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IMPLEMENTATION OF SUGENO'S FUZZY LOGIC IN ANALYZING RICE AVAILABILITY DURING THE COVID-19 PANDEMIC AT PERUM BULOG NORTH SUMATRA

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ABSTRACT

During the Covid-19 Pandemic economic activities in North Sumatra experienced problems because many people had been laid off and lost their jobs which made them worried about reaching the staple of rice. So that the government feels the need to provide rice assistance which is directly channeled through BULOG. With this direct social assistance to the community, it could lead to instability in the rice supply and expenditure stocks until at least February 2021. So it is necessary to analyze the availability of rice at Perum BULOG so that the rice stock supply at Perum BULOG remains stable during the Covid-19 Pandemic. With fuzzy logic, Sugeno will present uncertainty, uncertainty, inaccuracy which will then produce a model of a system that is able to estimate the amount of rice supplies during the Covid-19 pandemic. In January, in the calculation of realization from North Sumatra BULOG, the ending inventory was 42,941 tonnes, while the yield from the Sugeno fuzzy method was 34,833.06 tonnes. This shows that there is a mismatch between the amount of income and expenditure of rice.

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1. INTRODUCTION

Rice is a staple or main food for the people of Indonesia. To secure food supplies in order to enforce the existence of the new government, providing rice in Indonesia is one of the ways the government regulates the national economy. The government established the Logistics Affairs Agency (BULOG) as its role in maintaining the availability of food.

At the beginning of 2020 the Covid-19 pandemic (Corona Virus Disease 2019) had shaken the whole world, including Indonesia. In Indonesia itself, the Covid pandemic began to spread in mid-March 2020. The emergence of Covid-19 that attacked Indonesia had a great impact on Indonesia, especially the Indonesian economy.

In North Sumatra itself, Covid-19 (Corona Virus Disease 2019) has become very rampant and has made economic activities in North Sumatra experience problems because many people have been laid off and make them worried about reaching the staple food of rice. This made the President as well as the Provincial Government and City Governments to provide rice assistance which was directly channeled through BULOG so that BULOG Drive North Sumatra has ensured rice stocks are safe until August Due to this, BULOG has experienced problems in unstable rice production. So, to overcome this problem, BULOG must pay attention to the income and expenditure of rice during Covid-19 so that rice supplies remain stable.

2. RESEARCH METHODE

2.1 Covid-19 Pandemic

Covid-19 (Corona Virus Disease) was first reported in Wuhan, China. This virus is said to be a pandemic after spreading across international borders to countries around the world, including Indonesia.

2.2 Rice

Rice is the part of the grain (grain) that has been separated from the husk. Husk (Javanese merang) is anatomically called 'pala' (covered part) and 'lemma' (covered part). (Wikipedia, 2020)

2.3 BULOG (Logistics Affairs Agency)

BULOG is a state-owned public company engaged in food logistics. Its business scope includes logistics/warehousing, surveys and pest control, supply of plastic bags, transportation business, food commodity trading and retail business. As a company that continues to carry out tasks from the government, BULOG continues to carry out activities to maintain the Basic Purchase Price for grain, stabilize prices, especially basic prices, distribute public rice for the poor (Raskin) and manage food stocks. (BULOG, http://www.bulog.co.id/sekilas.php)

2.1 Stock and Demand

2.1.1 Stock

Inventories are materials or goods that are stored, then will be used to fulfill certain purposes, such as for the production or manufacturing process, for resale, or for spare parts of an equipment or machine. Inventories can be in the form of raw materials, auxiliary materials, materials in process, finished goods or spare parts (Putong, 2010).

2.1.2 Inventory Control

Inventory control is a technique that determines the amount of material inventory that must be held to ensure the smooth running of production operations, as well as determine the procurement schedule and the number of orders for goods that should be carried out by the company. An inventory control system can be defined as a series of control policies to determine the level of inventory that must be maintained, when orders to increase inventory must be made and how large orders must be held (Putong, 2010).

2.1.3 Demand

Demand is the amount of goods demanded at a certain place at a certain price level at a certain level of income and in a certain period.

2.2 Fuzzy Logic

Fuzzy logic was first introduced in 1965 by Lothfi A. Zhadeh. Fuzzy Logic is a logical set theory which was developed to overcome the concept of value that exists between truth (true) and error (false). (Setyawan & Nikicha, 2020)

2.3 Fuzzy Set Concept

According to Prof. Zadeh, fuzzy set is an object class with continuous membership value. In a firm set, the membership value of an item x in a set B which is often written as B[X] has 2 possibilities, namely:

(1) One (1), an item becomes a member in a set
(2) Zero (0), an item is not a member in a set

2.4 Membership Functions

The membership function is a curve that shows the mapping of data input points into their membership values which have an interval between 0 to 1.

2.4.1 Linear Representation

1. Ascending Linear Representation

The increase in the set starts at the domain value which has a membership degree of zero (0) moving to the right towards the domain value which has a higher membership degree (Setyawan & Nikicha, 2020).

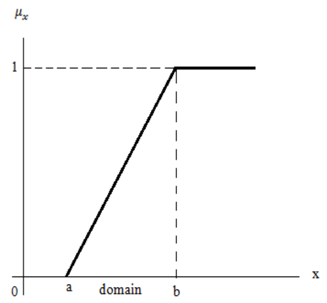

Figure 2.2 Ascending linear representation graph

membership function: $$\mu(x) = \begin{cases} 0 & ; x < p \\ \frac{x-p}{q-p} & ; p \le x \le q \\ 1 & ; x > q \end{cases} \quad (2.1)$$

2. Descending Linear Representation

The decrease in value starts from the value of the domain that has the highest degree of membership on the left side, moving down to the value of the domain that has a lower degree of membership (Setyawan & Nikicha, 2020).

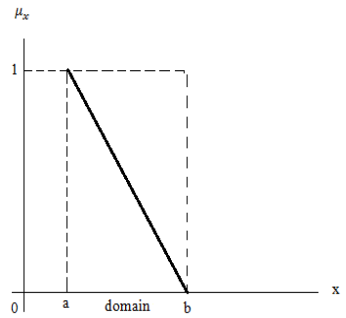

Figure 2.2 Descending linear representation graph

membership function: $$\mu(x) = \begin{cases} 1 & ; x < p \\ \frac{q-x}{q-p} & ; p \le x \le q \\ 0 & ; x > q \end{cases} \quad (2.2)$$

2.7.2 Triangle Curve Representation

This fuzzy membership function is a combination of an ascending linear membership function and a descending linear membership function (Setyawan & Nikicha, 2020).

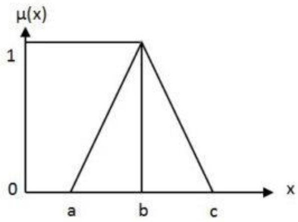

Figure 2.3 Triangle linear representation graph

$$\text{Membership function : } \mu\,(x) = \begin{cases} 0 \; ; x < p & arau\; x > r \\ \frac{q-x}{q-a} & ; p \le x \le q \\ \frac{r-x}{r-q} & ; q \le x \le r \end{cases} \qquad (2.3)$$

2.7.3. Trapezoidal Curve Representation

The trapezoidal curve has a shape like a triangle, where there is a point that has a membership value of 1 (Irwansyah & Faisal, 2019).

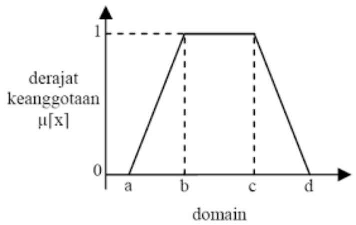

Figure 2.4 Trapezoidal curve representation graph

$$\text{membership function: } \mu\,[x] = \begin{cases} 0, & x \le p\; atau\; x \ge s \\ \frac{(x-p)}{(q-p)} & ; p \le x \le q \\ 1, & ; q \le x \le r \\ \frac{(s-x)}{(s-r)} & \end{cases} \qquad (2.4)$$

2.7.4. Linear Representation of the Shoulders

The area located in the middle of a variable which is presented in the form of a triangle, on the right and left sides will go up and down (Irwansyah & Faisal, 2019).

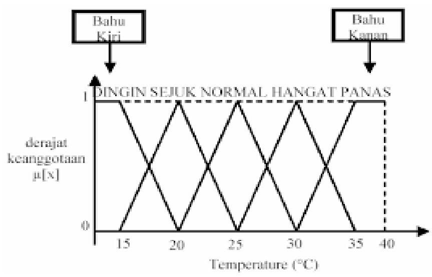

Figure 2.5 Representation of the Shoulders graph

$$\text{membership function: } \mu\,[x] = \begin{cases} 0, & x \le p\; atau\; x \ge s \\ \frac{(x-p)}{(q-p)} & ; p \le x \le q \\ 1, & ; q \le x \le r \\ \frac{(s-x)}{(s-r)} & \end{cases} \qquad (2.5)$$

2.8 Fuzzy Logic Operation

Fuzzy logic operations are operations that combine and modify 2 or more fuzzy sets. The new membership value resulting from the operation of two sets is called firing strength or predicate. There are 3 basic operations of fuzzy sets (Setyawan & Nikicha, 2020).

1. Operator OR (Union)

$$\mu(\mathrm{P} \cup \mathrm{Q})(\mathrm{x}) = \max\{\mu\mathrm{P}(\mathrm{x}), \mu\mathrm{Q}(\mathrm{x})\} \qquad (2.6)$$

2. Operator AND (Intersection)

$$\mu(\mathrm{PnQ})(\mathrm{x}) = \min\{\mu P(\mathrm{x}), \mu\mathrm{Q}(\mathrm{x})\} \qquad (2.7)$$

3. Operator NOT (Complement)

$$\mu\mathrm{Ac}(\mathrm{x}) = 1 - \mu\mathrm{A}(\mathrm{x}) \qquad (2.8)$$

2.9 Implication Function

Each rule (proposition) in the fuzzy knowledge base will be associated with a fuzzy relation. The general form of the rules used in functions (Sujarwata, 2014).

If x is P then y is Q (2.9)

2.10 Fuzzy Inference System

This system serves to make decisions through a certain process by using inference rules based on fuzzy logic. The inference system has 4 stages, namely:

1. Fuzzyfication

Fuzzification is a process of converting existing firm values into membership functions

2. Fuzzy Logic Reasoning

The implication process in reasoning the input value in order to determine the output value as a form of decision making.

3. Knowledge Base, which consists of two parts:

a) Database, which contains membership functions of fuzzy sets associated with the values of the linguistic variables used.

b) Rule Base, which contains rules in the form of fuzzy implications.

4. Defuzzification

The fuzzy inference system itself is divided into three, namely Mamdani fuzzy, Sugeno fuzzy and Tsukamoto fuzzy.

This study uses the Sugeno fuzzy method because the Sugeno fuzzy method is effective in computing and works well with optimization. Sugeno's fuzzy method also guarantees the continuity of the output surface and is more suitable for manual analysis

2.11 Sugeno Fuzzy

Fuzzy Sugeno is a fuzzy inference system for rules that are represented in the form of IF-THEN where the output is not a fuzzy set but a constant or linear equation (Puspita & Yulianti, Journal of Media Infotama, 1, February 2016). To get the output (results) of the Sugeno method, there are 4 steps as follows:

1. Formation of a Fuzzy Set

Specifies all related variables in the process to be determined. For each Input variable, define an appropriate fuzzification function.

2. Application Function Implicati

Develop a rule base, namely rules in the form of fuzzy implications that state the relationship between Input variables and output variables (Ridwan, Tesis, 2016).

If X is P and Y is Q, then Z = f(x,y) (2.10)

3. Composition Rules

In this method, the fuzzy set solution is obtained by taking the minimum value of the rule, then using that value to modify the fuzzy area and apply it to the output using the or (union) operator.

4. Affirmation

The input of the affirmation process is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is a firm real number. If the composition of the rules uses the Sugeno method, then the defuzzification (Z*) is done by finding the centralized average value.

$$Z^{\cdot} = \frac{\sum_{i}^{N}=_{1}\alpha_i z_i}{\sum_{i}^{N}=_{1}\alpha_i} \quad ; \quad i = 1, 2, 3, \ldots, N \qquad (2.12)$$

3. RESULT AND ANALYSIS

Collecting Data

The data obtained is processed data from the Public Company BULOG, North Sumatra Regional Division office. Where the data is income, expenditure and inventory data which is report data from January 2020 to October 2020. The data can be seen from Table 3.1

Month	**Initial Inventory (w)**	**Input (x)**	**Output (y)**	**Ending Inventory (z)**
January	44.711	2.020	3.791	42.941
February	42.941	1.742	4.400	40.283
March	40.283	1.994	4.720	37.558
April	37.558	3.557	9.086	32.029
May	32.029	1.476	4.530	28.975
June	28.975	2.816	6.584	25.207
July	25.207	884	1.853	24.238
Agust	24.238	3.219	6.825	20.632

Formation of a Fuzzy Set

Data processing is done by determining the variables and the universe of conversation followed by forming a fuzzy set

Table 4.2 Determination of Variables and Speaker Universe

Fungsi	Variabel	speaker universe	Information
Input	Initial Inventory	24.238 - 44.711	Total initial stock of rice per month (tons)
	Input	884 - 3.557	Total rice income per month (tons)
	Output	1.853 - 9.086	Total production of rice per month (tons)
Output	Ending Inventory	20.632 - 42.942	Total end of rice inventory per month (tons)

Table 4.3 Fuzzy set

Function	Variable	Fuzzy Set Name	speaker universe	Domain

Input	Initial Inventory	A LITTLE	0 – 44.711	0 - 24.238
		MUCH		24.238 – 44. 711
	Input	REDUCED	0 – 3.557	0 – 884
		INCREASE		884 – 3.557
	Output	REDUCED	0 – 9.086	0 – 1.853
		INCREASE		1.853 – 9.086
Output	Ending Inventory	A LITTLE	0 – 42.942	0 – 20.632
		MUCH		20.632 – 42.942

1. Beginning Inventory Variable (w)

Based on Formulas (2.1) and (2.2), from the smallest and largest initial inventory data from January to August 2020, the membership function is based on an up and down representation as follows:

$$\mu_{A\ LITTLE}\begin{cases} 1 & ; x \leq 24.238 \\ \frac{44.711 - x}{44.711 - 24.383} & ; 24.238 \leq x \leq 44.711 \\ 0 & ; x \geq 44.711 \end{cases}$$

$$\mu_{MUCH\ [x]} = \begin{cases} 0 & ; x \leq 24.238 \\ \frac{x - 24.238}{44.711 - 24.383} & ; 24.238 \leq x \leq 44.711 \\ 1 & ; x \geq 44.711 \end{cases}$$

2. Input Variable

Based on Formulas (2.1) and (2.2), from the smallest and largest amount of data entry from January to August 2020, the membership function is based on an increasing and decreasing representation as follows:

$$\mu_{REDUCED\ [x]} = \begin{cases} 1 & ; x \leq 884 \\ \frac{3.557 - x}{3.557 - 884} & ; 884 \leq x \leq 3.557 \\ 0 & ; x \geq 3.557 \end{cases}$$

$$\mu_{INCREASE\ [x]} = \begin{cases} 0 & ; x \leq 884 \\ \frac{x - 884}{3.557 - 884} & ; 884 \leq x \leq 3.557 \\ 1 & ; x \geq 3.557 \end{cases}$$

3. Output Variable

Based on Formulas (2.1) and (2.2), from the smallest and largest amount of expenditure data from January to August 2020, the membership function is based on an ascending and descending representation as follows:

$$\mu_{REDUCED\ [x]} = \begin{cases} 1 & ; x \leq 1.853 \\ \frac{9.086 - x}{9.086 - 1.853} & ; 1.853 \leq x \leq 9.086 \\ 0 & ; x \geq 9.086 \end{cases}$$

$$\mu_{INCREASE\ [x]} = \begin{cases} 0 & ; x \leq 1.853 \\ \frac{x - 1.853}{9.086 - 1.853} & ; 1.853 \leq x \leq 9.086 \\ 1 & ; x \geq 9.086 \end{cases}$$

4. Ending Inventory Variable

Based on Formulas (2.1) and (2.2), from the smallest and largest amount of ending inventory data from January to August 2020, the membership function is based on an ascending and descending representation as follows:

$$\mu_{A\ LITTLE[x]} = \begin{cases} 1 & ; x \leq 20.632 \\ \frac{42.941 - x}{42.941 - 20.631} & ; 20.632 \leq x \leq 42.941 \\ 0 & ; x \geq 42.941 \end{cases}$$

$$\mu_{MUCH\ [x]} = \begin{cases} 0 & ; x \leq 20.632 \\ \frac{x - 20.631}{42.941 - 20.631} & ; 20.632 \leq x \leq 42.941 \\ 1 & ; x \geq 42.941 \end{cases}$$

Formation of Fuzzy Ground Rules

After determining the membership function of the variable, fuzzy logic rules must be formed. Based on the data obtained, as follows:

Table 4.4 The results of the rules formed on fuzzy inference

Rules	Initial Inventory	Input	Output	Implication function	Ending Inventory
R1	Much	Increase	Increase	Then	Much
R2	Much	Increase	Reduced	Then	Much
R3	Much	Reduced	Increase	Then	A little
R4	Much	Reduced	Reduced	Then	Much
R5	A little	Increase	Increase	Then	A little
R6	A little	Increase	Reduced	Then	Much
R7	A little	Reduced	Increase	Then	A little
R8	A little	Reduced	Reduced	Then	A little

After knowing the fuzzy rules of the implication function, the form of the ending inventory will then be searched using the formula for the Zero Order Sugeno method as follows:

$$\text{IF } (X_1\ IS\ A_1) \cap (X_2\ IS\ A_2) \cap (X_3\ IS\ A_3) \cap \ldots \cap (X_n\ IS\ A_n)\ THEN\ z = k$$

For Information:

$$Z = \begin{cases} A\ Little, & k \leq 20.632 \\ Much, & k \geq 42.941 \end{cases}$$

In this study, the implication function that will be used is the minimum function, which is stated in the equation formula as follows:

$$\alpha_i = \mu_{Ai}(x) \cap \mu_{Bi}(X) = min\{\mu_{Ai}(X), \mu_{Bi}(X)\}$$

Then it can be calculated as follows:

- If it is known that in January 2020 the initial inventory (v) is 44,711 (tons) based on formula 2.1, then:

$$\mu_{A\ little[44.711]} = \frac{44.711 - 44.711}{44.711 - 24238} = 0$$

$$\mu_{much[44.711]} = \frac{44.711 - 24.238}{44.711 - 24.238} = 1$$

- If it is known that in January 2020 income (w) is 2,020 (tons) based on formula 2.1, then:

$$\mu_{Reduced[2.020]} = \frac{3.557 - 2.020}{3557 - 884} = 0{,}575$$
$$\mu_{Increase[2.020]} = \frac{2.020 - 884}{3557 - 884} = 0{,}424$$

- If it is known that in January 2020 expenditure (y) was 3,791 (tons) based on formula 2.1, then:

$$\mu_{increase[2.020]} = \frac{9.086 - 3791}{9.086 - 1.853} = 0{,}732$$

$$\mu_{reduced[2.020]} = \frac{3.791 - 1.853}{9.086 - 1.853} = 0{,}267$$

Next determine the value of αpredicate for each rule by finding the minimum.

Composition rules

Based on the results of the application function of each rule, the composition of the rules is used by taking the maximum level from all the conclusions of each rule. So that the composition of the rules for the max inventory function at the end of January 2020 is as follows:

1. Few = max(0,267)
2. Many = max(0,575)

defuzzification (Affirmation)

The method used is the output process in the form of crisp numbers. In the Sugeno method, the affirmation uses a weighted calculation (Weighted Average).

$$Z^{\cdot} = \frac{\sum_{i}^{N}=_1 \alpha_i z_i}{\sum_{i}^{N}=_1 \alpha_i}$$
$$= \frac{0{,}267\ (20.632) + 0{,}575\ (42.941)}{0{,}27 + 0{,}575}$$
$$= 34.833{,}06$$

Tabel 4.5 Comparison table of Perum BULOG inventory results with inventory results using fuzzy Sugeno (Ton)

Month	Initial Inventory	Input	Output	Ending Inventory	
				Realization	*Fuzzy* Sugeno
January	44.711	2.020	3.791	42.941	34.833,06
February	42.941	1.742	4.400	40.283	35.845,61
March	40.283	1.994	4.720	37.558	33.759,60
April	37.558	3.557	9.086	32.029	35.140,15
May	32.029	1.476	4.530	28.975	29.105,12
June	28.975	2.816	6.584	25.207	28.322,80

July	25.207	884	1.853	24.238	21.661,19
August	24.238	3.219	6.825	20.632	27.585,18

Results and Discussion

Based on Table 4.5, it is clear that there are differences in the calculation results of the final inventory of rice from Perum BULOG data using the Fuzzy Sugeno method. With one of the results of the differences found in January, where in the calculation of realization from the North Sumatran State Logistics Agency, the ending inventory was 42,941 tons, while the results from the Sugeno fuzzy method were 34,833.06 tons. That is, the results obtained by using the Sugeno fuzzy method are smaller than the results from the calculation of the North Sumatran State Logistics Agency (BULOG) North Sumatra. In addition, in August, the North Sumatra BULOG's Realization calculation result was 20,632 while the Sugeno fuzzy method calculation was 27,585.18 where the result of the Sugeno fuzzy method is greater than the result of the calculation of the realization of the BULOG North Sumatra.

Determine the value of Mean Absolute Percentage Error

$$MAPE = \frac{\sum_i^n \frac{[Yt - \hat{Y}t]}{Yt}}{n} x\ 100$$

Information : $\hat{Y}t$ = Predicted Value
Yt = Actual Value
N = Number of Observations

Table 4.6 MAPE Values for Performance Evaluation

Nilai MAPE	**Akurasi Prediksi**
MAPE ≤ 10%	High
10% < MAPE ≤ 20%	Good
20% < MAPE ≤ 50%	Reasonable
MAPE > 50%	Low

Table 4.7 Table MAPE

Month	Yt	$\hat{Y}t$	$Yt - \hat{Y}t$	$\lvert Yt - \hat{Y}t \rvert$	$\lvert Yt - \hat{Y}t/Yt \rvert$
January	42.941	34.833,06	8107.94	8107.94	0.188816
Februay	40.283	35.845,61	4437.39	4437.39	0.110155
March	37.558	33.759,60	3798.4	3798.4	0.101134
April	32.029	35.140,15	-3111.15	3111.15	0.097135
May	28.975	29.105,12	-130.12	130.12	0.004491

June	25.207	28.322,80	-3115.8	3115.8	0.123609
July	24.238	21.661,19	2576.81	2576.81	0.106313
August	20.632	27.585,18	-6953.18	6953.18	0.337009
Total					1.068662

$$MAPE = \frac{1.068662}{8} x\ 100$$
$$= 0{,}133583\ x\ 100$$
$$= 13{,}35\%$$

Based on the results obtained, that the MAPE value obtained is 13.35%, which according to Table 4.6 the value of 13% is included in the Good study and shows that the Sugeno fuzzy method is efficiently used in determining rice supplies.

4. Conclusioon

the results of the study indicate that there is a discrepancy between the amount of rice income and expenditure in Perum BULOG North Sumatra because from January to August 2020 the amount of rice expenditure is greater than the amount of rice income, which makes the final supply of rice smaller. So if the company has to pay more attention to the rice input factor and the rice expenditure factor, especially during the Covid-19 pandemic so that it does not accumulate or decrease in warehouses so that rice supplies remain safe and stable during the Covid-19 pandemic

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