Comparative Analysis of Tsukamoto and Mamdani Fuzzy Inference System on Market Matching to Determine the Number of Exports for MSMEs

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***Abstract*—The improvement of MSMEs export performance is one of the government's efforts to improve the economy of the community. Increased export performance is done by monitoring and controlling the amount of exports. the problem faced in determining the amount of exports is the difficulty of calculating the stock, capacity, and competition among MSMEs in influencing the amount of stock. The right amount will minimize the loss from the MSMEs side. This study uses export data of wood and other forest product sub-sector, that is commodity furniture. Fuzzy method in some study can give optimal result.. This study compares two methods to determine the effectiveness of products that benefit MSMEs. This study examines the effectiveness of Fuzzy Mamdani and Fuzzy Tsukamoto methods on market matching process. Based on this study, Fuzzy Mamdani gives a better performance than fuzzy Tsukamoto with the accuracy system is MAPE=6.49%.**

Keywords—market matching, fuzzy Mamdani, fuzzy Tsukamoto, export, MAPE

I. INTRODUCTION

Micro and Small Medium Enterprises (MSMEs) are community entrepreneurs who need a lot of help in the field of management. In conducting exports, MSMEs have problems in determining the right amount of exports. The right amount of export is very influential for MSMEs, considering the limited capital. The problem that occurs when determining the amount of exports is the determination of the amount of exports done manually. This method does not consider competitive factors, resulting in the accumulation of goods if every exporter serves importer demand. This accumulation of goods resulted in losses for MSMEs in terms of production costs and materials.

The lack of information on the number of demand and supply of products in each country greatly affect the turnover of goods. For the example, there are 5 industries with the same type of products send to Australia where the demand for the product is small. Without proper information the five industries only export products regardless of the availability of products in the country. So the number of products in Australia exceeds the number of requests. It can lead to the accumulation of products and industries suffered losses due to the lack of sales. Products with fast turnaround are goods sold out in a relatively quick time.

One of the businesses carried out by business actors is determining the right export market. Determining the right market is based on the criteria needed so as to increase profits and reduce losses due to the risk of late product changes. Exports of products to MSMEs are things that need more attention with consideration, among others: (1) financial limitations of MSMEs in producing commodities; (2) difficulties in knowing the needs of export markets; (3) difficulties in knowing the slow turnover of goods in the Market.

Market matching application for the determination of marketing location and the quantity of products that must be exported using fuzzy method is expected to reduce the number of losses due to the congestion of turnover of goods making it profitable for MSMEs.

Previous study [1] has succeeded in calculating the export amount using Fuzzy Tsukamoto method. This study aims to find a more effective method for determining the amount of exports. This study proposes the Fuzzy method to determine the right amount of exports. Fuzzy is chosen because it has a simple computation process [2]. Fuzzy has also been successfully implemented in various problems. One of them is the application of fuzzy to predict inflation rate in Indonesia. Sari, Mahmudy and Wibawa [4] combines Neural Network and Fuzzy to produce high accuracy forecasts. The accuracy of this research is RMSE=2.15 [3]. The further study, Sari, Mahmudy, and Wibawa (2017) combine Fuzzy and Neural Network with similar problems resulting in higher accuracy than previous studies RMSE = 1.81 [4]. Ghahraei, Yunus, and Halin (2017) use Fuzzy Mamdani to control the components and relative humidity. The accuracy of this research is 100% [5].

There are several studies that use fuzzy Mamdani and fuzzy Tsukamoto methods in various fields. Some studies show that fuzzy Mamdani is superior to fuzzy Tsukamoto that is to

determine software estimation [6], to determine incense production [7] and to determine the amount of *raskin* distribution in Bulog [8]. Some studies show that fuzzy Tsukamoto is superior to that of fuzzy Mamdani to diagnose tuberculosis in children [9], determining the amount of storage energy in AC [10] and reducing electrical energy consumption in washing machines [11]. In this research method fuzzy Mamdani and fuzzy Tsukamoto will be compared if applied to market matching to determine which method is most appropriate in this case. This study uses Mamdani fuzzy model as the main method which is expected to give more optimal result compared to Fuzzy Tsukamoto.

II. Proposed Method

Fuzzy logic is a study of principles and methods forming the possibility of some limitations or criteria. Fuzzy logic is a way to map an input space into an output space [12].

A. Fuzzy Set

The fuzzy set has two attributes including linguistic attributes and numeric attributes [13]. The linguistic attribute is a group of variables that is measured using natural language, while the numeric attribute is a value that indicates the size of a variable. In market matching there are 4 linguistic attributes:

- *Stock* is the amount of product inventory to the importer.
- *Capacity* is the ability of importers to receive products.
- *Competitive* is the level of competition between MSMEs for product exports.
- *Export* is the number of products that MSMEs should export.

Stock, capacity, and competitive are input variable. Export is represented as an output variable. In market matching, the fuzzy set determination and degree of membership of the fuzzy set are done in each product on each importer. There are two importers for furniture products namely Boss Limited (BL) and Century Co (CC). Each linguistic attribute has some fuzzy set:

- *Stock* consists of 3 fuzzy sets that are little, medium, many.
- *Capacity* consists of 2 fuzzy sets that are little and many.
- *Competitive* consists of 2 fuzzy sets of low and high.
- *Export* consists of 3 fuzzy sets of low, medium, high.

The value of fuzzy set "stock" on each importer can be seen in Table I.

TABLE I. Membership Function "Stock"

Fuzzy Set	Importer	
	Boss Limited	*Century Co*
Little	[10 - 50]	[10 - 40]
Medium	[30 - 100]	[30 - 70]
Many	[80 - 150]	[60 - 120]

The membership function for fuzzy set "Stock" on Boss Limited importer can be seen in Figure 1.

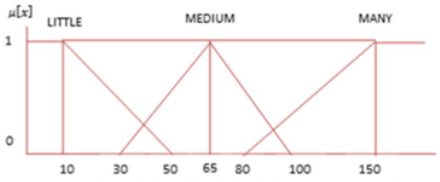

Fig.1. Membership function "Stock" Boss Limited

The membership function for the fuzzy set "Stock" on Boss Limited importers can be represented in (1), (2), and (3).

$$\mu StockLittle[x] = \begin{cases} 1, & x \le 10 \\ \dfrac{50-x}{50-10}, & 10 < x < 50 \\ 0, & x \ge 50 \end{cases} \quad (1)$$

$$\mu StockMedium[x] = \begin{cases} 0, & x \le 30 atau\ x \ge 100 \\ \dfrac{x-30}{65-30} & 30 < x \le 65 \\ \dfrac{100-x}{100-65} & 65 < x < 100 \end{cases} \quad (2)$$

$$\mu StockMany[x] = \begin{cases} 0, & x \le 80 \\ \dfrac{x-80}{150-80}, & 80 \le x \le 150 \\ 1, & x \ge 150 \end{cases} \quad (3)$$

The membership function for the fuzzy set "Stock" on Century Co importers can be seen in Figure 2.

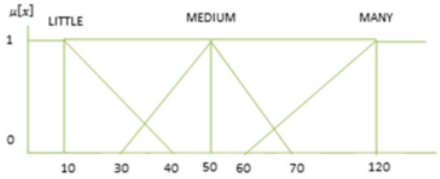

Fig. 2. Membership functions "Stock" Century Co

The membership function for the fuzzy set Stock on Century Co importers can be represented in (4), (5), and (6).

$$\mu StockLittle[x] = \begin{cases} 1, & x \le 10 \\ \dfrac{40-x}{40-10}, & 10 < x < 40 \\ 0, & x \ge 40 \end{cases} \quad (4)$$

$$\mu StockMedium[x] = \begin{cases} 0, & x \le 30\ atau\ x \ge 70 \\ \dfrac{x-30}{50-30}, & 30 < x \le 50 \\ \dfrac{70-x}{70-50}, & 50 < x < 70 \end{cases} \quad (5)$$

$$\mu StockMany[x] = \begin{cases} 0, & x \le 60 \\ \dfrac{x-60}{120-60}, & 60 \le x \le 120 \\ 1, & x \ge 120 \end{cases} \quad (6)$$

The value of fuzzy set "capacity" on each importer can be seen on Table II.

TABLE II. Membership Function "Capacity"

Fuzzy Set	Importer	
	Boss Limited	*Century Co*
Little	[30 - 100]	[30 - 80]
Many	[80 - 160]	[60 - 120]

Membership function for fuzzy set "Capacity" on Boss Limited importer can be seen in Figure 3.

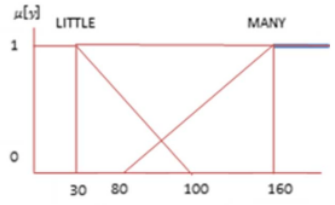

Fig. 3. Membership function "Capacity" Boss Limited

The membership function for the fuzzy set "Capacity" Boss Limited importers can be represented in (7) and (8).

$$\mu CapacityLittle[y] = \begin{cases} 1, & y \le 30 \\ \dfrac{100-y}{100-30}, & 30 < y < 100 \\ 0, & y \ge 100 \end{cases} \quad (7)$$

$$\mu CapacityMany[y] = \begin{cases} 0, & y \le 80 \\ \dfrac{y-80}{160-80}, & 80 < y < 160 \\ 1, & y \ge 160 \end{cases} \quad (8)$$

Membership function for fuzzy set "Capacity" Century Co importer can be seen in Figure 4.

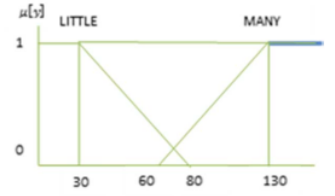

Fig. 4. Membership function "Capacity" Century Co

The membership function for the fuzzy set "Capacity" on Century Co importers can be represented as follows.

$$\mu CapacityLittle[y] = \begin{cases} 1, & y \le 30 \\ \dfrac{80-y}{80-30}, & 30 < y < 80 \\ 0, & y \ge 80 \end{cases} \quad (9)$$

$$\mu CapacityMany[y] = \begin{cases} 0, & y \le 60 \\ \dfrac{y-60}{130-60}, & 60 < y < 130 \\ 1, & y \ge 130 \end{cases} \quad (10)$$

"Competitive" fuzzy set value on each importer can be seen in Table III.

TABLE III. MEMBERSHIP FUNCTION "COMPETITIVE"

Fuzzy Set	Importer	
	Boss Limited	*Century Co*
Low	[1 - 5]	[1 - 5]
High	[3 - 10]	[4 - 10]

Membership function for the Competitive fuzzy set on Boss Limited importers can be seen on Figure 5.

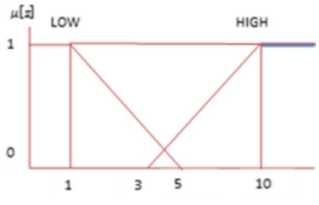

Fig. 5. Membership function "Competitive" Boss Limited

The membership function for the Competitive fuzzy set on Boss Limited importers can be represented in (11) and (12).

$$\mu CompetitiveLow[z] = \begin{cases} 1, & z \le 1 \\ \dfrac{5-z}{5-1}, & 1 < z < 5 \\ 0, & z \ge 5 \end{cases} \quad (11)$$

$$\mu CompetitiveHigh[z] = \begin{cases} 0, & z \le 3 \\ \dfrac{z-3}{10-3}, & 3 < z < 10 \\ 1, & z \ge 10 \end{cases} \quad (12)$$

Membership function for fuzzy set "Competitive" at Century Co importer can be seen in Figure 6.

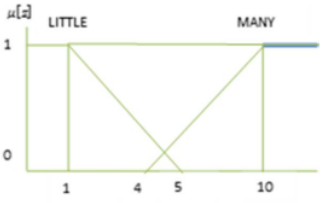

Fig. 6. Membership function "Competitive" Century Co

The membership function for the Competitive Fuzzy set on Century Co importers can be represented in (13) and (14).

$$\mu CompetitiveLow[z] = \begin{cases} 1, & z \le 1 \\ \dfrac{5-z}{5-1}, & 1 < z < 5 \\ 0, & z \ge 5 \end{cases} \quad (13)$$

$$\mu CompetitiveHigh[z] = \begin{cases} 0, & z \le 4 \\ \dfrac{z-4}{10-4}, & 4 < z < 10 \\ 1, & z \ge 10 \end{cases} \quad (14)$$

The value of fuzzy set of Export quantities on each importer can be seen on Table IV.

TABLE IV. MEMBERSHIP FUNCTION "EXPORT"

Fuzzy Set	Importer	
	Boss Limited	*Century Co*
Low	[15 - 50]	[20 - 60]
Medium	[40 - 100]	[50 - 100]
High	[90 - 160]	[90 - 140]

Membership function for fuzzy set "Export" on Boss Limited importer can be seen in Figure 7.

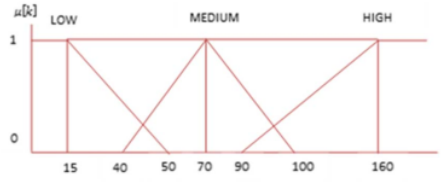

Fig. 7. membership function "Export" Boss Limited

The membership function for the fuzzy set "Export" on Boss Limited importers can be represented in (15), (16), and (17).

$$\mu ExportLow[k] = \begin{cases} 1, & k \le 15 \\ \dfrac{50-k}{50-15}, & 15 < k < 50 \\ 0, & k \ge 50 \end{cases} \quad (15)$$

$$\mu ExportMedium[k] = \begin{cases} 0, & k \le 40 \; atau \; k \ge 100 \\ \dfrac{k-40}{70-40}, & 40 < k \le 70 \\ \dfrac{100-k}{100-70}, & 70 < k < 100 \end{cases} \quad (16)$$

$$\mu ExpoetHigh[k] = \begin{cases} 0, & k \le 90 \\ \dfrac{k-90}{160-90}, & 90 < k < 160 \\ 1, & k \ge 160 \end{cases} \quad (17)$$

Membership function for fuzzy set "Export" on Century Co importer can be seen in Figure 8.

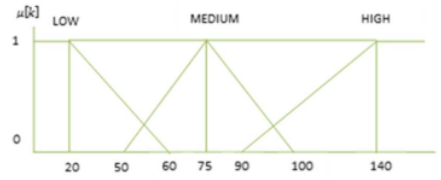

Fig. 8. Membership function "Export" Century Co

The membership function for the fuzzy set "Export" on Century Co importers can be represented in (18), (19), and (20).

$$\mu ExportLow[k] = \begin{cases} 1, & k \le 20 \\ \dfrac{60-k}{60-20}, & 20 < k < 60 \\ 0, & k \ge 60 \end{cases} \quad (18)$$

$$\mu ExportMedium[k] = \begin{cases} 0, & k \le 50 \; atau \; k \ge 100 \\ \dfrac{k-50}{75-50}, & 50 < k \le 75 \\ \dfrac{100-k}{100-75}, & 75 < k < 100 \end{cases} \quad (19)$$

$$\mu ExportHigh[k] = \begin{cases} 0, & k \le 90 \\ \dfrac{k-90}{140-90}, & 90 < k < 140 \\ 1, & k \ge 140 \end{cases} \quad (20)$$

B. Fuzzification

In this study the data used can be seen in Table V. The data used in this study were obtained from several companies, namely Boss Limited and Century Co.

TABLE V. DATA SET

Variable	Importer	
	Boss Limited (BL)	*Century Co (CC)*
Stock	12	30
Capacity	200	150
Competitive	2	3

Identify applicable funding agency here. DRPM Ristekdikti

The results of fuzzification calculations for stock variables on Boss Limited importers with a value of 12 and Century Co with a value of 30 shown in Table VI.

TABLE VI. FUZZIFICATION RESULT "STOCK"

"Stock" Fuzzy Set	Fuzzification Result	
	BL	*CC*
$\mu StockLittle[x]$	0.95	0.33
$\mu StockMedium[x]$	0	0
$\mu StockMany[x]$	0	0

While on the capacity variable, fuzzification calculation result between Boss Limited and Century Co is shown in Table VII.

TABLE VII. FUZZIFICATION RESULT "CAPACITY"

"Capacity" Fuzzy Set	Fuzzification Result	
	BL	*CC*
$\mu CapacityLittle[y]$	0	0
$\mu CapacityMany[y]$	1	1

The results of fuzzification calculations for competitive variables on importers Boss Limited and Century Co are shown in Table VIII.

TABLE VIII. FUZZIFICATION RESULT "COMPETITVE"

"Competitive" Fuzzy Set	Fuzzification Result	
	BL	*CC*
$\mu CompetitiveLow[z]$	0.75	0.5
$\mu CompetitiveHigh[z]$	0	0

C. Fuzzy Inference Rules

After the calculation results obtained in the fuzzification process, the next process is inference fuzzy rules. The implication function used is MIN [14]. This study uses fuzzy rules as many as 12 rules. The combination of fuzzy rules is shown in (21). In (21), X represents each variable (Stock, Capacity, Competitive, and Export). Whereas A represents the fuzzy set (Low, Medium, High, Many, and Little). *R is rules* and $i = 1,2,3,\ldots$.

$$[Ri] \; IF \; X_i \; is \; A_i \; AND \; X_i \; is \; A_i \; AND \; X_i \; is \; A_i \; THEN X_i \; is \; A_i \quad (21)$$

The method used in determining fuzzy rules is an interview with experts in the field of UMKM goods exports of goods management. Some of the fuzzy rules used in this study are shown in Table IX.

TABLE IX. FUZZY RULES

[Ri]	Stock	Capacity	Competitive	Export
1	Little	Little	High	Low
2	Little	Little	High	Low
3	Little	Many	Low	High
4	Little	Many	High	Medium
5	Medium	Little	Low	Low
6	Medium	Little	High	Low
7	Medium	Many	Low	High
8	Medium	Many	High	Medium
9	Many	Little	High	Medium
10	Many	Little	High	Low
11	Many	Many	low	High
12	Many	Many	High	Low

Decision determination begins with the process of calculating the degree of membership parameter values in each set that exists in each rule. The value of α-predicate depends on the operator used. On the AND operator, the value α-predicate given "$X_i \; is \; A_i \; AND \; X_i \; is \; A_i$ " formulated in (22).

$$\alpha_i = \mu_{A1 \cap A2} = \min(\mu_{A1}(X_1), \mu_{A2}(X_2)) \quad (22)$$

D. *Defuzzification*

To get the output value (crisp) is convert the input into a number in the fuzzy set domain. Fuzzy Tsukamoto uses a centralized mean defuzzification (23), while fuzzy Mamdani uses the centroid method (24).

$$Z = \sum_{i=1}^{n} \alpha_i k_i \frac{\sum_{i=1}^{n} \alpha_i k_i}{\sum_{i=1}^{n} \alpha_i} \quad (23)$$

$$Z = \frac{\sum_{j=1}^{n} k_j \, \mu(k_j)}{\sum_{j=1}^{n} \mu(k_j)} \quad (24)$$

III. Experiment Result

A. *Fuzzy Tsukamoto*

The inference process on Tsukamoto's fuzzy implements the MIN function for each rule. The result of inference process calculation is obtaining the value of α-predicate on each rule. The calculation results are shown in Table X.

[R1] IF stock is Little AND capacity is Little AND competitive is Low THEN export is Low

$$\alpha - predicate = \mu StockLittle \cap \mu CapacityLittle \cap \mu CompetitiveLow$$

$$= \min\left(\mu StockLittle(12), \mu CapacityLittle(200)\right),$$

$$\mu CompetitiveLow(2) = \min(0.95; 0; 0.75) = 0$$

$$0 = \frac{50 - k_1}{50 - 15} \; ; \; k_1 = 50$$

TABLE X. Fuzzification Result "Competitve"

	Boss Limited (BL)			Century Co (CC)		
[Ri]	*α*	*k*	*α ´ k*	*α*	*k*	*α ´ k*
1	0	50	0	0	60	0
2	0	50	0	0	60	0
3	0.75	142.5	106.88	0.33	106	34.98
4	0	40	0	0	50	0
5	0	50	0	0	60	0
6	0	50	0	0	60	0
7	0	90	0	0	90	0
8	0	40	0	0	50	0
9	0	40	0	0	50	0
10	0	50	0	0	60	0
11	0	90	0	0	90	0
12	0	50	0	0	60	0
	0.75		106.88	0.33		34.98
Z	**142.5**			**106**		

Based on the calculation result using (22) and (23), we get the final value of defuzzification for BL = 142.5 dan CC = 106.

B. *Fuzzy Mamdani*

The inference process on fuzzy Mamdani is similar to Tsukamoto's fuzzy. So the resulting α-predicate value is the same as Tsukamoto's fuzzy (Table X). But in the process of calculating the final value (defuzzification), fuzzy Mamdani using centroid method (24).

The stages in finding the final value (crisp) on Boss Limited using a centroid defuzzification are described as follows.

Composition rule using max function obtained:

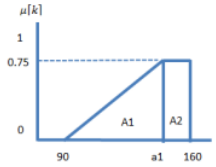

Fig. 9. Membership function "Export" Boss Limited

$\frac{a1-90}{160-90} = 0.33 \; ; a1 \; = \; 142.5$

The new membership functions "Export" are as follows.

$$\mu Export[k] = \begin{cases} 0, & k \le 90 \\ \dfrac{k-90}{160-90}, & 90 \le k \le 142.5 \\ 0.75, & k \ge 142.5 \end{cases} \quad (25)$$

The moments for each region are:

$$M1 = \int_{90}^{142.5} \frac{j-90}{70} \, jdj \; = 2919.4$$

$$M2 = \int_{142.5}^{160} 0.75 jdj = \; 1985.16$$

The large for each area is:

$$A1 = \frac{1}{2}(142.5 - 90)(0.75) = 19.7$$

$$A2 = (160 - 142.5)(0.75) = 13.125$$

Central point obtained:

$$j = \frac{2919.4 + 1985.16}{19.7 \; + \; 13.125} = 149$$

The defuzzification process on Century Co importers is as follows. Composition rule using max function obtained:

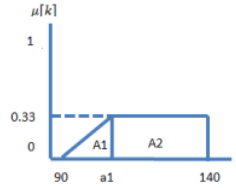

Fig. 10. Membership function "Export" Century Co

$\frac{\text{a1-90}}{\text{140-90}} = 0.33 \; ; \; \text{a1} \; = \; 106.5$

The new membership functions "Export" are as follows:

$$\mu Export[k] = \begin{cases} 0, & k \le 90 \\ \dfrac{k-90}{140-90}, & 90 \le k \le 106.5 \\ 0.33, & k \ge 106.5 \end{cases} \quad (26)$$

The moments for each area are:

$$M1 = \int_{90}^{106.5} \frac{j-90}{50} \, jdj = 290.93$$

$$M2 = \int_{106.5}^{140} 0.33 jdj = \; 1362.52$$

The large for each area is:

R

$$A1 = \frac{1}{2}(106.5 - 90)(0.33) = 2.73$$

$$A2 = (140 - 106.5)(0.33) = 11.1$$

Central point obtained:

$$j = \frac{290.93 + 1362.52}{2.73 + 11.1} = 119$$

The results of analysis to determine the amount of export in each importer for furniture products using fuzzy Tsukamoto and fuzzy Mamdani can be seen in Table XI.

TABLE XI. RESULT ANALYSIS OF TSUKAMOTO AND MAMDANI METHOD

Variable	Importer	
	Boss Limited	*Century Co*
Stock	12	30
Capacity	200	150
Competitive	2	3
Export	188	120
Export (Tsukamoto)	142.5	106
Export (Mamdani)	149	119

To measure the accuracy of Mamdani and Tsukamoto method, Mean Absolute Percentage Error (MAPE) is used to calculate the expected target value difference with method measurement value. The MAPE formula is shown in (27) [15], [16].

$$\boldsymbol{MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{e_i}{wd_i}\right| x100} \quad (27)$$

Where "*e*" is the expected target difference with the measurement method and "*wd*" is the expected target value. Based on Table VI, the MAPE value for Tsukamoto method calculation is as follows.

$$\boldsymbol{MAPE_{Tsukamoto} = \frac{1}{2}\left(\frac{(188 - 142.5) + (120 - 106)}{188 + 120}\right) = 9.65\%}$$

While MAPE value for Mamdani method calculation is as follows.

$$\boldsymbol{MAPE_{Mamdani} = \frac{1}{2}\left(\frac{(188 - 149) + (120 - 119)}{188 + 120}\right) = 6.49\%}$$

The MAPE value generated by fuzzy Mamdani and fuzzy Tsukamoto is still below 10%. This shows the accuracy obtained high. Based on MAPE calculations, it can be concluded that the proposed method (fuzzy Mamdani) has a better performance compared to Tsukamoto's fuzzy.

IV. CONCLUSION

Fuzzy Mamdani and fuzzy Tsukamoto are very good for determining export quantity because MAPE value is still below 10%. In the case of determining the amount of Mamdani fuzzy export is more optimal with MAPE value = 6.94% compared with Tsukamoto fuzzy with MAPE value 9.42%. This proves that Fuzzy Inference System Mamdani is more appropriate to be used to determine export quantity. Accuracy in this study can still be improved again. The determination of fuzzy membership restrictions in this study is still determined based on expert opinion. It could be the determination of membership function is not fit. Therefore, further research will be optimized on the fuzzy membership function so that the resulting accuracy can be higher than the current accuracy [2].

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