

Implementation of Fuzzy Logic Mamdani in Determining Employee Job Appraisal of PT Exclusive Panca Anugerah Using Matlab

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Abstract

Human resources are one of the important components of a company. With good employee performance, it can be interpreted that the system in the company is also running well. This method utilizes attendance and performance variables to assess the employee. This journal aims to see and monitor how an employee's performance in a company is working optimally or not. It uses the implementation of fuzzy logic Mamdani as a proof model, coupled with the Matlab application toolbox that allows evaluation and assessment of performance according to the existing scenario. The results of this experiment show the effectiveness of providing accurate scores and can also help management to make more informed decisions.

Keywords: Assesment, Fuzzy Mamdani, Matlab, Performance.

INTRODUCTION

Employees are one of the important things in the company ecosystem, where their performance assessment is also important. The previous researcher explained some of these things, such as how an employee's performance appraisal becomes an important point to find out what kind of assessment they receive with their performance each month, whether it is an A, B, or even C grade. (Arianto dan Siahaan 2018).

According to (Sumanto *et al.*, 2022), Performance appraisal is "a process of assessing employee performance carried out by company leaders systematically based on the work assigned to him." Performance appraisal must also be carried out fairly; that is, the assessment must be carried out on all employees to create fairness in the performance appraisal.

Then, according to (Nur Hidayat, 2022), "One way to determine the quality of human resources in an organization is to conduct a performance appraisal," where the performance appraisal is based on the achievements that have been achieved.

This research was conducted at PT Exclusive Panca Anugerah (EPA) by interviewing one of the administrative parties there; this interview was conducted on Thursday, February 22, 2024. This company sells fresh fish at the fish market in Muara Baru, East Jakarta.

Some of the variables used are the attendance list and job performance, each of which uses three parameters: low, medium, and high. This calculation will use the fuzzy logic Mamdani method, which will be assisted by the MATLAB application to prove it.

This research uses the fuzzy mamdani method which is newly used in research in this company. Then this mamdani fuzzy method is also driven by using MATLAB applications that can show the accuracy of this method.

METHODS

This research uses the interview method to find research data. The interview involved the author and also the company engaged in employee administration. Then to show the success of this research, it is assisted by an analysis method using fuzzy logic. Fuzzy logic here is used to determine the doubt between good, medium, or bad assessments. So Fuzzy Logic is needed so that these doubts can be resolved.

Interview Method

The method used by the author is the interview method, where the author asks directly about the company's situation to those who handle problems regarding attendance and employee injera. The author also uses a supporting application, namely Matlab.

Matlab is used to calculate the vague value generated from fuzzy logic; the author uses Mamdani fuzzy logic. Fuzzy logic is also called Vague Logic because the modern and systematic science of fuzzy logic was only discovered in 1965. Still, fuzzy logic has been inherent in humans since humans existed, according to (Bayu Setia, 2019).

This fuzzy logic uses several stages to produce a definite value, namely determining the membership function, creating a fuzzy rule base, and finally, defuzzification. There are two types of membership functions, namely, the triangular membership function and the trapezoidal membership function (Nur Hidayat, 2022). In this journal, the author uses both types of membership functions.

Membership Functions

Membership Functions have two types: the Triangular Membership Function (a,b,c) and the Trapezoidal Membership Function (a,b,c,d).

Triangular Membership Function

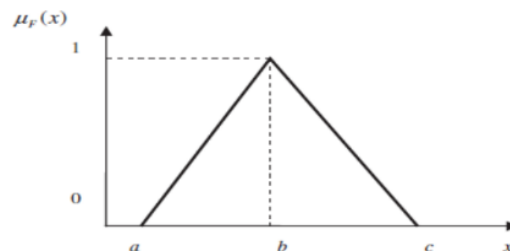


Figure 1. Triangular Membership Function

According to (Siskandar *et al.*, 2023), The triangular membership set graph is used to determine the degree of membership of the highest value. The membership set for the Triangular Membership Function graph $\mu_F(a, b, c)$.

Trapezoidal Membership Function

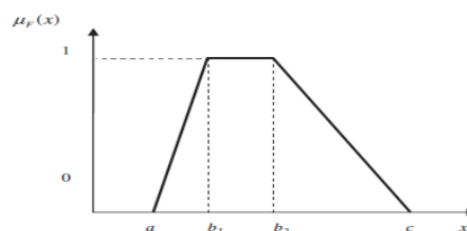


Figure 2. Trapezoidal Membership Function

Also, the Triangular Graph membership set has more than one degree of the highest membership value. The membership set for the Trapezoidal Membership Function graph $\mu_F(a, b_1, b_2, c)$ (Siskandar *et al.* 2023)

RESULTS AND DISCUSSION

From the interviews conducted by the author, several data were obtained to be processed, including the number of employees at PT EXCLUSIVE PANCA ANUGERAH, totaling 25 employees. Then, for the data to assess an employee's performance, there are two variables, namely attendance and also Karywana's performance. Each variable has three parameters, namely Low, Medium, and High. The last output is an assessment, which also has the three parameters above.

The data obtained will be grouped into raw data, which will later be included in a case study to prove this journal's results.

Interview Data

The following is a table of the results of data that has been obtained previously through the interview stage by the company. This data is taken through several questions that are answered by the company that handles this matter..

Table 1. Interview Data

Variable	Fuzzy Parameter	Range				
		Set	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>
Attendance	Low	13 - 19	13	16	19	-
	Medium	18 - 24	18	21	24	-
	High	22 - 28	22	25	28	-
Performance	Low	1 - 5	1	3	5	-
	Medium	4 - 8	4	6	8	-
	High	7 - 10	7	8	9	10
Assessment	Low	10 - 50	10	30	50	-
	Medium	40 - 80	40	60	80	-
	High	70 - 100	70	80	90	100

Case Study

The case study used has high attendance criteria with a value of **(26)** and low-performance criteria with a value of **(2)**, so an assessment will be produced later. After getting a case study, the next step is to solve it using the stages of the Fuzzy Inference System (FIS) as follows:

Determine Input and Output Variables

This stage determines the Input and Output variables obtained in the interview stage, namely the Attendance and Performance variables into Input variables and Assessment as Output variables with the Range that has been determined above. With the help of the Matlab application, the Membership Function will be created (Santosa *et al.* 2023).

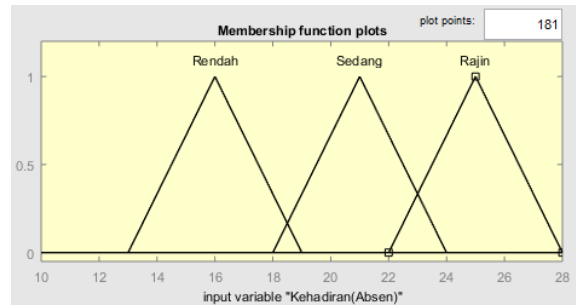


Figure 3. Input Attendance

This is an image that shows the attendance input variable with three parameters. The parameters are Low, Medium and High.

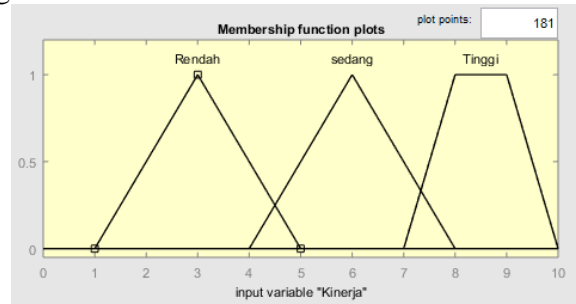


Figure 4. Input Performance

This is an image that shows the performance input variable with three parameters. The parameters are Low, Medium and High.

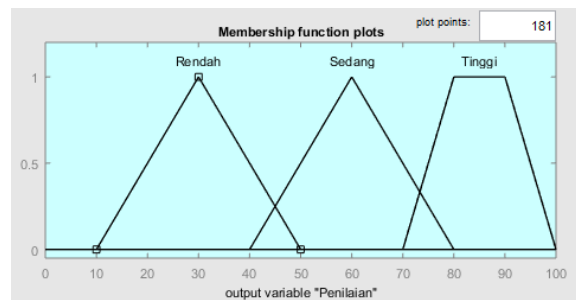


Figure 5. Output Assessment

This is an image that shows the assessment output variable with three parameters. The parameters are Low, Medium and High.

Building Fuzzy Membership Sets

The second stage in FIS is to determine the membership set based on the data that has been made above; this membership set will be used to determine the degree of membership.

Attendance Input Membership Set

The membership function for the input variable, Attendance, is divided into three fuzzy sets, each using a triangular curve. The membership function for the input variable "Attendance" in this study is divided into three fuzzy sets: "Low" with a center value of 16, "Medium" with a center value of 21, and "Diligent" with a center value of 25.

$$\mu_{Low} = \begin{cases} x < 13 & 0 \\ 13 \leq x < 16 & \frac{x - a}{b - a} \\ x = 16 & 1 \\ 16 < x \leq 19 & \frac{c - x}{c - b} \\ x > 19 & 0 \end{cases}$$

In the low parameter section, there are three sections that can be used as formulas. The first is the left side section (13-15), the second is the peak point section (16), and the third is the right side section (16-19).

$$\mu_{Medium} = \begin{cases} x < 18 & \frac{x-a}{b-a} \\ 18 \leq x < 21 & \frac{1}{c-b} \\ x = 21 & 1 \\ 21 < x \leq 24 & \frac{c-x}{c-b} \\ x > 24 & 0 \end{cases}$$

In the medium parameter section, there are also three sections that can be used as formulas. The first is the left side section (18-20), the second is the peak point section (21), and the third is the right side section (21-24).

$$\mu_{High} = \begin{cases} x < 22 & \frac{x-a}{b-a} \\ 22 \leq x < 25 & \frac{1}{c-b} \\ x = 25 & 1 \\ 25 < x \leq 28 & \frac{c-x}{c-b} \\ x > 28 & 0 \end{cases}$$

In the high parameter section, there are also three sections that can be used as formulas. The first is the left side section (22-24), the second is the peak point section (25), and the third is the right side section (25-28).

Performance Input Membership Set

Secondly, the membership function for the input variable, Performance, is divided into three fuzzy sets using a combination of triangular and trapezoidal curves. The membership functions for the input variable "Assessment" are "Low" with a center value of 3, "Medium" with a center value of 6, and "High" with center values of 7 and 8.

$$\mu_{Low} = \begin{cases} x < 1 & \frac{x-a}{b-a} \\ 1 \leq x < 3 & \frac{1}{c-b} \\ x = 3 & 1 \\ 3 < x \leq 5 & \frac{c-x}{c-b} \\ x > 5 & 0 \end{cases}$$

In the low parameter section, there are three sections that can be used as formulas. The first is the left side section (1-2), the second is the peak point section (3), and the third is the right side section (3-5).

$$\mu_{Medium} = \begin{cases} x < 4 & \frac{x-a}{b-a} \\ 4 \leq x < 6 & \frac{1}{c-b} \\ x = 6 & 1 \\ 6 < x \leq 8 & \frac{c-x}{c-b} \\ x > 8 & 0 \end{cases}$$

In the medium parameter section, there are also three sections that can be used as formulas. The first is the left side section (4-5), the second is the peak point section (6), and the third is the right side section (6-8).

$$\mu_{High} = \begin{cases} x < 7 & \frac{x-a}{b-a} \\ 7 \leq x < 8 & \frac{1}{d-c} \\ 8 = x = 9 & 1 \\ 9 < x \leq 10 & \frac{d-x}{d-c} \\ x > 10 & 0 \end{cases}$$

In the high parameter section, there are also three sections that can be used as formulas. The first is the left side section (7), the second is the peak point section (8-9), and the third is the right side section (10).

Assessment Output Membership Set

Furthermore, the membership functions for the output variable, Assessment, are divided into three fuzzy sets using a combination of triangular and trapezoidal curves. The membership functions for the input variable "Assessment" are "Low" with a center value of 30, "Medium" with a center value of 60, and "High" with center values of 70 and 80.

$$\mu_{Low} = \begin{cases} x < 10 & 0 \\ 10 \leq x < 30 & \frac{x-a}{b-a} \\ x = 30 & 1 \\ 30 < x \leq 50 & \frac{c-x}{c-b} \\ x > 50 & 0 \end{cases}$$

In the low parameter section, there are three sections that can be used as formulas. The first is the left side section (10-29), the second is the peak point section (30), and the third is the right side section (31-50).

$$\mu_{Medium} = \begin{cases} x < 40 & \frac{x-a}{b-a} \\ 40 \leq x < 60 & \frac{x-a}{b-a} \\ x = 60 & 1 \\ 60 < x \leq 80 & \frac{c-x}{c-b} \\ x > 80 & 0 \end{cases}$$

In the medium parameter section, there are also three sections that can be used as formulas. The first is the left side section (40-50), the second is the peak point section (60), and the third is the right side section (61-80).

$$\mu_{High} = \begin{cases} x < 70 & \frac{x-a}{b-a} \\ 70 \leq x < 80 & \frac{x-a}{b-a} \\ 80 = x = 90 & 1 \\ 90 < x \leq 100 & \frac{d-x}{d-c} \\ x > 100 & 0 \end{cases}$$

In the high parameter section, there are also three sections that can be used as formulas. The first is the left side section (70), the second is the peak point section (80-90), and the third is the right side section (100).

Determining Membership Degrees

After determining the membership set, focus on the case study above where the input is HIGH Attendance with a value of 26 and LOW Performance with a value of 2. Determine the membership degree of each input variable using the formula above according to its part.

Attendance Input: (High: 26)

To calculate the input variable, we need to consider the value of x. In this case, x is 26 which is in the high parameter.

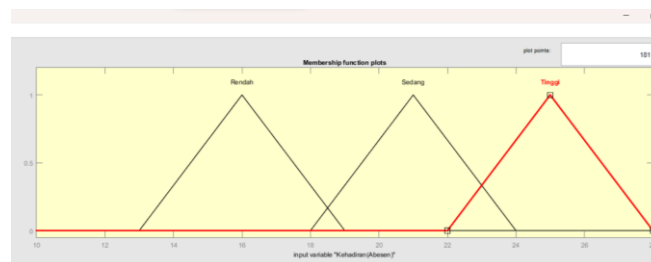


Figure 6. Input High Attendance 26

Because the x value is in the high parameter, here to calculate it, use the formula of the height parameter. After that, a straight line is drawn upwards and hits the right side.

$$\mu_{High} = \begin{cases} 0 & x < 22 \\ \frac{x-22}{25-22} & 22 \leq x < 25 \\ 1 & x = 25 \\ \frac{28-x}{28-25} & 25 < x \leq 28 \\ 0 & x > 28 \end{cases}$$

Since it is about the right side, the formula for calculating the right side is used. The result of the calculation is **0.29** in the membership degree of the attendance variable.

x = 26 use the right side formula

$$\frac{c-x}{c-b} = \frac{28-26}{28-25} = \frac{2}{3} = \mathbf{0,29}$$

Performance Input (Low: 2)

Just like the previous calculation, which must focus on the value of x. In this performance parameter, the x value is 2, which is included in the low parameter.

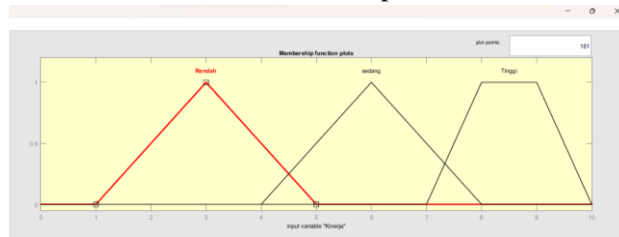


Figure 7. Input Low Performance 2

Because it is included in the low parameter, the low parameter formula will be used. After that, a straight line is drawn from x towards the triangle and touches the left side.

$$\mu_{Low} = \begin{cases} 0 & x < 1 \\ \frac{x-1}{3-1} & 1 \leq x < 3 \\ 1 & x = 3 \\ \frac{3-x}{3-5} & 3 < x \leq 5 \\ 0 & x > 5 \end{cases}$$

To calculate it, the left side formula is used, with the results obtained being **0.5** for the degree of membership in the performance variable.

x = 2 use the left side formula

$$\frac{x-a}{b-a} = \frac{2-1}{3-1} = \frac{1}{2} = \mathbf{0,5}$$

From the data processed above, two degrees of membership are obtained, namely **0.29** from the first input and **0.5** from the second input.

Determining Fuzzy Operators

The next stage after obtaining the membership degree is to determine the fuzzy operator, this fuzzy operator requires a Fuzzy Rule Base, where the rules must also be obtained by the interview stage by the expert who handles it (Santosa *et al.* 2021). The Fuzzy Rule Base data obtained by the author is:

1. If (Kehadiran(Absen) is Rendah) and (Kinerja is Rendah) then (Penilaian is Rendah) (1)
2. If (Kehadiran(Absen) is Rendah) and (Kinerja is sedang) then (Penilaian is Rendah) (1)
3. If (Kehadiran(Absen) is Rendah) and (Kinerja is Tinggi) then (Penilaian is Rendah) (1)
4. If (Kehadiran(Absen) is Sedang) and (Kinerja is Rendah) then (Penilaian is Sedang) (1)
5. If (Kehadiran(Absen) is Sedang) and (Kinerja is sedang) then (Penilaian is Sedang) (1)
6. If (Kehadiran(Absen) is Sedang) and (Kinerja is Tinggi) then (Penilaian is Tinggi) (1)
7. If (Kehadiran(Absen) is Rajin) and (Kinerja is Rendah) then (Penilaian is Sedang) (1)
8. If (Kehadiran(Absen) is Rajin) and (Kinerja is sedang) then (Penilaian is Tinggi) (1)
9. If (Kehadiran(Absen) is Rajin) and (Kinerja is Tinggi) then (Penilaian is Tinggi) (1)

Figure 8. Fuzzy Rule Base

The above rules use the "AND" formula from the Fuzzy Rule Base where the two input variables must be interconnected. Moreover, from the rules obtained, this case study is affected by rule number seven (7) with the output parameter Medium.

Because it uses the "AND" formula, the next step is to determine the minimum value of the two membership degrees obtained (0.29 and 0.5).

$$\alpha_7 = \min(\mu(x)_{High}[26] \cap (\mu(y)_{Low}[2]))$$

$$\alpha_7 = \min(0,29 ; 0,5)$$

$$\alpha_7 = \mathbf{0,29}$$

Determining the Implication Function

After getting the minimum value of the membership degree based on the Fuzzy Rule Base (0.29), the next step is to determine the function value of the Medium output variable.

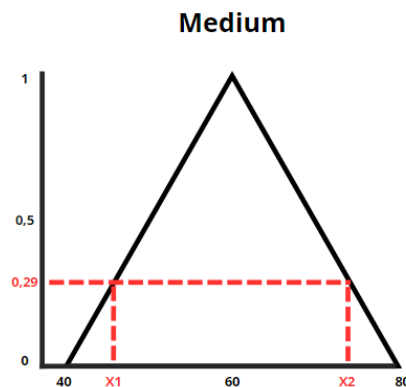


Figure 9. Implication Value

Determination of the implication value using the same formula in the output data above using the left side formula for X1 and the right side formula for X2..

$$\text{Left side output : } \alpha = \frac{x1-a}{b-a}$$

$$= 0,29 = \frac{x1-40}{60-40}$$

$$= 0,29 \cdot 20 = x1 - 40$$

$$= 5,8 = x1 - 40 \quad (\Rightarrow) \quad 5,8 + 40 = x1$$

$$= x1 = \mathbf{45,8}$$

$$\text{Right side output : } \alpha = \frac{c-x2}{c-b}$$

$$(\Rightarrow) \quad 0,29 = \frac{80-x2}{60-80} \quad (\Rightarrow) \quad 0,29 \cdot 20 = 80 - x2$$

$$(\Rightarrow) \quad x2 = 80 - 5,8 = \mathbf{74,2}$$

From the above calculations, the results of the X1 implication value are **45.8** and X2 **74.2**.

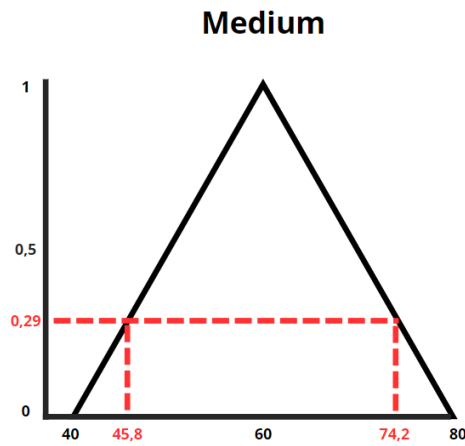


Figure 10. Implication Value of x_1 and x_2

Then the composition of data values into a new formula which becomes the formula for the last stage later, this formula is divided into three parts between (a, x_1) , (x_1, x_2) and (x_2, c) as below.

$$f(x, a, b, c) = \begin{cases} x < 40 & 0 \\ 40 \leq x < 45,8 & \frac{x - 40}{60 - 40} \\ 45,8 \leq x \leq 74,2 & 0,29 \\ 74,2 < x \leq 80 & \frac{80 - x}{80 - 60} \\ x > 80 & 0 \end{cases}$$

Defuzzification

The defuzzification process to determine this assessment uses the center of area (COA) method. This method compares the areas and moments generated by fuzzy operators (Santosa *et al.* 2022). The last stage is Defuzzification, which is divided into three parts, namely calculating the Area, Moment, and the Defuzzification stage itself.

Calculating the Area

The area calculation will be related to the next calculation in this stage. This calculation is focused on the output variable that its implication value has previously determined.

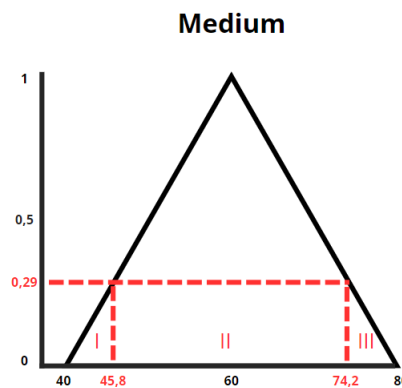


Figure 11. Area

Calculating this area uses the formula of the flat shapes formed. Areas 1 and 3 are formed as triangles where the formula is $\frac{a \times t}{2}$. And in area 2, it forms a rectangle with the formula $p \times l$. Then the calculation below is obtained.

$$A_1 (\text{Triangle}) : \frac{(45,8 - 40) \cdot 0,29}{2} = \frac{5,8 \cdot 0,29}{2} = \mathbf{0,84}$$

$$A2 \text{ (Rectangle)} : (74,2 - 45,8) \cdot 0,29 = 28,4 \cdot 0,29 = \mathbf{8,24}$$

$$A3 \text{ (Triangle)} : \frac{(74,2-80) \cdot 0,29}{2} = \frac{5,8 \cdot 0,29}{2} = \mathbf{0,84}$$

Moment Calculation

This moment calculation formula is an advanced description of the implication value formula, the formula becomes as below.

$$x < 40 = 0 ;$$

$$40 \leq x < 45,8 ; \frac{x - 40}{20} = \mathbf{0,05x - 2}$$

$$45,8 \leq x \leq 74,2 ; \mathbf{0,29}$$

$$74,2 < x \leq 80 ; \frac{80-x}{20} = \mathbf{4 - 0,05}$$

$$x > 80 = 0 ;$$

Get the moment calculation formula as above, ignore the formula that produces the value 0, then three moment formulas have been obtained. From the description of the implication formula, there is also an x value based on the area above. Enter the x value into the moment formula to continue the calculation.

Moment Calculation 1

This first moment uses the x-value 40 as the lower limit and 45.8 as the upper limit. Calculate it using the itegral formula of the upper limit minus the lower limit.

$$\begin{aligned} \int_{40}^{45,8} (0,05x - 2)x \cdot dx &= (0,05x^2 - 2x) \cdot dx = \left(\frac{0,05x^3}{3} - \frac{2x^2}{2} \right) = (0,0167x^3) - (x^2) \\ \int \{ (0,0167(45,8)^3 - (45,8)^2) \} - \{ (0,0167(40)^3 - (40)^2) \} \\ \int \{ (0,0167 \cdot 96071,912) - 2097,64 \} - \{ (0,0167 \cdot 64000) - 1600 \} \\ \int \{ 1604,40 - 2097,64 \} - \{ 1068,8 - 1600 \} \\ (-493,24) - (-531,2) &= \mathbf{37,96} \end{aligned}$$

After integral calculation, it is found that the first moment value is **37.96**.

Moment Calculation 2

The second moment calculation also uses an integral calculation. The lower limit is 45.8 with an upper limit of 74.2.

$$\begin{aligned} \int_{45,8}^{74,2} (0,29)x \cdot dx &= (0,29x)dx = \left(\frac{0,29x^2}{2} \right) = 0,145x^2 \\ \int \{ 0,145(74,2)^2 \} - \{ 0,145(45,8) \}^2 \\ \int \{ 0,145 \cdot 5505,64 \} - \{ 0,145 \cdot 2097,64 \} \\ \int (798,32) - (304,16) &= \mathbf{494,16} \end{aligned}$$

After integral calculation, it is found that the second moment value is **494,16**.

Moment Calculation 3

This last moment calculation uses a lower limit value of 74.2 and an upper limit value of 80. The calculation is as below.

$$\int_{74,2}^{80} (4 - 0,05x)x \cdot dx = (4x - 0,05x^2)dx = \left(\frac{4x^2}{2} - \frac{0,05x^3}{3}\right) = 2x^2 - 0,0167x^3$$

$$\int \{(2(80)^2) - (0,0167(80^3))\} - \{(2(74,2)^2) - (0,0167(74,2^3))\}$$

$$\int \{(2.6400) - (0,0167.512000)\} - \{(2.5505,64) - (0,0167.408518,488)\}$$

$$\int \{12800 - 8550,4\} - \{11011,28 - 6822,26\}$$

$$(4249,6) - (4189,02) = \mathbf{60,58}$$

After integral calculation, it is found that the last moment value is **60,58**.

Defuzzification

Entering the last calculation stage, namely defuzzification, this stage is proof that the above calculations are close to the expected results. Later the results of this manual calculation will also be proven using the Matlab application so that the results are appropriate.

$$Z^* = \frac{\sum \text{moment}}{\sum \text{area}} = \frac{37,96 + 494,16 + 60,58}{0,84 + 8,24 + 0,84} = \frac{592,7}{9,92} = \mathbf{59,75 \text{ rounded} = 60}$$

The manual calculation above gets a lift of 59.75, do the math rounding up, the result obtained is a value of 60.

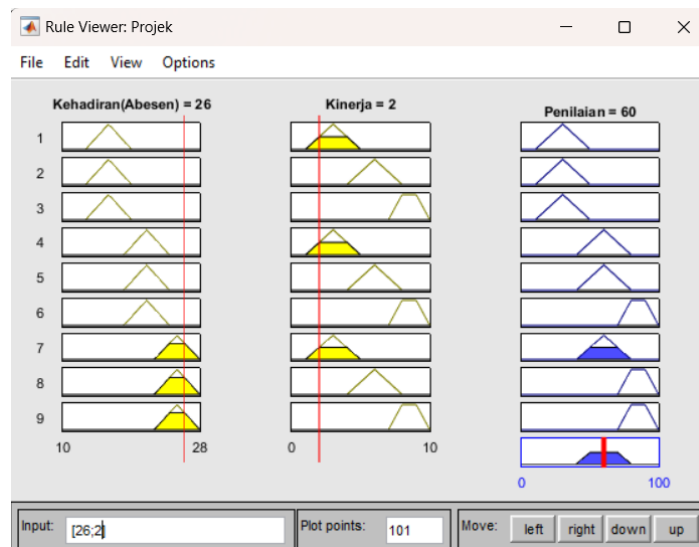


Figure 12. Matlab calculation

After using the matlab application, the results obtained are 60. It can be interpreted that the above calculations are appropriate.gf

CONCLUSION

In conclusion, the research conducted at PT Exclusive Panca Anugerah (EPA) utilized fuzzy logic Mamdani method, supported by MATLAB, to assess employee performance based on attendance and job performance variables. The study involved 25 fresh fish selling company employees, each variable having three parameters: low, medium, and high. The fuzzy logic employed triangular and trapezoidal membership functions to determine degrees of membership for attendance, performance, and assessment. A case study was presented, demonstrating the application of fuzzy inference system (FIS) to calculate the assessment for an employee with high attendance (26) and low performance (2). The FIS involved determining input and output variables, building fuzzy membership sets, determining membership degrees, fuzzy operators, and implication functions. Defuzzification was then applied to obtain a final assessment value. The research provided a comprehensive methodology for performance

appraisal using fuzzy logic, with the manual calculation aligning with the MATLAB results, reinforcing the validity of the approach in evaluating employee performance fairly and systematically. This research can be developed in the future to be even better, such as using additional variables, analyzing the impact that will be caused and can be an additional exploration in terms of the objectivity of employee performance.

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