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FUZZY APPLICATION (MAMDANI METHOD) IN DECISION-MAKING ON LED TV SELECTION

Erni Fatun Ma'rif [1*], Agus Maman Abadi[2]

[1,2] *Master of Mathematics Education Program, Universitas Negeri Yogyakarta*
Jln. Colombo No.1. Karangmalang, Caturtunggal, Yogyakarta, 55281, Indonesia

*Corresponding author's e-mail: *ernifatun.2022@student.uny.ac.id*

ABSTRACT

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Science is now developing very quickly. Information technology has been used in various places. Using computers in business, government, and personal activities shows how important science and technology are in helping human activities. One method used to solve various problems is fuzzy logic. Several types of Fuzzy are classified as Fuzzy Inference Systems (FIS), namely Tsukamoto, Mamdani, and Sugeno. The application of vague logic in making decisions about choosing an LED TV is to make it easier to select electronic media. This research aims to help people who need clarification on the many LED TV choices currently available. So, we need a decision-making method to help people choose an LED TV that suits their needs and budget. One of the methods used in this research is the Mamdani method. There were 50 LED TV brands in this research, and the criteria used in selecting LED TVs were based on size, resolution, and price. An LED TV that meets the medium size, high resolution, and normal price criteria will be purchased. The LED TV data that meets the medium size, high resolution, and normal price criteria is the Samsung UA43AU7000KXXD brand LED TV. However, the actual decision remains based on the buyer's decision.

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1. INTRODUCTION

In recent years, the world of technology has developed rapidly. In this way, people are increasingly pampered, making their lives easier by getting information more quickly and easily. Technological progress, especially in information technology, is so rapid that people are encouraged to use this technology to help in their work [1]. The notion of Artificial Intelligence was introduced in 1956 [2]. It encompasses a range of knowledge and methodologies aimed at addressing intricate systems and resolving challenging or impossible challenges to tackle through conventional means, such as decision-making processes. One method used to solve various problems is fuzzy logic [3]. These modeling techniques are constantly evolving to justify, develop, and employ an extensive array of methodological apparatus, mathematical tools, computer programs, and applications and to broaden the scope of problems that can be studied. Fuzzy set theory and fuzzy modeling are recent theoretical and methodological approaches [4]. Several types of Fuzzy are classified as Fuzzy Inference Systems (FIS), namely Tsukamoto, Mamdani, and Sugeno [5].

Fuzzy Logic is a part of mathematics and artificial intelligence that aims to organize, understand, and use reasoning processes that involve unclear or uncertain estimates and knowledge represented by linguistic variables [6]. Fuzzy Logic is a form of Logic that introduces the concepts of vague values, uncertainty, and partial levels of truth in a statement. Unlike Boolean Logic, which only uses values 0 and 1, Fuzzy Logic allows for using values between the two. Fuzzy Logic has an important role in the development of modern computers. This logic is the result of the development of Boolean Logic and has become the basis for various computer applications. Iranian mathematician Lofti A. Zadeh created Fuzzy Logic, a branch of mathematical logic, in 1965 [7]. He realized that classical Logic or Boolean Logic could not be applied effectively in various complex conditions and problems. In many Asian countries, including Iran, Fuzzy Logic and uncertainty are often used in decision-making, in contrast to classical logic, which uses definite values such as 0 and 1[8]. Although the idea of Fuzzy Logic has been around for a while, the science of modern, systematic Fuzzy Logic was only recently found. This is why fuzzy Logic is sometimes referred to as the "new old logic. [9]. Fuzzy linguistic variables are present in fuzzy logic propositions. Basic linguistic values (high, low, long, short, deep, etc.), linguistic modifiers (very, somewhat, moderate, strong), and linguistic connectives (and, or No) are examples of terms from natural language that are linguistic variable values [10]. According to Lotfi Zadeh, Fuzzy Logic, when combined with information systems and process engineering, results in more flexible, stable, and intelligent applications than traditional systems. Examples of these applications include control systems, home appliances, and decision-making systems [11]. Fuzzy Logic as a component of soft computing has been widely applied in various fields of life [12]. Moreover, Fuzzy Logic has applications in politics, economics, psychology, marketing, biology, and weather forecasting [13].

The Light Emitting Diode, or LED, was initially created by General Electric (GE) in the United States during the 1960s. It was formerly utilized as a part of electronic circuits. Still, in 1997, Nichia Chemical introduced white LED, which started to get attention as a new kind of lighting. LED is a semiconductor that emits light when current flows through it. By changing the type of compound, the color of light can be controlled, and all colors from red to purple can be expressed. Compared to existing light sources, LEDs have the advantage of being more efficient, consuming less power, and making it easier to implement small devices. It is attracting attention as a next-generation light source because it is environmentally friendly, has a long lifespan, is space efficient, and enables various production effects that were impossible with existing lighting [14].

LED television is a television that has an LCD panel with a backlight made using diode technology. The only difference is the backlight since LED and LCD televisions share the same glass panel. While LED TVs use LEDs (Light Emitting Diodes) with a low DC voltage, often using a voltage of 24 V DC, backdrop lights for LCD televisions use fluorescent lights that must operate at a high voltage. Many people need clarification on the many TV choices available today. So, a decision-making method is required to help people choose a TV that suits their needs and budget.

Based on the explanation above, this research aims to help people choose LED TVs using the Mamdani Method. The use of this method in the decision-making process to help people choose an LED TV that suits their needs and budget is still rare and has yet to be widely researched. Therefore, this research needs to be expanded further. In the context of this research, applying the Mamdani Method is expected to provide new contributions and more efficient solutions in choosing an LED TV, considering factors such as size, resolution, and price. Thus, it is hoped that this research can fill existing knowledge gaps, provide new insights, and become a valuable reference for the public in choosing an LED TV that suits their needs and budget.

2. RESEARCH METHODS

The creation of fuzzy inference models or algorithms starts with this process, known as mapping, which explains the connection between input and output variables. To get a result, this activity entails developing the proper algorithm that mimics the variables and the rules. Any fuzzy inference system (FIS) revolves around its fuzzy inference engine, capable of simulating "human" decision-making, which frequently relies on fuzzy ideas and approximative reasoning. In fuzzy logic theory, there are various fuzzy inference algorithms, also known as fuzzy inference methods or fuzzy inference models. The most widely used algorithms are the Sugeno model, also known as the Takagi Sugeno (TS) model, and the Mamdani model, the Assilian-Mamdani model [6]. The Mamdani model is widely regarded as the most favored fuzzy inference algorithm since all current findings on fuzzy systems as universal approximators exclusively focus on Mamdani fuzzy systems, with no available outcomes for TS fuzzy systems incorporating linear rule subsequences [15].

Mamdani's algorithm is suggested for handling non-linear and complicated systems, especially in multi-criteria decision problems [16]. This is due to its ability to incorporate human knowledge and intuition through approximation reasoning and fuzzy inference rules. MAX-MIN method, which is also known as the Mamdani method. In 1975 Ebrahim Mamdani introduced the Mamdani method in 1975. This method involves four stages to produce the desired output [17]. Fuzzy if-then rules improve the findings' interpretability and offer more details about the classifier's architecture and decision-making procedure [18]. In the subsequent sections, we delineate the procedures in the Mamdani fuzzy model depicted in Figure 1.

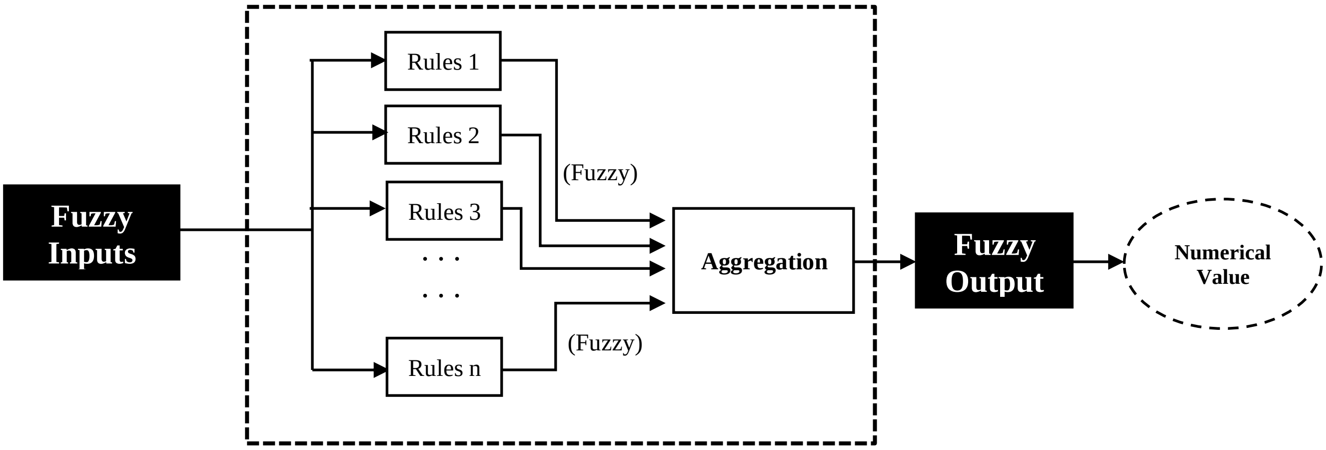

Figure 1. Mamdani Fuzzy Model

The data used for this case is LED TV data obtained through the Tokopedia marketplace, which is used to make decisions regarding the selection of LED TVs with a total of 50 LED TVs, where the factors that influence the purchase of LED TVs are based on size, resolution, and price.

Table 1. LED TV Brands and Specifications

Brand	Size (inches)	Resolution (p)	Price (Rp)
Weyon Animex	32	720	1,375,000
SAMSUNG 65AU7002	65	2160	7,680,000
Changhong	40	1080	2,399,000
POLYTRON PLD 43BAG9953	43	1080	3,975,000
Toshiba-43E31KP	43	1080	3,499,000
⋮	⋮	⋮	⋮
Toshiba 32S250R	32	720	1,819,000
Sharp C42BG1i	42	1080	3,635,000
Sharp C32DC1I	32	720	1,729,000
Sharp C42BD1i	42	1080	3,099,000

(**Data source**: *https://www.tokopedia.com/find/tv-led*) [19].

2.1 Fuzzification of Input Variables

A fuzzification step is the first in modeling a fuzzy inference system (see **Figure 2**). This involves converting numerical input values into fuzzy variables based on partial intervals of values within the system's entire value range that are characterized by linguistic variables. Determining the universe of discourse, which encompasses all values, and splitting it into many fuzzy classes for the membership functions is necessary.

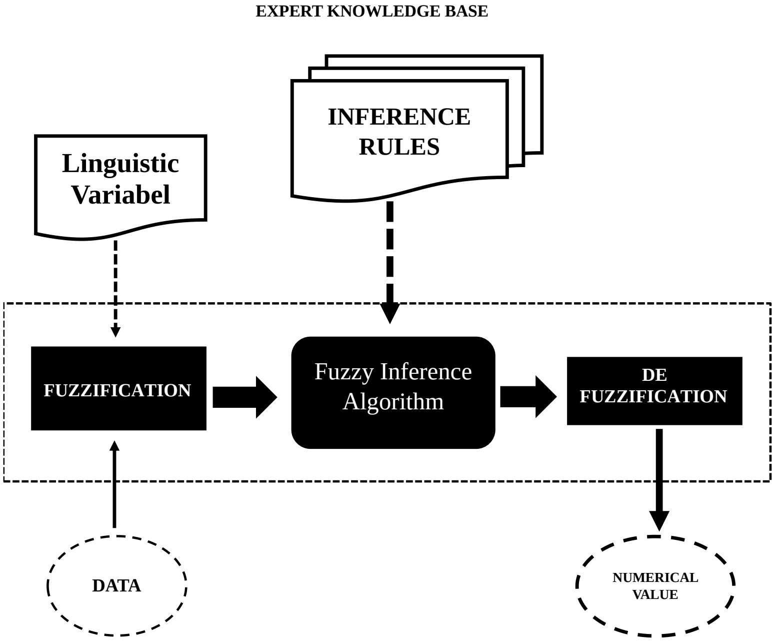

Figure 2. Structure of a Fuzzy Inference System (FIS)

To be more precise, this process involves specifying the entire range of values that can be assigned to numerical data and classifying this range according to linguistic variables, also known as fuzzy variables. For instance, a set can be split into three fuzzy classes: small, medium, and huge. The three subsets are represented by these linguistic variables, which range from 0% to 100%, or [0, 1].

2.2 Membership Functions

1. Fuzzy Logic Operations
   Some logic operations in fuzzy include:
   a. Intersection
      Consider again the two fuzzy sets Ã and B, defined in terms of U. The intersection of the fuzzy sets Ã and B, namely $A \cap B$, has a membership function defined as:
      $$\mu A \cap B = \min\left(\mu A(x), \mu B(x)\right) \quad (1)$$

   b. Union
      By considering a universal set U and two fuzzy sets Ã and B defined on the set U. Then the union of the fuzzy sets Ã and B, namely $A \cup B$, has a membership function defined as:

      $$\mu A \cup B = \max\left(\mu A(x), \mu B(x)\right) \quad (2)$$
   c. Complement
      Given a fuzzy set Ã defined on the universal set U, $\tilde{A}^c$ is another fuzzy set whose degree of membership is inverse to the degree of membership Ã.
      $$\mu\, \tilde{A}^c(x) = 1 - \mu_A(x) \quad (3)$$

2. Fuzzy Logic Membership Functions

a. Linear Curve Representation
In linear representation, the mapping of inputs to their membership degrees is illustrated as a straight line. This form is straightforward and is a good choice for addressing less apparent concepts. In linear representation, there are two types of functions, namely:
Monotonous Rise
An increasing linear representation is a form of function that increases monotonically starting from a domain with zero membership degrees and moving to the right towards domain values that have increasingly higher membership degrees.
The membership function is:

$$\mu(x) = \begin{cases} 0, \ x \leq a, \\ \frac{x-a}{b-a}, \quad a < x < b \\ 1, \ x \geq a \end{cases} \tag{4}$$

Monotony Down
The descending linear representation is a descending monotone function that starts from a domain value with a thickness degree of one and moves to the right towards a domain value with a lower thickness degree.
The membership function is:

$$\mu(x) = \begin{cases} 0, \ x \geq b, \\ \frac{b-x}{b-a}, \quad a < x < b \\ 1, \ x \leq a \end{cases} \tag{5}$$

b. Triangular Curve Representation
The triangular curve is a mixture of an upward linear line and a downward linear line.
The membership function is:

$$\mu(x) = \begin{cases} 0, \ x \leq a, x \geq c \\ \frac{x-a}{b-a}, \quad a < x < b \\ \frac{c-x}{c-b}, \ b \leq x < c \end{cases} \tag{6}$$

2.3 Fuzzy Inference Rules and Logical Operators

Compared to reasoning based on binary logic, which uses the concepts of true or false (0 or 1), inference rules represent fuzzy thinking. They use operators and syntax identical to binary logic, representing heuristics based on linguistic variables that reflect a certain scale in natural language.

These rules are expressions of the type:

IF <condition> THEN <consequence> (7)

The condition part, the antecedent of the expression, represents the state of the input variables, and the consequence part describes the state of the output variable. Fuzzy inference rules are built with the help of the binary logic operators AND, OR, and NOT because the antecedent of the expression can be a combination of many circumstances related to input variables that represent realistic situations. In this manner, the rules show how the input fuzzy variables affect the output variable together.

2.4 Defuzzification

Defuzzification, the final stage in the Mamdani fuzzy model, yields a numerical value from the output fuzzy variable, which is obtained by aggregating the fuzzy inference rules. It should be emphasized that the inference rules must be aggregated in a certain way to produce a conclusion, as judgments are predicated on testing all of the system's fuzzy inference rules. Combining the fuzzy sets of each rule's outputs into a single fuzzy set is called aggregation [16].

The Mamdani method produces a fuzzy output result as a membership function during the defuzzification stage. The result is then transformed from fuzzy to a numerical value. Defuzzification techniques, such as the Center of Gravity (COG) and Mean of Maximum (MOM) methods, are reportedly the most often used to carry out the conversion.

3. RESULTS AND DISCUSSION

3.1 Fuzzification of Input Variables

1. Input Variables

The input variables used in this application are size, resolution, and price.

1) Size

Table 2. Size Input Variable

universe of conversation	Linguistic Variables	Domain
21-85	Small	21-39
	Medium	40-59
	Large	60-85

2) Resolution

Table 3. Resolution Input Variable

universe of conversation	Linguistic Variables	Domain
720-4,320	Low	720-1,100
	Medium	1,200-2,000
	High	2,100-4,320

3) Price

Table 4. Price Input Variable

universe of conversation	Linguistic Variables	Domain
1,000,000-10,000,000	Cheap	1,000.000-3,500.000
	Normal	4,000.000-6,500.000
	Expensive	7,000.000-10,000.000

3.2 Membership Functions

1. Input Variables

The input variables used in this application are size, resolution, and price.

1) Size

For input variables, size has three fuzzy criteria: small (21-39), medium (40-59) and large (60-85), with membership function:

$$\mu_{Small}(x) = \begin{cases} 0, & x \geq 39, \\ \frac{39-x}{39-21}, & 21 < x < 39 \\ 1, & x \leq 21 \end{cases} \quad (8)$$

$$\mu_{Medium}(x) = \begin{cases} 0, & x \leq 21, x \geq 59 \\ \frac{x-21}{40-21}, & 21 < x < 40 \\ \frac{59-x}{59-40}, & 40 \leq x < 59 \end{cases} \quad (9)$$

$$\mu_{Large}(x) = \begin{cases} 0, & x \leq 40 \\ \frac{x-40}{60-40}, & 40 < x < 60 \\ 1, & x \geq 60 \end{cases} \tag{10}$$

Figure 3 is a replica of the screen and is generated directly when implementing the model in the fuzzy logic modeling component of the MATLAB toolbox. It represents the combination of membership functions of a linear curve and a triangular membership function for the input variable "size" with a universe of discourse (21-85), linguistic variable "small" with a domain (21-39), linguistic variable "medium" with a domain (40-59), and linguistic variable "large" with a domain (60-85).

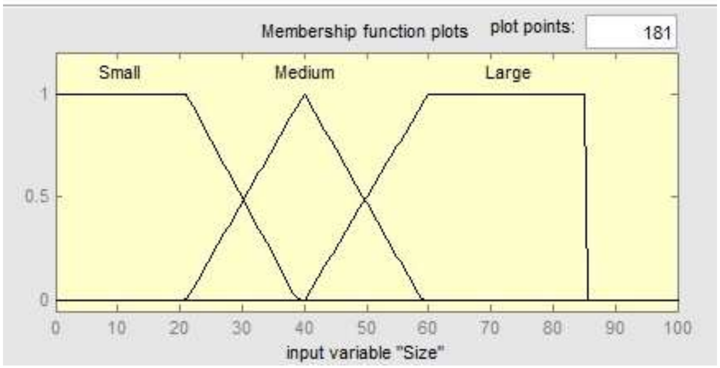

Figure 3. Size Variable Membership Function

2) Resolution

For input variables, resolution has three fuzzy criteria: Low (720-1,100), Medium (1,200-2,000) and High (2,100-4,320), with membership function:

$$\mu_{Low}(x) = \begin{cases} 0, & x \geq 1{,}100, \\ \frac{1100-x}{1100-720}, & 720 < x < 1{,}100 \\ 1, & x \leq 720 \end{cases} \tag{11}$$

$$\mu_{Medium}(x) = \begin{cases} 0, & x \leq 720, x \geq 2{,}000 \\ \frac{x-720}{1{,}200-720}, & 720 < x < 1{,}200 \\ \frac{2000-x}{2{,}000-1{,}200}, & 1{,}200 \leq x < 2{,}000 \end{cases} \tag{12}$$

$$\mu_{High}(x) = \begin{cases} 0, & x \leq 1{,}200 \\ \frac{x-1200}{2{,}100-1{,}200}, & 1{,}200 < x < 2{,}100 \\ 1, & x \geq 2{,}100 \end{cases} \tag{13}$$

Figure 4 is a replica of the screen and is generated directly when implementing the model in the fuzzy logic modeling component of the MATLAB toolbox. It represents the combination of membership functions of a linear curve and a triangular membership function for the input variable "resolution" with a universe of discourse (720-4320), linguistic variable "low" with a domain (720-1,100), linguistic variable "medium" with a domain (1,200-2,000), and linguistic variable "high" with a domain (2,100-4,320).

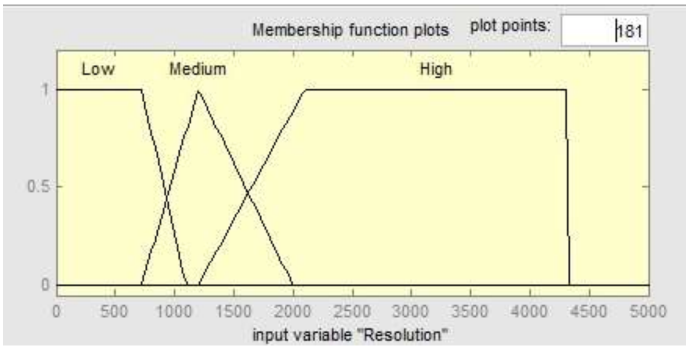

Figure 4. Resolution Variable Membership Function

3) Price

For input variables, price has three fuzzy criteria: Cheap (1,000,000-3,500,000), Normal (4,000,000-6,500,000) and Expensive (7,000,000-10,000,000). With membership function:

$$\mu_{Cheap}(x) = \begin{cases} 0, \ x \geq 3{,}500{,}000, \\ \frac{3{,}500.000 - x}{3{,}500{,}000 - 1{,}000{,}000}, \quad 1{,}000{,}000 < x < \ 3{,}500{,}000 \\ 1, \ x \leq 1{,}000{,}000 \end{cases} \tag{14}$$

$$\mu_{Normal}(x) = \begin{cases} 0, \ x \leq 1{,}000{,}000 \ , x \geq 6{,}500{,}000 \\ \frac{x - 1{,}000{,}000}{4{,}000{,}000 - 1.000.000}, \quad 1{,}000{,}000 \ < x < 4{,}000{,}000 \\ \frac{6{,}500{,}000 - x}{6{,}500{,}000 - 4{,}000{,}000} \ , \ 4{,}000{,}000 \leq x < 6{,}500{,}000 \end{cases} \tag{15}$$

$$\mu_{\text{Expensive}}(x) = \begin{cases} 0, \ x \leq 4{,}000{,}000 \\ \frac{x - 4{,}000{,}000}{7{,}000{,}000 - 4{,}000{,}000}, \quad 4{,}000{,}000 \ < x < 7{,}000{,}000 \\ 1 \ , \ x \geq 7{,}000{,}000 \end{cases} \tag{16}$$

Figure 5 is an exact replica of the screen and is generated directly when implementing the model in the fuzzy logic modeling component of the MATLAB toolbox. It represents the combination of membership functions of a linear curve and a triangular membership function for the input variable "price" with a universe of discourse (1,000,000-10,000,000), linguistic variable "cheap" with a domain (1,000,000-3,500,000), linguistic variable "normal" with a domain (4,000,000-6,500,000), and linguistic variable "expensive" with a domain (7,000,000-10,000,000).

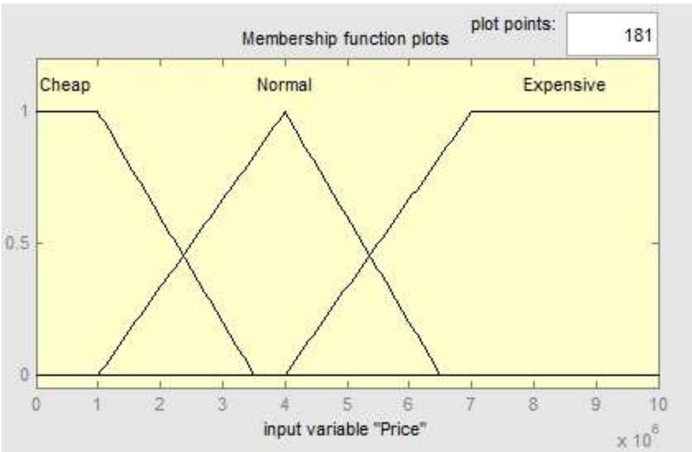

Figure 5. Price Variable Membership Function

2. Output Variables

The output variable used in this application is decision making. The output variable has three fuzzy criteria: Not Buy (0-30), Considered (40-60), and Buy (65-100), with membership function:

$$\mu_{Not\ buy}(x) = \begin{cases} 0, & x \geq 30, \\ \frac{30-x}{30-20}, & 20 \leq x < 30 \\ 1, & x \leq 20, \end{cases} \tag{17}$$

$$\mu_{Considered}(x) = \begin{cases} 0, & x \leq 20, x \geq 60 \\ \frac{x-20}{40-20}, & 20 < x < 40 \\ \frac{60-x}{60-40}, & 40 \leq x < 60 \end{cases} \tag{18}$$

$$\mu_{Buy}(x) = \begin{cases} 0, & x \leq 40 \\ \frac{x-40}{65-40}, & 40 < x < 65 \\ 1, & x \geq 65 \end{cases} \tag{19}$$

Figure 6 is a replica of the screen and is generated directly when implementing the model in the fuzzy logic modeling component of the MATLAB toolbox. It represents the combination of membership functions of a linear curve and a triangular membership function for the output variable is "decision making " with a universe of discourse (0-100); linguistic variable "Not Buy" with a domain (0-30), linguistic variable "Considered" with a domain (40-60), and linguistic variable "Buy" with a domain (65-100).

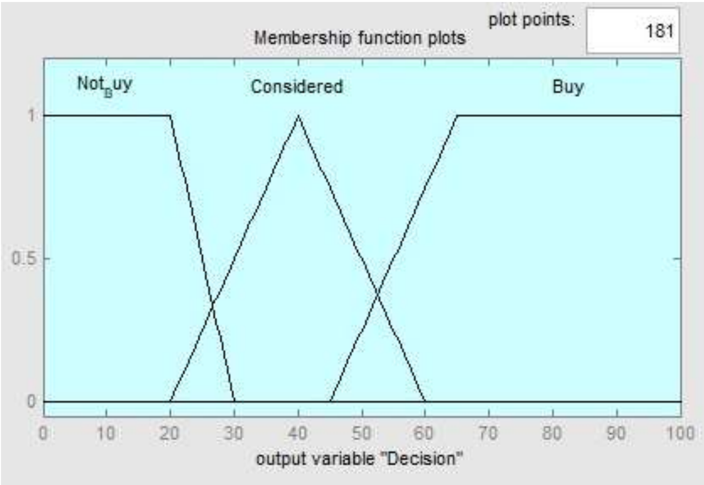

Figure 6. Decision Output Variable Membership Function

3.3 Fuzzy Inference Rules and Logical Operators

After fuzzification is carried out, the next step is to form fuzzy knowledge in the form of rules. Rules are created to express the relationship between input and output. Each rule is an implication [20]. This stage will produce 27 rule pairs.

The image of this information, which has already been entered into the MATLAB system on the computer, is shown in Figure 7 (an enlarged fragment). In total, 27 rules were defined and introduced (all variants of combinations of input parameters). The corresponding fields are located at the bottom of the interface, where the combination of parameters is selected, followed by the reflection of already defined relationships in the upper part of the displayed window of fuzzy logic inference rules.

Figure 7. **27 Rule pairs**

3.4 Defuzzification

The defuzzification method used is the Centroid method. So, the example shown is an LED TV brand with size 43 (medium size), resolution 2,160 (high resolution), and price 3,890,000 (normal price), indicating that the decision is in the interval 76.7, namely buy.

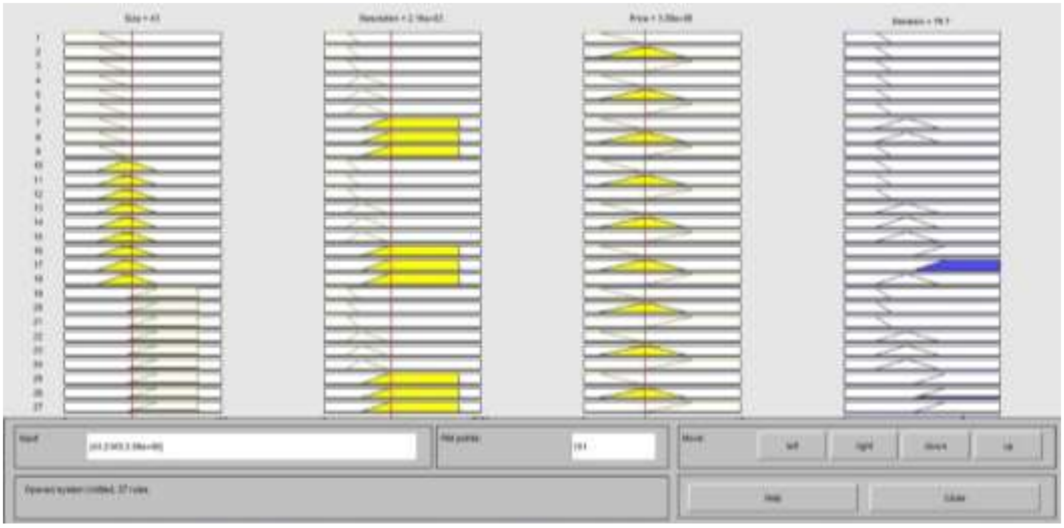

Figure 8. **Defuzzification**

The generated and entered fuzzy inference rules work as shown in **Figure 8**. In this case, in the lower-left corner of the window, there are data input columns for decision-making (the specified values are displayed in the headers of the first four columns of the overall function image). The integral forecast score (score result) is displayed in the upper right corner of the screen.

4. CONCLUSIONS

Based on the research results, it was concluded that the application of vague logic in decision-making using the Mamdani method was able to provide advice on obtaining an LED TV with the expected criteria. The results obtained indicate purchasing criteria based on medium size, high resolution, and normal price, but in fact, the decision is still based on the buyer's decision. The application of Fuzzy Logic (Mamdani method) in making decisions on selecting LED TVs using Matlab software is carried out in four ways, namely Fuzzification of Input Variables, Membership Functions, Fuzzy Inference Rules and Logical Operators, Defuzzification. Formation of fuzzy sets by dividing each variable into three fuzzy sets: implication function using the minimum function, rule composition using the maximum method, and defuzzification using the centroid of area method. Recommendations for future research include adding additional input variables related to the output and exploring fuzzy logic using various methods that can be compared to find more efficient methods. In addition, research can be expanded by applying a fuzzy logic system, especially the Mamdani method, in decision-making for other electronic goods.

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