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Analysis of Application of Fuzzy Grid Partition on Mamdani Method Fuzzy Inference System

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ABSTRACT- The Mamdani method has been widely used for various control devices, which is the beginning of fuzzy technology and has the advantage of being able to express concepts that are difficult to formulate and the use of fuzzy membership functions in making objective observations of subjective values, making it easier to make decisions that are full of uncertainty. The Mamdani method has also been widely used for various optimization problems. This study produces new findings on the analysis of the application of fuzzy grid partition on the fuzzy inference system of the Mamdani method for the issue of optimizing the amount of production of a food product. The research stage begins with determining the number of partitions that will form a grid structure. The grid formed from the combination of relations between each partition will have the potential to develop rules. Based on the results of the analysis, determining the amount of production using the Mamdani method produces a smaller amount of production but produces stock output that is not within the specified stock limit, while the application of fuzzy grid partition in the Mamdani method has a higher and correct amount of product because it produces stock output that is at the specified stock limit.

Keywords : Mamdani Method, Fuzzy Grid Partition, Stock Limit

1. INTRODUCTION

Some methods used in making decisions that are full of uncertainty in fuzzy logic are the Mamdani method, the Tsukamoto method, and the Sugeno method. The fuzzy inference system includes three methods used for various optimization problems [1][2][3].

Applications of fuzzy inference methods can be found in various aspects of the production or manufacturing industry [4]. Fuzzy inference systems can be an efficient tool to help make decisions about manufacturing re-engineering, optimize process parameters for process drilling, realize better batch process scheduling or design process-optimized injection moulded parts [5]. All these applications have in common that they all need to consider several factors together before reaching the final result. The relationship between inputs and outputs and the relationship between each input factor is quite complicated, and it is difficult to formulate an interactive or indirect relationship. Therefore, the advantages of fuzzy inference systems stand out because the If-then rule-based inference mechanism can be defined directly by practice experience. Although the most optimal results from accurate mathematical expressions are difficult to obtain, fuzzy inference dramatically simplifies and speeds up the computational process and produces results that are good enough for reference.

The application of Fuzzy Grid Partition has been tested to optimize the fuzzy inference system of the Tsukamoto method. The test uses labels linked to variables built by Fuzzy Grid Partition to correct the limitations of the Tsukamoto Fuzzy Inference System. Fuzzy Inference System using Fuzzy Grid Partition to get a fair optimal solution for the Fuzzy Tsukamoto problem. The new membership function as a result of the fuzzy grid partition can improve the limits of the fuzzy inference system of the Tsukamoto method, where the fuzzy grid partition can determine the number of fuzzy rules [6].

This study analyses the application of fuzzy grid partition in generating rules that can be used as labels that can be linked from variables to optimize the output of the Mamdani method. The Mamdani type inference output expects membership events to become fuzzy sets to be carried out after the aggregation process. Fuzzy set for each output variable; defuzzification needs to be done. It is efficient, and sometimes a single spike is used as an output function rather than a distributed fuzzy set. A single output function can be thought of as a pre-defuzzified fuzzy set. This can increase the efficiency of the defuzzification process because it greatly simplifies the calculations required by the more general Mamdani method, which finds the centre of mass of a two-dimensional function. The Mamdani type integrates all two-dimensional functions to find the centre of mass, the weighted average of several data points [7].

The fuzzy grid-partition approach can be used in the design of fuzzy systems because it is easier to use. Several studies have applied the fuzzy grid partition approach, among others, generating several rules [8][9], combine texture approach [10], choose features [11], partition feature space [12].

This study aims to analyze the application of fuzzy grid partition in the Mamdani method to produce optimal output in making conclusions or decisions with several stages, namely determining the number of partitions (K), forming fuzzy sets with grid partitions; implication function application; composition of rules; and defuzzification.

2. FUZZY GRID PARTITION ON MAMDANI METHOD

The fuzzy inference system of the Mamdani method is often also known as the min – max method which was introduced by Ebrahim Mamdani in 1975 [13]. The stages of the mamdani method to get the output consist of [14]:

a. Determination of the number of partitions (K)
b. Fuzzy set generate
Input variables and output variables are divided into one or more fuzzy sets. Input variables and output variables are divided into partitions to form a grid structure, the grid formed from the combination of relations between each partition will have the potential to develop rules, as illustrated in Fig. 1 in the following two attributes.

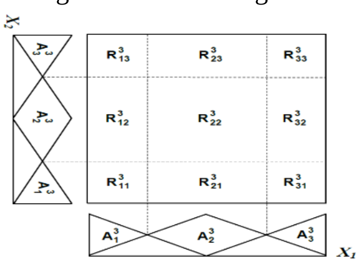

Figure 1. Grid Partition

c. Implication function
The implication function used is Min. The rules formed are derived from the rules for applying fuzzy grid partition with the number of partitions K.

d. Composition Rules
If the system consists of several rules, then the inference is obtained from combining the rules. The method used in performing fuzzy system inference is the max. The max method is a fuzzy set solution obtained by taking the maximum value of the rule, then using it to modify the fuzzy set area, and applying it to the output using the OR (union) operator. If all propositions have been evaluated, then the result will contain a fuzzy set that reflects the contribution of each proposition. In general, it can be written:

$$U_{sf}[x_i] = \max (U_{sf}[x_i], U_{kf}[x_i]) \qquad \text{.............(1)}$$

Where:

$U_{sf}[x_i]$ = fuzzy solution membership value up to the i-th rule
$U_{kf}[x_i]$ = fuzzy consequent membership value of rule – i

e. Defuzzification
The defuzzification method on the composition rule is the Centroid (Composite Moment) method. In this method, the crisp solution is obtained by taking the centre point of the fuzzy region. Generally formulated:

$$Z_0 = \frac{\int_a^b Z\,\mu(z)dz}{\int_a^b \mu(z)dz} \; for\ continuous \qquad \text{.............(2)}$$

where:
Z = i-th domain value
μ(z) = the degree of membership of the point
Z_0 = defuzzification result value

3. RESEARCH METHODS

To complete this research, it is necessary to have a clear framework for the stages. The stages of the analytical research framework for applying Fuzzy Grid Partition on the Mamdani method can be seen in Fig. 2 below.

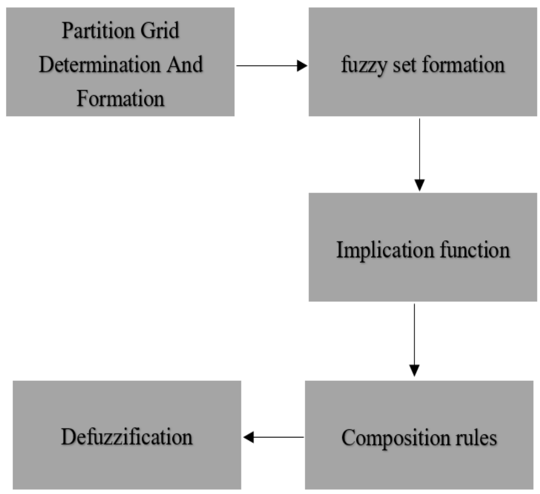

Figure 2. Research Framework

4. RESULTS AND DISCUSSION

4.1 Result

Suppose Company A wants to produce ABC type of food. It is known that the data from the last month are as follows, the greatest demand is 6500 packages/day, and the smallest demand is 2300 packages/day. The largest stock in the warehouse is 590 packages/day, and the smallest stock is 120 packages/day. With these limitations, company A can only produce 7150 packages/day, and the smallest production efficiency is 2000 packages/day. If the production process uses four rules:

1. If demand decreases and stock is large, then production decreases.
2. If the demand decreases and the stock is low, then production will decrease
3. If demand increases and there is a lot of stock, then production increases
4. If demand increases and stock is low, then production increases

The problem must be solved how many food products must be produced if there is a demand for 3900 packages and the stock in the warehouse is 310 packages?

The research stages are as follows:

1. Mamdani Method
   a. Demand with domain 0 – 6500 consisting of Demand Decrease and Demand Increase. Figure Variable demands as follows:

Figure 3. Demand Variables

The membership function of the Request variable is as follows:

$$\mu_{Demands\ Decrease}[x] = \begin{cases} 1 & , x \leq 2300 \\ \dfrac{6500 - x}{4200} & , 2300 \leq x \leq 6500 \\ 0 & , x \geq 6500 \end{cases}$$

$$\mu_{Demands\ Increase}[x] = \begin{cases} 0 & , x \leq 2300 \\ \dfrac{x - 2300}{4200} & , 2300 \leq x \leq 6500 \\ 1 & , x \geq 6500 \end{cases}$$

If there is a request for 3900 packages, then:

$$\mu_{Demands\ Decrease}[3900] = \frac{6500 - 3900}{4200}$$

$$= \frac{2600}{4200} = 0.62$$

$$\mu_{Demands\ Increase}[3900] = \frac{3900 - 2300}{4200}$$

$$= \frac{1600}{4200} = 0.38$$

   b. Stock with domain 0 – 590 which consists of little stock and large stock. Picture of stock variables as follows::

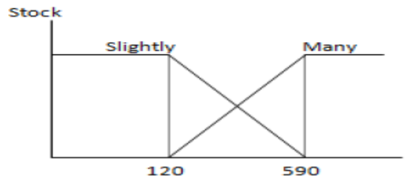

Figure 4. Stock Variable

Stock variable membership function as follows: $\mu_{Stock\ Slightly}[y] =$

$$\begin{cases} 1 & , y \leq 120 \\ \frac{590-y}{470} & , 120 \leq y \leq 590 \\ 0 & , y \geq 590 \end{cases}$$

$$\mu_{Stock\ Many}[y] = \begin{cases} 0 & , y \leq 120 \\ \dfrac{y - 120}{470} & , 120 \leq y \leq 590 \\ 1 & , y \geq 590 \end{cases}$$

If the stock in the warehouse is 310 packages, then:

$$\mu_{Stock\ Slightly}[310] = \frac{590 - 310}{470}$$

$$= \frac{280}{470} = 0.60$$

$$\mu_{Stock\ Many}[310] = \frac{310 - 120}{470}$$

$$= \frac{190}{470} = 0.40$$

   c. Production with a domain of 0 – 7150 consists of decreased and increased production. The image of the production variable is as follows:

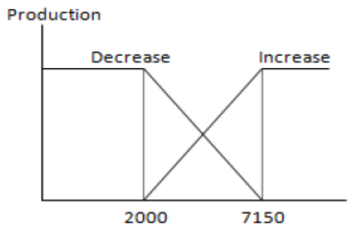

Figure 5. Production Variable

The membership function of the Production variable is as follows:

$$\mu_{Production\ Decrease}[Z] = \begin{cases} 1 & , z \leq 2000 \\ \dfrac{7150 - z}{5150} & , 2000 \leq z \leq 7150 \\ 0 & , z \geq 7150 \end{cases}$$

$$\mu_{Production\ Increase}[Z] = \begin{cases} 0 & , z \le 2000 \\ \dfrac{z-2000}{5150} & , 2000 \le z \le 7150 \\ 1 & , z \ge 7150 \end{cases}$$

d. Formation of Variable Fuzzy Set Request 3900 packets.

$\mu_{Demands\ Decrease}[3900] = 0.62$
$\mu_{Demands\ Increase}[3900] = 0.38$

e. Formation of Stock Variable Fuzzy Set 310 packages.
$\mu_{Stock\ Slightly}[310] = 0.60$
$\mu_{Stock\ Many}[310] = 0.40$

f. Implication Function
There are four implication function rules in the Fuzzy Mamdani Method, namely:

R[1] If the demand is reduced and there is a lot of stock, the production will decrease.
$$\alpha - predikat_1 = \mu_{Demands\ Decrease} \cap \mu_{Stock\ Slightly} = Min\ (0.62, 0.40) = 0.40$$

R[2] If the demand is reduced and the stock is low, the production will decrease.
$$\alpha - predikat_2 = \mu_{Demands\ Decrease} \cap \mu_{Stock\ Slightly} = Min\ (0.62, 0.60) = 0.60$$

R[3] If demand increases and there is a lot of stock then production increases
$$\alpha - predikat_3 = \mu_{Demands\ Increase} \cap \mu_{Stock\ many} = Min\ (0.38, 0.40) = 0.3$$

R[4] If demand increases and stock is low then production increases
$$\alpha - predikat_4 = \mu_{Demands\ Increase} \cap \mu_{Stock\ Slightly} = Min\ (0.38, 0.60) = 0.38$$

g. Composition Rules
$\mu_{sf\ (Z)} = Max\ (\mu_{Production\ Decrease}, \mu_{Production\ Increase})$
= max (0.6; 0.38)
At the time $\mu_{Production\ Decrease}(z) = 0.6$ then value z = 4060
At the time $\mu_{Production\ Increase}(z) = 0.38$ then value z =5193
Thus the membership function for the composition result is :

$$\mu[Z] = \begin{cases} 0.6 & , z \le 4060 \\ \dfrac{5193 - z}{1133} & , 4060 \le z \le 5193 \\ 0.38 & , z \ge 5193 \end{cases}$$

h. Defuzzification

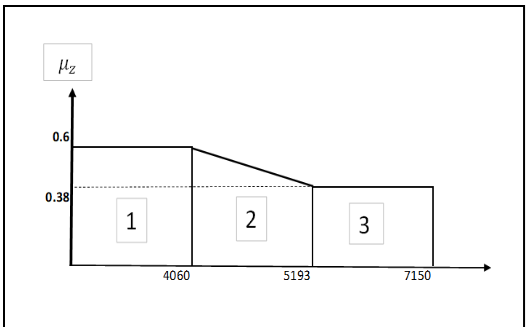

Figure 6. Defuzzification Function

The defuzzification process uses the centroid method to determine the crisp z value. It is carried out by dividing the area into three parts, namely 1, 2, and 3, with the respective regions of A1, A2, and A3, and the moment to the membership value are M1, M2, and M3.

$$M_1 = \int_0^{4060} 0.6\, z\, dz = 0.3\, z^2 \Big|_0^{4060}$$
$$= 4945080$$
$$M_2 = \int_{4060}^{5193} \frac{5193 - z}{1133}\, z\, dz$$
$$= \int_{4060}^{5193} 4.58\, z - 0.000883 z^2\, dz$$
$$= 2.29\, z^2 - 0.000294 z^3 \Big|_{4060}^{5193}$$
$$= 2511008,841$$

$$M_3 = \int_{5193}^{7150} 0.38\, z\, dz$$
$$= 0.19\, z^2 \Big|_{5193}^{7150} = 4589498$$

area as follows:

$$A_1 = 4060 * 0.6 = 2436$$
$$A_2 = \frac{(0.6 - 0.38) * (5193 - 4060)}{2} = 124.63$$
$$A_3 = (7150 - 5193) * 0.38 = 743.66$$

Based on these calculations, the central point of the fuzzy area is obtained, namely:

$$z = \frac{4945080 + 25511008,841 + 4589498}{2436 + 124.63 + 743.66}$$
$$z = 3645.44$$

2. Application of Fuzzy Grid Partition on Mamdani Method
   a. Determination of the number of partitions (K) = 2
   b. Formation of Demand Variable Function (D)

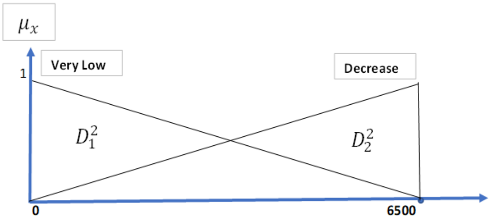

Figure 7. Reduced demand function

$$\mu_{PD_1^2} = \frac{6500-x}{6500} = 0.4$$
$$\mu_{PD_2^2} = \frac{x-0}{6500} = 0.6$$

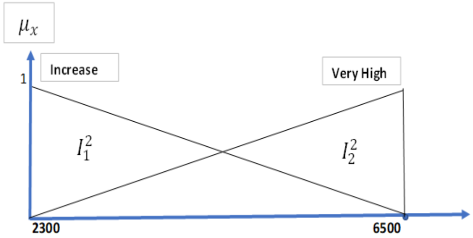

Figure 8. Demand function increases

$$\mu_{PI_1^2} = \frac{6500-x}{4200} = 0.62$$
$$\mu_{PI_2^2} = \frac{x-2300}{4200} = 0.38$$

c. Fungsi Variabel Stok (S)

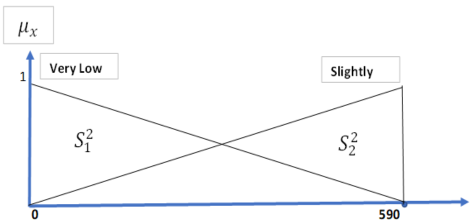

Figure 9. Few stock functions

$$\mu_{SS_1^2} = \frac{590-x}{590} = 0.47$$
$$\mu_{SS_2^2} = \frac{x-0}{590} = 0.53$$

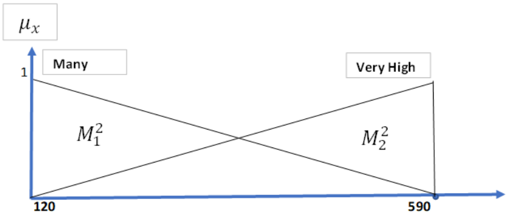

Figure 10. Multiple stock function

$$\mu_{SM_1^2} = \frac{590-x}{470} = 0.6$$
$$\mu_{SM_2^2} = \frac{x-120}{470} = 0.62$$

d. Implication Function
There are 16 implication function rules in the Fuzzy Mamdani Method with the application of Grid Partition, namely:

[R1] If demand D_1^2 and Stock M_1^2 then production is reduced
$\alpha_1 = \min(0.4\,; 0.6) = 0.4$
[R2] If demand D_1^2 and Stock M_2^2 then production is reduced
$\alpha_2 = \min(0.4\,; 0.62) = 0.4$
[R3] If demand D_1^2 and Stock M_1^2 then production is reduced
$\alpha_3 = \min(0.6\,; 0.6) = 0.6$
[R4] If demand D_1^2 and Stock M_2^2 then production is reduced
$\alpha_4 = \min(0.6\,; 0.62) = 0.6$
[R5] If demand D_1^2 and Stock S_1^2 then production is reduced
$\alpha_5 = \min(0.4\,; 0.47) = 0.4$
[R6] If demand D_1^2 and Stock S_2^2 then production is reduced
$\alpha_6 = \min(0.4\,; 0.53) = 0.4$
[R7] If demand D_1^2 and Stock S_1^2 then production is reduced
$\alpha_7 = \min(0.4\,; 0.47) = 0.4$
[R8] If demand D_1^2 and Stock S_2^2 then production is reduced
$\alpha_8 = \min(0.4\,; 0.53) = 0.4$
[R9] If demand I_1^2 and Stock M_1^2 then production increases
$\alpha_9 = \min(0.62\,; 0.6) = 0.6$
[R10] If demand I_1^2 and Stock M_2^2 then production increases
$\alpha_{10} = \min(0.62\,; 0.62) = 0.62$
[R11] If demand I_1^2 and Stock M_1^2 then production increases
$\alpha_{11} = \min(0.38\,; 0.6) = 0.38$
[R12] If demand I_1^2 and Stock M_2^2 then production increases
$\alpha_{12} = \min(0.38\,; 0.62) = 0.38$
[R13] If demand I_1^2 and Stock S_1^2 then production increases
$\alpha_{13} = \min(0.62\,; 0.47) = 0.47$

[R14] If demand I_1^2 and Stock S_2^2 then production increases
$\alpha_{14} = \min(0.62\,; 0.53) = 0.53$

[R15] If demand I_1^2 and Stock S_1^2 then production increases
$\alpha_{15} = \min(0.38\,; 0.47) = 0.38$

[R16] If demand I_1^2 and Stock S_2^2 then production increases
$\alpha_{16} = \min(0.38\,; 0.53) = 0.38$

e. Composition Rules

$\mu_{sf}(z) = Max\,(\mu_{Production\ Decrease}, \mu_{Production\ Increase})$
= max (0.6; 0.62)

When $\mu_{Production\ Decrease}(z) = 0.6$ then the value of z as follows:

$$0.6 = \frac{7150 - z_1}{5150}$$
$$z_1 = 4060$$

$$0.5 = \frac{7150 - z_2}{5150}$$

$$z_2 = 4575$$

When $\mu_{Production\ Increase}(z) = 0.62$ then the value of z as follows:

$$\frac{z_3 - 2000}{5150} = 0.62$$

$$z_3 = 5193$$

Thus the membership function for the composition result is:

$$\mu[Z] = \begin{cases} 0.6 & z \le 4060 \\ \dfrac{4575 - z}{519} & 4060 \le z \le 4575 \\ \dfrac{z - 4575}{618} & 4575 \le z \le 5193 \\ 0.62 & z \ge 5193 \end{cases}$$

f. Defuzzification

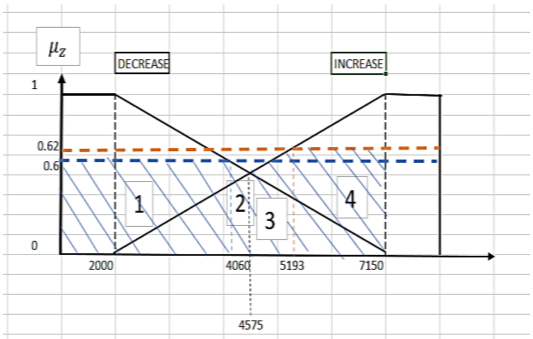

Figure 11. The Defuzzification Function of the Partititon Grid method

The defuzzification process uses the centroid method to determine the crisp z value. It is done by dividing the area into four parts, namely 1, 2, 3 and 4, with the respective regions of A1, A2, A3, and A4, as well as the moment of the membership value. -respectively M1, M2, M3, and M4.

$$M_1 = \int_0^{4060} 0.6\, z\, dz = 0.3\, z^2 \Big|_0^{4060} = 4945080$$

$$M_2 = \int_{4060}^{4575} \frac{4575 - z}{519}\, z\, dz$$
$$= 4.407\, z^2 - 0.000642 z^3 \Big|_{4060}^{4575}$$
$$= 1081256.06$$

$$M_3 = \int_{4575}^{5193} \frac{z - 4575}{618}\, z\, dz$$
$$= 0.00054 z^3 - 3.7014 z^2 \Big|_{4575}^{5193}$$
$$= 1569029.855$$

$$M_4 = \int_{5193}^{7150} 0.62\, z\, dz$$
$$= 0.31\, z^2 \Big|_{5193}^{7150} = 7488127.8$$

Area as follows:

$$A_1 = 4060 * 0.6 = 2436$$
$$A_2 = \frac{(0.6 - 0.5) * (4575 - 4060)}{2}$$
$$= 25.75$$
$$A_3 = \frac{(0.62 - 0.5) * (5193 - 4575)}{2}$$
$$= 37.08$$
$$A_4 = (7150 - 5193) * 0.62$$
$$= 1213.34$$

Based on these calculations, the central point of the fuzzy area is obtained, namely:

$$z = \frac{4945080 + 1081256.06}{2436 + 25.75}$$
$$\frac{+1569029.855 + 7488127.8}{+37.08 + 1213.34}$$

$$z = 4063.255$$

4.2 Discussion

4.2.1 Mamdani Method Analysis

Based on the calculation of the central point value (z), the number of food products that must be produced if there is a demand for 3900 packages and stock in the warehouse for 310 packages is 3645. Based on the analysis of the Mamdani method, it can be seen that the remaining stock for the next period in the warehouse is (3645+310) – 3900 = 55 packages.

It is known that the minimum stock allowed in the warehouse is 120, and the maximum stock is 590 packages. The application of the Mamdani method with a total production of 3645 packages is incorrect because it does not meet the minimum limit of the number of stocks.

4.2.2 Analysis of the Application of Fuzzy Grid Partition on the Mamdani Method

Based on the calculation of the centre point value (z), the number of food products produced if there is a demand for 3900 packages and stock in the warehouse for 310 packages is 4063. Based on the analysis of the application of fuzzy grid partition in the Mamdani method, it can be seen that the remaining stock for the following stock in the warehouse is (4063+310) – 3900 = 473 packages.

It is known that the minimum stock allowed in the warehouse is 120, and the maximum stock is 590 packages. The application of fuzzy grid partition in the Mamdani method with a total production of 4063 packages is correct because it meets the maximum limit of the allowable stock.

5. CONCLUSION

The application of fuzzy grid partition to the fuzzy inference system of the Mamdani method produces correct and optimal output. The application of the Mamdani method in determining the amount of production resulted in a stock output that did not meet the minimum limit of 55 packages. While the application of fuzzy grid partition in the Mamdani method produces stock output with the number of stocks at the maximum limit of 473 packages.

The amount of food production using the Mamdani method for the demand for 3900 packages with a stock of 310 is 3645 packages, while the amount of output using the application of fuzzy grid partition in the Mamdani method is 4063 packages. The application of the Mamdani method resulted in a smaller amount of production compared to the application of the fuzzy grid partition in the Mamdani method. Still, applying the fuzzy grid partition in the Mamdani method resulted in the correct stock output, namely 473 packages, which were still in the range of 120 - 590 packages.

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