Volume 1 Number 3 October 2024
E-ISSN: 3047-4337

https://journal.antispublisher.com/index.php/IPTEKS/index

IMPLEMENTATION OF FUZZY INVENTORY METHOD AND ARTIFICIAL NEURAL NETWORK IN DETERMINING SAFETY INVENTORY OF BAG PRODUCTS

Muhammad Miftah Arzaq Rahmansyah [1], Tedjo Sukmono[*,2]
[1,2] Industrial Engineering Study Program, Muhammadiyah Universitas of Sidoarjo, Indonesia

Article Info

Article history:
Received Sep 13, 2024
Revised Sep 28, 2024
Accepted Oct 11, 2024

Keywords:
Prediction, Safety Stock, Artificial Neural Network, Fuzzy Inventory

ABSTRACT

General Background: Effective inventory management is crucial for small and medium enterprises (SMEs) to address fluctuating demand and avoid shortages, especially in sectors like handcrafted products. **Specific Background:** In the context of PTK MSMEs (Karangtanjung Bag Craftsmen) in Sidoarjo Regency, bag product sales often vary monthly, necessitating accurate demand forecasting and optimal inventory levels. **Knowledge Gap:** While previous studies have explored demand prediction and inventory management, few have integrated advanced methodologies like Artificial Neural Networks (ANN) and Fuzzy Inventory approaches to cater specifically to SMEs in the handicraft sector. **Aims:** This research aims to predict the sales demand for bag products and establish safety inventory levels using ANN and Fuzzy Inventory methods, ultimately to control demand and reduce inventory costs. **Results:** The study yielded a Root Mean Square Error (RMSE) of 45.031 from the ANN analysis, indicating a good forecasting performance, while the Fuzzy Inventory method calculated a safety stock of 43,647 pieces for 2023. **Novelty:** The integration of ANN for demand forecasting and Fuzzy Inventory for safety stock determination offers a novel approach for SMEs, enabling them to respond proactively to market fluctuations. **Implications:** The findings provide a framework for MSMEs to enhance their inventory management practices, thus improving operational efficiency and reducing holding costs, which can significantly impact their sustainability and competitiveness in the market.

Corresponding Author:
Tedjo Sukmono
Industrial Engineering Study Program, Muhammadiyah Universitas of Sidoarjo
E-mail: thedjoss@umsida.ac.id
DOI : https://doi.org/10.61796/ipteks.v1i3.214

INTRODUCTION

Safety supplies and demand prediction are problems that are often faced by MSME actors, MSMEs are activities carried out by individuals or groups in running small-scale businesses [1]. The problem that often occurs is demand by consumers that

cannot be predicted well, causing shortages in production. Inventory is also difficult to predict and causes a shortage of stock in the warehouse or if there is too much stock in the warehouse it will incur excessive costs.

Demand prediction is the process of analyzing future needs either in the form of data or the number of requests that will be purchased by people who want the goods [2]. Prediction can analyze a future event caused by a need by relying on past events [3]. Inventory is the willingness of an item stored in a warehouse that is ready to be distributed or traded [4]. Good inventory management will make planning more organized so that inventory management can be more controlled [5].

High inventory costs will be the main problem for MSMEs, inventory costs are costs that arise due to the availability of product inventory in the warehouse to supply buyers without having to wait long or buyers can immediately have the goods they want [6]. Inventory costs are part of the order port, where the order port, is where the products are stored in the warehouse [7]. PTK MSMEs (Karangtanjung Bag Craftsmen) are MSMEs engaged in tanning leather and focus on production on bags. The demand for MSME bag sales fluctuates every week so that the inventory of bag products in the warehouse is uncertain. Total monthly production in 2021 reaches an average of 3200 pcs of bags while the demand for bags from buyers every month reaches 3500 pcs of bags, this shortfall of 15% can be met if the stock of bags in the warehouse is more than 15%, while the stock in the PTK MSME warehouse is only 150 pcs bags or around 7.5%.

The planning of bag product inventory is not paid attention to here because MSMEs often experience a shortage of bag products in storage in warehouses, as a result consumer demand is not met and makes MSMEs have to pursue quite a lot of buyer demand, therefore a method is needed so that product storage can meet sales demand. Inventory is the storage of finished goods that are carried out to meet sales demand. [8].

Mining data is a tool or system that implements artificial intelligence and machine learning to read and find hidden data [9]. Method Artificial Neural Network It is a technique that can imitate human nerves consisting of the top layer and the output layer so that it can predict and solve complex problems characterized by many variables [10]. Lead time is the time used for the production process to be completed, including waiting and delays [11]. The length of time is sometimes unpredictable, therefore to complete the order request, it is necessary to estimate the appropriate time and prepare the inventory well [12].

By the method of Artificial Neural Network It is hoped that the demand for PTK MSMEs can be more controlled. Functions of the Artificial Neural Network is able to map patterns input become output, can optimize a demand problem, and can predict future demand [13]. After doing the next forecasting, it is to manage the inventory so that there is no shortage or excess so that it can reduce storage costs.

Based on previous research conducted by Lussa with the title Utilization Artificial Neural Network and Fuzzy Inventory Model for Determination of Safety Inventory, the impact of the study is able to reduce data that is not in accordance with the actual data, this makes inventory calculations more optimal [8]. Meanwhile, the previous research conducted by Rahmah with the title Planning for Inventory Control Using the Fuzzy Inventory Control & Forecasting At Pt. Beurata Subur Persada, the impact of the research was able to optimize the amount of finished product inventory in the company so that consumer demand could be met [14].

Fuzzy Inventory is a method used to analyze safety stocks [14]. logic Fuzzy is a description of the cavity Input to the cavity Output that has a high tolerance value for previous data [14]. Logical reasoning Fuzzy is a way to draw conclusions from a known fact [15]. The concept of logic Fuzzy can model in a complex manner and is able to tolerate inaccurate data [16]. Purpose of the method Fuzzy Inventory to make availability predictions, helping to process storage-level inventory to reduce storage costs [17]. The relationship between the ANN method and fuzzy inventoy This is to determine what the sales demand will be in the next period and what the level of inventory is safe.

From the problems and introductions above, it can be concluded that past data is needed to find out the number of consumer demand in the future and an inventory planning method is needed that can manage the inventory of bag products in the warehouse so that there is no shortage or excess where it can meet the demand from consumers

METHODS

The research activity was carried out for 6 months and was carried out at PTK MSMEs (Karangtanjung Bag Craftsmen) located in Karangtanjung Village, Tanggulangin District, Sidoarjo Regency. The data used for the research is primary data obtained from the results of interviews with MSME owners of Karangtanjung Bag Artisans. Bag sales data every week that takes place from 2021-2022, with the average production in 2021 being 100-130 products per day, while in 2022 the average production is 200-250 products per day.

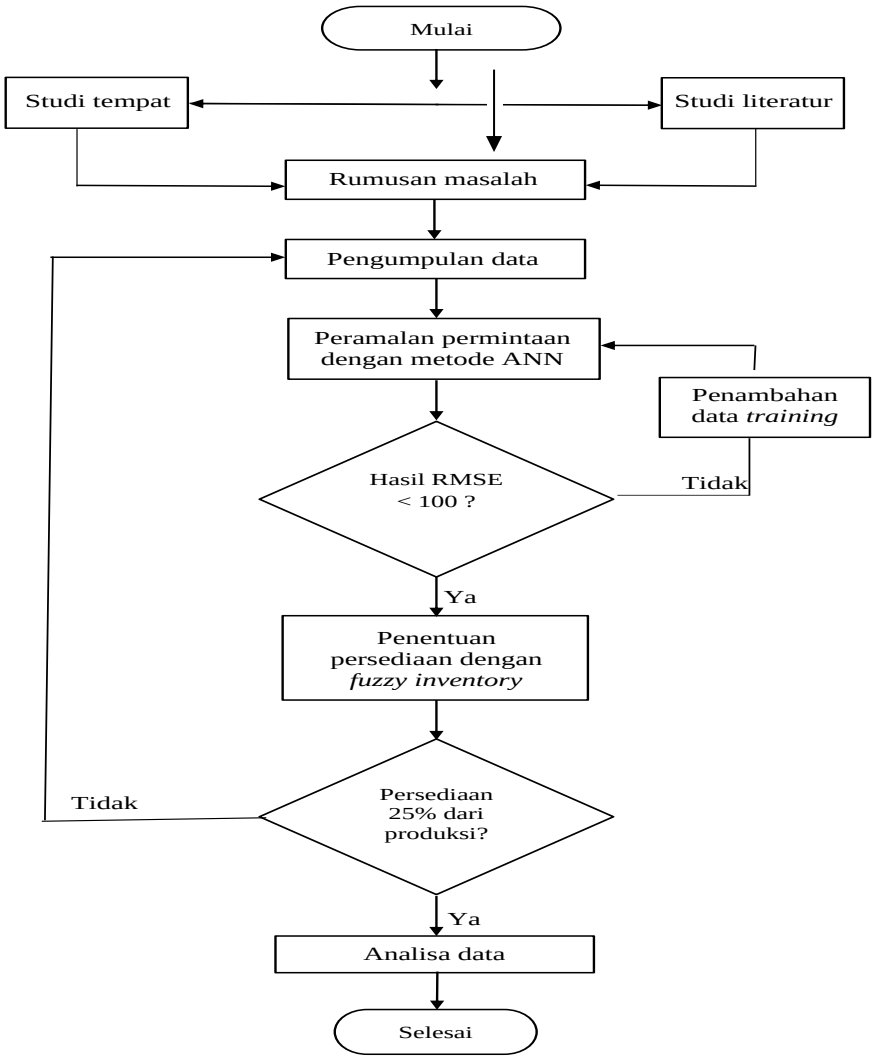


Figure 1. Flow Diagram

Data collection was obtained using primary data obtained from interviews with PTK MSME owners. Where the data taken at that time was demand data for the previous 2 years. After that, the data obtained will be predicted through the *artificial neural network* by wearing *software rapidminer*, Then the data from the demand prediction will be processed by the *fuzzy inventory* to find out the level of sufficient product safety stock, *fuzzy inventory* will be processed using *software matlab. Fuzzy Inventory* is a method used to analyze the safety inventory of bag products [14].

To perform data processing using *artificial neural network* then rapidminer software is needed, *Rapidminer* Is *software* applications used for data mining, information analysis, research and education, application development, data *Mining* and forecasting for the next period [18] Forecasting on *rapidminer* determined by how low the RMSE level (*Root Mean Square Error)* where the numbers 0-100 are good forecasting results, 101-299 are fairly good forecasting results and 300-499 are poor forecasting

results [18]. Here are the steps of the processing method *artificial neural network* Using *Software RapidMiner*: [12].

a. Data sharing

The data that has been obtained is first divided into *training* data and testing data , training data is data that amounts to 70% of the research data while *testing* data is data that amounts to 30% of the research data. After that, normalization is carried out with the following formula:

$$Vnorm = \frac{Vi-Vmin}{Vmax-Vmin} \quad (1)$$

Information:

Vi = Old value

Vmin = Minimization value

Vmax = Maximization value

b. Training and testing

The training will use *training* data and testing will use *testing* data to find out the forecast results and *RMSE values.*

$$RMSE = \Sigma_{t=1}^{n}(A_t - F_t)^2 \quad (2)$$

Information:

At = Actual data value

Ft = Prediction result value

n = Large amount of data

Meanwhile, to carry out the product safety supply method, it is necessary *Software means, means* be *software* for programming, matrix prediction, analysis and matrix-based mathematics in addition to *matlab* can also be used for the supply of goods [19]. A safe supply of finished goods is to have a value of 25% of the total finished goods produced [8]. Use *fuzzy inventory* at *software matlab* are as follows: [8].

a. Enter the forecast data that has been provided from *rapidminer software* in excel form using the following formula:

$$SS\tau = (25\%\ X\ F\tau) - P\tau_{-1} \quad (3)$$

Information:

Pt = Remaining inventory of the first week

Ft = Inventory demand prediction

b. Determine membership functions consisting of low, medium, and high.

c. Define *rules* using *if, then, and statement statements*.

d. Determine the safety supply by using *command input*.

e. Know product inventory levels with the help of demand prediction data and sales data

RESULT AND DISSCUSION

The data used in the study is data on demand for bag products with a span of 2 years starting from January 2021 to December 2022.

1. Determination of *the Artificial Neural Network* (ANN) system.

In determining the ANN system, a data normality is needed to show the data to be processed using *rapidminer software.*

a. Normality test

The normality test serves to find out that a data has a number that is no more than 1 [20]. The following is a normalization of sales data.

Table 1. Data Normalization

Sunday	Sales Quantity	Normalisasi	Sunday	Sales Quantity	Normalisasi	Sunday	Sales Quantity	Normalisasi
1	750 pcs	0,046138	13	810	0,106319	25	781	0,077232
2	809 pcs	0,105316	14	856	0,152457	26	767	0,063190
3	810 pcs	0,106319	15	829	0,125376	27	830	0,126379
4	807 pcs	0,10331	16	801	0,097292	28	799	0,095286
5	763 pcs	0,059178	17	845	0,141424	29	809	0,105316
6	782 pcs	0,078235	18	764	0,060181	30	845	0,141424
7	840 pcs	0,136409	19	855	0,151454	31	727	0,023069
8	794 pcs	0,090271	20	818	0,114343	32	813	0,109328
9	815 pcs	0,111334	21	720	0,016048	33	704	0,000000
10	821 pcs	0,117352	22	803	0,099298	34	819	0,115346
11	824 pcs	0,120361	23	787	0,083250	35	833	0,129388
12	828 pcs	0,124373	24	798	0,094283	36	781	0,077232

Table 1. Data Normalization (Advanced...)

Sunday	Sales Quantity	Normalisasi	Sunday	Sales Quantity	Normalisasi	Sunday	Sales Quantity	Normalisasi
37	833	0,129388	61	1556	0,854564	85	1572	`0,870612
38	781	0,077232	62	1363	0,660983	86	1488	0,786359
39	776	0,072217	63	1572	0,870612	87	1563	0,861585
40	782	0,078235	64	1599	0,897693	88	1580	0,878636
41	812	0,108325	65	1564	0,862588	89	1562	0,860582
42	822	0,118355	66	1513	0,811434	90	1558	0,856570
43	818	0,114343	67	1536	0,834504	91	1463	0,761284
44	759	0,055165	68	1584	0,882648	92	1546	0,844534
45	839	0,135406	69	1648	0,946841	93	1598	0,896690
46	834	0,130391	70	1581	0,879639	94	1568	0,866600
47	802	0,098295	71	1564	0,862588	95	1546	0,844534
48	805	0,101304	72	1580	0,878636	96	1587	0,885657
49	833	0,129388	73	1569	0,867603	97	1527	0,825476
50	798	0,094283	74	1556	0,854564	98	1701	1,000000
51	786	0,082247	75	1573	0,871615	99	1552	0,850552
52	828	0,124373	76	1585	0,883651	100	1625	0,923771
53	714	0, 010030	77	1558	0, 856570	101	1609	0, 907723
54	1200	0,497492	78	1511	0,809428	102	1578	0,876630
55	1515	0,813440	79	1506	0,804413	103	1557	0,855567
56	1418	0,716148	80	1574	0,872618	104	1618	0,916750
57	1531	0,829488	81	1353	0,650953	105	1587	0,885657
58	1620	0,918756	82	1409	0,707121			
59	1613	0,911735	83	1463	0,761284			
60	1607	0,905717	84	1572	0,870612			

In table 1, a data normality test was carried out and normal results were obtained, all of which can be seen in the normalization column, there are no numbers that indicate abnormalities, so all data are declared normal.

b. Data *partion*

The partion data contains *training* data and *testing data*, this data is a 70/30 division of sales data.

Table 2. Partion Data

Data *Training*				Data *Testing*	
No	Sales	No	Sales	No	Sales
1	750 pcs	37	833 pcs	1	1569 pcs
2	809 pcs	38	781 pcs	2	1556 pcs
3	810 pcs	39	776 pcs	3	1573 pcs
4	807 pcs	40	782 pcs	4	1585 pcs
5	763 pcs	41	812 pcs	5	1558 pcs
6	782 pcs	42	822 pcs	6	1511 pcs
7	840 pcs	43	818 pcs	7	1506 pcs
8	794 pcs	44	759 pcs	8	1574 pcs
9	815 pcs	45	839 pcs	9	1353 pcs
10	821 pcs	46	834 pcs	10	1409 pcs
11	824 pcs	47	802 pcs	11	1463 pcs

Table 2. Partion Data (Advanced...)

Data *Training*				Data Testing	
No	Sales	No	Sales	No	Sales
12	828 pcs	48	805 pcs	12	1572 pcs
13	806 pcs	49	833 pcs	13	1572 pcs
14	810 pcs	50	798 pcs	14	1488 pcs
15	856 pcs	51	786 pcs	15	1563 pcs
16	829 pcs	52	828 pcs	16	1580 pcs
17	801 pcs	53	714 pcs	17	1562 pcs
18	845 pcs	54	1200 pcs	18	1558 pcs
19	764 pcs	55	1515 pcs	19	1463 pcs
20	855 pcs	56	1418 pcs	20	1546 pcs
21	818 pcs	57	1531 pcs	21	1598 pcs
22	720 pcs	58	1620 pcs	22	1568 pcs
23	803 pcs	59	1613 pcs	23	1546 pcs
24	787 pcs	60	1607 pcs	24	1587 pcs
25	798 pcs	61	1556 pcs	25	1527 pcs
26	803 pcs	62	1363 pcs	26	1701 pcs
27	781 pcs	63	1572 pcs	27	1552 pcs
28	767 pcs	64	1599 pcs	28	1625 pcs
29	830 pcs	65	1564 pcs	29	1609 pcs
30	799 pcs	66	1513 pcs	30	1578 pcs
31	809 pcs	67	1536 pcs	31	1557 pcs
32	845 pcs	68	1584 pcs	32	1618 pcs
33	727 pcs	69	1648 pcs	33	1587 pcs
34	813 pcs	70	1581 pcs		
35	704 pcs	71	1564 pcs		
36	819 pcs	72	1580 pcs		

In table 2, data is divided where *training* data is 70% of the request data, while *testing* data is 30% of the request data. The function of this data sharing is to determine past data as a reference to produce predictions in the future period.

c. Application of ANN using *Rapidminer*

The application of the *Aritificial Neural Network* (ANN) design using *rapidminer software* is shown in figure 2 below.

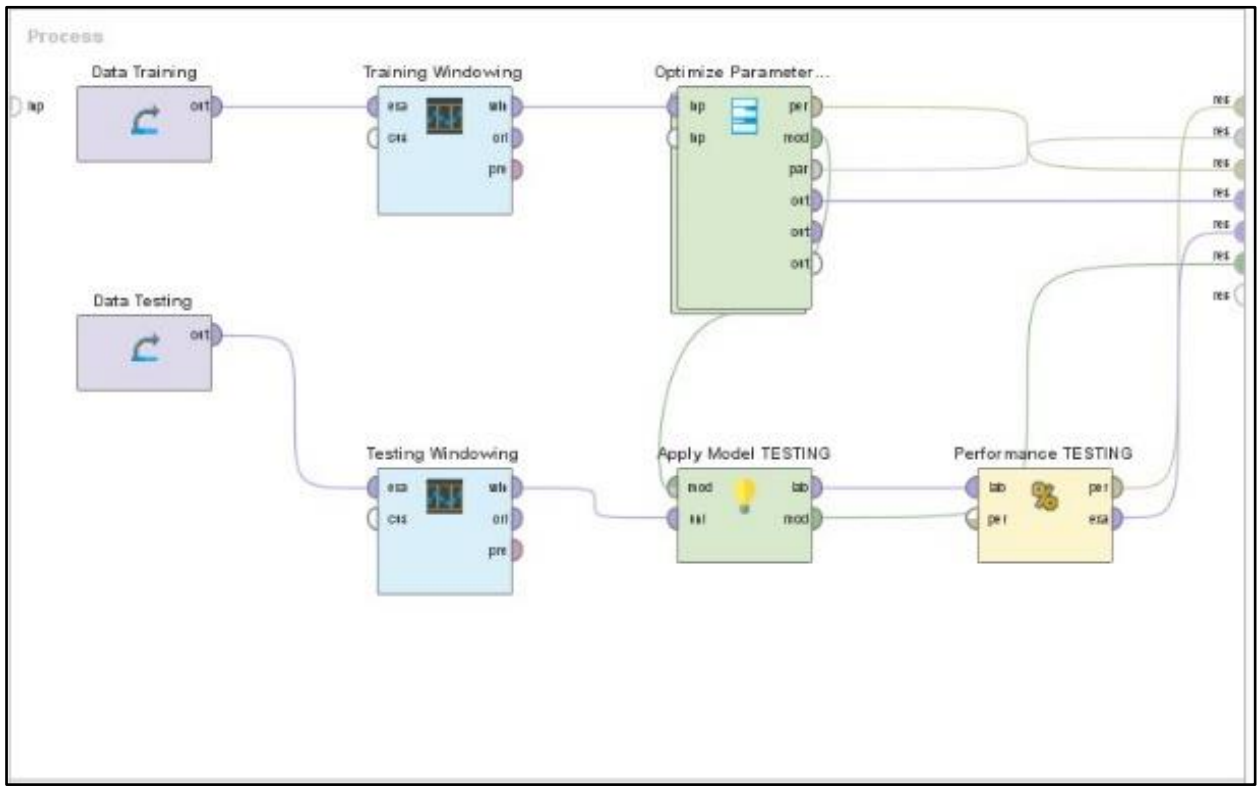


Figure 2. The structure of the *Artificial Neural Network* design uses *Rapidminer software.*

In Figure 2 is an ANN design using *Rapidminer software.* From the image above, it can be seen that *the training* and *testing data* will be processed through *windowing* which is useful for filtering normalized data, then the *testing data* will be forwarded to *the apply model* to determine the prediction level and then enter *performance* to find out the accuracy level of the testing data. For *training* data, it is first processed through *optimizing parameters* to determine the level of *momentum* and *neural net.*

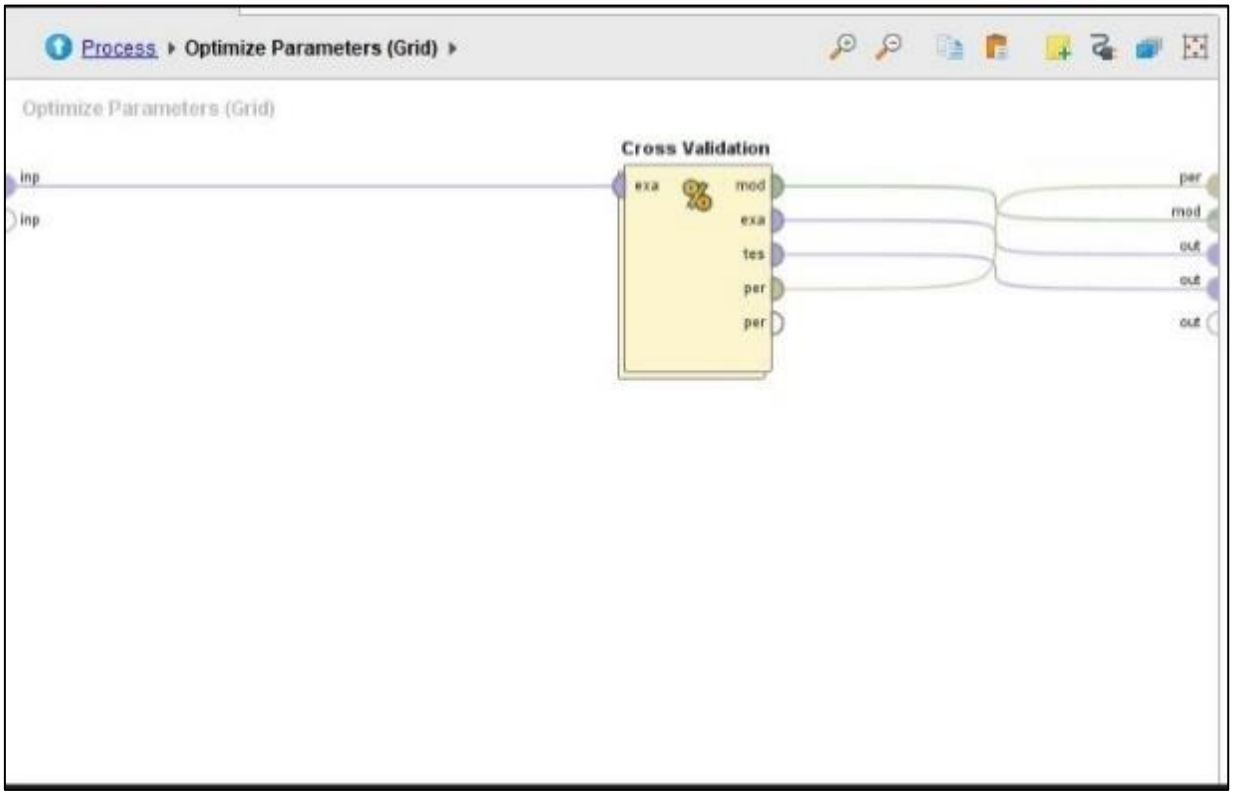


Figure 3. Subprocess *Optimize Parameter*

After the *training data* enters the *optimization parameters*, the data will first be processed with *crossvalidation* which serves as a prediction network design for the upcoming period by determining the amount of *learning rate* 0.1 and momentum 0.9.

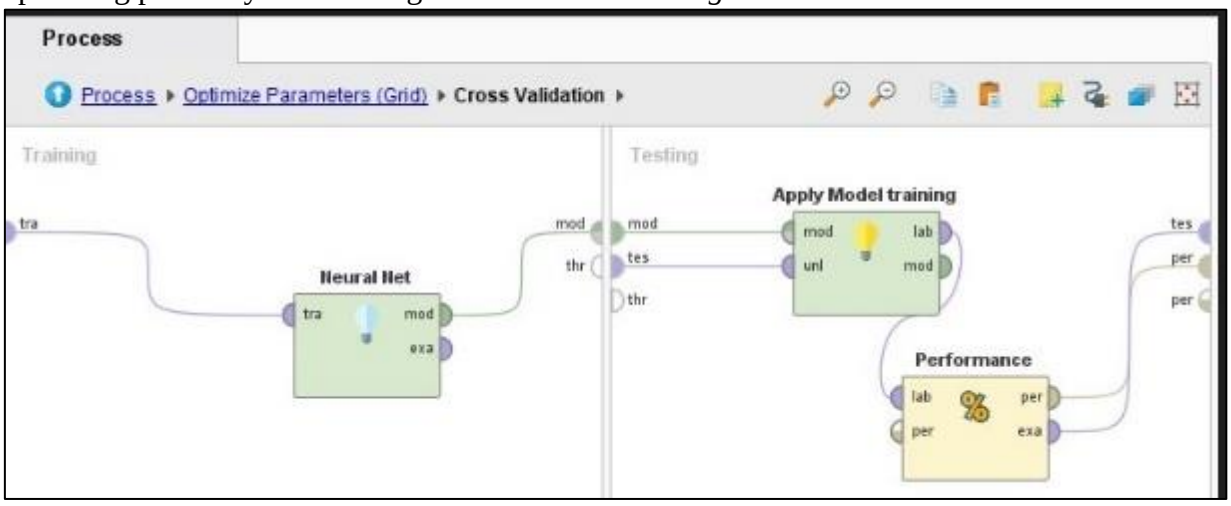


Figure 4. Crossvalidation Subprocess

Figure 4 shows the subprocess of *crossvalidation* where *the training* data that has gone through *crossvalidation* will be processed by *the neural net* to determine the data results and then *apply the model* and *performance* to know the final result of the *training*

data. From the results of the image above, it will be used as a reference for forecasting and testing data and obtaining demand prediction data in the next period.

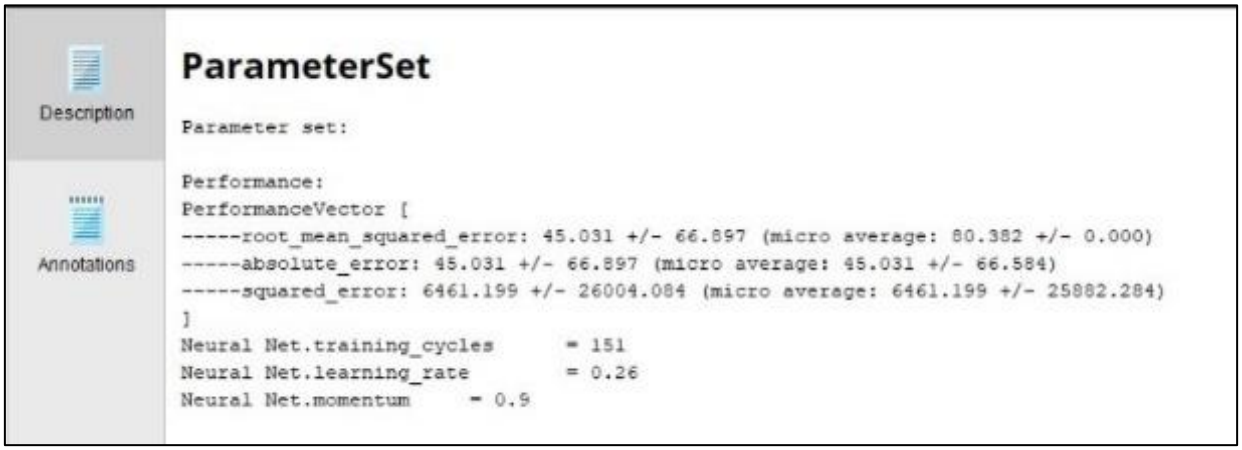


Figure 5. *ParameterSet Rapidminer*

Figure 5 shows a root *mean square error* (RMSE) value of 45,031, *neural net training cycles* of 151, *neural net learning rate* of 0.26 and *neural net* momentum of 0.9.

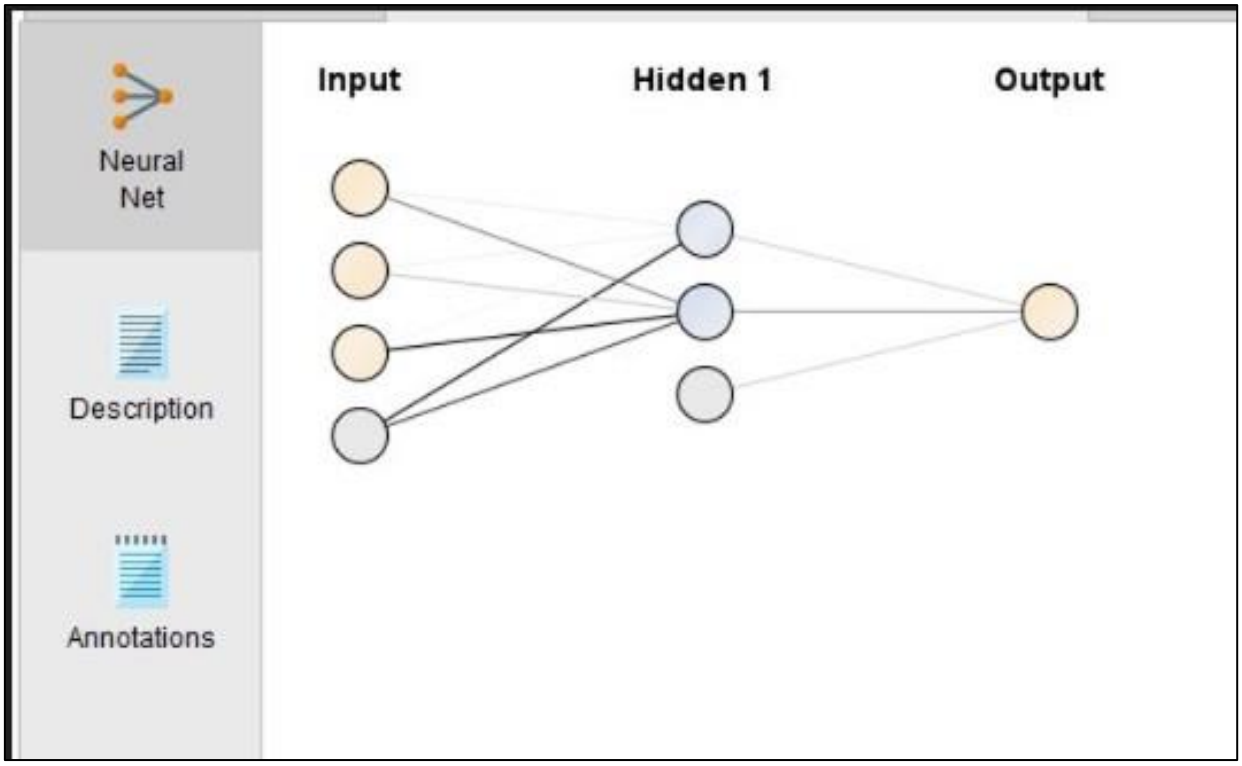


Figure 6. *Rapidminer Neural Net Design*

Figure 6 shows that it produces 4 layers of input, then *3 layers of hidden* and 1 layer of output, where 2 nodes have different *sigmoid* functions. Then the prediction results can be seen in table 3.

Table 3. Demand Prediction Results Using the ANN Method

Sunday	Result	Sunday	Result	Sunday	Result
1	797 pcs	6	764 pcs	11	833 pcs
2	788 pcs	7	855 pcs	12	781 pcs
3	801 pcs	8	818 pcs	13	776 pcs
4	804 pcs	9	720 pcs	14	782 pcs
5	816 pcs	10	803 pcs	15	812 pcs

Table 3. The results of demand prediction using the ANN method (Advanced...)

Sunday	Result	Sunday	Result	Sunday	Result
16	797 pcs	29	787 pcs	42	822 pcs
17	800 pcs	30	798 pcs	43	818 pcs
18	824 pcs	31	803 pcs	44	759 pcs
19	815 pcs	32	781 pcs	45	839 pcs
20	821 pcs	33	767 pcs	46	834 pcs
21	824 pcs	34	830 pcs	47	802 pcs
22	828 pcs	35	799 pcs	48	805 pcs
23	806 pcs	36	809 pcs	49	833 pcs
24	810 pcs	37	845 pcs	50	798 pcs
25	856 pcs	38	727 pcs	51	786 pcs
26	829 pcs	39	813 pcs	52	828 pcs
27	801 pcs	40	704 pcs		
28	845 pcs	41	819 pcs		

Based on table 3 above, the results of the request with the ANN method during 2023 were obtained where, in January there was a demand for bags of 3190 pcs, in February 3232 pcs, March 3284 pcs, April 3323 pcs, May 3306 pcs, June 3264 pcs, July 3208 pcs, August 3237 pcs, September 3213 pcs, October 3230 pcs, November 3247 pcs and in

December there was a demand for bags of 3274 pcs. The highest demand fell in April which was 3323 pcs because in that month there were many orders from pilgrims, and the lowest demand was in January of 3190 pcs due to Christmas and New Year orders that had been fulfilled in December.

2. Determination of Safety Inventory with *Fuzzy Inventory*

To carry out finished product safety supplies using *fuzzy inventoy* assisted by *Matlab software* , there are several stages as shown in figure 7.

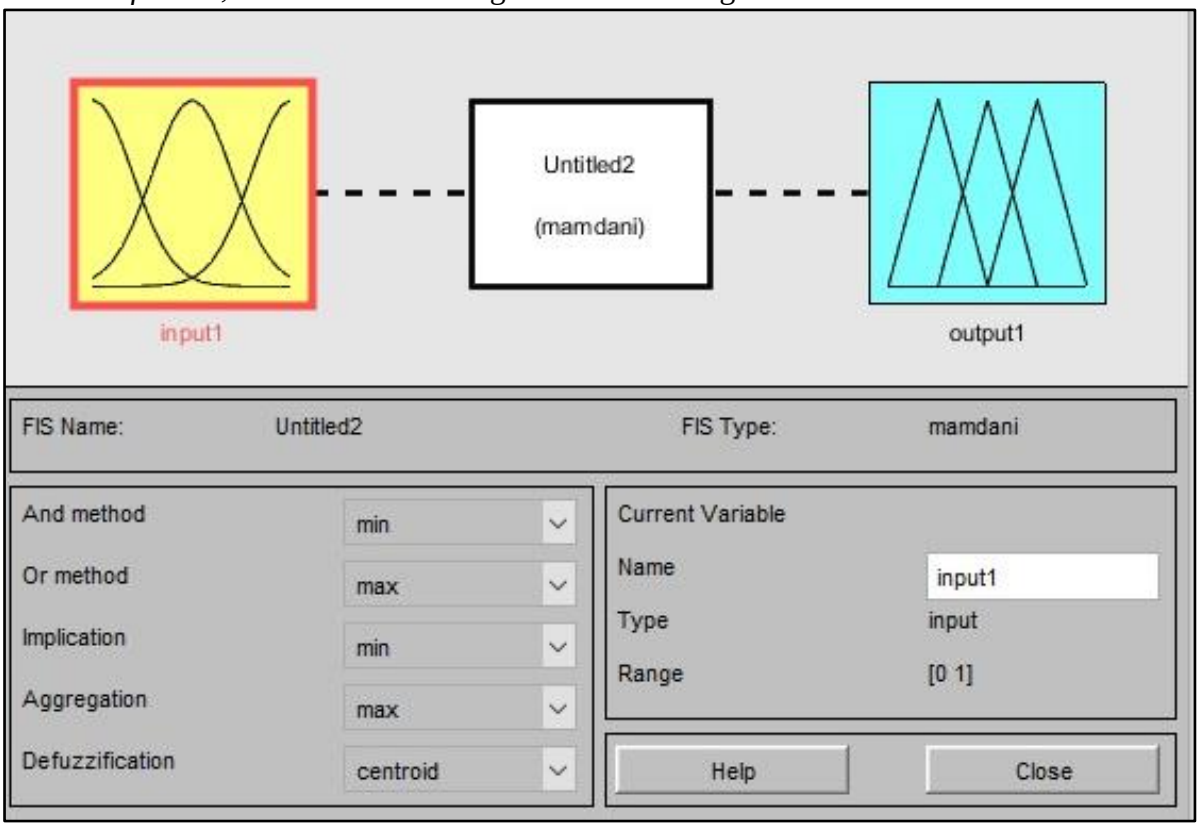
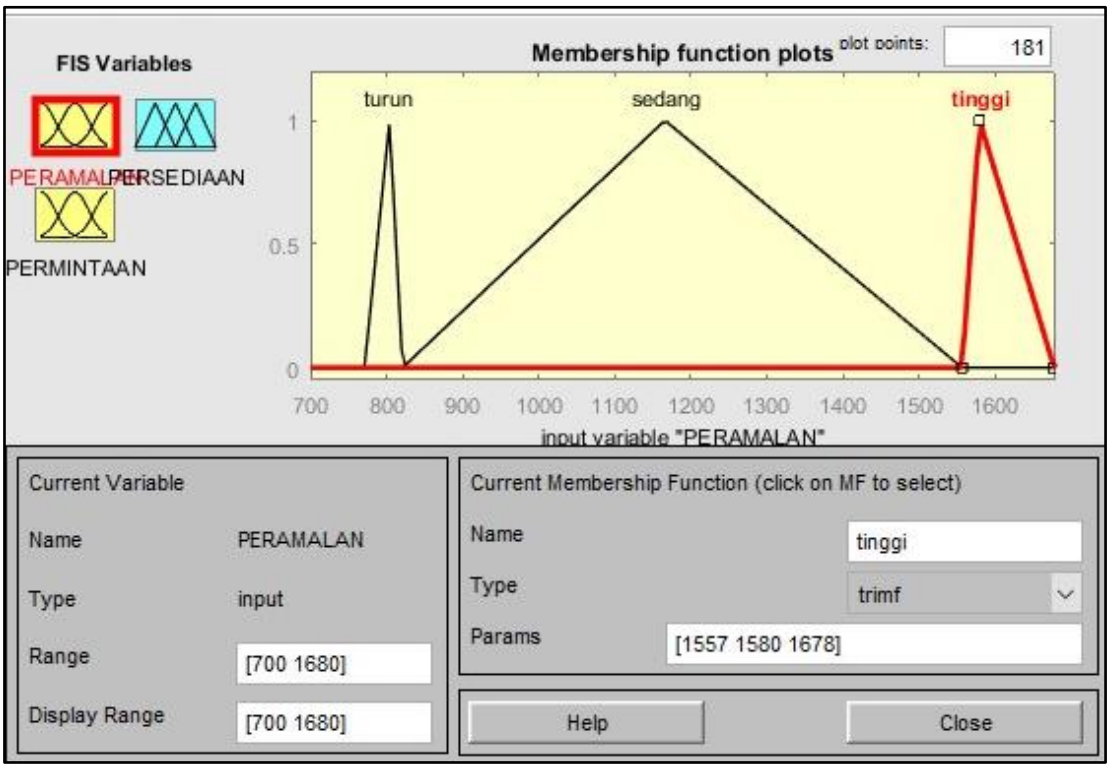


Figure 7. *Fuzzy Inventory* on *Matlab*

In figure 7, the variable input *stage is carried out* in the form of demand and sales prediction, the function of the *variable* data *input* is to get a sufficient level of inventory, it can be seen in the figure above that *the data input* will be processed first so that it will produce an *output*.



Gambar 8. Parameter *Fuzzy Inventory*

In figure 8 is the parameter or *membership function of fuzy inventory*, there are 3 function members that function to determine the level of inventory yield. On the down function will produce a down supply when the forecast and demand are down, on the medium function will produce a medium supply level when the forecast and demand are in the middle and on the high function the inventory will go up when the forecast and demand are at a high level.

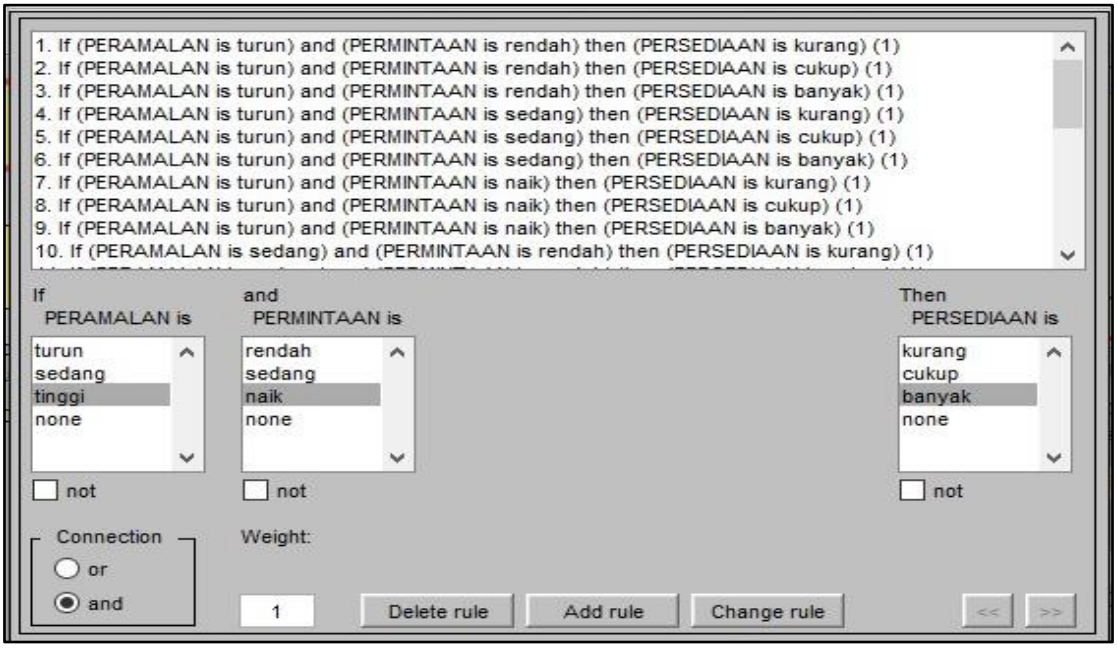


Figure 9. *Fuzzy Inventory Rule* Function Implications

Based on figure 9, 27 rules are made to determine the level of safety inventory of finished products, it can be seen that to determine the supply of less, sufficient, or abundant inventory, then the if rule is needed in forecasting and rules *and* on demand. If the forecast goes down and the demand goes down, then the automatic inventory will be enough, if the forecast is high and the demand goes up, the inventory will be *a lot of variable inputs* and if the forecast and demand are medium, the inventory will also be enough.

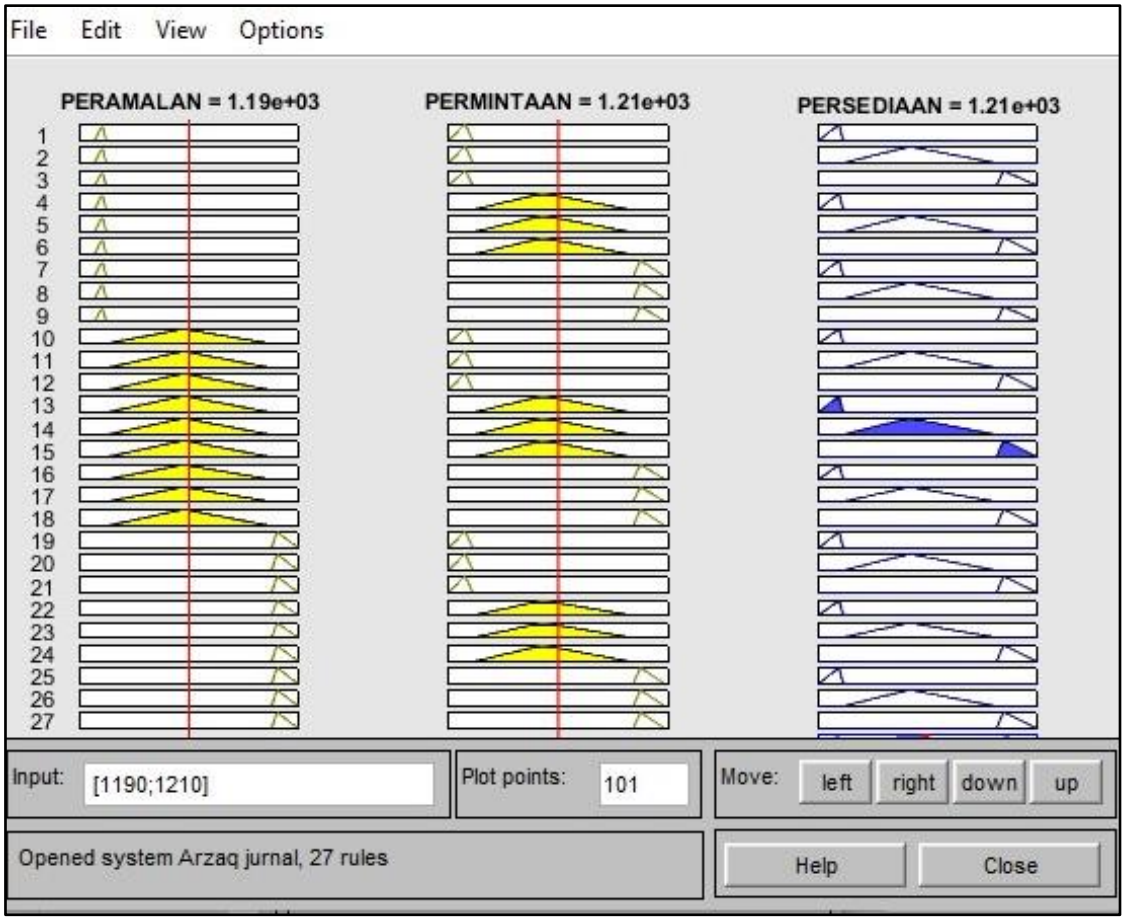


Figure 10. Results of Determining Product Inventory Using *Fuzzy Inventory*

In Figure 10 is shown the results of the safety inventory that has gone through several processes, the above results are an implementation of *fuzzy inventory* where to see the inventory is required to enter the forecast value and demand value in the input column. The results of the safety supplies can be seen in table 4.

Table 4. Finished Product Safety Supplies for the 2023 Period

Sunday	Demand	Demand Prediction	Safety Supplies
1	750	797	780
2	809	788	770
3	810	801	772
4	807	804	770
5	763	816	769
6	782	797	775
7	840	800	1100
8	794	819	765
9	815	807	764
10	821	827	1101

Table 4. Finished Product Safety Supplies for the 2023 Period (Continued...)

Sunday	Demand	Demand Prediction	Safety Supplies
11	824	821	1203
12	828	829	1109
13	806	833	800
14	810	822	780
15	856	822	1000
16	829	846	1100
17	801	835	763
18	845	828	1100
19	764	844	770
20	855	799	1108

21	818	851	1200
22	720	816	750
23	803	790	771
24	787	807	776
25	798	790	773
26	803	808	771
27	781	808	775
28	767	802	775
29	830	795	800
30	799	817	768
31	809	805	769
32	845	820	1109
33	727	836	763
34	813	787	766
35	704	819	820
36	819	771	830
37	833	812	1108
38	781	806	776
39	776	808	775
40	782	804	777
41	812	796	766
42	822	808	1107
43	818	818	1123
44	759	825	850
45	839	798	1113

46	834	831	1139
47	802	821	1105
48	805	824	1000
49	833	821	960
50	798	828	1095
51	786	813	960
52	828	810	1087
Total	41740 pcs	42280 pcs	43647 pcs

Based on table 4. The results of the 2023 period of finished product safety supplies were obtained where, in January 3586 pcs were obtained, in February 4177 pcs were obtained, in March 3680 pcs, in April 3741 pcs, in May 3497 pcs, in June 3094 pcs, in July 3446 pcs, in August 3179 pcs, September is 3436 pcs, October is 3846 pcs, November is 4357 pcs and December is 4102 pcs. The total supply of finished product safety in the 2023 period is 43647 pcs.

CONCLUSION

Fundamental Finding: This study successfully integrates Artificial Neural Networks (ANN) and Fuzzy Inventory methods to predict sales demand and determine safety inventory levels for bag products in PTK MSMEs, achieving a Root Mean Square Error (RMSE) of 45.031 and a calculated safety stock of 43,647 pieces for 2023. **Implication:** These findings provide a robust framework for MSMEs to enhance inventory management practices, thereby minimizing shortages and reducing associated costs, ultimately contributing to improved operational efficiency and competitiveness in the market. **Limitation:** However, this research is limited by its reliance on historical data from a single MSME, which may not account for broader market dynamics and consumer behavior variability. **Further Research:** Future studies should consider expanding the scope to include multiple MSMEs across different product categories and incorporate external factors such as market trends and economic indicators to refine demand forecasting and inventory management strategies further.

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