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Application of Mamdani Fuzzy Method in Herbal Soap Production Planning

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Abstract: Fuzzy logic is a logic that has a value of fuzzyness between true or false. This study discusses the application of the Mamdani fuzzy logic in solving production planning problems based on demand, remains and stock shortages. The variables used for the production of herbal soap are 4 variables, namely 3 input variables which consist of the demand variable, residual variable and shortage variable, and 1 output variable, the production variable. The demand variable consists of 3 fuzzy sets, namely decreasing, fixed and increasing, residual and shortage variables consist of 3 fuzzy sets, namely little, moderate and many, while the production variable consists of 3 fuzzy sets, namely reduced, fixed and added. Therefore, a system is needed to determine the amount of herbal soap production so that there will be no problems. The results of this study aim to apply the Mamdani fuzzy logic method in predicting the amount of herbal soap production based on demand, remains and stock shortage data. Based on the calculations carried out, there were only 8,333% of the data that had actual results. At the same time, the remaining 91.667% are the data that have planned results that are not in accordance with the actual data.

Keywords: *fuzzy inference system; determination of production quantities; Mamdani fuzzy logic.*

Mathematics Subject Classification (2010): 03B52, 03E72, 94D05.

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1 Introduction

Bath soap products have developed into the primary needs of people of all social classes. Soap can be used to treat diseases such as skin diseases caused by bacteria or fungi. In other words, soap can be used as a medicine cleaning the body to minimize the possibility of suffering from diseases. The advantages of herbal soap compared to common soaps are: it is easy to carry, it is easy to store, it offers various uses and benefits, and it has an exclusive packaging appearance. Based on the data obtained, the producers often experienced either shortages of products or overproduction in their day to day production.

Determining the production target or the number of products by the application of the method allows membership values between 0 and 1 [1]. Various theories in the development of fuzzy logic show that basically, fuzzy logic can be used to model various systems [2]. Fuzzy logic is believed to be very flexible and has tolerance for existing data. Based on the fuzzy logic, a model of a system capable of estimating the number of product units to be produced will be generated [3–6].

The previous research has been carried out using the same method, that is, the Mamdani Fuzzy Method but with four variables, and each variable had only two sets. The residual variable had only two sets, that is, few and many. The sales and demand variable had two sets, that is, decreasing and increasing. And the order variable had two sets, decreasing and increasing. And in this study, there are four variables, and each has three sets [7–9].

Based on the description above, the researches in this paper are interested in carrying out a study entitled "The Application of the Fuzzy Mamdani Method in Herbal Soap Production Planning". The aim is to help determine the number of herbal soap product units to be produced and to introduce the Fuzzy Mamdani method to solve the herbal soap production problems.

2 Method

2.1 Research procedures

Software needs analysis is done to find out all the problems and requirements. The analysis is done by finding and determining the problems encountered, as well as all the requirements such as problem analysis, system analysis, system input and output, and the functions required [10, 11].

Based on the data obtained, the producer often experiences production shortages and excesses in the day to day production as shown in Table 1.

In general, the system to be developed attempts to apply the Mamdani Fuzzy method in the herbal soap production planning based on the demand for the product units, the remaining product units, and the shortages. The testing has to be carried out by comparing the number of product units at the shops to that of the production results planned. As a result, the system provides the output in the form of herbal soap production using the Fuzzy Mamdani method. The data used in this study are the production, demand, and shortage data in January-February, 2019 as shown in Table 1. The data indicate the remaining units of 29 out of 48 and the shortage of 19 out of 48.

2.2 Research Design

Context Diagram

Table 1: Data of Production for the January-February period.

Dates	Production	Demand	Remains	Shortage
03-Jan	610	211	399	0
04-Jan	399	944	0	545
05-Jan	655	201	454	0
07-Jan	454	1208	0	754
08-Jan	946	218	728	0
09-Jan	728	658	70	0
10-Jan	870	988	0	118
11-Jan	882	249	633	0
12-Jan	633	431	202	0
14-Jan	802	388	414	0
15-Jan	414	857	0	443
16-Jan	857	410	447	0
17-Jan	447	945	0	498
18-Jan	902	369	533	0
19-Jan	533	867	0	334
21-Jan	866	188	678	0
22-Jan	678	256	422	0
23-Jan	422	966	0	544
24-Jan	856	402	454	0
25-Jan	454	1157	0	703
26-Jan	997	310	687	0
28-Jan	657	1525	0	868
29-Jan	962	297	665	0
30-Jan	665	981	0	316
31-Jan	984	220	764	0
01-Feb	764	228	536	0
02-Feb	536	101	435	0
04-Feb	435	1139	0	704
06-Feb	896	1822	0	926
07-Feb	1074	454	620	0
08-Feb	620	198	422	0
09-Feb	422	603	0	181
11-Feb	819	336	483	0
12-Feb	483	1175	0	692
13-Feb	818	193	625	0
14-Feb	625	165	460	0
15-Feb	460	720	0	260
16-Feb	740	211	529	0
18-Feb	529	765	0	236
19-Feb	764	415	349	0
20-Feb	349	1408	0	1059
21-Feb	1141	299	842	0
22-Feb	842	180	662	0
23-Feb	662	218	444	0
25-Feb	444	910	0	466
26-Feb	734	154	580	0
27-Feb	580	206	374	0
28-Feb	374	897	0	523

Context diagram is an overview of the interactions occurring between the system and the user. The user enters the input variables, that is, the demand, the remains and the shortage for further processing. After the processing, the system produces the output in the form of the number of herbal soap units to be produced.

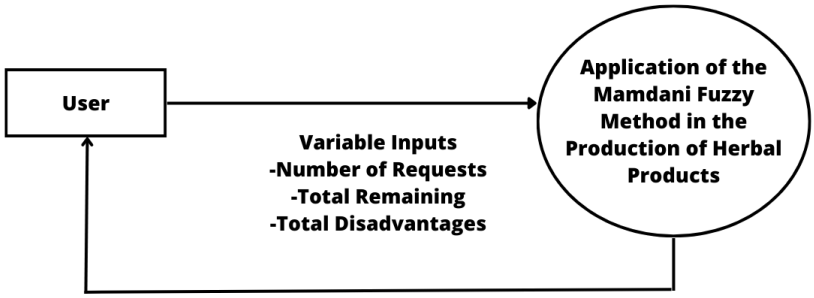

Figure 1: Context Diagram.

Interface Design.

We present the interface design for the production planning system into which the user enters the variables: the number of product units demanded, the number of the remaining product units and the number of shortages. The results of the calculations or the output for the production are immediately displayed in the form below.

Figure 2: Production Planning Form.

In the input column, there is the column matrix to be filled, that is, the first column for the demand variable value, the second column for the remains variable value, and the third column for the shortage variable value.

Data Analysis.

1. Determine the variables related to the process and the appropriate fuzzification function. There are 4 variables in the model, that is,

   - The demand variable consists of 3 fuzzy sets, that is, Decreasing, Fixed and Increasing.
     The function of the demand variable membership is

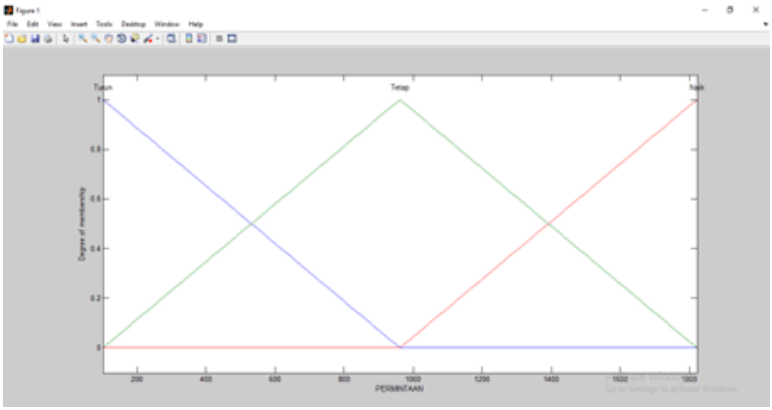

Figure 3: Demand Variable.

$$\mu_{decreasing\ demand} = \begin{cases} 1 & ; w \leq 101 \\ \frac{961.5-w}{961.5-101} & ; 101 \leq w \leq 961.5 \\ 0 & ; w \geq 961.5 \end{cases}$$

$$\mu_{fixed\ demand} = \begin{cases} 0 & ; w = 961.5 \\ \frac{w-101}{961.5-101} & ; 101 \leq w \leq 961.5 \\ \frac{1822-w}{1822-961.5} & ; 961.5 \leq w \leq 1822 \\ 1 & ; w \leq 101, w \geq 1822 \end{cases}$$

$$\mu_{increasing\ demand} = \begin{cases} 0 & ; w \leq 961.5 \\ \frac{w-961.5}{1822-961.5} & ; 961.5 \leq w \leq 1822 \\ 1 & ; w \geq 961.5 \end{cases}$$

   - The remains variable consists of 3 fuzzy sets, that is, **Few**, **Fair** and **Many**. The function of the remains variable membership is

$$\mu_{few\ remaining} = \begin{cases} 1 & ; x \leq 0 \\ \frac{421-x}{421-0} & ; 0 \leq x \leq 421 \\ 0 & ; x \geq 421 \end{cases}$$

$$\mu_{fair\ remaining} = \begin{cases} 0 & ; x = 421 \\ \frac{x-0}{421-0} & ; 0 \leq x \leq 421 \\ \frac{842-x}{842-421} & ; 421 \leq x \leq 842 \\ 1 & ; x \leq 0, x \geq 842 \end{cases}$$

$$\mu_{many\ remaining} = \begin{cases} 0 & ; x \leq 421 \\ \frac{x-421}{842-421} & ; 421 \leq x \leq 842 \\ 1 & ; x \geq 421 \end{cases}$$

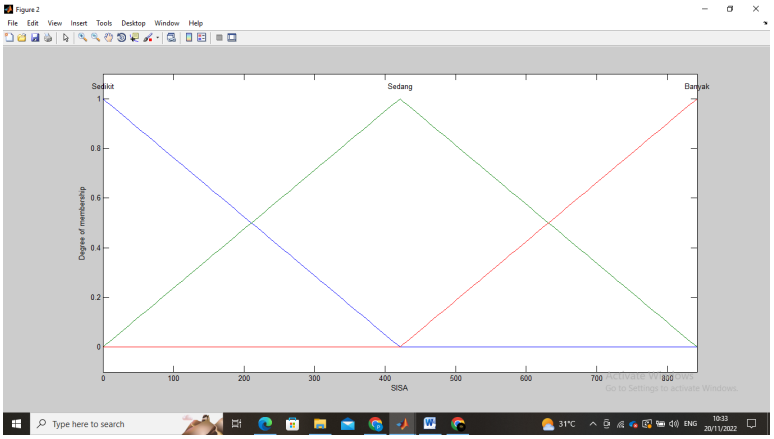

Figure 4: Remains Variable.

- The shortage variable consists of 3 fuzzy sets, that is, **Few**, **Fair** and **Many**.

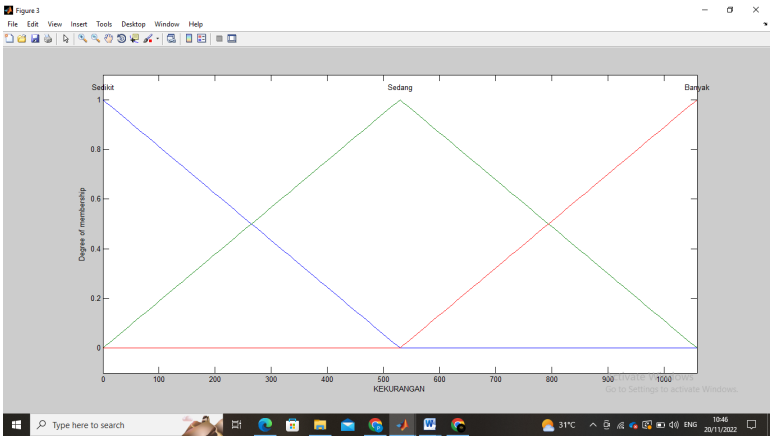

Figure 5: Shortage Variable.

The function of the shortage variable membership is

$$\mu_{few\ \ shortage} = \begin{cases} 1 & ;y \leq 0 \\ \frac{529.5-y}{529.5-0} & ;0 \leq y \leq 529.5 \\ 0 & ;y \geq 529.5 \end{cases}$$

$$\mu_{fair\ \ shortage} = \begin{cases} 0 & ;y = 529.5 \\ \frac{y-0}{529.5-0} & ;0 \leq y \leq 529.5 \\ \frac{1059-y}{1059-529.5} & ;529.5 \leq y \leq 1059 \\ 1 & ;y \leq 0, y \geq 1059 \end{cases}$$

$$\mu_{many\ shortage} = \begin{cases} 0 & ; y \leq 529.5 \\ \frac{y-529.5}{1059-529.5} & ; 529.5 \leq y \leq 1059 \\ 1 & ; y \geq 529.5 \end{cases}$$

- The production variable consists of 3 fuzzy sets, that is, **Reduced**, **Fixed** and **Added**.

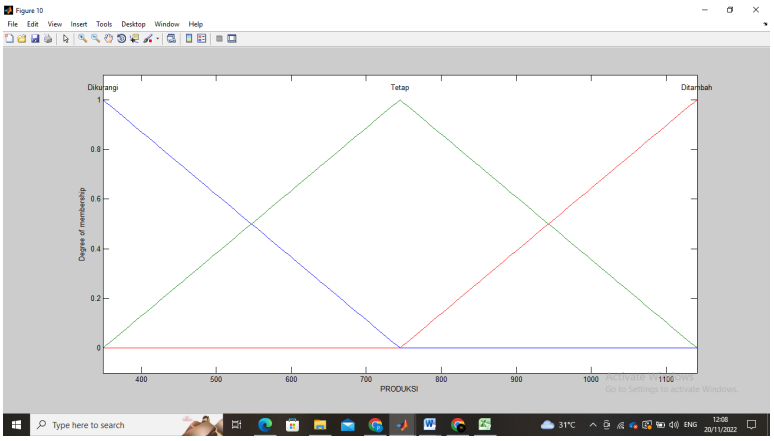

Figure 6: Production Variable.

The function of the production variable membership is

$$\mu_{reduced\ production} = \begin{cases} 1 & ; z \leq 349 \\ \frac{745-z}{745-349} & ; 349 \leq z \leq 745 \\ 0 & ; z \geq 745 \end{cases}$$

$$\mu_{fixed\ production} = \begin{cases} 0 & ; z = 745 \\ \frac{z-349}{745-349} & ; 349 \leq z \leq 745 \\ \frac{1141-z}{1141-745} & ; 745 \leq z \leq 1141 \\ 1 & ; z \leq 349, z \geq 1141 \end{cases}$$

$$\mu_{added\ production} = \begin{cases} 0 & ; z \leq 745 \\ \frac{z-745}{1141-745} & ; 745 \leq z \leq 1141 \\ 1 & ; z \geq 745 \end{cases}$$

Take the data on January 3, 2019, the value of the demand variable is 211, and the remains is 399. If the remains is known, the deficiency is automatically equal to 0 and vice versa. Fuzzification of the demand variable with the demand value 211 is

$$\mu_{decreasing\ demand}(211) = \frac{961.5 - 211}{961.5 - 101} = 0.872,$$

$$\mu_{fixed\ demand}(211) = \frac{211 - 101}{961.5 - 101} = 0.128.$$

Fuzzification of the remains variable with the remains value 399 is

$$\mu_{few\ remaining}(399) = \frac{421 - 399}{421 - 0} = 0.052,$$

$$\mu_{fair\ remaining}(399) = \frac{399-0}{421-0} = 0.948.$$

Based on the data analysis on the limits of each Fuzzy set of each variable, the fuzzy rules formed are as follows:
[$R1$] If (Demand is Decreased) And (Remains is Few) Then (Production is Fixed)
[$R2$] If (Demand is in Decreased) And (Remains is Fair) Then (Production is Reduced)
[$R3$] If (Demand is Decreased) And (Remains is Many) Then (Production is Reduced)
[$R4$] If (Demand is Fixed) And (Remains is Few) Then (Production is Added)
[$R5$] If (Demand is Fixed) And (Remains is Fair) Then (Production is Fixed)
[$R6$] If (Demand is Fixed) And (Remains is Many) Then (Production is Reduced)
[$R7$] If (Demand is Increasing) And (Remains is Few) Then (Production is Added)
[$R8$] If (Demand is Increasing) And (Remains is Fair) Then (Production is Added)
[$R9$] If (Demand is Increasing) And (Remains is Many) Then (Production is Fixed)
[$R10$] If (Demand is Decreased) And (Shortage is Few) Then (Production is Fixed)
[$R11$] If (Demand is Decreased) And (Shortage is Fair) Then (Production is Reduced)
[$R12$] If (Demand is Decreased) And (Shortage is Many) Then (Production is Reduced)
[$R13$] If (Demand is Fixed) And (Shortage is Few) Then (Production is Fixed)
[$R14$] If (Demand is Fixed) And (Shortage is Fair) Then (Production is Fixed)
[$R15$] If (Demand is Fixed) And (Shortage is Many) Then (Production is Added)
[$R16$] If (Demand is Increasing) And (Shortage is Few) Then (Production is Fixed)
[$R17$] If (Demand is Increasing) And (Shortage is Fair) Then (Production is Added)
[$R18$] If (Demand is Increasing) And (Shortage is Many) Then (Production is Added)

2. Implication Function Application.
   The function application we use is Minus function application:
   [$R1$] If (Demand is Decreased) And (Remains is Few) Then (Production is Fixed)

$$\alpha_1 = min(0.872; 0.052) = 0.052$$

   [$R2$] If (Demand is in Decreased) And (Remains is Fair) Then (Production is Reduced)

$$\alpha_1 = min(0.872; 0.948) = 0.872$$

   [$R4$] If (Demand is Fixed) And (Remains is Few) Then (Production is Added)

$$\alpha_2 = min(0.128; 0.052) = 0.052$$

   [$R5$] If (Demand is Fixed) And (Remains is Fair) Then (Production is Fixed)

$$\alpha_3 = min(0.128; 0.948) = 0.128$$

3. Rules of Composition.
   The MAX method is used to produce composition between all rules. $\mu_z =$

$max(0.052; 0.128) = 0.128$. It is known that the degree of the membership function for production is

$$\mu_{fixed\ production}(z) = \begin{cases} 0 & ; z = 745, \\ \frac{z-349}{745-349} & ; 349 \leq z \leq 745, \\ \frac{1141-z}{1141-745} & ; 745 \leq z \leq 1141, \\ 1 & ; z \leq 349, z \geq 1141, \end{cases}$$

$$\begin{aligned} \mu_z &= \frac{z-349}{745-349} = 0.128, \\ z-349 &= 0.128 \times 396, \\ z-349 &= 50.688, \\ z &= 399.688, \end{aligned}$$

$$\begin{aligned} \mu_z &= \frac{1141-z}{1141-745} = 0.128, \\ 1141-z &= 0.128 \times 396, \\ 1141-z &= 50.688, \\ z &= 1090.321. \end{aligned}$$

4. Defuzzification.
The input of the defuzzification process is a fuzzy set obtained from the composition of the fuzzy rules, while the resulting output is a number in the domain of the fuzzy set. The method used for defuzzification is centroid.
The calculation of Moment 1

$$\begin{aligned} M_1 &= \int_{349}^{399.688} \mu a_1 z dz \\ &= \int_{349}^{399.688} \frac{z-349}{745-349} z dz \\ &= \frac{1}{396} \int_{349}^{399.688} z^2 - 349 dz \\ &= 1241.7896439. \end{aligned}$$

The calculation of Moment 2

$$\begin{aligned} M_2 &= \int_{399.688}^{1090.312} \mu a_2 z dz \\ &= \int_{399.688}^{1090.312} 0.128 z dz \\ &= 0.128 \frac{1}{2} \left[z^2\right]_{399.688}^{1090.312} dz \\ &= 65857.904637. \end{aligned}$$

Thus, the value of each moment is

- $M_1 = 1241.7896439$,
- $M_2 = 65857.904637$.

3 Results and Discussion

3.1 Research Measurement

The pre-test and post-test are used in the measurement of this study. It aims to find out the difference test between the grouping of production ranges done manually based on the actual data and that of the prediction developed using the Mamdani fuzzy method.

Below is the percentage of the comparison between the manual grouping and the planning system developed:

1. The Results of the Comparison of the Groups under the Reduced category within the Range of 349-547.
   The results obtained from the Groups under the Reduced category indicate no data in conformance to those by manual grouping.
   Based on Table 2, out of 16 existing data, there is 1 planning result in conformance to the actual data, and the rest of 15 planning results do not conform to the actual data. It can be seen that the data in conformance is 6.25% and those which do not conform are 93.75%.

Table 2: Comparison of Groups under the Reduced category within the Range of 349-547.

No	Dates	Production	Demand	Remains	Shortage	Actual Group	Mamdani Fuzzy Group	Remark
1	4 Jan	399	944	0	545	Reduced	Fixed	Not match
2	7 Jan	454	1208	0	754	Reduced	Fixed	Not match
3	15 Jan	414	857	0	443	Reduced	Fixed	Not match
4	17 Jan	447	945	0	498	Reduced	Fixed	Not match
5	19 Jan	533	867	0	334	Reduced	Fixed	Not match
6	23 Jan	422	966	0	544	Reduced	Fixed	Not match
7	25 Jan	454	1157	0	703	Reduced	Fixed	Not match
8	2 Feb	536	101	435	0	Reduced	Reduced	Match
9	4 Feb	435	1139	0	704	Reduced	Fixed	Not match
10	9 Feb	422	603	0	181	Reduced	Fixed	Not match
11	12 Feb	483	1175	0	692	Reduced	Fixed	Not match
12	15 Feb	460	720	0	260	Reduced	Fixed	Not match
13	18 Feb	529	765	0	236	Reduced	Fixed	Not match
14	20 Feb	349	1408	0	1059	Reduced	Added	Not match
15	25 Feb	444	910	0	466	Reduced	Fixed	Not match
16	28 Feb	374	897	0	523	Reduced	Fixed	Not match

2. The Results of the Comparison of the Groups under the Fixed category within the Range of 547-943.
   The results obtained for the groups under the Fixed category indicate three of the data are in conformance to those by manual grouping. Based on Table 3, of 26 existing data, there are 3 planning results in accordance with the actual data, and 23 other data have the planning results which do not conform to the actual data. It can be seen that the data in conformance is 11.538%, those not in conformance are 88.462%.

3. The Results of the Comparison of the Groups under the Added category within the Range of 943-1141.

Table 3: Comparison of the groups under the Fixed category within the Range of 547-943.

No	Dates	Production	Demand	Remains	Shortage	Actual Group	Mamdani Fuzzy Group	Remark
1	3 Jan	610	211	399	0	Fixed	Reduced	Not match
2	5 Jan	655	201	454	0	Fixed	Reduced	Not match
3	9 Jan	728	658	70	0	Fixed	Reduced	Not match
4	10 Jan	870	988	0	118	Fixed	Fixed	Sesuai
5	11 Jan	882	249	633	0	Fixed	Reduced	Not match
6	12 Jan	633	431	202	0	Fixed	Fixed	Sesuai
7	14 Jan	802	388	414	0	Fixed	Reduced	Not match
8	16 Jan	857	410	447	0	Fixed	Reduced	Not match
9	18 Jan	902	369	533	0	Fixed	Reduced	Not match
10	21 Jan	866	188	678	0	Fixed	Reduced	Not match
11	22 Jan	678	256	422	0	Fixed	Reduced	Not match
12	24 Jan	856	40	454	0	Fixed	Reduced	Not match
13	28 Jan	657	1525	0	868	Fixed	Added	Not match
14	30 Jan	665	981	0	316	Fixed	Fixed	Match
15	1 Feb	764	228	536	0	Fixed	Reduced	Not match
16	6 Feb	896	1822	0	926	Fixed	Added	Not match
17	8 Feb	620	198	422	0	Fixed	Reduced	Not match
18	11 Feb	819	336	483	0	Fixed	Reduced	Not match
19	13 Jan	818	193	625	0	Fixed	Reduced	Not match
20	14 Feb	625	165	460	0	Fixed	Reduced	Not match
21	16 Feb	740	211	529	0	Fixed	Reduced	Not match
22	19 Jan	764	415	349	0	Fixed	Reduced	Not match
23	22 Feb	842	180	662	0	Fixed	Reduced	Not match
24	23 Feb	662	218	444	0	Fixed	Reduced	Not match
25	26 Feb	734	154	580	0	Fixed	Reduced	Not match
26	27 Feb	580	206	374	0	Fixed	Reduced	Not match

The results obtained for the groups under the Added category indicate no conformance to those by manual grouping at all. Based on Table 4, out of 6 existing data all have planning results not in accordance with those of the actual data. It can be seen that the data in conformance is 100%.

Table 4: Comparison of the Groups under the Fixed category within the Range of 943-1141.

No	Dates	Production	Demand	Remains	Shortage	Actual Group	Mamdani Fuzzy Group	Remarks
1	8 Jan	964	218	728	0	Added	Reduced	Not match
2	26 Jan	997	310	687	0	Added	Reduced	Not match
3	29 Jan	962	297	665	0	Added	Reduced	Not match
4	31 Jan	984	220	764	0	Added	Reduced	Not match
5	7 Feb	1074	454	620	0	Added	Reduced	Not match
6	21 Feb	1141	299	842	0	Added	Reduced	Not match

4 Conclusion

Based on the results above, we can see that only 8.333% of the data have the planning results matching the actual results. At the same time, the remaining 91.667% are the data having the planning results not in accordance with the actual ones. The presentage of the data having the planning results not in accordance with the actual results shows that before applying the Mamdani fuzzy method, the production planning resulted in a large number of the remaining product units unsold or shortages of herbal products. The contribution of the Mamdani fuzzy method is to minimize the remains and shortage of stocks, and its implementation helps to optimize capital, customer satisfaction is improved, and much more. And the producers can easily take advantage of this method to expand their business.

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