

Comparison of three fuzzy logic algorithm methods for cellular selection

Gunawan¹, Wresti Andriani², Sawaviyya Anandianskha³

^{1,2} Teknik Informatika, STMIK YMI Tegal, Kota Tegal, Indonesia

³ Sistem Informatika, STMIK YMI Tegal, Kota Tegal, Indonesia

Article Info

Article history:

Received Aug 19, 2023

Revised Aug 23, 2023

Accepted Aug 24, 2023

Keywords:

Cellular

Fuzzy Logic

Fuzzy Mamdani

Fuzzy Sugeno

Fuzzy Tsukamoto

ABSTRACT

Many cell phone types are on the market today, increasingly making users feel confused and confused about choosing the cell that suits their needs. As one of the most essential needs at this time, users must be able to match their cellular needs with their income. Many smartphone products are offered. To help users in this study using three methods from the Fuzzy Logic algorithm for Decision Support Systems in choosing cellular according to their needs and desires; from the research that has been done, it is found that using the Fuzzy Tsukamoto method the accuracy is better than Mamdani which is equal to 0.02135, Mamdani is as large as 0.0643, while Sugeno is 0.1007. The cellular chosen is the Samsung A73 brand.

This is an open access article under the [CC BY-NC](https://creativecommons.org/licenses/by-nc/4.0/) license.



Corresponding Author:

Gunawan,

Informatics Engineering,

STMIK YMI Tegal,

Pendidikan Street #1, Pesurungan Lor, Margadana, Kota Tegal, Jawa Tengah, 52142, Indonesia.

Email: gunawan.gayo@gmail.com

Introduction

Mobile or cell phones have become one of the main items in everyday life (Lunde et al., 2018), used for business and personal purposes, especially for educational purposes (Bala, 2020). For users choosing cellular, it should be adjusted to their needs; many factors must be considered, including appearance, technical specifications, price, features, and so on (Darmawan, 2018). However, in reality, electoral fraud that is taken simultaneously cannot follow the expectations of the candidates because there are differences in preferences and the level of interest in each factor.

Using a decision support system (DSS) with a fuzzy logic algorithm can be an alternative solution to assist users in choosing a cell phone that suits their preferences and needs (Davvaz et al., 2021). The fuzzy logic method is often used in Decision Making Systems because this method can solve non-linear data (Castillo & Melin, 2021). The Fuzzy Logic used in this study is the Fuzzy Tsukamoto, Sugeno, and Mamdani methods, each of which has the advantage of handling fuzzy and uncertain variables for cell phone selection (Jane & Ganesh, 2019).

The Mamdani method of fuzzy system is known as the min-max method (Seno et al., 2022). In the Mamdani method, there are four steps: the formation of fuzzy sets, the application of implication functions, and the composition of rules and assertions (Rajesh Mavani et al., 2021). Sugeno's method is almost the same as Mamdani's reasoning, only the system output is not in the form of fuzzy sets but can be in the form of constants or linear equations for linear regression research. This method is a rule presented in the form of IF-THEN and was introduced by Takagi Sugeno in 1985 (Silva et al., 2020). The

most popular method is the Tsukamoto method, discovered by Lotfi A Zadeh in 1978, which determines the input value into a fuzzy set which is then operated with fuzzy rules; the output value is the result of the aggregation of all the fuzzy sets involved. This method is the easiest to implement, especially for relatively simple applications, because it only contains one input and one output (Zaaidatunni et al., 2021).

Previously there were several who conducted research using fuzzy logic, among others (Qafzezi et al., 2020); the study completed the application of the two methods, the results of which concluded that these two methods could be used to improve cloud management. In another research viz (Yudono et al., 2022) who researched using fuzzy logic on student admissions, the result is that fuzzy logic can be used properly. Another study analyzed rice productivity in Indonesia using fuzzy Mamdani, Tsukamoto, and Sugeno and concluded that fuzzy Mamdani and Sugeno had better accuracy than Tsukamoto. (Burhanuddin, 2023). In addition, research predicts the export value of leather shoes using fuzzy logic, which concludes that Fuzzy Mamdani is recommended to predict the most optimal amount (Rohimah, 2019). Research (et al., 2021) explain that the Fuzzy Multi-Criteria Decision Making (FMCDM) is better and produces less accuracy than the Simple Multi-Attribute Rating Technique (SMART), besides research (Yunan & Ali, 2020) who analyzed the comparison between Mamdani and Sugeno the results for Mamdani 0.86 were better than Sugeno's 0.72.

Based on the background described above, the problem in this study is to find the most accurate method of fuzzy logic for a Decision Making System in Cellular Selection to help users get cellular according to the criteria the user wants.

Method

The research method used for this study is shown in Figure 1. From Figure 1, it appears from the identification of the problem for this research then the data used is obtained online, namely from the website <https://www.pricebook.co.id>. The cell phones received consisted of cellular brands Samsung and OPPO. These two cellular providers were chosen because they were considered to have almost the same features, thus making it difficult for users to choose between the two brands; the variables taken are Price, OS version, Screen, RAM, Internal Memory, Camera, and Battery as much as 44 data, then processed using each method and then obtained the best accuracy of the three methods.

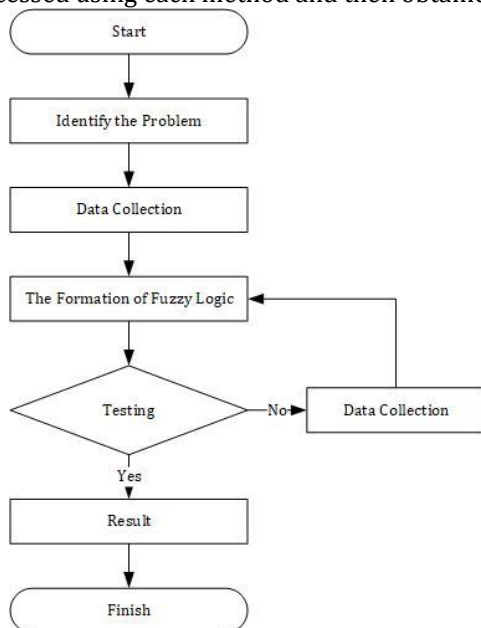


Figure 1. Research Flowchart

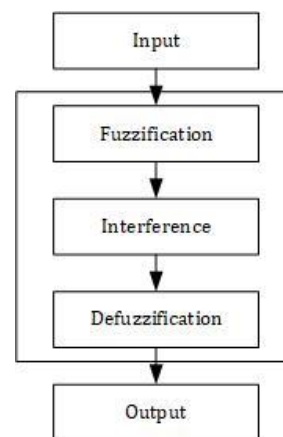


Figure 2. Fuzzy Logic Process

The method used is Fuzzy Mamdani, Fuzzy Tsukamoto, and Fuzzy Sugeno. In general, the stages of these three methods can be seen in Figure 2, from the input data set, then processed using three stages namely Fuzzification, Interference and defuzzification and getting the Output. Fuzzy Mamdani (Karyaningsih & Rizky, 2020), the stages include Fuzzyfication, which converts input variables into fuzzy variables, consisting of a membership curve which is represented by the level of membership, Inference, application of fuzzy rules to get output, then combinations that combine fuzzy variables into one result (Almeida et al., 2023). They are using Equation 1.

$$\alpha = (\mu V_1 \times \mu V_2 \times \mu V_2 \dots) \dots\dots\dots (1)$$

The next step is defuzzification, changing the fuzzy output variables into numeric output values.

In Fuzzy Tsukamoto (Nugraha et al., 2019), the stages include: The first step is to determine the input and output variables The variables used, then choose the domain of each variable, after that select the membership function to determine how close the input value is to the output in a particular category (Milošević et al., 2021), with equation 2.

$$\mu[x] = \begin{cases} 0; & x \leq a \\ (x - a)/(b - a); & a \leq x \leq b \\ 1; & x = b \end{cases} \dots\dots\dots (2)$$

Where μ =Fuzzy membership Crips Vallue; X= Variabel data; a=Minimum Value and b= Maximum Value. Then determine, the fuzzy rules, which include the statement of the relationship between input and output in the form of IF-THEN (Pavement et al., 2022); the following process is Inference, namely by receiving input values to produce output values. Then defuzzification, namely converting the crips value to create the final deal, using equation 3.

$$Z = \frac{\sum \alpha_1 Z_1}{\sum \alpha_1} \dots\dots\dots (3)$$

After that, the Sugeno method (Wahyuni et al., 2022), which determines the fuzzy set for each input and output variable, determines the fuzzy rules that contain if A, then B, and then C, which are used in one system. Then give a numerical weight, select the membership degree, and assess the output.

Results and Discussions

Mamdani Method

The data used is 44 data as in Table 1.

Table 1. Mobile Brand and Specifications

Merk	Price	Operating System	RAM	Memori Internal	Camera	Battery
Samsung A24	3200	13	8	128	50	5000
Samsung A34	4400	13	8	256	48	5000
Samsung A54	5200	13	8	128	50	5100
Samsung A14	2600	13	6	128	50	5000
Samsung A04	1500	12	4	64	50	5000
Samsung A23	3200	12	6	128	50	5000
Samsung A04S	1700	12	4	64	50	5000
Samsung A73	7200	12	8	256	108	5000
Samsung A13	1900	12	4	128	50	5000
...
Oppo Find X5 Pro	15000	12	12	256	50	5000

The steps for selecting decisions using the Mamdani method are as follows: Define the fuzzy set on the variables used in cellular selection.

The mobile selection graph with the variables can be seen in Figure 3.

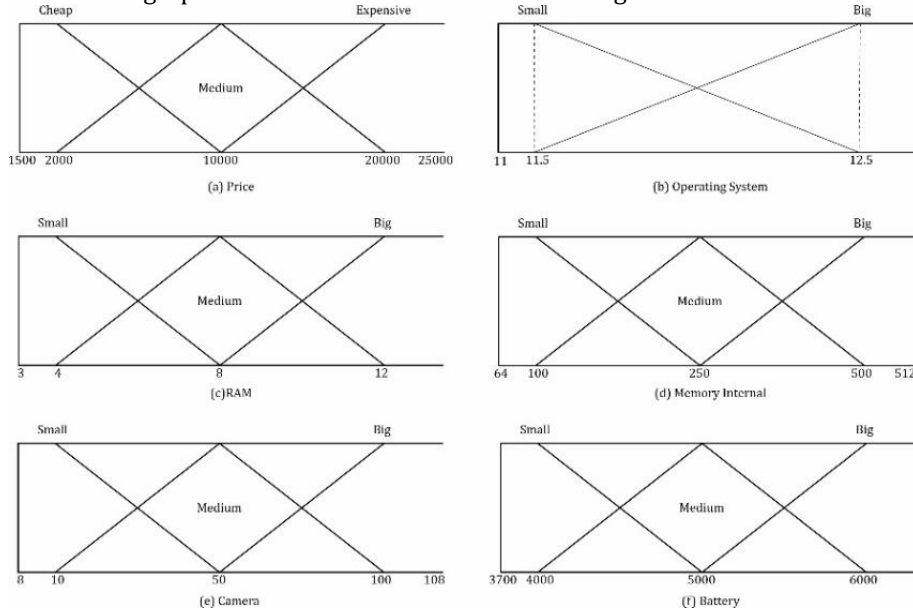


Figure 3. Variable Membership Function

Price

In Figure 3, you can see the minimum limit of 2000, being 10000 and a maximum of 20000, so the following formula is obtained

$$\mu_{HLow}(x) \begin{cases} 2000 - x & x \leq 2000 \\ 1 & 2000 < x < 10000 \\ 0 & x \geq 10000 \end{cases}$$

$$\mu_{HMed}(x) \begin{cases} 0 & x \leq 10000; x \geq 20000 \\ 2000 & 2000 < x < 10000 \\ 10000 & 10000 < x < 20000 \end{cases}$$

$$\mu_{HHigh}(x) \begin{cases} x - 10000 & x \leq 10000 \\ 0 & 2000 < x < 10000 \\ 1 & 10000 < x < 20000 \end{cases}$$

Operating System

In Figure 3, it can be seen that the minimum limit is 11.5, and the maximum is 12.5, so the following formula is obtained. The universal set for the operating system variable is $\mu_{OS} = (11, 13)$, and it is defined by two sets, namely small and large, at μ_{OS} with membership functions being

$$\mu_{OSSmall}(x) \begin{cases} 11,5 - x & x \leq 11,5 \\ 1 & 11,5 < x < 12 \\ 0 & x \geq 12 \end{cases} \quad \mu_{OSLarge}(x) \begin{cases} x - 12,5 & x \leq 12 \\ 1 & 12 < x < 12,5 \\ 0 & x \geq 12,5 \end{cases}$$

The mobile selection graph with Operating System variables can be seen in Figure 3 (b).

RAM

In Figure 3, it can be seen that the minimum limit is 4, while it is 8 and the maximum is 12, so the following formula is obtained. The universal set for the RAM variable is $\mu_{RAM} = (3, 12)$, and it is defined by three sets, namely small, medium, and large, at μ_{RAM} With membership functions being.

$$\mu_{RAMSmall}(x) \begin{cases} 4 - x & x \leq 4 \\ 1 & 4 < x < 6 \\ 0 & x \geq 6 \end{cases}$$

$$\mu_{RAM}Medium(x) \begin{cases} 0 & x \leq 4; x \geq 8 \\ 1 & 4 < x < 6 \\ & 6 < x < 10 \end{cases}$$

$$\mu_{RAM}Large(x) \begin{cases} x - 10 & 0 & x \leq 6 \\ & 1 & 6 < x < 8 \\ & & x \geq 8 \end{cases}$$

A graph of mobile selection with variable RAM can be seen in Figure 3 (c)

Memory Internal

In Figure 3, it can be seen that the minimum limit is 100, while it is 250 and the maximum is 500, so the following formula is obtained. The universal set for the Memory Internal variable is $\mu_{MI} = (64, 512)$, and it is defined by three sets, namely small, medium, and large, at μ_{MI} With membership functions being.

$$\mu_{MI}Low(x) \begin{cases} 75 - x & 1 & x \leq 75 \\ & 0 & 75 < x < 150 \\ & & x \geq 150 \end{cases}$$

$$\mu_{MI}Medium(x) \begin{cases} 0 & x \leq 75; x \geq 150 \\ 150 & 75 < x < 150 \end{cases}$$

$$\mu_{MI}Large(x) \begin{cases} x - 150 & 0 & x \leq 75 \\ & 1 & 75 < x < 150 \\ & & x \geq 150 \end{cases}$$

A mobile selection graph with Internal Memory variables can be seen in Figure 3 (d)

Camera

In Figure 3, it can be seen that the minimum limit is 10, while it is 50 and the maximum is 100, so the following formula is obtained. The universal set for the Camera variable is $\mu_C = (8, 108)$, and it is defined by three sets, namely Low, Medium, and big at μ_C With membership functions being.

$$\mu_CLow(x) \begin{cases} 10 - x & 1 & x \leq 10 \\ & 0 & 10 < x < 50 \\ & & x \geq 50 \end{cases}$$

$$\mu_CMedium(x) \begin{cases} 0 & x \leq 10; x \geq 50 \\ 100 & 10 < x < 50 \\ & & 50 < x < 100 \end{cases}$$

$$\mu_CBig(x) \begin{cases} x - 100 & 0 & x \leq 50 \\ & 1 & 50 < x < 100 \\ & & x \geq 100 \end{cases}$$

A mobile selection graph with a camera variable can be seen in Figure 3 (e)

Battery

In Figure 3, it can be seen that the minimum limit is 4000, while it is 5000 and the maximum is 6000, so the following formula is obtained. The universal set for the Battery variable is $\mu_B = (3700, 6000)$, and it is defined by three sets, namely small and large, at μ_B With membership functions being.

$$\mu_BSmall(x) \begin{cases} 4000 - x & 1 & x \leq 4000 \\ & 0 & 4000 < x < 5000 \\ & & x \geq 5000 \end{cases}$$

$$\mu_BMedium(x) \begin{cases} 0 & x \leq 4000; x \geq 6000 \\ 6000 & 4000 < x < 5000 \\ & & 5000 < x < 6000 \end{cases}$$

$$\mu_BLarge(x) \begin{cases} x - 6000 & 0 & x \leq 5000 \\ & 1 & 5000 < x < 6000 \\ & & x \geq 6000 \end{cases}$$

A mobile selection graph with battery variable can be seen in Figure 3 (f). After obtaining the membership function of each variable, the next step is to determine the degree of membership obtained from each cellular and then, applied in the equation according to the membership function of each variable, then accept the degree of membership given, as in Table 2.

Table 2. Variables Membership Degrees

Price			OS		RAM			Memory Internal			Camera			Battery		
Cheap	Med	Exp	Low	High	Small	Med	Large	Small	Med	Large	Low	Med	High	Small	Med	Big
0.034	0.074	0.084	-0.116	-0.038	-0.33	0.00	0.333	0.000	0.244	0.744	-1.333	-1.000	0.667	-0.286	-1.095	0.191

0.028	0.068	0.078	-0.116	-0.038	-0.33	0.00	0.333	0.256	-0.012	0.488	-1.267	-0.933	0.600	-0.286	-1.095	0.191
0.024	0.064	0.074	-0.116	-0.038	-0.33	0.00	0.333	0.000	0.244	0.744	-1.333	-1.000	0.667	-0.310	-1.119	0.191
0.037	0.077	0.087	-0.116	-0.038	-0.17	0.17	0.500	0.000	0.244	0.744	-1.333	-1.000	0.667	-0.286	-1.095	0.191
0.043	0.083	0.093	-0.038	0.038	0.00	0.33	0.667	-0.128	0.372	0.872	-1.333	-1.000	0.667	-0.286	-1.095	0.191
0.034	0.074	0.084	-0.038	0.038	-0.17	0.17	0.500	0.000	0.244	0.744	-1.333	-1.000	0.667	-0.286	-1.095	0.191
0.042	0.082	0.092	-0.038	0.038	0.00	0.33	0.667	-0.128	0.372	0.872	-1.333	-1.000	0.667	-0.286	-1.095	0.191
0.014	0.054	0.064	-0.038	0.038	-0.33	0.00	0.333	0.256	-0.012	0.488	-3.267	-2.933	2.600	-0.286	-1.095	0.191
0.041	0.081	0.091	-0.038	0.038	0.00	0.33	0.667	0.000	0.244	0.744	-1.333	-1.000	0.667	-0.286	-1.095	0.191
0.028	0.068	0.078	-0.038	0.038	-0.33	0.00	0.333	0.000	0.244	0.744	-1.267	-0.933	0.600	-0.286	-1.095	0.191

This step applies to all variables so that results such as Table 3.

Table 3. Membership Degrees

Cheap	Price		OS			RAM		Memory Internal			Camera		Battery			
	Med	Exp	Low	High	Small	Med	Large	Small	Med	Large	Low	Med	High	Small	Med	Big
0.034	0.074	0.084	0.00	0.000	0.00	0.00	0.333	0.000	0.244	0.744	0.00	0.00	0.667	0.00	0.00	0.191
0.028	0.068	0.078	0.00	0.000	0.00	0.00	0.333	0.256	0.000	0.488	0.00	0.00	0.667	0.00	0.00	0.191
0.024	0.064	0.074	0.00	0.000	0.00	0.00	0.333	0.000	0.244	0.744	0.00	0.00	0.667	0.00	0.00	0.214
0.037	0.077	0.087	0.00	0.000	0.00	0.17	0.500	0.000	0.244	0.744	0.00	0.00	0.667	0.00	0.00	0.191
0.043	0.083	0.093	0.00	0.039	0.00	0.33	0.667	0.000	0.372	0.872	0.00	0.00	0.667	0.00	0.00	0.191
0.034	0.074	0.084	0.00	0.039	0.00	0.17	0.500	0.000	0.244	0.744	0.00	0.00	0.667	0.00	0.00	0.191
0.042	0.082	0.092	0.00	0.039	0.00	0.33	0.667	0.000	0.372	0.872	0.00	0.00	0.667	0.00	0.00	0.191
0.014	0.054	0.064	0.00	0.039	0.00	0.00	0.333	0.256	0.000	0.488	0.00	0.00	1.000	0.00	0.00	0.191
0.041	0.081	0.091	0.00	0.039	0.00	0.33	0.667	0.000	0.244	0.744	0.00	0.00	0.667	0.00	0.00	0.191
0.028	0.068	0.078	0.00	0.039	0.00	0.00	0.333	0.000	0.244	0.744	0.00	0.00	0.667	0.00	0.00	0.191

When the membership degree has been obtained, it is continued by applying the AND operator to get cellular recommendations close to the user's wishes. For example, if someone buys a cellular with the criteria: Medium Price, Large Internal Memory, Medium Camera, Medium Battery, Medium RAM, High Operating System. So to get a cellular close to the desired criteria, find the value of fire strength in each cellular.

$\alpha = \mu_{Price\ Med} \times \mu_{MI\ Large} \times \mu_C\ Med \times \mu_B\ Med \times \mu_{RAM\ Med} \times \mu_{OS\ High} = 0.064$. This step applies to all variables so that results such as tables 14 to 19 are obtained.

Table 4. Membership Values

Cheap	Price		OS			RAM		Memory Internal			Camera		Battery			
	Med	Exp	Low	High	Small	Med	Large	Small	Med	Large	Low	Med	High	Small	Med	Big
0.034	0.074	0.084	0.00	0.000	0.00	0.00	0.333	0.000	0.244	0.744	0.000	0.000	0.667	0.000	0.000	0.191
0.028	0.068	0.078	0.00	0.000	0.00	0.00	0.333	0.256	0.000	0.488	0.000	0.000	0.667	0.000	0.000	0.191
0.024	0.064	0.074	0.00	0.000	0.00	0.00	0.333	0.000	0.244	0.744	0.000	0.000	0.667	0.000	0.000	0.214
0.037	0.077	0.087	0.00	0.000	0.00	0.17	0.500	0.000	0.244	0.744	0.000	0.000	0.667	0.000	0.000	0.191
0.043	0.083	0.093	0.00	0.038	0.00	0.33	0.667	0.000	0.372	0.872	0.000	0.000	0.667	0.000	0.000	0.191
0.034	0.074	0.084	0.00	0.038	0.00	0.17	0.500	0.000	0.244	0.744	0.000	0.000	0.667	0.000	0.000	0.191
0.042	0.082	0.092	0.00	0.038	0.00	0.33	0.667	0.000	0.372	0.872	0.000	0.000	0.667	0.000	0.000	0.191
0.014	0.054	0.064	0.00	0.038	0.00	0.00	0.333	0.256	0.000	0.488	0.000	0.000	1.000	0.000	0.000	0.191
0.041	0.081	0.091	0.00	0.038	0.00	0.33	0.667	0.000	0.244	0.744	0.000	0.000	0.667	0.000	0.000	0.191
0.028	0.068	0.078	0.00	0.038	0.00	0.00	0.333	0.000	0.244	0.744	0.000	0.000	0.667	0.000	0.000	0.191

When the membership degree has been obtained, it is continued by applying the AND operator to get cellular recommendations close to the user's wishes. For example, if someone buys a cellular with the criteria: Medium Price, High Internal Memory, Medium Camera, Medium Battery, Medium RAM, High Operating System. So to get a cellular close to the desired criteria, find the value of fire strength in each cellular.

$\alpha = \mu_H\ Sedang \times \mu_{MI\ Tinggi} \times \mu_K\ Besar \times \mu_B\ Besar \times \mu_{RAM\ Besar} \times \mu_{OS\ Tinggi} = 0.064$

Table 5. Fire Strength

Brand	Fire Strength
Samsung A24	0.0000000
Samsung A34	0.0000000
Samsung A54	0.0000000
Samsung A14	0.0000000

Samsung A04	0.2343950
Samsung A23	0.1344704
Samsung A04S	0.2315539
Samsung A73	0.0642953
Samsung A13	0.1951402
Samsung A33	0.0816908

The results of Table 5 show that the Samsung A73 cellular has the closest fire strength value to the user's desire, which is 0.064.

Tsukamoto Method

Using the same data, the steps taken are to determine the criteria, alternatives and initialize the Assessment criteria. For the Assessment criteria table, as in Table 6.

Table 6. Judging Criteria

No	Code	Variable
1	P	Price
2	Ba	Battery
3	RAM	RAM
4	OS	Operating System
5	MI	Memory Internal
6	Ca	Camera

Table 7. Alternative Types

No	Code	Alternative
1	P-1	Samsung A24
2	P-2	Samsung A34
3	P-3	Samsung A54
4	P-4	Samsung A14
5	P-5	Samsung A04
6	P-6	Samsung A23
7	P-7	Samsung A04S
8	P-8	Samsung A73
9	P-9	Samsung A13
10	P-10	Samsung A33
...
...
44	P-44	Oppo Find X5 Pro

Furthermore, Alternative Data is chosen as the name of the cellular types that will be used for alternative selection, consisting of 45 pieces of data as in Table 7. The results of the overall alternative calculation can be seen in Table 8.

Table 8. Tsukamoto Membership Degrees

Cheap	Price		OS		RAM			Memory Internal			Camera			Battery		
	Med	Exp	Low	High	Small	Med	Large	Small	Med	Large	Low	Med	High	Small	Med	Big
0.850	0.150	0.00	0.00	1.00	0.00	1.00	1.00	0.93	0.07	0.00	0.00	1.00	0.00	0.00	1.00	0.00
0.700	0.300	0.00	0.00	1.00	0.00	1.00	1.00	0.61	0.39	0.00	0.05	0.95	0.04	0.00	1.00	0.00
0.600	0.400	0.00	0.00	1.00	0.00	1.00	1.00	0.93	0.07	0.00	0.00	1.00	0.00	0.00	1.00	0.00
0.925	0.075	0.00	0.00	1.00	0.05	0.50	1.00	0.93	0.07	0.00	0.00	1.00	0.00	0.00	1.00	0.00
1.000	0.000	0.00	0.00	0.50	1.00	0.00	1.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00
0.850	0.150	0.00	0.00	0.50	0.50	0.50	1.00	0.93	0.07	0.00	0.00	1.00	0.00	0.00	1.00	0.00
1.000	0.000	0.00	0.00	0.50	1.00	0.00	1.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00
0.350	0.650	0.00	0.00	0.50	0.00	1.00	1.00	0.61	0.39	0.00	0.00	1.00	0.00	0.00	1.00	0.00
1.000	0.000	0.00	0.00	0.50	1.00	0.00	1.00	0.93	0.07	0.00	0.00	1.00	0.00	0.00	1.00	0.00
0.690	0.320	0.00	0.00	0.50	1.00	0.00	1.00	0.93	0.07	0.00	0.00	1.00	0.00	0.00	1.00	0.00

The next step is to determine the rules, for example, as in Table 9

Table 9. Rules of Truth

No.	Variables Input						Output
	Price	OS	RAM	MI	Camera	Battery	

1		Cheap	Low	Small	Small	Medium	Medium	Selected
2		Cheap	High	Large	Medium	High	Medium	Not Selected
3		Cheap	Low	Small	Large	High	Medium	Not Selected
4		Cheap	High	Large	Medium	Low	Large	Selected
5	IF	Cheap	High	Large	Small	Low	Large	THEN Not Selected
6		Med	Low	Small	Large	Low	Large	Not Selected
7		Expen	High	Large	Small	Medium	Small	Not Selected
8		Expen	Medium	Medium	Medium	Medium	Small	Not Selected
9		Expen	Low	Small	Large	Medium	Small	Not Selected
10		Medium	High	Large	Large	High	Large	Selected

$\alpha = \mu H \text{ Sedang} \times \mu MI \text{ Tinggi} \times \mu K \text{ Sedang} \times \mu B \text{ Besar} \times \mu RAM \text{ Besar} \times \mu OS \text{ Tinggi}$
 Sugeno Method

Using the same data, the stages carried out are also almost the same; the difference is when determining the predicate at the end of the process using the minimum of the decision.

$\alpha = \min (\mu H \text{ Sedang} \times \mu MI \text{ Tinggi} \times \mu K \text{ Sedang} \times \mu B \text{ Besar} \times \mu RAM \text{ Besar} \times \mu OS \text{ Tinggi})$

So that the results obtained are, users will decide to use branded cellular.

Table 10. Results According to User Criteria

Brand	Tsukamoto	Mamdani	Sugeno
Samsung A24	0.790500	0.000000	0.000000
Samsung A34	0.405650	0.000000	0.000000
Samsung A54	0.558000	0.000000	0.000000
Samsung A14	0.860250	0.000000	0.000000
Samsung A04	1.000000	0.234395	0.000000
Samsung A23	0.790500	0.134471	0.000000
Samsung A04S	1.000000	0.231554	0.000000
Samsung A73	0.021350	0.064295	0.100780
Samsung A13	0.930000	0.195140	0.211300
Samsung A33	0.607406	0.081691	0.131230
...
...
Oppo Find X5 Pro	0.000000	0.000000	0.000000

Conclusions

In this study, by comparing the three methods of fuzzy logic, namely the Tsukamoto, Mamdani and Sugeno methods to choose a cellular that suits the needs of the user, namely moderate price, high internal memory, medium camera size, large battery, large RAM and high operating system, the results obtained the Tsukamoto method is 0.0213, Mamdani is 0.0643 and Sugeno is 0.100, meaning that the Tsukamoto method is better than Mamdani and Sugeno while the cellular carrier is the Samsung A73 brand. For future research, it is recommended to choose other variables that are more suitable and more cellular brands so that cellular alternatives can be selected more accurately..

References

Almeida, R. S., Vasconcelos da Silva, F., & Vianna, S. S. V. (2023). Combining the bow-tie method and fuzzy logic using Mamdani inference model. *Process Safety and Environmental Protection*, 169(November 2022), 159–168. <https://doi.org/10.1016/j.psep.2022.11.005>

Bala, B. P. (2020). Significant of Smartphone: An Educational Technology Tool for Teaching and Learning. *International Journal of Innovative Science and Research Technology*, 5(5), 1634–1638.

Burhanuddin, A. (2023). Analisis Komparatif Inferensi Fuzzy Tsukamoto, mamdani dan Sugeno Terhadap Produktivitas Padi di Indonesia. *LEDGER: Journal Informatic and Information Technology*, 2(1), 48–57.

Castillo, O., & Melin, P. (2021). A new fuzzy fractal control approach of non-linear dynamic systems: The case of controlling the COVID-19 pandemics. *Chaos, Solitons and Fractals*, 151, 111250. <https://doi.org/10.1016/j.chaos.2021.111250>

Darmawan, M. D. (2018). The effect of price, product quality, promotion, social factor, brand image on purchase decision process of loop product on youth segment (Case Study of PT Telekomunikasi Selular). *International Seminar & Conference on Learning Organization ISCL0*, 6, 1–16.

- Davvaz, B., Mukhlash, I., & Soleha, S. (2021). Himpunan Fuzzy dan Rough Sets. *Limits: Journal of Mathematics and Its Applications*, 18(1), 79. <https://doi.org/10.12962/limits.v18i1.7705>
- Jane, J. B., & Ganesh, E. N. (2019). A review on big data with machine learning and fuzzy logic for better decision making. *International Journal of Scientific and Technology Research*, 8(10), 1221–1225.
- Kahar, N., & Riki. (2021). Comparative Study of SMART and FMCDM Methods in Smartphone Selection Decision Support System. *International Journal of Image, Graphics and Signal Processing*, 13(4), 1–13. <https://doi.org/10.5815/ijigsp.2021.04.01>
- Karyaningsih, D., & Rizky, R. (2020). Implementation of Fuzzy Mamdani Method for Traffic Lights Smart City in Rangkasbitung, Lebak Regency, Banten Province (Case Study of the Traffic Light T-junction, Cibadak, By Pas Sukarno Hatta Street). *Jurnal KomtekInfo*, 7(3), 176–185. <https://doi.org/10.35134/komtekinfo.v7i3.78>
- Lunde, P., Nilsson, B. B., Bergland, A., Kværner, K. J., & Bye, A. (2018). The effectiveness of smartphone apps for lifestyle improvement in noncommunicable diseases: Systematic review and meta-analyses. *Journal of Medical Internet Research*, 20(5), 1–12. <https://doi.org/10.2196/jmir.9751>
- Milošević, T., Pamučar, D., & Chatterjee, P. (2021). Model for selecting a route for the transport of hazardous materials using a fuzzy logic system. *Vojnotehnicki Glasnik*, 69(2), 355–390. <https://doi.org/10.5937/vojtehg69-29629>
- Nugraha, E., Wibawa, A. P., Hakim, M. L., Kholifah, U., Dini, R. H., & Irwanto, M. R. (2019). Implementation of fuzzy tsukamoto method in decision support system of journal acceptance. *Journal of Physics: Conference Series*, 1280(2). <https://doi.org/10.1088/1742-6596/1280/2/022031>
- Pavement, P., Index, C., Fuzzy, U., & Technique, L. (2022). *Logic Technique*. 1–15.
- Qafzezi, E., Bylykbashi, K., Ikeda, M., Matsuo, K., & Barolli, L. (2020). Coordination and management of cloud, fog and edge resources in SDN-VANETs using fuzzy logic: A comparison study for two fuzzy-based systems. *Internet of Things (Netherlands)*, 11, 100169. <https://doi.org/10.1016/j.iot.2020.100169>
- Rajesh Mavani, N., Lim, C. Y., Hashim, H., Abd. Rahman, N., & Mohd Ali, J. (2021). Fuzzy Mamdani based user-friendly interface for food preservatives determination. *Food and Bioprocess Technology*, 126, 282–292. <https://doi.org/10.1016/j.fbp.2021.01.012>
- Rohimah, L. (2019). Prediksi Nilai Ekspor Sepatu Kulit HS 6403 ke Jepang dengan Metode Mamdani, Sugeno dan Tsukamoto. *Jurnal Ilmu Pengetahuan Dan Teknologi Komputer*, 4(Februari), 239–244.
- Seno, N. I., Salman, M. A. W., & Farhan, R. N. (2022). A comparative study of multiband mamdani fuzzy classification methods for west of Iraq satellite image. *Bulletin of Electrical Engineering and Informatics*, 11(3), 1624–1632. <https://doi.org/10.11591/eei.v11i3.3561>
- Silva, S. N., Lopes, F. F., Valderrama, C., & Fernandes, M. A. C. (2020). Proposal of Takagi–Sugeno fuzzy-PI controller hardware. *Sensors (Switzerland)*, 20(7), 1–28. <https://doi.org/10.3390/s20071996>
- Wahyuni, D., Sumarminingsih, E., & Astutik, S. (2022). COVID-19 Vaccination and PPKM Policy with the Implementation of the Fuzzy Sugeno Method to Income Classification. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, 6(4), 937. <https://doi.org/10.31764/jtam.v6i4.10096>
- Yudono, M. A. S., Faris, R. M., De Wibowo, A., Sidik, M., Sembiring, F., & Aji, S. F. (2022). Fuzzy Decision Support System for ABC University Student Admission Selection. *Proceedings of the International Conference on Economics, Management and Accounting (ICEMAC 2021)*, 207(Icemac 2021), 230–237. <https://doi.org/10.2991/aebmr.k.220204.024>
- Yunan, A., & Ali, M. (2020). Study and Implementation of the Fuzzy Mamdani and Sugeno Methods in Decision Making on Selection of Outstanding Students at the South Aceh Polytechnic. *Jurnal Inotera*, 5(2), 152–164. <https://doi.org/10.31572/inotera.vol5.iss2.2020.id127>
- Zaaidatunni, U., Dewi, M. T., & Hakim, M. F. Al. (2021). Implementation of fuzzy tsukamoto in employee performance assessment. *Journal of Soft Computing Exploration*, 2(2). <https://doi.org/10.52465/josce.v2i2.52>