Matrik: Jurnal Manajemen, Teknik Informatika, dan Rekayasa Komputer
Vol. 22, No. 3, July 2023, pp. 505∼518
ISSN: 2476-9843, accredited by Kemenristekdikti, Decree No: 200/M/KPT/2020
DOI: 10.30812/matrik.v22i3.2938

Optimizing The Amount of Production Using Hybrid Fuzzy Logic and Census II

Susana Limanto, Vincentius Riandaru Prasetyo, Mirella Mercifia
Universitas Surabaya, Surabaya, Indonesia

Article Info

Article history:

Received April 30, 2023
Revised June 21, 2023
Accepted July 05, 2023

Keywords:

Census II
Forecasting
Fuzzy logic
Hybrid method
Optimal amount of production

ABSTRACT

The owner of a plastic spoon company in Gresik, East Java, was experiencing several problems related to consumer demand and uncertain changes in raw material prices, especially during the Covid-19 pandemic. This resulted in uncertainty in the purchase of raw materials and the amount of product produced. As a result, the company sometimes could not meet consumer demands, or there was a buildup of products in the warehouse. This study aimed to predict the amount of consumer demand and determine the amount of production. Prediction of the amount of consumer demand was calculated using Census II. While the determination of the optimal amount of production was done using the Fuzzy method. A consumer demand prediction process trial was carried out using sales data from January 2019 to December 2021 to predict January 2022 to May 2022. The prediction results provided an average accuracy of 82%. The sales, inventory, and production data of colored ducks spoons from May 2018 to May 2022 were used to determine the amount of production from January 2022 to May 2022. The results of determining the monthly average production were 77% accurate. The contribution of this research will simplify and speed up plastic spoon companies in determining the amount of production.

Corresponding Author:

Susana Limanto, +62822-2111-8110,
Faculty of Engineering and Informatics Engineering Study Program,
Universitas Surabaya, Surabaya, Indonesia,
Email: susana@staff.ubaya.ac.id

How to Cite:
S. Limanto, vincentius Prasetyo, and M. Mercifia, ”Optimizing the Amount of Production Using Hybrid Fuzzy Logic and Cencus II”, MATRIK : Jurnal Manajemen, Teknik Informatika dan Rekayasa Komputer, vol. 22, no. 3, pp. 505-518, Jul. 2023.

1. INTRODUCTION

Before production, a company must carry out production planning to run smoothly and efficiently [1–4]. The existence of production planning allows companies to reduce production costs so that they can market products at competitive prices [5–7]. Many things need to be considered in production planning, such as the availability of raw materials, production capacity, storage capacity, existing product stock, customer orders, the amount that should be produced, and production time.

Production planning that could be better can result in a company experiencing losses. One problem that arises due to the absence of good planning is excess or insufficient product stock [5, 6, 8, 9]. Excess product stocks can result in the deposition of business capital, reducing the availability of space [9], incurring storage costs [10], and losses in the event of product damage due to storage for too long. Meanwhile, a shortage of stock can result in non-fulfillment of customer demand, opening up opportunities for customers to switch to other companies. So far, there are still many companies that need help in planning production. Some causes of difficulties in production planning are fluctuations in customer demand for products produced occasionally [6, 10, 11], and the human resources' limited capabilities [5].

CV "X" is a company in the Gresik area, East Java. This company produces processed goods from plastic pellets. Goods produced include clear duck spoons, colored duck spoons, and teaspoons. So far, determining the type and quantity of goods to be produced is only based on customer demand and the availability of raw materials. However, customer demand has been erratic, especially during the COVID-19 pandemic. Likewise, the price of plastic pellets as the main raw material also fluctuates because it depends on the price index of plastic materials, oil prices, the rupiah exchange rate against the US dollar, and the availability and demand for world plastic pellets. This often makes it difficult for the company to carry out production planning. Therefore we need a system that can help the company to recommend the number of products that should be produced.

One of the supporting data needed to determine the number of raw materials that must be provided [8] and the number of products that must be produced [7] is the estimated number of customer requests in the coming period. The more accurate the supporting data available, the better the results of production planning are expected to be. Therefore we need a customer demand forecasting method that has high accuracy. One of the forecasting methods that have high accuracy is Census II. This forecasting method works by decomposing the seasonal, cycle, trend, and random elements contained in the data to provide a high-accuracy of results [8].

Fuzzy methods have been widely used to assist decision-making in various fields, such as analyzing customer satisfaction [12], detecting diseases [13], stock optimization [14–16], and determining the amount of production from various business fields. The use of the Fuzzy method to help determine the amount of apparel production is carried out by [11, 17, 18]. The input variables used by [11] are the number of customer requests and the number of workers. Reference [17] uses the number of customer requests, sales, and raw material inventory as input variables [17]. Meanwhile, [18] uses the number of customer requests and inventory as input variables. The system developed by [11] can deal with fluctuations in customer orders with an accuracy of 96%. Meanwhile, the system built by [18] can provide a better estimate of the amount of production than the system used by the previous Salman Collection.

Research conducted by [10, 19, 20] uses the Fuzzy method to determine the optimal production in the food business sector. Determination of the amount of egg roll cake production was carried out by [19] by using two input variables, namely: the number of customer requests and the amount of inventory. The same input variables are used by [10] at the Cinderella Bread House Factory. Meanwhile, [20] uses three input variables: the number of customer requests, the amount of finished goods inventory, and the amount of raw material inventory for PJ Menara Kudus. The results of an evaluation by [10] on the amount of boxed bread production in one day for three months (June - August 2018) at the Cinderella Bread House Factory, Ambon, gave an accuracy of 90.3%. Therefore, based on research conducted by [10, 11], it can be concluded that the Fuzzy method is very suitable to be implemented to determine the amount of production in a company because it has an accuracy above 90%. In addition, the Fuzzy method can also overcome fluctuating customer requests [11].

Several other studies using the Fuzzy method to determine the amount of production are the determination of the amount of rubber production [6] and the determination of the amount of palm oil production [21]. The input variables used by [6] are the number of customer requests and the amount of inventory. In contrast, those used by [21] are the number of receipts, the amount of inventory, and the amount of palm oil demand.

Based on the studies that have been done, this research implements the Fuzzy method to determine the amount of production, where the two inputs that are often used are the number of customer requests and product supplies [10, 11, 17–20, 22, 21]. The Fuzzy method is used because it can produce high accuracy [10, 11]. In addition, the Fuzzy method was chosen because the results of forecasting the number of customer requests are uncertain, and this is a characteristic of the Fuzzy method [17, 18, 21, 23, 24]. In addition to implementing the Fuzzy method, this research also applies the Census II method as a forecasting method. The Census II method was chosen because this method can handle data fluctuations and has high results accuracy. So this research combined the two methods to get the optimal production recommendations. In contrast, previous studies only used one method to optimize production recommendations.

The rest of this article is organized as follows. The methods used in this study are described in section 2. Section 3 presents the research results and discusses the results in relation to previous research. Finally, Section 4 presents the conclusion and future work.

2. RESEARCH METHOD

The simulation method was used to conduct this research. The case study of this research is to determine the optimal amount of production for a plastic spoon company in Gresik, East Java, Indonesia. The data used in this study were sales, inventory, and production data of colored duck spoon products, which was obtained directly from CV "X." The amount of demand will be forecasted using data from January 2019 to December 2021. Meanwhile, the recommended production quantities will be calculated from January 2022 to May 2022.

Two main methods will be used sequentially: Census II and Fuzzy. The Census II method will forecast the number of customer requests for a certain period. Forecasting results will be used as one of the inputs of the Fuzzy method. The Fuzzy method will determine an item's optimal production amount in a certain period in future problems. Evaluation of the results of each method is carried out using the Mean Absolute Error (MAE) and accuracy.

2.1. Census II

Forecasting the number of requests is done by using historical sales data. The forecasting process begins with determining the goods and the forecasting period. After that, several stages of the process will be carried out to get the prediction results. Figure 1 shows the stages of the process carried out in forecasting.

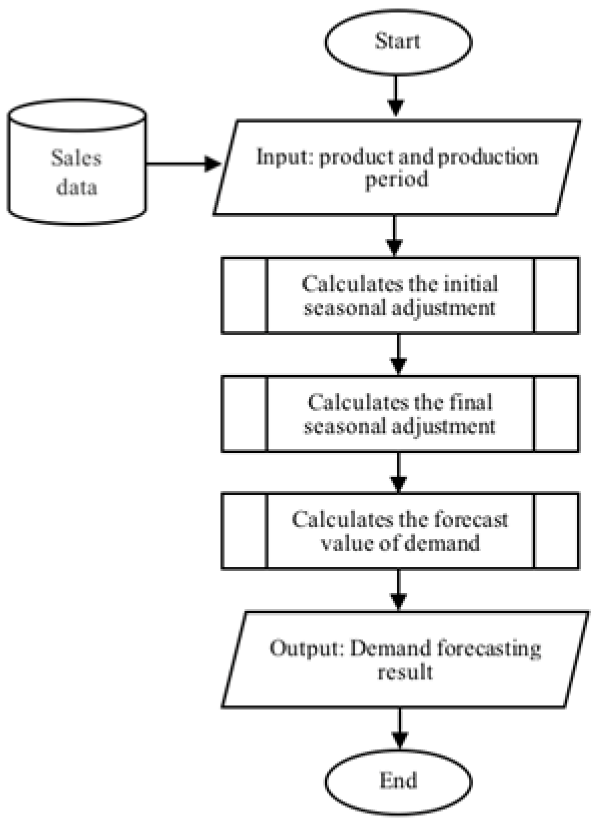

Figure 1. Stages of Customer Demand Forecasting Process

After the input product and production period, the first process is to calculate the initial seasonal adjustment. This process is done to separate the seasonal elements from other elements. There are six steps to performing the initial seasonal adjustment. The first step is calculating a centralized double moving average using the Moving Average (MA 2x12) method. Initially, we will calculate the centered moving average of each 12 data points. After that, a moving average calculation of the two data results from the previous calculation will be carried out. This step smooths out seasonal and random elements and establishes trends. The second step is calculating the ratio between the actual data, and the calculation results in step 1a to produce a centralized ratio. This step is taken to take seasonal and random elements. Calculations are made using Equation (1) [8].

$$R_t = \frac{X_t}{M_t} = S_t * E_t \tag{1}$$

Where Rt is the ratio of the t period, Xt is the actual data in the t period, Mt is the double moving average centered in the t period, St is the seasonal element in the t period, and Et is the random/error element in the t period. The next step is to calculate a moving average to remove random elements. The moving average is calculated using a 3x3 moving average. First, we will calculate the centralized moving average of the three data sets. After that, a moving average will be calculated from the three previously calculated data. The following step is to calculate the standard deviation by calculating the average of the squared deviations of the 3x3 MA value to the centered ratio. After that, the result is in the square root. The values obtained will be used to determine extreme value limits. The extreme value limits are usually from plus or minus two standard deviations. Suppose a value is found that exceeds the limit. In that case, the value will be replaced with the average of the three previous period values or the following three periods. After that, we need to adjust the initial seasonal factor by dividing the centralized ratio value by the average extreme value per period and multiplying it by 100%. The next step is calculating a moving average using a 5x5 moving average to get the initial seasonality factor. First, we will calculate the centralized moving average of each of the five data points. After that, a moving average will be calculated from the five previously calculated data. Finally, form the initial seasonal adjustment data series by dividing the actual data by the initial seasonal factor.

After calculating the initial seasonal adjustment, the following process is to compute the final seasonal adjustment. This process eliminates the influence of seasonal and random elements not detected in the first process by isolating trend and cycle elements. The process carried out in this process is the same as the first process, only different in the first step. In this process, the first step is carried out by calculating the moving average of the data series from the first process using the Moving Average 15 (MA 15). The last process is calculating the forecast value of customer demand. Initially, calculations will be done using the Moving Average 3 (MA 3). In this calculation, the final seasonal adjustment data series is used. The results will be used to calculate the forecast value of trend and cycle elements using the least squares method as in Equation (2) [25]. The value of b in Equation (2) is calculated using Equation (3), while the value of a is calculated by Equation (4). Finally, the multiplication between the prediction results of trend and cycle elements will be performed with the forecast value of the seasonal element.

$$\hat{y} = a + bx \tag{2}$$

$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} \tag{3}$$

$$a = \bar{y} - b\bar{x} \tag{4}$$

Where $\hat{y}$ is the forecast result, n is the number of periods, x is the forecast period, and y is the demand history data.

2.2. Fuzzy Method

In this study, the Fuzzy method used is Fuzzy Mamdani, where the optimal amount of production is determined using two kinds of input, namely the results of predictions of customer demand and the amount of inventory. Each input variable is divided into two categories. Two possible values for the variable amount of demand are increases and decreases. At the same time, the possible values for a stock variable are low and a lot. The output of the Fuzzy method is the amount of production. The possible values for the production quantity variable are also divided into two, namely: decreasing and increasing.

Before the Fuzzy method is run, for the first time, a minimum and maximum value of each variable used is searched, namely the number of customer requests, inventory, and production quantities. The search for minimum and maximum values uses related historical data. After that, the Fuzzy method is run according to the process stages in Figure 2.

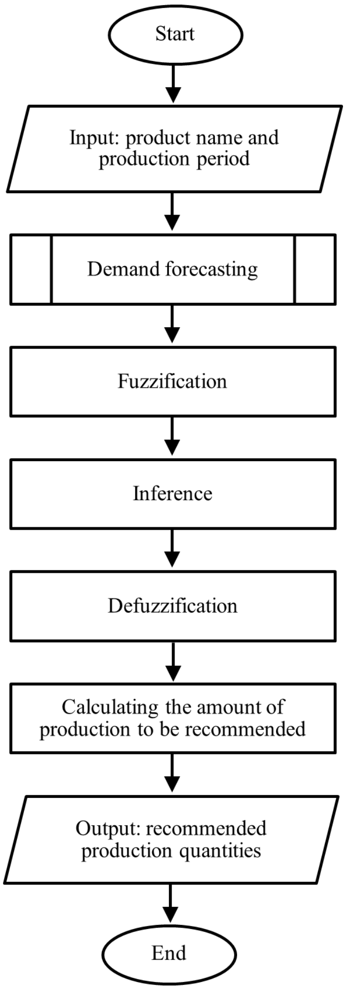

Figure 2. Stages of the Process of Determining the Amount of Production

The implementation of the Fuzzy method consists of three main stages. The first stage is Fuzzification. At this stage, the membership degree of each input variable is calculated according to the membership function used. The shape of the membership function of each input variable category is linear, as shown in Figure 3.

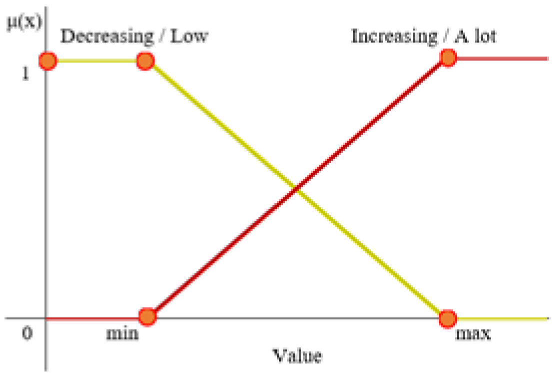

Figure 3. Input/Output Membership Functions

The next stage is Inference. This stage calculates the minimum degree of membership for each inference rule. There are four kinds of inference rules used, and the first rule is IF the demand decreases and the stock is a lot, THEN the amount of production decreases. The second rule is that IF the demand decreases and the stock is low, THEN the amount of production decreases. The next rule is IF the demand increases and the stock is a lot, THEN the amount of production increases. The last rule is that IF the demand increases and the stock is low, THEN the amount of production increases.

After that, the implication value is calculated by choosing the inference rule that gives the most significant result for each membership function of the output variable. The implication function is the implication function max, as in Equation (5). This study used two membership functions of the output variable (amount of production): decreasing and increasing. The form of the output variable membership function used is the same as the input variable membership function.

$$\mu_c = max(\mu_a, \mu_b) \tag{5}$$

Where c is a categorical output variable, a, and b are the smallest crisp values from the inference rules corresponding to c. After obtaining the maximum value of each category of the output variable, then look for the intersection point between the two implication values obtained. The cut points obtained are the limits of each Fuzzy region of the modified output variable. Suppose the implication value for reduced production is more significant than that for increased production. In that case, the cutoff point is calculated using Equations 6 and 7. Otherwise, Equations 8 and 9 are used.

$$Z_1 = (1-\mu_1) * (max - min) + min \tag{6}$$
$$Z_2 = (1-\mu_2) * (max - min) + min \tag{7}$$
$$Z_1 = \mu_1 * (max - min) + min \tag{8}$$
$$Z_2 = \mu_2 * (max - min) + min \tag{9}$$

Where max is the maximum production value, and min is the minimum. The last stage in the Fuzzy method is Defuzzification. Output calculations are performed using the Centroid method as in Equation (10). The quantifier is the moment, and the denominator is the area.

$$Z^* = \frac{\sum_{i=1}^{n} m_i}{\sum_{i=1}^{n} A_i} \tag{10}$$

Where Z^* is the center point, n is the number of modified output regions, m_i is the moment of the i-th region, and A_i is the area of the i-th region. Suppose the implication value for production increases equals zero, and the value for decreases does not equal zero. In that case, the moment of the modified output area is calculated using Equation (11) and Equation (12). At the same time, the area is calculated using Equation (13) and Equation (14).

$$m_1 = \frac{\mu_1 * Z_1^2}{2} \tag{11}$$
$$m_2 = \frac{-\frac{Z_2^3}{3} + \frac{max}{2} * Z_2^2}{2(max - min)} - \frac{-\frac{Z_1^3}{3} + \frac{max}{2} * Z_1^2}{2(max - min)} \tag{12}$$
$$A_1 = Z_1 * \mu_1 \tag{13}$$
$$A_2 = \frac{Z_2 - Z_1}{2} \tag{14}$$

Z_1 is calculated from Equation (6) or (8), Z_2 from Equation (7) or (9), max is the maximum production value, min is the minimum production value, μ_1 is the implication value for reduced production, and μ_2 is the implication value for increased production. Suppose the implication value for reduced production equals zero, and the value for increased production does not equal zero. In that case, the moment of the modified output area is calculated using Equation (15) and Equation (16). At the same time, the area is calculated using Equation (17) and Equation (18).

$$m_1 = \frac{\mu_2 * (max + Z_1)^2}{2} - \frac{\mu_2 * Z_2^2}{2} \quad (15)$$

$$m_2 = \frac{-\frac{Z_2^3}{3} - \frac{min}{2} * Z_2^2}{2(max - min)} - \frac{-\frac{Z_1^3}{3} - \frac{min}{2} * Z_1^2}{2(max - min)} \quad (16)$$

$$A_1 = (min + (max - Z_1)) * \mu_2 \quad (17)$$

$$A_2 = \frac{Z_2 - Z_1}{2} \quad (18)$$

Suppose the implication value for reduced production is more significant than that for increased production. In that case, the moment of the modified output area is calculated using Equation (11), Equation (19), and Equation (20). In contrast, the area is calculated using Equation (13), Equation (21), and Equation (22).

$$m_2 = \frac{\frac{Z_2^3}{3} - \frac{min}{2} * Z_2^2}{(max - min)} - \frac{\frac{Z_1^3}{3} - \frac{min}{2} * Z_1^2}{(max - min)} \quad (19)$$

$$m_3 = \frac{\mu_2 * max^2}{2} - \frac{\mu_2 * Z_2^2}{2} \quad (20)$$

$$A_2 = \frac{(\mu_1 + \mu_2) * (Z_2 - Z_1)}{2} \quad (21)$$

$$A_3 = (max - Z_2) * \mu_2 \quad (22)$$

Suppose the implication value for reduced production is smaller than that for increased production. In that case, the moment of the modified area output is calculated using Equation (11), Equation (19), and Equation (20). In contrast, the area is calculated using Equation (13), Equation (21), and Equation (22). After the moment and area of each area are calculated, the total moment and total area are calculated. Finally, the center point is calculated using Equation (10).

The last process after implementing the Fuzzy method is calculating the recommended product amount. This process requires data on the number of products that have been or are currently in the production process and the number of products that should have been produced in the previous period but have not yet been produced. The recommended production amount is calculated by Equation (23).

$$R = Z - X_b + X_a \quad (23)$$

Where R is the recommended number of products to be produced, Z is the number of products that should be produced based on the results of the Fuzzy method, X_b is the number of products that have been or are in the production process, and X_a is the number of products that should have been produced in the previous period but have not been produced.

2.3. Evaluation Method

The amount of error from forecasting results and determining the amount of production is calculated using MAE. The equation used to calculate the MAE can be seen in Equation (24) [26]. While the accuracy of the forecasting results and determining the amount of production is calculated using Equation (25).

$$MAE = \frac{\sum_{i=1}^{n} | f_i - y_i|}{n} \quad (24)$$

$$Accuracy = 100 - (\frac{MAE}{\sum_{i=1}^{n} y_i} * 100) \quad (25)$$

Where n is the amount of data, f_i is the forecast result, and y_i is the actual data.

3. RESULT AND ANALYSIS

This demand prediction will be calculated using the Census II method. The prediction process begins by selecting the items to be predicted, then selecting the period to be displayed. There are three main processes for predicting demand: calculating initial adjustments, calculating final adjustments, and calculating demand prediction results. The output of these processes is the result of predicting demand.

Incoming demand data will calculate the 12-month moving average (12-month MA). The demand data (original data) will be divided with the 12-month MA results to produce a centralized 12-month ratio. Then, from the 12-month ratio, the extreme value will be extracted by calculating the 3x3 month moving average and the standard deviation. This standard deviation is used as a control limit for identifying extreme values; if a value is outside the limit, the value must be replaced with the average values before and after.

After that, the value lost due to the calculation of the 12-month MA will be filled in using the value of the previous or following year. The completed values will be adjusted to the monthly ratio so that the total annual ratio will be 1200. Then, the ratio adjustment results will be calculated on an average of 5x5 months to obtain the initial seasonal factors. The demand data (original data) will be divided by the seasonal factors to produce an initial seasonal adjustment data series.

The adjusted data series will be calculated as a 15-month weighted moving average. Given the 15-month weighted moving average result, the demand data (original data) will be divided by the moving average result to generate a random seasonal ratio. Random seasonal ratio values will replace extreme values and adjust ratios to 1200. After ratio adjustments, a 5x5 moving average (final seasonal adjustment factor) will be performed again; the results will be adjusted by dividing the demand data (original data) and the adjusted results from previous ratios and producing a seasonally adjusted final series.

The value is obtained from the final seasonal adjustment factor by multiplying the last row by three, subtracting the previous row's factor, and dividing the result by two. This seasonal factor can be used as a variable for predictions for the following year. The results of the final seasonal adjustment series will be calculated by MA 3 to calculate the estimated value of the cyclical trend. After that, the cycle trend will be determined using the least squares method. Then, the prediction results can be calculated by multiplying the results of the cyclical trend estimate with the seasonal forecast value. Actual data on the number of customer requests and forecasting results can be seen in Table 1, columns two and three. At the same time, the magnitude of the error and accuracy of the forecasting results can be seen in Table 1, fourth and fifth columns.

Table 1. Accuracy of Forecasting Results of Total Demand in 2022

Month	Actual Data	Forecast	MAE	Accuracy (%)
January	2.955	2.601	354	88,01
February	2.281	2.084	197	91,34
March	2.626	1.979	647	75,35
April	1.637	1.162	475	70,95
May	839	710	129	84,04

The average accuracy for the five forecasting periods is 81.94%, with the lowest accuracy of 70.95% and the highest accuracy of 91.34%. The accuracy of the prediction results is quite good. However, this condition differs from a study conducted by [8], which used the same method. The results of forecasting sales of 19-liter aqua gallons carried out by [8] from 2013 to 2018 provided an average accuracy above 90%.

Determining this production begins by selecting the period, product to be calculated, demand data, production, and inventory. If the required data is complete, then the data will be used to create a fuzzy set. The fuzzy variables used for each variable are a few and a lot; each variable's membership function will also be calculated. After getting the membership function, the next step is to find the implication function; the calculation for the implication function will be based on the existing rules. The next stage is to calculate the output (Defuzzification); the output is the amount of production determined based on the number of requests and the amount of supply. The Defuzzification will use the centroid method. The recommended number of colored duck plastic spoons that should be produced can be seen in Table 2, third column. The second column shows the number of products that should be produced. Meanwhile, the fourth and fifth columns show the error's magnitude and the recommendations' accuracy.

Table 2. Accuracy of 2022 Production Amount Recommendation Results

Month	Production	Recommendation	MAE	Accuracy (%)
January	2.392	1.902	490	79,5
February	1.896	1.661	235	87,6
March	2.337	1.483	854	63,5
April	1.345	1.146	199	85,2
May	774	539	235	69,6

The average accuracy of the recommended production quantities is 77.07%, with the lowest accuracy of 63.5% and the highest accuracy of 87.6%. This differs from research conducted by [10] at the Cinderella Bread House bakery company, which used the same variables and methods. The recommendation for the number of square bread production (days) from research [10] was carried out for three months, from June to August 2018, and gave an average accuracy of 90.3%.

The results of this study are also different from the research results from [20] for combined *jenang* products at PJ Menara Kudus. However, they align with research [20] for sesame *jenang* products. Research conducted by [20] using data from January 2020 to March 2021 used the same method as this study but with three input variables: demand, supply, and raw materials. The average error obtained for the combined *jenang* product was 7.5%, while for the sesame *jenang* product, it was 21.7%.

Figure 4 shows the number of customer requests for colored duck plastic spoons from January 2019 to December 2021. The graph shows many sharp fluctuations due to the unstable economy during the Covid-19 pandemic. This can be one of the causes; the accuracy of the research conducted is only around 77% for production quantity recommendations and 82% for forecasting customer demand. This is also recognized by the company and often causes difficulties for the company and needs to be corrected in calculating the amount of production.

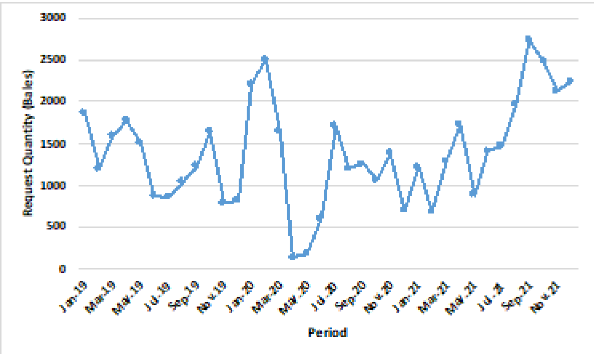

Figure 4. Colored Duck Plastic Spoon Request Chart

The research results conducted by [8] and [10] provided accuracy above 90%. However, this research was conducted before the Covid-19 pandemic, when economic conditions tended to be more stable. When viewed from the research data used by [8], there was no sharp fluctuation in data, while research [10] did not display the data used in his research. The accuracy resulting from research [11] was also above 90%, and when viewed from the input data used, the existing data did not fluctuate too much. Unlike the research conducted by [21], some of the input data used fluctuated quite highly. As a result, the maximum accuracy resulting from this research was 73.4%.

The study [20] was carried out during the Covid-19 pandemic. However, there is a sharp error difference between combined *jenang* products and sesame *jenang*. When viewed from the demand data for each product, it can be seen that the sharp fluctuations in data for combined *jenang* products are less than for sesame *jenang* products. Sharp fluctuations in combined *jenang* product data only occurred twice during the study period. However, when compared to the data used in this study, fluctuations occur more frequently in the data used in this study. The graph of the number of customer requests for sesame *jenang* from research [20] can be seen in Figure 5.

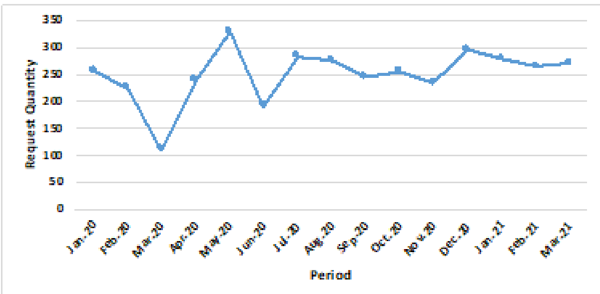

Figure 5. Graph of Sesame *Jenang* Demand from Research [20]

Based on previous research, most researchers only used only one method, and the values of all input variables used were constant (predetermined by the parties concerned). Meanwhile, in this research, the researcher used two methods which were run sequentially. One method, Census II, was used to predict the number of requests in the future whose results were used as input in determining the production amount. So, a probabilistic variable was one of the input variables used in determining the amount of production. The use of probabilistic variables is not seen in other studies. A summary of the comparisons of the research made with previous research can be seen in Table 3.

Table 3. Comparison of Research Results with Previous Research

Research Year	Research Title	Method	Results from Previous Research	Research Results	GAP
2019	Prediction of Total Palm Oil Production Using Mamdani's Fuzzy Inference System	Fuzzy	The accuracy of the Fuzzy system developed to determine the amount of palm oil production ranged from 16.14% to 73.41%.	The Fuzzy system's average accuracy for determining the production amount was 77%.	The input variables used in previous studies were obtained from user input. Users must estimate the number of customer requests for the upcoming production period. Whereas in this study, the number of customer requests was obtained from forecasting results which were carried out automatically by the system using the Census II method.
2019	Design of a Decision Support System for Determining Production Amounts Using the Fuzzy Tsukamoto Method	Fuzzy	The accuracy of the Fuzzy system developed to determine the amount of clothing production was 96%.	The Fuzzy system's average accuracy for determining the production amount was 77%.	The input data used in previous studies did not fluctuate too much, while the data used in this study often fluctuated sharply. In addition, input variables used in previous studies were obtained from user input. Users must estimate the number of customer requests for the upcoming production period. Whereas in this study, the number of customer requests was obtained from forecasting results which were carried out automatically by the system using the Census II method.
2019	Recommendations for Purchasing Goods in the Retail System Using the Census II Decomposition Method	Census II	The accuracy of the demand forecasting results using the Census II method for the monthly period was between 94.8% to 97.2%. In comparison, the accuracy for the annual period was between 86.5% and 99.2%.	Demand forecasting results using the Census II method provide an accuracy of 82%.	The data used in previous research was relatively constant, while the data used in this study often fluctuated sharply. Previous research used a single method, while this study combined two methods.
2020	Application of Mamdani Fuzzy Inference System to Determine Bread Production Amount Based on Demand and Supply Data (Case Study of Cinderela Bread House Factory in Ambon City)	Fuzzy	Using the Fuzzy method to determine the amount of production Bread based on supply and demand data provided an accuracy of 90.3%.	The Fuzzy system's average accuracy for determining the production amount was 77%.	The input variables used in previous studies were obtained from user input. Users must estimate the number of customer requests for the upcoming production period. Whereas in this study, the number of customer requests was obtained from forecasting results which were carried out automatically by the system using the Census II method.

Research Year	Research Title	Method	Results from Previous Research	Research Results	GAP
2022	Application of the Mamdani Fuzzy Method and the Sugeno Fuzzy Method in Determining Production Amounts	Fuzzy	The Mean Absolute Percentage Error from the Fuzzy system, which was developed to determine the amount of combination *jenang* production, was 7.5%, while for the sesame *jenang* production was 21.7%.	The Fuzzy system's average accuracy for determining the production amount was 77%.	The input variables used in previous studies were obtained from user input. Users must estimate the number of customer requests for the upcoming production period. Whereas in this study, the number of customer requests was obtained from forecasting results which were carried out automatically by the system using the Census II method. The demand data used to determine the amount of combined *jenang* production did not fluctuate too much compared to the sesame *jenang* demand. However, this study's demand for plastic spoons fluctuated more than the demand for sesame *jenang*.

The number of customer requests and product inventory are two input variables widely used in determining the amount of production. In previous research, the company determined the value of these two input variables. However, the number of customer requests fluctuates from time to time. For this reason, the company needs to do an analysis using historical sales data to estimate the number of customer requests in the coming period. In addition, the company needs to check the existing stock. Both of these things often require time and effort, especially if the company's records are still traditionally using paper. In contrast to previous research, in this study, the company does not need to determine the value of each input variable. The system will automatically calculate the value of each input variable based on historical sales and product inventory stored in the system database. After that, the system will calculate the recommended production amount for the company. So, the results of this study will simplify and speed up the company in determining the amount of production.

4. CONCLUSION

The results of forecasting the number of customer requests provide an average accuracy of 82% using the Census II method. The sharp fluctuations in the number of requests are suspected to be one of the causes; the average accuracy of forecasting results for the number of requests is only around 82%. On the other hand, the accuracy of the forecasting results for the number of requests affects the accuracy of the recommendations for the amount of production because the forecasting results become one of the inputs for the recommendation system. Hence, the recommendation results' accuracy is below the forecast results', equal to 77%. In future research, demand forecasting will be carried out using other methods and/or changing the minimum and maximum value parameters of the supply and production variables used in the recommendation system. The minimum and maximum values of the supply and production variables will be replaced with each variable's minimum and maximum capacities, not calculated from historical data.

5. DECLARATIONS

AUTHOR CONTIBUTION

SL and VRP were MM supervisors who contributed to directing research. In addition, SL also contributed to writing, analyzing research results, and revising the manuscript. MM contributed to collecting data and conducting research.

FUNDING STATEMENT

This research was funded independently by the authors.

COMPETING INTEREST

The authors declare that there are no competing interests regarding this publication.

REFERENCES

[1] F. A. Reicita, "Analisis Perencanaan Produksi pada PT. Armstrong Industri Indonesia dengan Metode Forecasting dan Agregat Planning," *Jurnal Ilmiah Teknik Industri*, vol. 7, no. 3, pp. 160–168, 2019.

[2] F. Izzatunnisaa and E. Prasetyaningsih, "Perencanaan Produksi dan Persediaan untuk Mengurangi Keterlambatan dan Biaya Penalti," *Jurnal Riset Teknik Industri*, vol. 2, no. 2, pp. 117–128, 2022.

[3] A. Eunike, N. W. Setyanto, R. Yuniarti, I. Hamdala, R. P. Lukodono, and A. A. Fanani, *Perencanaan Produksi dan Pengendalian Persediaan*, revisi ed. Malang: UB Press, 2021.

[4] K. Belmo and M. S. Neno, "Analisis Biaya-Volume-Laba sebagai Alat Perencanaan Laba pada Pabrik Tahu Pink Jaya Oebufu, Kupang," *Journal of Management (SME's)*, vol. 13, no. 3, pp. 285–298, 2020.

[5] M. B. Soeltanong and C. Sasongko, "Perencanaan Produksi dan Pengendalian Persediaan pada Perusahaan Manufaktur," *Jurnal Riset Akuntansi & Perpajakan (JRAP)*, vol. 8, no. 01, pp. 14–27, 2021.

[6] E. A. Rachma, "Optimasi Perencanaan Produksi dengan Menggunakan Model Sistem Dinamik di PT X," *Jurnal Optimasi Teknik Industri*, vol. 2, no. 1, pp. 36–42, 2020.

[7] F. Ahmad, "Penentuan Metode Peramalan pada Produksi Part New Granada Bowl ST di PT.X," *JISI: Jurnal Integrasi Sistem Industri*, vol. 7, no. 1, pp. 31–39, 2020.

[8] E. Tjandra, S. Limanto, and A. Indrawan, "Rekomendasi Pembelian Barang pada Sistem Retail dengan Metode Dekomposisi Census II," *Jurnal Teknika*, vol. 8, no. 2, pp. 126–132, 2019.

[9] M. J. Siregar, "Pengendalian Stok Spareparts Mobil Dengan Metode EOQ dan Min-Max Inventory," *Jurnal Serambi Engineering*, vol. 6, no. 3, pp. 2096–2101, 2021.

[10] S. E. R. Yunita, H. J. Wattimanela, and M. S. N. V. Delsen, "Penerapan Fuzzy Inference System Tipe Mamdani untuk Menentukan Jumlah Produksi Roti Berdasarkan Data Jumlah Permintaan dan Persediaan (Studi Kasus Pabrik Cinderela Bread House di Kota Ambon)," *BAREKENG: Jurnal Ilmu Matematika dan Terapan*, vol. 14, no. 1, pp. 79–90, 2020.

[11] R. Taufiq and H. P. Sari, "Rancang Bangun Sistem Pendukung Keputusan Penentuan Jumlah Produksi Menggunakan Metode Fuzzy Tsukamoto," *Jurnal Teknik*, vol. 8, no. 1, pp. 6–10, 2019.

[12] N. Iriadi, P. Priatno, and P. A. Sulistia, "Analisa Kepuasaan Pelanggan dalam Layanan Jasa Travel and Tour pada PT. Denar Pesona Menggunakan Metode Fuzzy Servqual," *MATRIK : Jurnal Manajemen, Teknik Informatika dan Rekayasa Komputer*, vol. 18, no. 2, pp. 192–201, 2019.

[13] A. Anggrawan and Mayadi, "Application of KNN Machine Learning and Fuzzy C-Means to Diagnose Diabetes," *MATRIK : Jurnal Manajemen, Teknik Informatika dan Rekayasa Komputer*, vol. 22, no. 2, pp. 405–418, 2023.

[14] C. T. Utari, M. Zarlis, and Sutarman, "Optimization of Production Scheduling and Actual Stock Using Fuzzy Genetic Algorithm," in *Journal of Physics: Conference Series*, vol. 1235, no. 1. Medan: IOP Publishing Ltd, sep 2019.

[15] N. Nurhasanah, S. W. Fauzia, B. Aribowo, R. Safitri, B. Samiono, C. F. Lutfia, M. Devana, P. Kalifa, and A. Supriyanto, "Inventory Level Optimization of Raw Materials for Ready-Made Garment Industry XYZ Pty Ltd using Mamdani Method of Fuzzy Interference System," in *IOP Conference Series: Materials Science and Engineering*, vol. 528, no. 1. Makasar: IOP Publishing Ltd, nov 2019.

[16] G. Indrawan, I. P. A. S. Putra, L. J. E. Dewi, and I. G. A. Gunadi, "Application of Fuzzy Logic in Sales Inventory System: A Literature Review," in *Proceedings of Seventh International Congress on Information and Communication Technology*, X. S. Yang, S. Sherratt, N. Dey, and A. Joshi, Eds., vol. 2. London: Springer, Singapore., feb 2022, pp. 543–549.

[17] A. Shoniya and A. Jazuli, "Penentuan Jumlah Produksi Pakaian dengan Metode Fuzzy Tsukamoto Studi Kasus Konveksi Nisa," *JIPI (Jurnal Ilmiah Penelitian dan Pembelajaran Informatika)*, vol. 4, no. 1, pp. 54–65, 2019.

[18] V. M. Nasution and G. Prakarsa, “Optimasi Produksi Barang Menggunakan Logika Fuzzy Metode Mamdani,” *Jurnal Media Informatika Budidarma*, vol. 4, no. 1, pp. 129–135, 2020.

[19] R. Purwandito, H. Suyitno, and Alamsyah, “Penerapan Sistem Inferensi Fuzzy Metode Mamdani untuk Penentuan Jumlah Produksi Eggroll,” *Unnes Journal of Mathematics*, vol. 8, no. 1, pp. 107–116, 2019.

[20] K. Muflihunna and M. Mashuri, “Penerapan Metode Fuzzy Mamdani dan Metode Fuzzy Sugeno dalam Penentuan Jumlah Produksi,” *Unnes Journal of Mathematics*, vol. 11, no. 1, pp. 27–37, 2022.

[21] C. P. P. Maibang and A. M. Husein, “Prediksi Jumlah Produksi Palm Oil Menggunakan Fuzzy Inference System Mamdani,” *Jurnal Teknologi dan Ilmu Komputer Prima (JUTIKOMP)*, vol. 2, no. 2, pp. 400–407, 2019.

[22] D. L. Rahakbauw, F. J. Rianekuay, and Y. A. Lesnussa, “Penerapan Metode Fuzzy Mamdani untuk Memprediksi Jumlah Produksi Karet (Studi Kasus: Data Persediaan dan Permintaan Produksi Karet pada Ptp Nusantara Xiv (Persero) Kebun Awaya, Teluk Elpaputih, Maluku-Indonesia),” *Jurnal Ilmiah Matematika Dan Terapan*, vol. 16, no. 1, pp. 119–127, 2019.

[23] L. P. Wanti and Lina Puspitasari, “Optimization of the Fuzzy Logic Method for Autism Spectrum Disorder Diagnosis,” *Jurnal RESTI (Rekayasa Sistem dan Teknologi Informasi)*, vol. 6, no. 1, pp. 16–24, 2022.

[24] B. I. Gunawan and U. Y. Oktiawati, “Sistem Pemantau dan Pengendali Suhu Ruang Server Menggunakan Fuzzy Berbasis Mikrokontroler RobotDyn,” *Jurnal Rekayasa Sistem dan Teknologi Informasi*, vol. 4, no. 1, pp. 1–9, 2020.

[25] B. W. I. Taylor, *Introduction to Management Schience*, 11th ed. United States of America: Pearson Education, Inc., 2013, vol. 11.

[26] G. C. A. Wibowo, S. Y. J. Prasetyo, and I. Sembiring, “Tsunami Vulnerability and Risk Assessment Using Machine Learning and Landsat 8,” *MATRIK : Jurnal Manajemen, Teknik Informatika dan Rekayasa Komputer*, vol. 22, no. 2, pp. 365–380, 2023.

[This page intentionally left blank.]