 1 / (1 + ((Z(i) - 80)/10)^2)$$

$$Sometimes = 1 / (1 + ((Z(i) - 50)/10)^2)$$

$$No = 1 / (1 + ((Z(i) - 20)/10)^2)$$

Description:

Value i = Input value based on answer choices from damage symptoms

The knowledge base applied in this study uses fuzzy logic, especially fuzzy Inference System with the Tsukamoto method. The input value used is the original data that is processed. The input variable used is the variable of damage symptoms of this electric motorbike which can be seen in the following table 1.

Table 1. Symptom Variables

Symptom Code	Symptom Name
GJL01	Molis is powerless
GJL02	Battery drains quickly/leaks
GJL03	When charged, it immediately fills up quickly
GJL04	The engine is limping
GJL05	The motor can rotate when assisted at the start
GJL06	The engine sound is rough and lacks power
GJL07	The engine rotation is slow and jerky
GJL08	The BLDC motor spins for a moment then stops due to improper installation
GJL09	Hall sensor malfunction
GJL10	3 phase motor failure
GJL11	Damage to the seat assembly
GJL12	Axle damage

Symptom Code	Symptom Name
GJL13	Carrying load that is too heavy
GJL14	A short circuit occurred in the 3 phases of the motor
GJL15	When the condition is ON, but the motor does not want to turn when the gas is pressed, there is a small "tick" sound from the controller
GJL16	When the motor is rotated manually, it feels jerky/stuttering
GJL17	Micro damage to the controller
GJL18	Gas handle damage
GJL19	Voltage too low or too high
GJL20	Unequal phase voltage
GJL21	One of the phases is broken

Table 2. Damage table

Damage Code	Damage Name
KR01	Battery Damage
KR02	BLDC Motor/Dynamo
KR03	Controller
KR04	Supply Network

3. Result and Discussion

This research and damage detection system on electric motorcycles was created as a medium to help bogi power workshops so that handling of damage to their electric motorcycles is faster. The admin inputs data based on the symptoms experienced by the customer's electric motorcycle. The system will show what damage is experienced after that the customer can submit it to the workshop mechanic to repair the damage directly. The calculation in this system begins when the admin inputs an answer based on the symptoms given by the customer (Answer Choices Yes, Sometimes, No). The value of the answer Yes (60-100), Sometimes (30-70), No (0-40). An overview of the questions can be seen in figures 2 to 4.

Figure 2. Question 1

Figure 3. Question 2

Figure 4. Question 3

Next, the weight calculation is carried out using the following formula:

$$\text{Weight (a)} = 1 / (1 + ((Z(i) - M_c) / (10^2)))$$

Perhitungan Bobot

Rumus: $1 / (1 + ((Z(i) - M_c) / (10^2)))$

No	Endek	Nilai	Rumus	Bobot
1	Endek	85	$1 / (1 + ((85 - 100) / (10^2)))$	0.8
2	Endek	90	$1 / (1 + ((90 - 100) / (10^2)))$	0.9
3	Endek	80	$1 / (1 + ((80 - 100) / (10^2)))$	0.7
4	Endek	85	$1 / (1 + ((85 - 100) / (10^2)))$	0.8
5	Endek	90	$1 / (1 + ((90 - 100) / (10^2)))$	0.9
6	Endek	80	$1 / (1 + ((80 - 100) / (10^2)))$	0.7

Figure 5. Weight calculation

The next step is the defuzzification calculation and the last zscore calculation, then the conclusion of the damage to the electric motorbike is drawn. The Z formula is as follows:

$$Z = z_1 * a_1 + z_2 * a_2 \dots z_n * a_n / a_1 + a_2 + a_n$$

Fuzzy Defuzzifikasi			
Kategori	Nilai	Bobot	Hasil
Kerusakan	40	1.0	40
Kondisi	30	1.0	30
Kerusakan	50	1.0	50
Kondisi	40	1.0	40
Kerusakan	60	1.0	60
Kondisi	50	1.0	50
Kerusakan	70	1.0	70
Kondisi	60	1.0	60
Kerusakan	80	1.0	80
Kondisi	70	1.0	70
Kerusakan	90	1.0	90
Kondisi	80	1.0	80
Kerusakan	100	1.0	100
Kondisi	90	1.0	90
Kerusakan	110	1.0	110
Kondisi	100	1.0	100
Kerusakan	120	1.0	120
Kondisi	110	1.0	110
Kerusakan	130	1.0	130
Kondisi	120	1.0	120
Kerusakan	140	1.0	140
Kondisi	130	1.0	130
Kerusakan	150	1.0	150
Kondisi	140	1.0	140
Kerusakan	160	1.0	160
Kondisi	150	1.0	150
Kerusakan	170	1.0	170
Kondisi	160	1.0	160
Kerusakan	180	1.0	180
Kondisi	170	1.0	170
Kerusakan	190	1.0	190
Kondisi	180	1.0	180
Kerusakan	200	1.0	200
Kondisi	190	1.0	190
Kerusakan	210	1.0	210
Kondisi	200	1.0	200
Kerusakan	220	1.0	220
Kondisi	210	1.0	210
Kerusakan	230	1.0	230
Kondisi	220	1.0	220
Kerusakan	240	1.0	240
Kondisi	230	1.0	230
Kerusakan	250	1.0	250
Kondisi	240	1.0	240
Kerusakan	260	1.0	260
Kondisi	250	1.0	250
Kerusakan	270	1.0	270
Kondisi	260	1.0	260
Kerusakan	280	1.0	280
Kondisi	270	1.0	270
Kerusakan	290	1.0	290
Kondisi	280	1.0	280
Kerusakan	300	1.0	300
Kondisi	290	1.0	290
Kerusakan	310	1.0	310
Kondisi	300	1.0	300
Kerusakan	320	1.0	320
Kondisi	310	1.0	310
Kerusakan	330	1.0	330
Kondisi	320	1.0	320
Kerusakan	340	1.0	340
Kondisi	330	1.0	330
Kerusakan	350	1.0	350
Kondisi	340	1.0	340
Kerusakan	360	1.0	360
Kondisi	350	1.0	350
Kerusakan	370	1.0	370
Kondisi	360	1.0	360
Kerusakan	380	1.0	380
Kondisi	370	1.0	370
Kerusakan	390	1.0	390
Kondisi	380	1.0	380
Kerusakan	400	1.0	400
Kondisi	390	1.0	390
Kerusakan	410	1.0	410
Kondisi	400	1.0	400
Kerusakan	420	1.0	420
Kondisi	410	1.0	410
Kerusakan	430	1.0	430
Kondisi	420	1.0	420
Kerusakan	440	1.0	440
Kondisi	430	1.0	430
Kerusakan	450	1.0	450
Kondisi	440	1.0	440
Kerusakan	460	1.0	460
Kondisi	450	1.0	450
Kerusakan	470	1.0	470
Kondisi	460	1.0	460
Kerusakan	480	1.0	480
Kondisi	470	1.0	470
Kerusakan	490	1.0	490
Kondisi	480	1.0	480
Kerusakan	500	1.0	500
Kondisi	490	1.0	490
Kerusakan	510	1.0	510
Kondisi	500	1.0	500
Kerusakan	520	1.0	520
Kondisi	510	1.0	510
Kerusakan	530	1.0	530
Kondisi	520	1.0	520
Kerusakan	540	1.0	540
Kondisi	530	1.0	530
Kerusakan	550	1.0	550
Kondisi	540	1.0	540
Kerusakan	560	1.0	560
Kondisi	550	1.0	550
Kerusakan	570	1.0	570
Kondisi	560	1.0	560
Kerusakan	580	1.0	580
Kondisi	570	1.0	570
Kerusakan	590	1.0	590
Kondisi	580	1.0	580
Kerusakan	600	1.0	600
Kondisi	590	1.0	590
Kerusakan	610	1.0	610
Kondisi	600	1.0	600
Kerusakan	620	1.0	620
Kondisi	610	1.0	610
Kerusakan	630	1.0	630
Kondisi	620	1.0	620
Kerusakan	640	1.0	640
Kondisi	630	1.0	630
Kerusakan	650	1.0	650
Kondisi	640	1.0	640
Kerusakan	660	1.0	660
Kondisi	650	1.0	650
Kerusakan	670	1.0	670
Kondisi	660	1.0	660
Kerusakan	680	1.0	680
Kondisi	670	1.0	670
Kerusakan	690	1.0	690
Kondisi	680	1.0	680
Kerusakan	700	1.0	700
Kondisi	690	1.0	690
Kerusakan	710	1.0	710
Kondisi	700	1.0	700
Kerusakan	720	1.0	720
Kondisi	710	1.0	710
Kerusakan	730	1.0	730
Kondisi	720	1.0	720
Kerusakan	740	1.0	740
Kondisi	730	1.0	730
Kerusakan	750	1.0	750
Kondisi	740	1.0	740
Kerusakan	760	1.0	760
Kondisi	750	1.0	750
Kerusakan	770	1.0	770
Kondisi	760	1.0	760
Kerusakan	780	1.0	780
Kondisi	770	1.0	770
Kerusakan	790	1.0	790
Kondisi	780	1.0	780
Kerusakan	800	1.0	800
Kondisi	790	1.0	790
Kerusakan	810	1.0	810
Kondisi	800	1.0	800
Kerusakan	820	1.0	820
Kondisi	810	1.0	810
Kerusakan	830	1.0	830
Kondisi	820	1.0	820
Kerusakan	840	1.0	840
Kondisi	830	1.0	830
Kerusakan	850	1.0	850
Kondisi	840	1.0	840
Kerusakan	860	1.0	860
Kondisi	850	1.0	850
Kerusakan	870	1.0	870
Kondisi	860	1.0	860
Kerusakan	880	1.0	880
Kondisi	870	1.0	870
Kerusakan	890	1.0	890
Kondisi	880	1.0	880
Kerusakan	900	1.0	900
Kondisi	890	1.0	890
Kerusakan	910	1.0	910
Kondisi	900	1.0	900
Kerusakan	920	1.0	920
Kondisi	910	1.0	910
Kerusakan	930	1.0	930
Kondisi	920	1.0	920
Kerusakan	940	1.0	940
Kondisi	930	1.0	930
Kerusakan	950	1.0	950
Kondisi	940	1.0	940
Kerusakan	960	1.0	960
Kondisi	950	1.0	950
Kerusakan	970	1.0	970
Kondisi	960	1.0	960
Kerusakan	980	1.0	980
Kondisi	970	1.0	970
Kerusakan	990	1.0	990
Kondisi	980	1.0	980
Kerusakan	1000	1.0	1000
Kondisi	990	1.0	990
Kerusakan	1010	1.0	1010
Kondisi	1000	1.0	1000
Kerusakan	1020	1.0	1020
Kondisi	1010	1.0	1010
Kerusakan	1030	1.0	1030
Kondisi	1020	1.0	1020
Kerusakan	1040	1.0	1040
Kondisi	1030	1.0	1030
Kerusakan	1050	1.0	1050
Kondisi	1040	1.0	1040
Kerusakan	1060	1.0	1060
Kondisi	1050	1.0	1050
Kerusakan	1070	1.0	1070
Kondisi	1060	1.0	1060
Kerusakan	1080	1.0	1080
Kondisi	1070	1.0	1070
Kerusakan	1090	1.0	1090
Kondisi	1080	1.0	1080
Kerusakan	1100	1.0	1100
Kondisi	1090	1.0	1090
Kerusakan	1110	1.0	1110
Kondisi	1100	1.0	1100
Kerusakan	1120	1.0	1120
Kondisi	1110	1.0	1110
Kerusakan	1130	1.0	1130
Kondisi	1120	1.0	1120
Kerusakan	1140	1.0	1140
Kondisi	1130	1.0	1130
Kerusakan	1150	1.0	1150
Kondisi	1140	1.0	1140
Kerusakan	1160	1.0	1160
Kondisi	1150	1.0	1150
Kerusakan	1170	1.0	1170
Kondisi	1160	1.0	1160
Kerusakan	1180	1.0	1180
Kondisi	1170	1.0	1170
Kerusakan	1190	1.0	1190
Kondisi	1180	1.0	1180
Kerusakan	1200	1.0	1200
Kondisi	1190	1.0	1190
Kerusakan	1210	1.0	1210
Kondisi	1200	1.0	1200
Kerusakan	1220	1.0	1220
Kondisi	1210	1.0	1210
Kerusakan	1230	1.0	1230
Kondisi	1220	1.0	1220
Kerusakan	1240	1.0	1240
Kondisi	1230	1.0	1230
Kerusakan	1250	1.0	1250
Kondisi	1240	1.0	1240
Kerusakan	1260	1.0	1260
Kondisi	1250	1.0	1250
Kerusakan	1270	1.0	1270
Kondisi	1260	1.0	1260
Kerusakan	1280	1.0	1280
Kondisi	1270	1.0	1270
Kerusakan	1290	1.0	1290
Kondisi	1280	1.0	1280
Kerusakan	1300	1.0	1300
Kondisi	1290	1.0	1290
Kerusakan	1310	1.0	1310
Kondisi	1300	1.0	1300
Kerusakan	1320	1.0	1320
Kondisi	1310	1.0	1310
Kerusakan	1330	1.0	1330
Kondisi	1320	1.0	1320
Kerusakan	1340	1.0	1340
Kondisi	1330	1.0	1330
Kerusakan	1350	1.0	1350
Kondisi	1340	1.0	1340
Kerusakan	1360	1.0	1360
Kondisi	1350	1.0	1350
Kerusakan	1370	1.0	1370
Kondisi	1360	1.0	1360
Kerusakan	1380	1.0	1380
Kondisi	1370	1.0	1370
Kerusakan	1390	1.0	1390
Kondisi	1380	1.0	1380
Kerusakan	1400	1.0	1400
Kondisi	1390	1.0	1390
Kerusakan	1410	1.0	1410
Kondisi	1400	1.0	1400
Kerusakan	1420	1.0	1420
Kondisi	1410	1.0	1410
Kerusakan	1430	1.0	1430
Kondisi	1420	1.0	1420
Kerusakan	1440	1.0	1440
Kondisi	1430	1.0	1430
Kerusakan	1450	1.0	1450
Kondisi	1440	1.0	1440
Kerusakan	1460	1.0	1460
Kondisi	1450	1.0	1450
Kerusakan	1470	1.0	1470
Kondisi	1460	1.0	1460
Kerusakan	1480	1.0	1480
Kondisi	1470	1.0	1470
Kerusakan	1490	1.0	1490
Kondisi	1480	1.0	1480
Kerusakan	1500	1.0	1500
Kondisi	1490	1.0	1490
Kerusakan	1510	1.0	1510
Kondisi	1500	1.0	1500
Kerusakan	1520	1.0	1520
Kondisi	1510	1.0	1510
Kerusakan	1530	1.0	1530
Kondisi	1520	1.0	1520
Kerusakan	1540	1.0	1540
Kondisi	1530	1.0	1530
Kerusakan	1550	1.0	1550
Kondisi	1540	1.0	1540
Kerusakan	1560	1.0	1560
Kondisi	1550	1.0	1550
Kerusakan	1570	1.0	1570
Kondisi	1560	1.0	1560
Kerusakan	1580	1.0	1580
Kondisi	1570	1.0	1570
Kerusakan	1590	1.0	1590
Kondisi	1580	1.0	1580
Kerusakan	1600	1.0	1600
Kondisi	1590	1.0	1590
Kerusakan	1610	1.0	1610
Kondisi	1600	1.0	1600
Kerusakan	1620	1.0	1620
Kondisi	1610	1.0	1610
Kerusakan	1630	1.0	1630
Kondisi	1620	1.0	1620
Kerusakan	1640	1.0	1640
Kondisi	1630	1.0	1630
Kerusakan	1650	1.0	1650
Kondisi	1640	1.0	1640
Kerusakan	1660	1.0	1660
Kondisi	1650	1.0	1650
Kerusakan	1670	1.0	1670
Kondisi	1660	1.0	1660
Kerusakan	1680	1.0	1680
Kondisi	1670	1.0	1670
Kerusakan	1690	1.0	1690
Kondisi	1680	1.0	1680
Kerusakan	1700	1.0	1700
Kondisi	1690	1.0	1690
Kerusakan	1710	1.0	1710
Kondisi	1700	1.0	1700
Kerusakan	1720	1.0	1720
Kondisi	1710	1.0	1710
Kerusakan	1730	1.0	1730
Kondisi	1720	1.0	1720
Kerusakan	1740	1.0	1740
Kondisi	1730	1.0	1730
Kerusakan	1750	1.0	1750
Kondisi	1740	1.0	1740
Kerusakan	1760		

-
- 500, 2018.
- [13] I. Inda, V. P. Rantung, and K. Santa, “Penerapan Fuzzy Tsukamoto Pada Sistem Irigasi Sawah Berbasis Internet of Things Di Kecamatan Remboken Sulawesi Utara,” *J. Innov. Futur. Technol.*, vol. 6, no. 2, pp. 185–192, 2024, doi: 10.47080/iftech.v6i2.3314.
- [14] J. N. Baraputri and F. I. Sanjaya, “Penerapan Metode Fuzzy Tsukamoto Dalam Sistem Pakar Diagnosis Penyakit Pada Sapi,” vol. 6, no. 2, pp. 1144–1152, 2025, doi: 10.47065/josh.v6i2.6568.
- [15] D. Setiawan, A. Arbansyah, and A. J. Latipah, “Fuzzy Inference System Metode Tsukamoto Untuk Penentuan Program Studi Fakultas Sains Dan Teknologi Di Universitas Muhammadiyah Kalimantan Timur,” *JIKO (Jurnal Inform. dan Komputer)*, vol. 7, no. 1, p. 23, 2023, doi: 10.26798/jiko.v7i1.657.
- [16] E. N. Hidayah *et al.*, “Implementasi Fuzzy Inference System Tsukamoto Pada Penentuan Kelayakan Pemberian Pinjaman,” vol. 14, no. 2, pp. 399–408, 2024.