Research Article

Comparison of Sugeno and Tsukamoto Fuzzy Inference System Method for Determining Estimated Production Amount

Murnawan[1], R.A.E. Virgana[2], Sri Lestari[3]

[1] Department, Widyatama University, Bandung, Indonesiamurnawan@widyatama.ac.id
[2] Department, Widyatama University, Bandung, Indonesia rae.virgana@widyatama.ac.id
[3] Department, Widyatama University, Bandung, Indonesia sri.lestari@widyatama.ac.id

Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 20 April 2021

Abstract One of the solutions to solve the problem of decision making of goods production is a decision support system to estimate the amount of production of goods using the reasoning method, Fuzzy Inference System (FIS) which is a development of the fuzzy set theory. In this study, a comparison will be made between the method Sugeno and Tsukamoto in the application of fuzzy logic to the production of goods in the company. In this research, the problem to be discussed is which method is closest to the production amount in the original data. The purpose of this study is to determine how many goods the company should produce if the variables are numbers fuzzy with calculations using the method Fuzzy Inference System Sugeno and Tsukamoto. Comparing the two results from Fuzzy Inference System Sugeno and Tsukamoto with company data. The method that comes closest to company data will be used as an application to determine the amount of production. From the calculation of the Fuzzy Inference System Sugeno and Tsukamoto, it can be concluded that the Tsukamoto method is most suitable for determining the amount of the company's goods production.

Keywords—decision making, fuzzy inference system, production, sugeno, tsukamoto.

1. Introduction

O balance the demand for goods with the amount of production, a company is certain will conduct research and analysis of the products that will be offered to the market or consumers. In the company, the production of goods will have a big influence, because in addition to optimizing the raw materials used, this will also have a big impact on the cost or financial sector.

The number of factors involved in the calculation will be an obstacle for decision makers in making policies in determining the amount of goods to be produced. These factors are: maximum demand at a certain period, minimum demand at a certain period, maximum supply at a certain period, minimum supply at a certain period, maximum production at a certain period, minimum production at a certain period, current demand, and current supply. For that we need a method to solve this problem.

The method most often used is theory unequivocal set. However, firm set theory is inoperable or used by the general public (analysis people only), because apart from being a bit complicated in calculation, constraints in production will also complicate things solving the optimization problem of production of goods. In addition to strict set logic, theory fuzzy can also be used in the optimization of goods production problems.

In the problem of making goods production decisions, one solution to overcome this problem is a decision support system to estimate the amount of goods produced using the reasoning method, Fuzzy Inference System (FIS) which is a development of the set fuzzy theory.

In this research, a comparison will be made between the method Sugeno and Tsukamoto in the application of fuzzy logic to the production of goods in the company. In this research, the problem to be discussed is which method is closest to the production amount of the original data.

The objectives of this research are:

1. To determine how many goods the company should produce if the variables are numbers fuzzy, the calculation uses the method Fuzzy Inference System Sugeno and Tsukamoto.
2. Comparing the two results from Fuzzy Inference System Sugeno and Tsukamoto with company data. The method that comes closest to company data will be used as an application to determine the amount of production.

2. Literature Review

An Fuzzy Inference System (FIS) contains the knowledge and experience of an expert, in the design of a system that controls a process whose input–output relations are defined by a set of fuzzy control rules, e.g., IF–THEN rules [2]. Fuzzy logic-reasoning contains two types of information. The first concerns the labels and membership functions assigned to the input and output variables. The accurate selection of these represents one of the most critical stages in the design model. The other type of information is related to rule-base which processes the fuzzy values of the inputs to fuzzy values of the outputs [3].

An FIS is composed of three blocks. The first, fuzzification, converts crisp value input to a linguistic variable using the membership functions kept in the knowledge base. To the second block, the inference engine, is assigned the task of evaluating the input's degree of membership to the fuzzy output sets using the fuzzy rules. Finally, the defuzzifier block transforms the fuzzy output into a crisp value. The inference engine is the FIS heart, and can reproduce the human decision-making process by performing approximate reasoning in order to achieve a control strategy [2]. The inference stage utilizes the fuzzy input values to activate the inference rules and generate the fuzzy output value. The generic architecture of the fuzzy expert system is shown in Fig. 1.

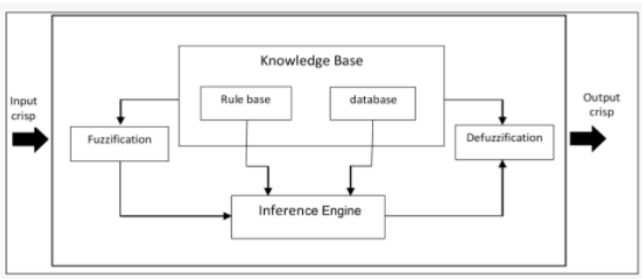

Fig. 1. Architecture of a fuzzy expert system.

In a fuzzy inference model (approximate reasoning) the reasoning process is based on a series of if-then rules as a kind of expert knowledge [4,5]. The conditional statement (or proposition) contains a premise, the if-part, and a conclusion, the then-part [4,6]. The knowledge included in a fuzzy control system is made up of a group of several rules of the form "if X is A then Y is B", or, more generally, "if X1 is A1 and ...and Xn is An then Y is B", where A, An, B are fuzzy sets [7]. The knowledge base, which comprehends general knowledge concerning a problem domain, joins antecedents with consequences or premises with conclusions [8] (see Figure 1). The most commonly used fuzzy inference technique was proposed by Mamdani. However, in Mamdani-type FIS the number of rules grows with the number of premise-part variables. As the number of rules grows the activity of assembling rules can become very burdensome and sometimes it becomes difficult to comprehend the relationships between the premises and consequences [9]. A Sugeno-type method (or Takagi-Sugeno-Kang) has fuzzy inputs and a crisp output (linear combination of the inputs). It is computationally efficient and suitable to work with optimization and adaptive techniques, so it is very adequate for control problems, mainly for dynamic nonlinear systems [10]. Sugeno method develops a systematic approach to generate fuzzy rules from a given input-output data set. It changes the consequent (then part) of Mamdani rule with a function (Equation) of the input variables. The T-S style fuzzy rule is: IF x is A AND y is B THEN z is f (x, y) where x, y and z are linguistic variables, A and B are fuzzy sets on universe of discourses X and Y and f (x, y) is a mathematical function [10]. Sugeno-type FIS uses weighted average to compute the crisp output while Mamdani-type FIS uses the technique of defuzzification of a fuzzy output. The first two parts of the fuzzy inference process, fuzzifying the inputs and applying the fuzzy operator, are the same [1]. The main difference is that the Sugeno output membership functions are either linear or constant [1]. In Figure 2 different types of fuzzy systems are shown. Type two is Mamdani FIS with output function based on overall fuzzy output, while type three is the Takagi-Sugeno fuzzy inference.

Fuzzy sets theory has been applied successfully in recent years for dealing with sustainability and environmental topics. The pioneers are certainly Phillis and Andriantiatsaholiniaina [11], Phillis et al. [12], Phillis et al. [13]. They proposed a model called Sustainability Assessment by Fuzzy Evaluation (SAFE). Ocampo-Duque et al. [14], Icaga [15], and Lermontov et al. [16] proposed the use of fuzzy set for dealing with water quality. Fisher [17] applied the fuzzy sets to the study of air quality. Prato [18] developed a fuzzy adaptive management tool for evaluating the vulnerability of an ecosystem as a result of climate change. Marchini et al. [19] described a framework for designing fuzzy indices of environmental conditions. Gonzalez et al. [20] integrated life cycle assessment (LCA) methodology and fuzzy reasoning. Silvert [21] showed how fuzzy logic can be applied to analysis of ecological impacts.

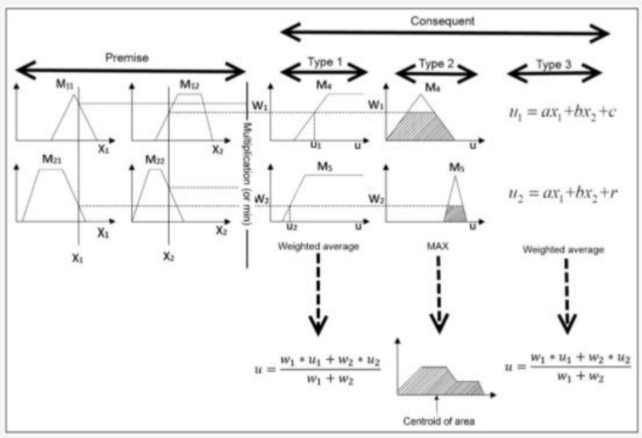

Fig. 2. Different types of Fuzzy inference system

3. Results and Discussion

In order to solve the problems faced by the company, a calculation program will be made by comparing 2 not much different reasoning methods to calculate the amount of production, then comparing with the results of the actual number of production, which one is closest to the actual result, the decision will be chosen from the method that is closest the production amount. The reasoning method used is the Sugeno and Tsukamoto fuzzy inference system.

A. Data Analysis

1) Problems

Fuzzy decision support systems are used in various fields. This paper will discuss the determination of the amount of packaging production in one example category "Food and Drink" by the company PT. XYZ. The production process begins with the purchase of raw materials, especially packaging bottles, until they become whole packaging bottles. Production at one customer does not always occur every month, but it can happen every 2 months, even if there are no design changes on the packaging. Initially there was no inventory in the first month of production. Then initially more than the existing demand will be produced. After that, in the next production month, the previous excess production will be calculated as inventory. Then it will produce about 10% more of the demand needed or it could be the same as the demand, and so on for the following month. The data taken is data on demand and supply of packaging production during 2019.

TABLE I
DATA ON DEMAND AND SUPPLY FOR PACKAGING PRODUCTION IN 2019

Month	Demand (pcs)	Inventory (pcs)	Production (pcs)
January	75,000	0	100,000
March	75,000	25,000	57,500
May	75,000	7,500	75,000
July	75,000	7,500	75,000
September	100,000	7,500	100,000
November	75,000	7,500	75,000

From 2019 data, it can be concluded that the minimum demand is 75,000 pcs and the maximum is 100,000 pcs. The minimum stock was out of stock in January, and the maximum was 25,000 pcs in March. The minimum number of production reaches 57,500 pcs and the maximum reaches 100,000 pcs. The amount of production depends on the quantity demanded and is deliberately produced less than what is required to prevent damage to goods or to keep supplies low.

In this case there are 3 variables, namely: 2 input variables, demand and supply variables, while for output there is 1 variable, namely the production of goods. The demand variable has 2 linguistic values, namely down and up. The inventory variable has 2 linguistic values, namely a little and a lot. Meanwhile, the production variable has 2 linguistic values, namely increasing and decreasing.

Based on the unit of reasoning for inference in the form:

If x is A, and y is B, then z is C.

If x is associated with the demand variable and A is the linguistic values, y is associated with the supply variable and B is the linguistic values, Z is associated with the production variable and C is its linguistic values, so the rules formed can be presented in Table II below:

TABLE II
RESULTS OF THE RULES SHAPED BY INFERENCE FUZZY

Rules	Demand	Inventory	Function Implications	Production
R1	DOWN	MANY	⟹	DECREASE
R2	DOWN	MANY	⟹	INCREASE
R3	DOWN	LESS	⟹	DECREASE
R4	DOWN	LESS	⟹	INCREASE
R5	UP	MANY	⟹	DECREASED
R6	UP	MANY	⟹	INCREASE
R7	UP	LESS	⟹	DECREASE
R8	UP	MANY	⟹	INCREASE

From the rules formed in Table II, based on the rules on fuzzy inference, there are 4 possible rules and according to the knowledge base, namely:

TABLE III
CONCLUSIONS THE RESULTS OF THE RULES WERE FORMED ON INFERENCE FUZZY

Rules	Demand	Inventory	Function Implications	Production
R1	DOWN	MANY	⟹	DECREASED
R2	DOWN	LESS	⟹	DECREASED
R3	UP	MANY	⟹	INCREASE
R4	UP	LESS	⟹	INCREASE

The results of the conclusion from Table III are as follows:

[R1] IF Demand is DOWN, and Inventory is MANY, THEN Production of goods is DECREASED

[R2] IF Demand is DOWN, and Inventory is LESS, THEN PRODUCTION GOODS IS DECREASED

OF[R3] IF Demand is UP, and Inventory is MANY, THEN Production of goods is INCREASE

INCREASED [R4] IF Demand is increasing, and supply is LITTLE, THEN Production of goods is INCREASE

2) Sugeno Method Completion

The rules used will be slightly modified, assuming that the amount of demand is always higher than the supply. From the rules formed based on the rule base oninference fuzzy, there are 4 possible rules according to the knowledge base, namely:

[R1] IF Demand is DOWN, and Inventory is MANY, THEN (Z) Production of goods = Demand-Supply

[R2] IF Demand DOWN, and Supply is LESS, THEN (Z) Production of goods = Demand

[R3] IF Demand is increasing, and supply is MANY, THEN (Z) Production of goods = Demand

[R4] IF Demand is increasing, and supply is LESS, THEN (Z) Production of goods = 1.1 * (Demand-Supply)

Problem solving with Sugeno:

1. Determine the variables involved in the process to be determined and the fuzzification function accordingly.

$$\mu[x] = \begin{cases} 0; & x \le a \\ (x-a)/(b-a) & a \le x \le b \\ 1; & x \ge b \end{cases}$$

$$\mu[x] = \begin{cases} 1; & x \le a \\ (b-x)/(b-a) & a \le x \le b \\ 0; & x \ge b \end{cases}$$

The value of a shows the minimum value and b shows the maximum value of a variable. shows the value of the membership function in a variable x. Equations (1) and (2) will be used for each variable in this first step. In this case, there are 3 variables to be modeled:

a. Demand (Pmt (x)) consists of 2 linguistic values, namely DOWN and UP. Based on the data on the smallest and largest demand in 2014, the membership function is formulated as follows.

$$\mu_{Pmt\ TURUN}(x) = \begin{cases} 1; & x < 75.000 \\ \frac{100.000-x}{100.000-75.000}; & 75.000 \le x \le 100.000 \\ 0; & x > 100.000 \end{cases} \quad (5)$$

$$\mu_{Pmt\ NAIK}(x) = \begin{cases} 0; & x < 75.000 \\ \frac{x-75.000}{100.000-75.000}; & 75.000 \le x \le 100.000 \\ 1; & x > 100.000 \end{cases} \quad (6)$$

Based on equations (5) and (6), if the demand is 80,000 pcs, then:

$$\mu_{Pmt\ TURUN}(80.000) = \frac{100.000-x}{100.000-75.000} = \frac{100.000-80.000}{25.000} = 0{,}8$$

$$\mu_{Pmt\ NAIK}(80.000) = \frac{x-75.000}{100.000-75.000} = \frac{80.000-75.000}{25.000} = 0{,}2$$

b. Inventory (Psd (y)) consists of 2 linguistic values, namely LESS and MANY. Based on the data on the smallest and largest demand in 2014, the membership function is formulated as follows.

$$\mu_{Psd\ SEDIKIT}(y) = \begin{cases} 1; & y < 0 \\ \frac{25.000-y}{25.000-0}, & 0 \le y \le 25.000 \\ 0; & y > 25.000 \end{cases} \quad (7)$$

$$\mu_{Psd\ BANYAK}(y) = \begin{cases} 0; & y < 0 \\ \frac{y-0}{25.000-0}; & 0 \le y \le 25.000 \\ 1; & y > 25.000 \end{cases} \quad (8)$$

Based on equations (7) and (8), if the supply is 10,000 pcs, then:

$$\mu_{Psd\ SEDIKIT}(10.000) = \frac{25.000-y}{25.000-0} = \frac{25.000-10.000}{25.000} = 0{,}6$$

$$\mu_{Psd\ BANYAK}(10.000) = \frac{y-0}{25.000-0} = \frac{10.000}{25.000} = 0{,}4$$

c. Production (z) consists of 2 linguistic values, namely DECREASED and INCREASED. This variable in the Sugeno method is in the form of a linear constant, not aset fuzzy.

2. Application of the implication function

Based on equations (5) and (6), if the demand is 80,000 pcs, then:

$$\mu_{Pmt\,TURUN}(80.000) = \frac{100.000 - x}{100.000 - 75.000} = \frac{100.000 - 80.000}{25.000} = 0{,}8$$

$$\mu_{Pmt\,NAIK}(80.000) = \frac{x - 75.000}{100.000 - 75.000} = \frac{80.000 - 75.000}{25.000} = 0{,}2$$

Based on equations (7) and (8), if the supply is 10,000 pcs, then:

$$\mu_{Psd\,SEDIKIT}(10.000) = \frac{25.000 - y}{25.000 - 0} = \frac{25.000 - 10.000}{25.000} = 0{,}6$$

$$\mu_{Psd\,BANYAK}(10.000) = \frac{y - 0}{25.000 - 0} = \frac{10.000}{25.000} = 0{,}4$$

Now we find and z value for each rule:
[R1] IF Demand is DOWN, and Supply is MANY, THEN (Z)
Production of goods = Demand-Supply

$$\alpha_1 = \mu_{pmtTURUN} \cap \mu_{psdBANYAK} \quad (9)$$
$$= \min(\mu_{pmtTURUN}(80.000), \mu_{psdBANYAK}(10.000))$$
$$= \min(0{,}8;0{,}4) = 0{,}4$$

From the rule [R1], the value is: = 80,000-10,000 = 70,000
[R2] IF Demand is DOWN, and Inventory is LESS, THEN (Z)
Production of goods = Demand

$$\alpha_2 = \mu_{pmtTURUN} \cap \mu_{psdSEDIKIT} \quad (10) \quad = \min(\mu_{pmtTURUN}(80.000), \mu_{psdSEDIKIT}(10.000))$$
$$= \min(0{,}8;0{,}6) = 0{,}6$$

From the [R2] rule, the value is = 80,000
[R3] IF Demand is UP, and Inventory is MANY, THEN (Z)
Production of goods = Demand

$$\alpha_3 = \mu_{pmtNAIK} \cap \mu_{psdBANYAK} \quad (11)$$
$$= \min(\mu_{pmtNAIK}(80.000), \mu_{psdBANYAK}(10.000))$$
$$= \min(0{,}2;0{,}4) = 0{,}2$$

From the rule [R3], the value is = 80,000
[R4] IF Demand is LESS, THEN (Z)
Production of goods = 1.1 * (Supply-Demand)

$$\alpha_4 = \mu_{pmtNAIK} \cap \mu_{psdSEDIKIT} \quad (12)$$
$$= \min(\mu_{pmtNAIK}(80.000), \mu_{psdSEDIKIT}(10.000))$$
$$= \min(0{,}2;0{,}6) = 0{,}2$$

From the [R4] rule, the value is:
= 1.1 * (80,000-10,000) = 77,000

3. Rule Composition (Aggregation)

The result of the application of the implication function of each rule, the MIN method is used to make the composition between all the rules.

$$\sum_{r=1}^{R} \propto_r z_r$$

With R the number of rules, the $\propto_r$ *fire strength* is r and the output is in the antecedent of the r-rule

4. Defuzzification

After output of each rule (), defuzzification is carried out by calculating the average centered weight of each rule.

$$Z_0 = \frac{\sum_{i=1}^{4} \alpha_i Z_i}{\sum_{i=1}^{4} \alpha_i}$$

$$= \frac{0{,}4 * 70.000 + 0{,}6 * 80.000 + 0{,}2 * 80.000 + 0{,}2 * 77.000}{0{,}4 + 0{,}6 + 0{,}2 + 0{,}2}$$

$$= 76.714{,}285$$

Z_0 is the result of packaging production. This result is also modified if it exceeds the maximum production limit, then it is changed to the maximum amount itself because it is impossible to produce more than the maximum production capacity.

3) Tsukamoto Method

The rules used still use the same assumptions, namely the assumption that the amount of demand is always higher than the supply. What is different lies in the production output of goods. In Sugeno, the output is a linear constant, while the Tsukamoto method produces a fuzzy set of output. From the rules formed based on the rule base on inference fuzzy, there are 4 possible rules and according to the knowledge base, namely:

[R1] IF Demand is DOWN, and Inventory is MANY, THEN (Z) Production of goods is DECREASED
[R2] IF Demand DOWN, and Inventory is LITTLE, THEN (Z) Production of goods is DECREASED
[R3] IF Demand is increasing, and Inventory is MANY, THEN (Z) Production of goods is INCREASED
[R4] IF Demand is UP, and Inventory is LESS, THEN (Z) Production of goods INCREASED

Completion problems with Tsukamoto:

1. Determine the variables involved in the process to be determined and the appropriate fuzzification function:

The calculation is the same as the Sugeno method, only differs in the production variables. In this case, there are 3 variables to be modeled:

a. Demand (Pmt (x)) consists of 2 linguistic values, namely DOWN and UP. Based on the data on the smallest and largest demand in 2018, the membership function is formulated as follows.

$$\mu_{Pmt\ TURUN}(x) = \begin{cases} 1; & x < 75.000 \\ \frac{100.000 - x}{100.000 - 75.000}; & 75.000 \le x \le 100.000 \\ 0; & x > 100.000 \end{cases}$$

$$\mu_{Pmt\ NAIK}(x) = \begin{cases} 0; & x < 75.000 \\ \frac{x - 75.000}{100.000 - 75.000}; & 75.000 \le x \le 100.000 \\ 1; & x > 100.000 \end{cases}$$

If the request is as many as 80,000 pcs, then:

$$\mu_{Pmt\ TURUN}(80.000) = \frac{100.000 - x}{100.000 - 75.000} = \frac{100.000 - 80.000}{25.000} = 0{,}8$$

$$\mu_{Pmt\ NAIK}(80.000) = \frac{x - 75.000}{100.000 - 75.000} = \frac{80.000 - 75.000}{25.000} = 0{,}2$$

b. Inventory (Psd (y)) consists of 2 linguistic values, namely LESS and MANY. Similar to equations (3) and (4) the first step of themethod Sugeno. Based on the data on the smallest and largest demand in 2018, the membership function is formulated as follows.

$$\mu_{Psd\ SEDIKIT}(y) = \begin{cases} 1; & y < 0 \\ \frac{25.000 - y}{25.000 - 0}; & 0 \le y \le 25.000 \\ 0; & y > 25.000 \end{cases}$$

$$\mu_{Psd\ BANYAK}(y) = \begin{cases} 0; & y < 0 \\ \frac{y - 0}{25.000 - 0}; & 0 \le y \le 25.000 \\ 1; & y > 25.000 \end{cases}$$

If the stock is 10,000 pcs, then:

$$\mu_{Psd\ SEDIKIT}(10.000) = \frac{25.000 - y}{25.000 - 0} = \frac{25.000 - 10.000}{25.000} = 0{,}6$$

$$\mu_{Psd\ BANYAK}(10.000) = \frac{y - 0}{25.000 - 0} = \frac{10.000}{25.000} = 0{,}4$$

c. Production (prod (z)) consists of 2 linguistic values, namely DECREASED and INCREASED.

The fuzzy set membership functions are as follows.

$$\mu_{Prod\ BERKURANG}(z) = \begin{cases} 1; & z < 57.500 \\ \frac{100.000 - z}{100.000 - 57.500}; & 57.500 \le z \le 100.000 \\ 0; & z > 100.000 \end{cases}$$

$$\mu_{Prod\ BERTAMBAH}(z) = \begin{cases} 0; & z < 57.500 \\ \frac{z-57.500}{100.000-57.500}; & 57.500 \leq z \leq 100.000 \\ 1; & z > 100.000 \end{cases}$$

2. Application function implications

If the request is as many as 80,000 pcs, then:

$$\mu_{Pmt\ TURUN}(80.000) = \frac{100.000-x}{100.000-75.000} = \frac{100.000-80.000}{25.000} = 0{,}8$$

$$\mu_{Pmt\ NAIK}(80.000) = \frac{x-75.000}{100.000-75.000} = \frac{80.000-75.000}{25.000} = 0{,}2$$

If the stock is 10,000 pcs, then:

$$\mu_{Psd\ SEDIKIT}(10.000) = \frac{25.000-y}{25.000-0} = \frac{25.000-10.000}{25.000} = 0{,}6$$

$$\mu_{Psd\ BANYAK}(10.000) = \frac{y-0}{25.000-0} = \frac{10.000}{25.000} = 0{,}4$$

Now we find $\alpha_{predikat}$ and z value for each rule:

[R1] IF Demand is DOWN, and Supply is MANY, THEN (Z) Production of goods is DECREASED

$\alpha_1 = \mu_{pmtTURUN} \cap \mu_{psdBANYAK}$

$= \min(\mu_{pmtTURUN}(80.000), \mu_{psdBANYAK}(10.000))$

= min(0,8;0,4) = 0,4

From the rule [R1] above, the value is

= 100,000-0.4 (100,000-57,500) = 83,000

[R2] IF Demand is DOWN, and Supply is LESS, THEN (Z) Production of goods DECREASED

$\alpha_2 = \mu_{pmtTURUN} \cap \mu_{psdSEDIKIT}$

$= \min(\mu_{pmtTURUN}(80.000), \mu_{psdSEDIKIT}(10.000))$

= min(0,8;0,6) = 0,6

From the [R2] rule above, the value is

= 100,000-0.6 (100,000-57,500) = 74,500

[R3] IF Demand is UP, and Supply is MANY, THEN (Z) Production of goods is INCREASED

$\alpha_3 = \mu_{pmtNAIK} \cap \mu_{psdBANYAK}$

$= \min(\mu_{pmtNAIK}(80.000), \mu_{psdBANYAK}(10.000))$

= min(0,2;0,4) = 0,2

From the rule [R3] above, the value is

= 0.2 (100,000-57,500) + 57,500 = 66,000

[R4] IF Demand is UP, and Supply is LESS, THEN (Z) Production of goods = INCREASED

$\alpha_4 = \mu_{pmtNAIK} \cap \mu_{psdSEDIKIT}$

$= \min(\mu_{pmtNAIK}(80.000), \mu_{psdSEDIKIT}(10.000))$

= min(0,2;0,6) = 0,2

From the rule [R4] above, the value is obtained:

= 0.2 (100,000-57,500) + 57,500 = 66,000

3. Composition of Rules

The result of the application of the implication function of each rule, the MIN method is used to make the composition between all the rules the same as Sugeno. After the composition of the rules is carried out, the output is obtained through the defuzzification step which will be explained in the next step

4. Defuzzification

Defuzzification used the same approach with Sugeno, which is the average weight centered(weighted average)

$$Z_0 = \frac{\sum_{i=1}^{4} \alpha_i Z_i}{\sum_{i=1}^{4} \alpha_i}$$

$$= \frac{0{,}4*83.000 + 0{,}6*74.500 + 0{,}2*66.000 + 0{,}2*66.000}{0{,}4+0{,}6+0{,}2+0{,}2}$$

= 74.500

Z_0 is the result of packaging production. This result is also modified if the production result is less than the difference between demand and supply, then it is converted into the difference in demand and supply itself because it is assumed that the amount of production is not less than demand but still not more than the limit of the maximum production amount.

B. Calculation of Data

The data to be calculated is the data in Table I processed using Sugeno and Tsukamoto's method, so it will be concluded which method is closer to the company's actual production data.

TABLE IV
PACKAGING PRODUCTION DATA

Month	Request (pcs)	Inventories (pcs)	Production Company (pcs)	Yield	
				Sugeno	Tsukamoto
January	75,000	0	100,000	75,000	75,000
March	75,000	25,000	57,500	50,000	57,500
May	75,000	7,500	75,000	72 750	75,350
July	75,000	7,500	75,000	72 750	75,350
September	100,000	7,500	100,000	100,000	92,500
November	75,000	7,500	75,000	72,750	75,350

Based on Table IV, the results of production calculations using the Sugeno and Tsukamoto method are not so far from the results compared to the production data of the company PT. XYZ. From Table IV, it can be seen and compared which method is closer to the actual company data. In January, Sugeno and Tsukamoto's results were as big as the company's production data with a difference of 25,000 pcs. In March, Tsukamoto's results have the same data as the company's production data compared to Sugeno's results which have a difference of 7,500 pcs. In May, July and November, Tsukamoto's results have350data pieces of onlycompared to Sugeno's results which have a difference of 2,250 pcs.

4. Conclussion

Based on the discussion of the inference system fuzzy Sugeno method and Tsukamoto method, the following conclusions can be draw.

From Sugeno and Tsukamoto's FIS calculations, it can be calculated how much data is closest to company data. The following is the approximate data for each method:

a) Sugeno method: 1 data is closest compared to Tsukamoto
b) Tsukamoto method: 4 data closest compared to Sugeno
c) Sugeno and Tsukamoto's method: 1 the value data of both are the same.

So it can be concluded that the Tsukamoto method is most suitable for determining the amount of goods produced by PT. XYZ.

5. References

1. Cavallaro, F.; Ciraolo, L. Design and implementation of a fuzzy inference model for mapping the sustainability of energy crops. In *Soft Computing Applications for Renewable Energy and Energy Efficiency*; García-Cascales, M., Sánchez-Lozano, J.M., Masegosa, A.D., Cruz-Corona, C., Eds.; IGI Global: Hershey, PA, USA, 2015.
2. Camastra, F.; Ciaramella, A.; Giovannelli, V.; Lener, M.; Rastelli, V.; Staiano, A.; Staiano, G.; Starace, A. A fuzzy decision system for genetically modified plant environmental risk assessment using Mamdani inference. *Exp. Sys. App.* 2015, *42*, 1710–1716.
3. Pappis, C.P.; Siettos, C.I. Fuzzy reasoning. In *Introductory Tutorials in Optimization and Decision Support Techniques*; Burke, E.K., Kendall, G., Eds.; Kluwer: Boston, MA, USA, 2005.

4. Cornelissen, A.M.G.; van den Berg, J.; Koops, W.J.; Grossman, M.; Udo, H.M.J. Assessment of the contribution of sustainability indicators to sustainable development: A novel approach using fuzzy set theory. *Agr. Eco. Env.* 2001, *86*, 173–185.
5. Öztaysi, B.; Behret, H.; Kabak, Ö.; Uçal Sarı, I.; Kahraman, C. Fuzzy inference systems for disaster response. In *Decision Aid Models for Disaster Management and Emergencies*; Vitoriano, B., Montero, J., Ruan, D., Eds.; Atlantis-Springer: Amsterdam, Holland, 2013.
6. Bezdek, J.C. Fuzzy models—What are they, and why? *IEEE Trans. Fuzzy Sys.* 1993, *1*, 1–6.
7. Dubois, D.; Esteva, F.; Godo, L.; Prade, H. Fuzzy-set based logics—An history-oriented presentation of their main developments. In *Handbook of the History of Logic*; Gabbay, D.M., Woods, J., Eds.; Elsevier: Amsterdam, The Netherlands, 2007.
8. Klir, G.J.; Yuan, B. *Fuzzy Sets and Fuzzy Logic—Theory and Applications*; Prentice Hall: Upper Saddle River, NJ, USA, 1995.
9. Tanaka, K. *An Introduction to Fuzzy Logic for Practical Applications*; Springer-Verlag: New York, NY, USA, 1991.
10. Takagi, T.; Sugeno, M. Fuzzy identification of systems and its applications to modeling and control. *IEEE Trans. Sys. Man. Cybern.* 1985, *15*, 116–132.
11. Phillis, Y.A.; Andriantiatsaholiniaina, L.A. Sustainability: An ill-defined concept and its assessment using fuzzy logic. *Ecol. Econ.* 2001, *37*, 435–456.
12. 19. Hussain, H.I., Kamarudin, F., Thaker, H.M.T. & Salem, M.A. (2019) Artificial Neural Network to Model Managerial Timing Decision: Non-Linear Evidence of Deviation from Target Leverage, *International Journal of Computational Intelligence Systems*, 12 (2), 1282-1294.
13. Phillis, Y.A.; Kouikoglou, V.S.; Andriantiatsaholiniaina, L.A. Sustainable development: A definition and assessment. *Env. Eng. Manag. J.* 2003, *2*, 345–355.
14. William Ocampo-Duque, W.; Ferré-Huguet, N.; Domingo, J.L.; Schuhmacher, M. Assessing water quality in rivers with fuzzy inference systems: A case study. *Env. Int.* 2006, *32*, 733–742.
15. Shi, X., Dini, A., Shao, Z., Jabarullah, N.H. & Liu, Z. (2019) Impacts of photovoltaic/ wind turbine/ microgrid turbine and energy storage system for binding model in power system, Journal of Cleaner Production, 226, 845-857.
16. Lermontov, A.; Yokoyama, L.; Lermontov, M.; Machado, M.A.S. River quality analysis using fuzzy water quality index: Ribeira do Iguape river watershed, Brazil. *Ecol. Indic.* 2009, *9*, 1188–1197.
17. Fischer, B.E.A. Fuzzy approaches to environmental decisions: Application to air quality. *Env. Sci. Pol.* 2006, *9*, 22–31.
18. Prato, T. Adaptively managing wildlife for climate change: A fuzzy logic approach. *Env. Manag.* 2011, *48*, 142–149.
19. Marchini, A.; Facchinetti, T.; Mistri, M. F-IND: A framework to design fuzzy indices of environmental conditions. *Eco. Indic.* 2009, *9*, 485–496.
20. Gonzalez, B.; Adenso-Daz, B.; Gonzalez-Torre, P.L. A fuzzy logic approach for the impact assessment in LCA. *Res. Cons. Rec.* 2002, *37*, 61–79.
21. Silvert, W. Ecological impact classification with fuzzy sets. *Ecol. Model.* 1997, *96*, 1–10.