JURNAL ILMIAH TEKNIK INDUSTRI
ISSN: 1412-6869 (Print), ISSN: 2460-4038 (Online)
Journal homepage: http://journals.ums.ac.id/index.php/jiti/index
doi:10.23917/jiti.v19i1.10295

Fuzzy Logic Approach to Determine the Optimum Nugget Production Capacity

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Abstract. *This research aimed to present the Fuzzy approach in determining the optimal production capacity of the Nugget Production. The Fuzzy Model was developed by using two membership sets, i.e., the Overall Equipment Effectiveness (OEE) variable membership set of the production machine and Nugget Demand Forecasting. Nugget demand forecasting uses an exponential smoothing method due to its time-series type of query history data. OEE values were calculated using Availability, Performance, and Quality Yield. In the Fuzzy approach, the Forecasting Membership Set uses the Triangular Membership Function type, and the OEE Membership Set uses the Trapezoidal Membership Function type. The fuzzy set model produced can be used as a tool for the company in determining the value of the Optimal Capacity production so that demands can be fulfilled and the product stocks decrease.*

Keywords: *fuzzy approach, OEE, forecasting, membership set, optimal capacity*

I. INTRODUCTION

Increasing demand for nugget products requires companies to evaluate the effectiveness of the production machine periodically. The problem currently arises is that the company cannot determine the optimal level of nugget production based on the effectiveness value of production machine owned. This condition causes companies to experience excess stocks or insufficient products to sell to consumers. The company's two variables in determining the optimal production amount include the demand forecasting and Overall Equipment Effectiveness (OEE) value of the nugget production line.

Nugget demand forecasting is an activity carried out by the Production Planning and Inventory Control (PPIC) division. Nugget is a processed food product consumed by the community with chicken meat as the primary raw material. The characteristic of this product is that it is easily damaged if stored too long in a warehouse so that the production level produced by the company must be following the amount of market demand to reduce the accumulation of product stocks in the warehouse.

The determination of the nugget production amount must be based on the machine's capability and demand level. If they are not suitable, the product will be damaged as it is stored too long in the warehouse, and the company will suffer losses. Optimal production capacity can support the efficiency of the production process.

The PPC system is conducted by taking into account several factors, i.e., material planning, demand management, machine capacity planning, scheduling, and work order (Stevenson et al., 2005). Suitability between the amount of production and demand can maintain the amount of stock owned by the company in optimal condition.

The company's optimal production level is affected by the readiness of the production machine and accurate demand forecasting so that market demand can be fulfilled. These two variables should be used as a basis to determine the ideal amount of production level in the company.

The capability of the nugget production machine must be evaluated by examining the

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Submited: 19-02-2020 Revised: 03-05-2020
Accepted: 19-06-2020

machine's effectiveness in the production process. The effectiveness of the production machine can be determined from the operating time of machine (Availability), time used for production (Performance), and the capability to produce quality products (Quality Yield). These three variables can produce the effective value of the machine in production, or also called as the Overall Equipment Effectiveness (OEE).

OEE is a measurement tool that can be used to evaluate the achievement of the actual production time of the machine in producing quality products under the machine's operating time available in the company (Da Costa & De Lima, 2002). OEE can be used to evaluate the machine's performance based on the operating time of machine (Availability), machine's performance to utilize the production time (Performance), and quality of the product produced (Quality yield) (Singh et al., 2013). The better the OEE value, the better the machine's capability to produce nuggets with quantity and quality suitable with the production target that can be achieved.

Planning the production process can be done using a mathematical approach called the hierarchical concept of Production planning (Maravelias, 2009). To determine the amount of nugget production, nugget demand forecasting is necessary to conduct by using sales history data owned by the company. Demand forecasting is a PPIC's activity required to maintain stock availability in the warehouse. Demand forecasting produces data of the upcoming production amount so that the company can prepare the production machine to achieve the production targets set by the company.

The process of determining the nugget production level must be conducted by examining each influential variable, including the production machine's ability and the nugget demand history data. These two variables are necessary to achieve the optimal production level of the company. They must be integrated into one optimal production model by using the fuzzy approach. Variables that can be fuzzified in determining the optimal nugget production level are the effectiveness value of the production machine and product demand forecasting as these two variables significantly affect the achievement of the company's production targets.

Aggregate planning is a tool in production planning that examines the production unit's decision variables, working time, and production level (Baykasoglu & Gocken, 2010a). The model of determining the optimal production amount by using the fuzzy approach can provide accurate information about the optimal production level. In the fuzzy mathematical model, all influential parameters can be defined as fuzzy numbers so that the model issued follows the condition of the variables that influence it (Baykasoglu & Gocken, 2010b).

Demand forecasting requires 5 stages, including analysis of history demand data type owned, determination of the forecasting model following the history data type, smoothing data, forecasting calculation based on the suitable forecasting model, and error level calculation from the forecasting results. These stages must be carried out so that demand forecasting results can be used as a basis for the company's production planning (Brown & Meyer, 1961). Several factors affect machine productivity in achieving production targets, including the ability of operators, raw materials, machines' capacity to operate, and production scheduling (Oechsner et al., 2002).

The capacity of production facilities by examining the characteristics of existing machine types can determine the company's operational management in production planning (Taylor et al., 2007). Adequate machine productivity is supported by considerate production planning and supervision. The decision approach in determining production planning and scheduling focuses on strategic planning, tactics, and operational supervision (Bitran, 1993). The importance of the coordination approach is a solution to production planning and supervision.

Adequate coordination in production planning activities is implemented by integrating master production schedules with the level of raw material requirements (Rishel & Christy, 1996). In reverse logistics, the remanufacturing system is one concept in planning and controlling products on the product cycle (manufacturing to recycling) and can produce maximum profits (Dejax et al., 2012). The uncertainty factor in the manufacturing system becomes an obstacle for the company in conducting production planning (Mula et al., 2006).

Development in aggregate planning needs to be considered with the number of stakeholders within the company network, multi-product produced, and seasonal demand situation. In a supply chain network, retail companies are important stakeholders in aggregate planning to the number of products ordered to factories and product pricing (Yaghin et al., 2012).

Set-Up/Adjustment is planned downtime following the maintenance schedule and can be managed by the company; however, unreasonable downtime is a condition of a dysfunctional engine outside the maintenance schedule which can cause company losses as the machine availability decreases and production targets will not be achieved (Anvari et al., 2010). The effectiveness of the production machine can be seen from the performance of the machine. The decline in engine performance can be caused by monetizing engine speed (speed loss), creating production targets not to be achieved (Tsarouhas, 2013). The number of defective products produced will affect the OEE value caused by the machine not working properly (Muchiri & Pintelon, 2008).

The weakness of OEE calculation is that the losses generated are deterministic as they originate from variables only related to the production machine. Other variables need to be considered in determining the machine effectiveness value of the to achieve production targets. Fuzzy logic can be used in developing a method to calculate machine effectiveness because it can build a model based on variables affecting their effectiveness so that the calculation results are accurate as there are linguistic variables in it (Zammori, 2015).

Fuzzy logic can be used to solve complex production problems and supervise the production process in which several variables influence it, so that decision making becomes more accurate (Figueroa-García et al., 2012). Product stock, labor, machine capacity, storage space, and time value can be used as a reference in determining the fuzzy logic of production decision making (Wang & Liang, 2004).

II. RESEARCH METHOD

Exponential Smoothing

The exponential smoothing forecasting model involves historical data with time-series data types. This method uses the error forecast (value α) so that the results obtained will be following the trust level on the data. The error value is in the range of 0-1. The formulation of forecasting using the exponential smoothing method is as follows (Cadenas et al., 2010).

$$F_{t+1} = F_t + \alpha (Y_t - F_t) \qquad ....(1)$$

Note

F_{t+1} = History demand data n

F_t = History demand forecasting data n-1

Y_t = Actual demand data n-1

α = Real level

Determination of Forecasting Accuracy Level

It is necessary to make a statistical comparison of the error results generated by the exponential smoothing method to see the smallest error value. One calculation method to determine statistical error is the use of the Mean Absolute Percentage Error (MAPE) (Cadenas et al., 2010). The formulation of MAPE is as follows.

$$\mathrm{MPE} = \frac{1}{n}\sum_{t=1}^{n} PE_t \qquad ....(2)$$

Determination of OEE Value

There are 3 variables that affect OEE calculations, namely, Availability, Performance, and Quality Yield. Availability (A) is the ability of a machine to operate and is affected by unplanned downtime (Garza-Reyes et al., 2010). The availability formulation is as follows.

$$\mathrm{A} = \frac{\text{Loading Time} - \text{Downti}}{\text{Loading Time}} \qquad ....(3)$$

Performance (P) is the ability of a machine to use the time for production. The performance value will be influenced by the production level produced and the sufficient time achieved by the machine for production (Garza-Reyes et al., 2010). The performance formulation is as follows.

$$P = \frac{\text{Ideal Cycle Time x Output}}{\text{Operating Time}} \quad \text{...(4)}$$

Quality Yield (Q) is the ability of a machine to produce products that are not defective or in accordance with the company quality (Garza-Reyes et al., 2010). The quality yield formulation is as follows.

$$Q = \frac{\text{Input x Volume of Quality Defect}}{\text{Input}} \quad \text{...(5)}$$

OEE value can indicate the effectiveness of a production machine. OEE value is influenced by the value of Availability (A), Performance (P), and Quality Yield (Q) (Wudhikarn, 2012). The OEE value formulation is as follows:

$$\text{OEE} = A \times P \times Q \quad \text{....(6)}$$

Fuzzy Membership Function

The Fuzzy membership function uses the Trapezoidal Membership Function if there is more than one value of the highest membership degree that is 1, on the membership set graph. Meanwhile, the Triangular Membership Function is used if there is one value of the highest membership degree that is 1, on the membership set graph that occurs. The graph of the Trapezoidal membership set (a, b1. b2, c) can be seen in Figure 1 (Amindoust et al., 2012).

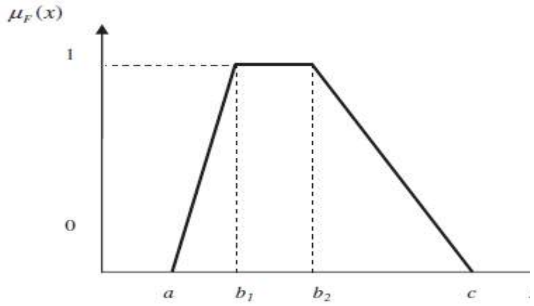


Figure 1. Trapezoidal fuzzy number.

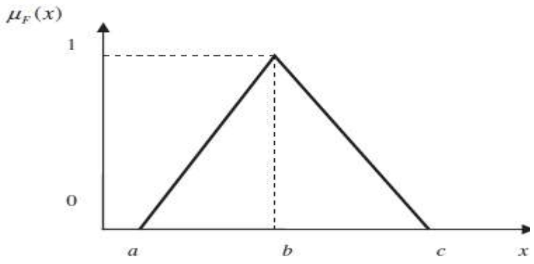


Figure 2 Triangular Fuzzy Number

Based on the graph of the Trapezoidal membership function, the Fuzzy membership function μF (a b b1, b2 bc): R → [0 , 1] obtained is as follows.

$$Fx(a,b1,b2,c) \begin{cases} (x-a)/(b1-a) & a \le x \le b1 \\ 1 & b1 \le x \le b2 \\ (c-x)/(c-b2) & b2 \le x \le c \\ 0 & \text{Otherwise} \end{cases}$$

The membership set graph of Triangular (a, b, c) can be seen in Figure 2 (Rezaei & Ortt, 2013).

Based on the graph of the Triangular membership function, the membership function μF (a, b, c): R → [0,1] used in the model is as follows.

$$Fx(a, b, c) \begin{cases} (x-a)/(b-a) & a \le x \le b \\ 1 & x = b \\ (c-x)/(c-b) & b \le x \le c \\ 0 & \text{Otherwise} \end{cases}$$

Fuzzy Rule Base System

The logic used in fuzzy to solve problems in the system without mathematical explanation adopts the IF Than Else rule principle. There are several uses of a fuzzy rule-based system, including changing the input value of possible variables that occur using knowledge from the database and rule base to the membership degree, then defuzzification can be done (Phillis & Andriantiatsaholiniaina, 2001). If the selected operator in the Fuzzy Rule-Based is "and", the operator value is the minimum (min), and if the selected operator is "Or", the operator value is the maximum (max) (Mamdani, 1976).

Defuzzification

Center of Area (COA) is a defuzzification method that can be used to determine the value of the fuzzy set based on the area and moment of the generated fuzzy set (Amindoust et al., 2012).

COA method in determining the defuzzification value can be formulated as follows.

$$Xcoa = \frac{\sum_{i=1}^{n} xi.\mu i(xi)}{\sum_{i=1}^{n} \mu i(xi)} \qquad ...(7)$$

III. RESULT AND DISCUSSION

Nugget Demand Forecasting

One variable that influences the determination of optimal production capacity is the demand for nuggets. The problem currently occurs is that the company has a high demand, but the production capacity cannot fulfill the demand. This condition requires the company to have a model to determine the optimal production capacity based on the market. The company must conduct production planning, one of which is product demand forecasting.

Table 1. Demand for Nuggets in 2018

No	Month	Nugget Production (Kg)
1	January	99,375
2	February	108,789
3	March	104,410
4	April	113,388
5	May	120,480
6	June	97,725
7	July	110,606
8	August	117,542
9	September	120,816
10	October	114,159
11	November	111,308
12	December	122,301

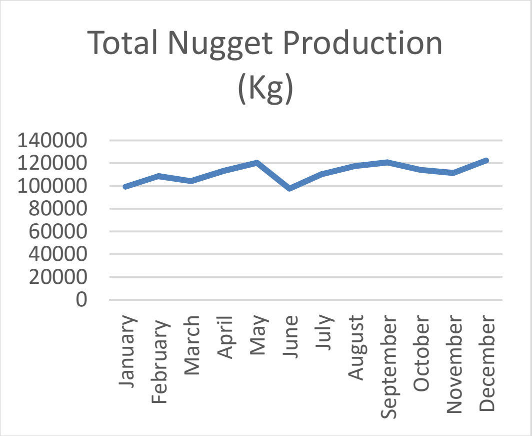


Figure 3. Data of Nugget Demand in 2018

Demand forecasting was conducted using nugget demand data for one year in 2018. Data on nugget demand from the company in 2018 can be seen in Table 1. The data showed demand trends in 2018. The demand type is a time series in which demand for nuggets tends to increase. Nugget demand trends can be seen in Figure 3.

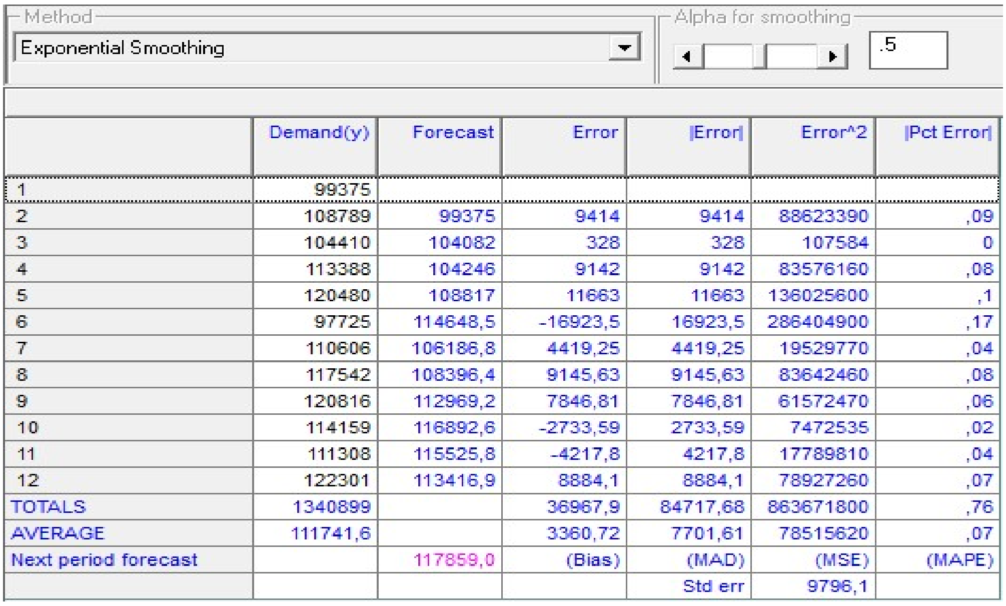
The demand data are the time series type, so the exponential smoothing method can be used to determine the demand forecasting in 2019. Forecasting uses an exponential smoothing method. At the demand forecasting stage, the accuracy level was compared by α = 0.5 The results of demand forecasting with the smallest errors were then be used as the result of nugget demand forecasting in the following month in 2019, which were included in the membership set of demand levels for nugget products. The calculation results of the accuracy level can be seen in Figure 4.

Based on the calculation of the accuracy level, the value of Mean Absolute Percentage Error (MAPE) 0,07 and the forecasting result of nugget demand in January 2019 was 117,859 kg.

Calculation of OEE Nugget Production Line

The production process is inseparable from the readiness of the production machine. Its availability will support the company in achieving production targets successfully. The result of the demand for nuggets is the company's next production target, so the production machine must work optimally to reach the target. The company currently faces a problem in determining the optimal production capacity based on the demand forecasting value and the machine effectiveness on the production line.

The method used in determining the effectiveness of production machines was Overall Equipment Effectiveness (OEE). In this research, OEE 1 was calculated for the nugget production line in 2018. This OEE value was then included in the Fuzzy Membership Set to determine the membership degree.



Method: Exponential Smoothing

Alpha for smoothing: .5

	Demand(y)	Forecast	Error	|Error|	Error^2	|Pct Error|
1	99375					
2	108789	99375	9414	9414	88623390	,09
3	104410	104082	328	328	107584	0
4	113388	104246	9142	9142	83576160	,08
5	120480	108817	11663	11663	136025600	,1
6	97725	114648,5	-16923,5	16923,5	286404900	,17
7	110606	106186,8	4419,25	4419,25	19529770	,04
8	117542	108396,4	9145,63	9145,63	83642460	,08
9	120816	112969,2	7846,81	7846,81	61572470	,06
10	114159	116892,6	-2733,59	2733,59	7472535	,02
11	111308	115525,8	-4217,8	4217,8	17789810	,04
12	122301	113416,9	8884,1	8884,1	78927260	,07
TOTALS	1340899		36967,9	84717,68	863671800	,76
AVERAGE	111741,6		3360,72	7701,61	78515620	,07
Next period forecast		117859,0	(Bias)	(MAD)	(MSE)	(MAPE)
				Std err	9796,1	

Figure 4. Forecasting Demand Nugget Result Using POM for Windows

Table 4. OEE Value of Nugget Production Line (2018-2019)

No	Month	Availability	Performance	Quality Yield	OEE
1	January	68.95%	28.57%	99.72%	19.64%
2	February	65.68%	53.03%	99.56%	34.68%
3	March	67.23%	66.89%	99.65%	44.81%
4	April	68.94%	69.06%	99.51%	47.37%
5	May	69.63%	59.82%	99.78%	41.56%
6	June	63.04%	74.78%	99.72%	47.02%
7	July	64.02%	94.20%	99.72%	60.14%
8	August	64.01%	71.74%	99.75%	45.81%
9	September	72.99%	98.67%	99.69%	71.80%
10	October	84.04%	37.10%	99.87%	31.13%
11	November	53.60%	97.71%	99.68%	52.21%
12	December	70.36%	96.58%	99.90%	67.89%
13	January	91.23%	91.94%	91.94%	**77.12%**

OEE values were obtained from the Availability, Performance, and Quality Yield values of the Nugget Production Line. The OEE value of the nugget production line in 13 months, from January 2018 to January 2019, can be seen in Table 4.

Based on the results of OEE calculations, the company's OEE value of the nugget production line in January 2019 was 77.12%. This condition was still considered bad because, according to Seiichi Nakajima, a good OEE value should be at least 85%. Looking at the trend, the problems of low OEE values were on the values of Availability and Performance of Production Line. The average value of availability for the past 13 months was 69.52% (machines only operated by 69.52% of the effective time they had), and the average performance value was 72.31% (only 72.31% of the machine's effective time was used for production). This condition was caused by frequent engine downtime outside the company's maintenance schedule.

OEE values affected the achievement of production targets set by the company through nugget demand forecasting. The company must determine optimal production based on OEE values and demand forecasting so that the company's demand can be fulfilled. The OEE value in January was 77.12%. It was included in the OEE Membership Set, and the Defuzzification process was carried out to obtain the company's ideal production level.

Fuzzy Model of Optimal production capacity

The initial stage of this research was to determine the ideal capacity membership set fuzzy model. This fuzzy model was obtained based on the data and interviews with the company's production department in which the highest nugget production level in this company was 200,000 kg/month.

The membership set in the Fuzzy model to determine the Optimal Nugget Capacity used the Trapezoidal membership set. The membership degree value of 1 was obtained when the production parameter values were 150,000 Kg—200,000 Kg. Based on interviews with the company's managers, the Membership Set parameters are as seen in Table 5.

The membership set in the fuzzy model of Optimal Capacity production of nuggets in this company uses the Trapezoidal type. Based on the parameter values, there is 2 membership graph. The membership graphs for high and low production types.

The membership degree value of 1 for high production parameter was 150,000 kg - 200,000 kg, while the membership degree value of 1 for low production parameter was 40,000 kg - 110,000 kg. The graph of the Optimal Capacity of Membership Set can be seen in Figure 5.

Based on the membership set graph above, the ideal production capacity of the membership set was obtained. Determination of the optimal nugget capacity was conducted by using 2 variables: the nugget demand forecasting and the OEE value of the production line. The optimal membership set of the nugget production capacity (in kg) is as follows.

$$Fx(a,b1,b2,c)\begin{cases} 0 & x \le 0 \\ 1 & 0 \le x \le 40{,}000 \\ \dfrac{110{,}000 - x}{70{,}000} & 40{,}000 \le x \le 110{,}000 \\ \dfrac{X - 110{,}000}{40{,}000} & 110{,}000 \le x \le 150{,}000 \\ 1 & 150{,}000 \le x \le 200{,}000 \end{cases}$$

Membership Set of Nugget Demand Forecasting

Demand forecasting for the company's nugget products was done by an exponential smoothing method in which this forecast used historical data of nuggets for 12 months in 2018. Based on the forecasting results with $\alpha = 0.5$, the demand in January 2019 was 117,859 kg. The results of this forecast are included in the Fuzzy membership set for the demand forecasting variables.

The nugget demand forecasting membership set is designed to use the Trapezoidal type as it has 2 parameters: high and low demands. Both parameters have a membership level of 1 at the request value of 0 - 40,000 kg and 130,000 kg - 160,000 kg. The nugget demand membership set parameters are seen in Table 6.

Based on the membership value above, the membership set graph of the amount of nugget demand forecasting can be determined using the Trapezoidal type. The graph of the demand forecasting membership set with a value of 117,859 kg can be seen in Figure 6.

Based on the demand forecasting results by

Table 5. Parameter of Optimal Nugget Production

Parameter	Parameter Value (kg)
High	0, 0, 40,000 , 110,000
Low	110,000 , 150,000 , 200,000 , 200,000

Table 6. Graph Parameter of Demand Forecasting Membership Set

Parameter	Parameter Value (kg)
High	0, 0, 40,000, 90,000
Low	90,000, 130,000, 160,000, 160,000

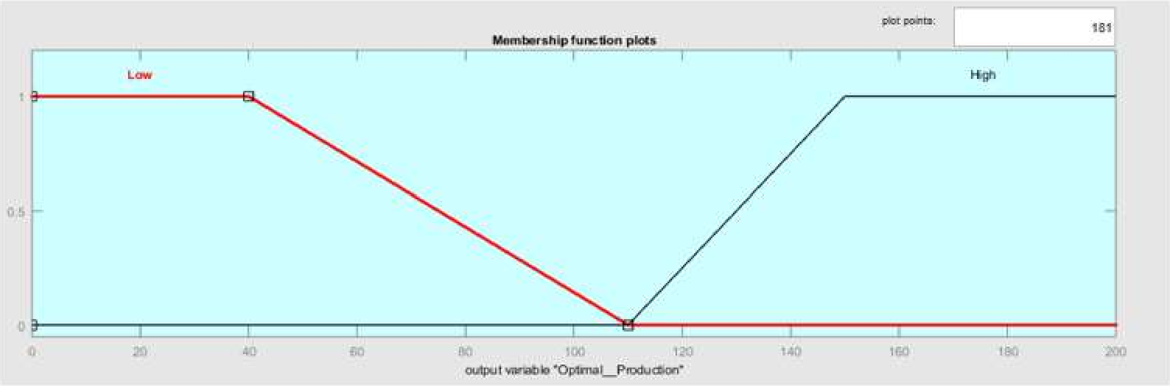


Figure 5. Optimal Production Capacity of Membership Set

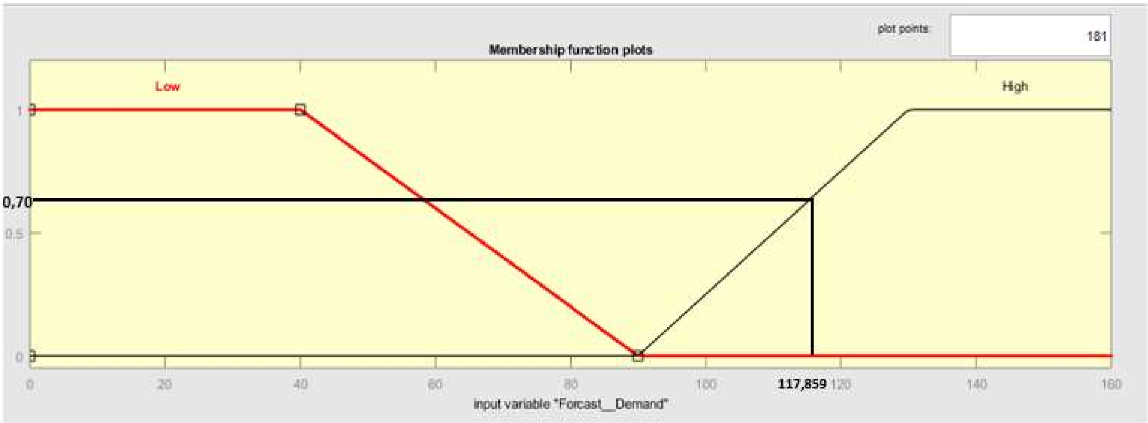


Figure 6. Membership Set Forecasting Nugget Requests (x1000 Kg)

using an exponential smoothing method with α = 0.5, the number of nuggets demand in January 2019 was 117,859 kg. The forecasting results were then put into the forecasting membership set chart to determine the membership degree of the forecasting results. Based on the forecasting results, the forecasting membership set is obtained as follows.

$$
Fx(a,b1,b2,c) \begin{cases} 0 & x \leq 0 \\ 1 & 0 \leq x \leq 40{,}000 \\ \dfrac{90{,}000 - x}{50{,}000} & 40{,}000 \leq x \leq 90{,}000 \\ \dfrac{X - 90{,}000}{40{,}000} & 90{,}000 \leq x \leq 130{,}000 \\ 1 & 130{,}000 \leq x \leq 160{,}000 \end{cases}
$$

Based on the forecasting membership set, the membership degree can be determined for the demand results of 117,859 kg. The forecasting demand results are at high parameter, and the results of the membership degree of forecasting nugget demand results are as follows.

$$
117{,}859 = \frac{X - 90{,}000}{40{,}000}
$$

$$
X = 0.70
$$

Based on the membership set with a parameter of high demand forecasting value, the membership degree obtained $\mu_{\text{Forecasting Result\_High}}$ $_{[17{,}859]}$ is 0.70. This value is used as an operator to determine fuzzy rule-based.

OEE Value Membership Set of Production Line

Based on the results of OEE calculations in the company's nugget production line, the OEE value in January 2019 was 77.12%. Based on the

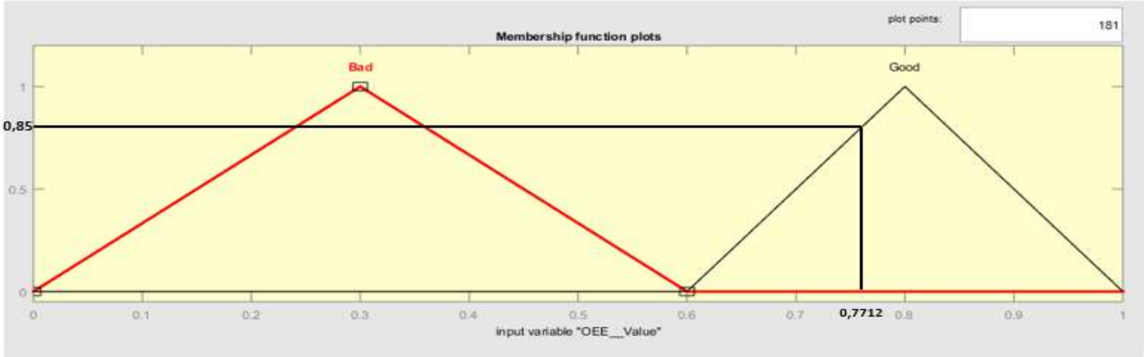


Figure 7. OEE Value Membership Set of Production Line

OEE value, the membership set graph of the value can be determined.

The membership set graph uses the Triangular type because the OEE value has a membership rate of 1 at the time of 30% and 80%. This set is the best OEE condition achieved by the company by looking at the capability of equipment, available raw materials, and human resources. Based on the membership set, there are two parameters obtained, namely: Good and Bad (see Table 7).

Based on the results of OEE calculations, the OEE value of the production line in January 2019 was 77.12%. The OEE value was then determined by the membership degree. The graph of the OEE value membership set can be seen in Figure 7.

The OEE value of the nugget production line in January 2019 was 77.12%. The OEE value was then put into the OEE value membership set of the nugget production line to determine the membership degree. Based on the OEE value, the OEE membership set of a production line is as follows.

Based on the membership set of OEE values, the membership degree for the OEE value is 77.12%. Based on the membership set with the OEE value parameter of the high production line, the membership degree of μOEE Value_High [77.12%] is 0.85. This value will be used as an operator in determining fuzzy rule-based.

Fuzzy Rule-Based System

Fuzzy Rule System Based is the process of determining the rules in fuzzy based on the value of membership degree of the demand forecasting variable and OEE value of the nugget production line. The principle of Fuzzy Rule-Based is to use the IF Then Else principle. Based on the membership set of nugget production level, there are 8 IF Then Else principles that may occur based on the membership set. The results of the Fuzzy Rule Base combination can be seen in Figure 8.

Based on the set of fuzzy demand forecasting and OEE value of the production line, we get 2 selected fuzzy rule-based, namely demand to forecast with high parameter values and good OEE parameter values. These two selected fuzzy rule-based will be used to determine the operator's value, which will be included in the company's optimal production capacity set graph.

The selected fuzzy rule-based produces a

Table 7. Graph Parameter of OEE Value Membership Set of Production Line

Parameter	Parameter Value (%)
Good	60, 80, 100
Bad	0, 30, 60

fuzzy operator value that will be used to determine the area and moment of the defuzzification process. The operator used is "and" in which the value of the selected operator is the minimum. The selected operator value is as follows.

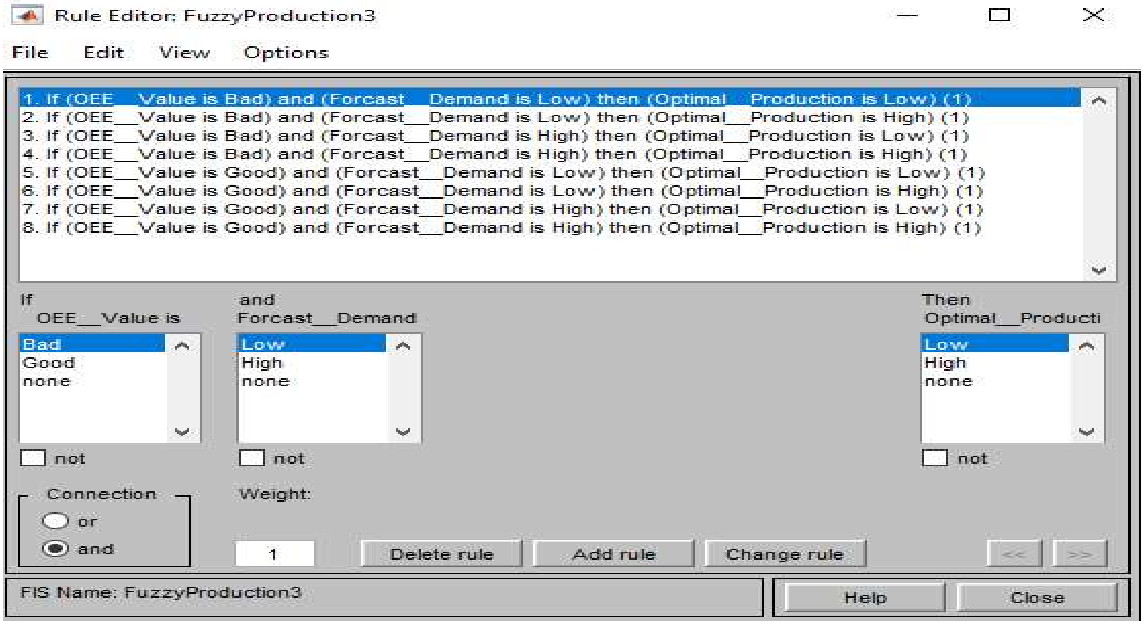
$$\alpha = \min\left(\mu_{\text{Forecasting Result\_High [17,859]}} \cap \mu_{\text{OEE Value\_High [77.12\%]}}\right)$$

$$= \min(0.70 \cap 0.85) = 0.70$$

Based on the results of determining the operator value, the fuzzy operator value was 0.70. This value was used as the degree of fuzzy membership set of optimal capacity and used to determine the area and moment to determine the optimal nugget production capacity. Based on the operator value, the graph of the optimal production capacity membership set is as can be seen in Figure 9.

Membership Set Area Widths

The area of the membership set was determined next based on the results of determining the operator value on the membership set of optimal production levels. There were 4 (four) area widths occurred based on the Fuzzy operator graph. The area widths occurred are as follows.



1. If (OEE__Value is Bad) and (Forcast__Demand is Low) then (Optimal__Production is Low) (1)
2. If (OEE__Value is Bad) and (Forcast__Demand is Low) then (Optimal__Production is High) (1)
3. If (OEE__Value is Bad) and (Forcast__Demand is High) then (Optimal__Production is Low) (1)
4. If (OEE__Value is Bad) and (Forcast__Demand is High) then (Optimal__Production is High) (1)
5. If (OEE__Value is Good) and (Forcast__Demand is Low) then (Optimal__Production is Low) (1)
6. If (OEE__Value is Good) and (Forcast__Demand is Low) then (Optimal__Production is High) (1)
7. If (OEE__Value is Good) and (Forcast__Demand is High) then (Optimal__Production is Low) (1)
8. If (OEE__Value is Good) and (Forcast__Demand is High) then (Optimal__Production is High) (1)

Figure 8. Fuzzy Rule-Based on Optimal Capacity of Nugget Production

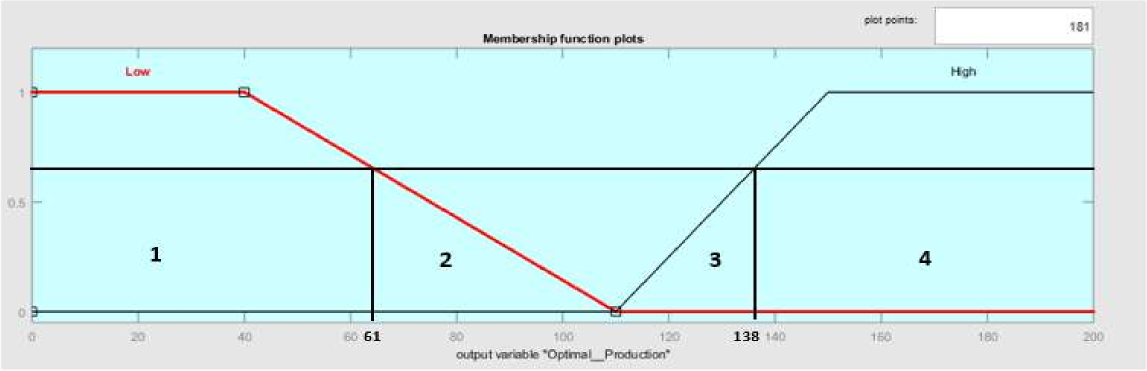


Figure 9. Graph of Fuzzy Operator Membership Set = 0.7 (x1000)

$$\text{WA 1} = (60{,}000 - 0) \times 0.7 = 42{,}700$$

$$\text{WA 2} = \frac{(110{,}000 - 61{,}000) \times 0.7}{2} = 17{,}250$$

$$\text{WA 3} = \frac{(138{,}000 - 61{,}000) \times 0.7}{2} = 9{,}800$$

$$\text{WA 4} = (200{,}000 - 138{,}000) \times 0.7 = 43{,}400$$

There were 4 (four) area widths occurred in the membership set graph of optimal production capacity. The total of four areas in the graph were 113.05. The area widths were used in the defuzzification process by using the Center of Area (COA) method.

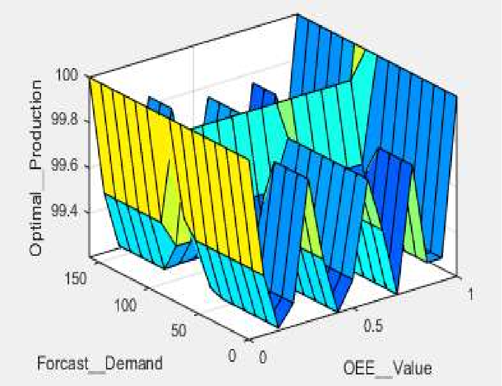
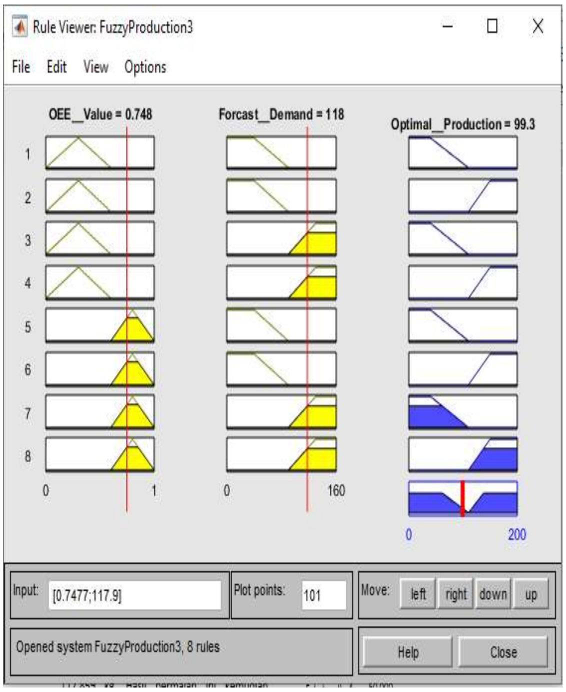


Figure 5. Graph of Optimal Production



OEE_Value = 0.748

Forcast_Demand = 118

Optimal_Production = 99.3

Input: [0.7477;117.9]

Plot points: 101

Opened system FuzzyProduction3, 8 rules

Figure 6. The Optimal Nugget Production Determination Model

Determination of Membership Set Moments

Five membership sets were obtained based on the Optimal Capacity Membership Set Graph of the Nugget Production Line. The limit of these membership sets was based on the area width that occurred. The membership set for Optimal Capacity based on the results of nugget demand forecasting and the OEE value of the nugget production line that arises is as follows.

$$Fx(a,b1,b2,c) \begin{cases} 0 & x \leq 0 \\ 0.7 & 0 \leq x \leq 61{,}000 \\ \dfrac{110{,}000 - x}{70{,}000} & 61{,}000 \leq x \leq 110{,}000 \\ \dfrac{X - 110{,}000}{40{,}000} & 110{,}000 \leq x \leq 138{,}000 \\ 0.7 & 138{,}000 \leq x \leq 200{,}000 \end{cases}$$

There are five membership sets formed from the Optimal Capacity membership set graph. Based on the five membership sets created, moments that occurred in this set were determined. Moments that occurred in the Optimal Capacity membership set (in 1000) are as follows.

$$\text{Moment 1} = \int_0^{61} 0.7 \;\; x \, dx$$

$$\text{Moment 2} = \int_{61}^{110} 1.57\, x - 0.014\, x2 \, dx$$

$$\text{Moment 3} = \int_{110}^{138} 0.25\, x2 - 2.75\, x \, dx$$

$$\text{Moment 4} = \int_{138}^{200} 0.7\, x \, dx$$

Based on the results, the total moments obtained after the integral process was 11230.2. The results of these total moments were then included in the defuzzification process by using the Center of Area (COA) method to get the Optimal Capacity value of the nugget production line.

The nugget production line's optimal capacity was obtained based on the defuzzification results of demand forecasting variables and the OEE value of the production machine. Based on the membership set results of optimal nugget production capacity, the area width occurred was 113.05, and the total moment occurred was 11230.02.

Based on the Center of Area (COA) method, the optimal production capacity in January 2019 was 99,300 kg/month. The characteristics of the fuzzy model in determining optimal capacity based on the above conditions can be seen in Figure 10.

Figure 10 shows that the company has gotten the optimal profit; however, if the company produces above the production, there will be excess stock, which can cause losses. The defuzzification model of optimal production capacity was developed by using the Matlab R2015a software to plan the next nugget production by the company. The planning model of optimal nugget production can be seen in Figure 11.

Based on the fuzzy model and forecasting demand, results obtained the difference in the amount of optimal production nuggets. Based on the fuzzy model received, an optimal production nugget is 99,300 kg, and according to forecasting, the result is 117,859 kg.

The difference in the optimal amount of production using the fuzzy model and demand forecasting shows that the level of production of nuggets is experiencing excess production, thereby increasing the amount of stock. By using this fuzzy model, the company can make identification in determining the optimal production of machines based on the condition of the effectiveness machine and forecasting demand nugget.

IV. CONCLUSION

The company experiences high demand; however, with the OEE production line of 77.12%, a demand of 117,859 kgs will not be profitable as the production line's optimal production capacity is only achievable 9,300 kgs. Based on the fuzzy approach, the company must conduct improvements to the maintenance system of its production machine, the availability of raw materials, and human resources used in the nugget production so that the OEE value can increase, and optimal production targets can be achieved.

ACKNOWLEDGMENT

The authors would like to thank all parties who have supported this research, especially the Industrial Management Study Program College of Vocational Studies IPB University, Management, Faculty of Economics and Business, University of Muhammadiyah Jakarta, and the nugget processing company who supported the provision of data needed by the authors. We hope this research can help companies in making decisions to determine the optimal capacity of nugget production using the fuzzy model that has been produced.

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