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COMPARING OF ARTIFICIAL NEURAL NETWORK AND MULTIPLICATIVE HOLT WINTERS EXPONENTIAL SMOOTHING METHODS IN FORECASTING DEMAND

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ABSTRACT

General Background: Fluctuations in raw material orders pose significant challenges for business operators, especially during peak seasons like holidays and the new year, often resulting in shortages or excess inventory. **Specific Background:** This study focuses on forecasting demand for wallet products from UMKM Pengerajin Dompet Khas Tanggulangin (PDKT) by comparing two forecasting methods: Artificial Neural Networks (ANN) and the Multiplicative Holt-Winters method, which is tailored for seasonal data. **Knowledge Gap:** While existing literature recognizes the effectiveness of various forecasting techniques, there is limited comparative analysis of ANN and Holt-Winters specifically in the context of UMKM wallet production, highlighting the need for empirical validation. **Aims:** This research aims to identify the most accurate forecasting method to optimize raw material usage and production planning. Results: The findings indicate that the ANN method yields a superior Root Mean Square Error (RMSE) of 14.249, compared to 93.436 for the Holt-Winters method, establishing its higher predictive accuracy. **Novelty:** The study contributes to the field by providing a comparative analysis of forecasting methods tailored to the specific context of UMKM, demonstrating the efficacy of ANN over traditional methods. **Implications:** These results suggest that adopting ANN for demand forecasting can significantly enhance inventory management and production efficiency for PDKT MSMEs, ultimately leading to better resource allocation and reduced operational costs.

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INTRODUCTION

Forecasting is a process used to forecast or predict the future condition of a company. Although forecasting is not always 100% accurate, by choosing the appropriate method, the rate of forecasting errors can be minimized. Using data from the past, this

forecasting is used to anticipate situations that may occur in the future. The results of this forecasting can be the basis for making decisions and assist companies in determining the best options [1].

In the production process, PDKT MSMEs only rely on estimates to determine the amount of production, which is based on the average of the previous month. This approach can lead to variations in demand, with fluctuations of up to 11%. If raw material orders exceed production quantities, this can result in excessive storage costs and quality degradation. On the other hand, if orders are too few, the risk of running out of stock can occur, leading to production stalls, sales delays, or even loss of customers [2].

Forecasting is a tool for projecting future needs, including the quantity and quality needed to meet fluctuating demand [3]. There are various approaches that can be used in forecasting. One of them is the exponential smoothing method, which continuously performs forecasting calculations by considering the most recent data. [4]. By reducing the average value of smoothing on time series data, exponential smoothing is a technique that consistently improves forecasting accuracy. Holt-Winters is one of the time series methods that considers trend and seasonal factors, such as celebrations and holidays. [5].

The Artificial Neural Network Method has several characteristics, such as the relationships between neurons that form patterns (network architecture), weight determination, and activation functions. Artificial neural networks have three types of architecture, namely networks with one layer of connection weight, single layer, or single. A network that has many layers (multilayer) has more than one layer of connection weights. There are also competitive networks, where a group of neurons compete to be active [6]

Holt-Winters or Triple Exponential Smoothing, a method that uses three constants for levels, trends, and seasons, effectively addressing seasonal trends and patterns in time series with low error rates. In this method, there are two models, namely the additive model and the multiplication model. In general, when dealing with data that fluctuates over time, multiplication modeling is more commonly used, while additive modeling is more suitable for data that has constant variation over time spans [7].

In processing data using the artificial neural network method, the data will be processed using software RapidMiner. RapidMiner is a framework that provides a unified environment for predictive analytics, data mining, machine learningand deep learning. These applications can be implemented in the context of business and commercial applications, as well as for research, training, prototyping, and application development purposes. RapidMiner It also supports all stages of the machine learning process, including data preparation, results visualization, validation, and optimization [8].

One of the requirements forecasting The good thing is accuracy. Consistent forecasting results show relatively small forecasting errors. If the forecast is not accurate, the inventory will run out and cannot meet customer demand. This is a serious impact because MSMEs have experienced a decrease in sales profits and lost customers. [9].

The use of data mining methods can be a solution to face this challenge. Data mining is an approach method to process large volumes of data, consisting of data sets, with the aim of obtaining new information. The information generated can be an important consideration in the decision-making process. The data mining approach involves the process of processing data using mathematical techniques, statistics, artificial intelligence, and machine learning, including the application of recognition techniques

[10]. Taking these problems into account, it is necessary to do forecasting to forecast the amount of demand needed in the production process. The initial stage in the development and regulation of the production system involves determining the estimated demand for the products and services to be produced. This is the basis for designing production management and utilizing forecasting techniques to project future demand needs [11].

This research aims to forecast the number of wallet requests in MSMEs Tanggulangin Typical Wallet Craftsmen (PDKT) and can find out which method has the accuracy of the two methods by comparing the results of Root Mean Square Error (RMSE)

METHODS

This research was conducted at PDKT MSMEs (Tanggulangin Typical Wallet Craftsmen) located in Ketegan Village, Tanggulangin District, Sidoarjo Regency, East Java, and was carried out for a period of 6 months. The data collection process in this study includes the acquisition of historical data, especially requests every month during the 2021-2022 time span. In addition, an interview approach with questions and answers is used to understand the methods applied in determining production volumes.

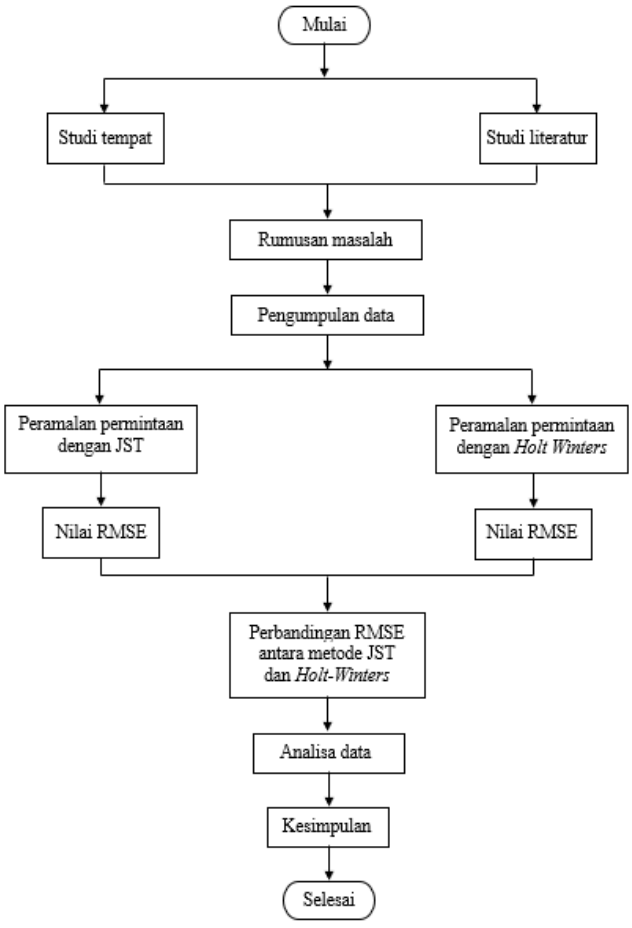

Figure 1. Research Flow Diagram

The research began by identifying problems in PDKT MSMEs, through place studies and literature. The main problem is the use of raw materials that are not optimal, often experiencing shortages or excesses. The data collection stage was obtained from the results of observations and interviews with the owners who manage the MSMEs. After the data is obtained, the next is to make predictions using the artificial neural network method and *multiplicative holt winters exponential smoothing*. The method used in this study is by comparing the forecasting method between the artificial neural network method and the *multiplicative holt winters exponential smoothing*.

Based on research conducted by Aini, et al. in 2021 with the title Average Monthly Rainfall Prediction in Pasuruan Using the *Holt-Winters Exponential Smoothing*, an error result was obtained from the prediction calculation using the *Holt–Winters Exponential Smoothing* Using the *Multiplicative* is 41% which means that it is quite good in making predictions [12].

Meanwhile, the research conducted by Putri with the title Analysis of Shrimp Cracker Sales Forecasting Using the *Artificial Neural Network* (ANN), obtained the method *artificial neural network* has more accurate calculations because they have a *roat mean square error* smaller when compared to using the *double exponential smoothing holt* [13].

Steps to process data with *RapidMiner* as follows [14].

a. Data transformation, namely by dividing data with training data and data testing with a ratio of 70:30. With the introduction of data normalization and network architecture design. After that, normalization is carried out to optimize the form of data on the network, the value range is between 0-1.
b. Training, using training data that has been shared previously.
c. Testing, by using testing data so that later the forecast results and also the RMSE value will be known.

As for data processing for the *multiplicative holt winters exponential smoothing* Using *MS Excel* with the following formula equation [15]:

lt = α () + 1- α ($l\frac{Y_t}{S_{t-s}}$t-1 + BT-1) (1)

bt = b (l_t - lt-1) + (1- β) bt-1 (2)

st = γ + (1- γ) s$\frac{Y_t}{l_t}$t-s (3)

Ft = (lt-1 + bt-1) s_{t-s} (4)

Ft-m = (l_t + b_{tm}) s_{t-s+m} (5)

Information:

lt = Tth smoothing value
A = Constant refinement for data
Yt = Actual value in the period t
bt = T-trend estimate
B = Constant refinement for trend estimation
st = Seasonal component estimates

C = Constant refinement for seasonal estimation
m = Number of periods in the forecast period
s = Season length (number of periods in a season)
Ft+m = Forecast for m period ahead

After doing forecasting using this method, the next step is to compare using the *Root Mean Square Error* (RMSE). The RMSE serves as an indicator of how much error between the prediction model and the actual data generated by the forecasting model. The RMSE calculation is done by taking the average of the number of squared errors. The RMSE results can then be analyzed to conclude which method is better, taking into account the lowest RMSE value as the main parameter. One of the evaluation methods used to measure the accuracy of data forecasting results is by looking at the RMSE value. A low RMSE score indicates a high level of accuracy in forecasting. Account *Root Mean Square Error* (RMSE) is [16]. The following is the calculation formula to calculate *root mean square error* [15]:

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}(At-Ft)^2}{n}} \quad (6)$$

Information:
At = Actual data value
Ft = Forecast result value
n = Amount of data

RESULT AND DISSCUSION

The data used is wallet product demand data for a period of 3 years, namely from 2020-2022. From data processing using the artificial neural network method, the following results were obtained.

a. Normality test

Table 1 Results of the Normality Test

No	Date	Sales Quantity	Normalisasi
1	11/01/20	150	0,043716
2	18/01/20	155	0,071038
3	25/01/20	153	0,060109
4	31/01/20	152	0,054645
5	08/02/20	142	0

b. Data Partion

Table 2 *Partion Data*

Data *Training*			Data *Testing*		
No	Date	Demand	No	Date	Demand
1	11/01/20	150	1	12/02/22	187
2	18/01/20	155	2	12/02/22	187
3	25/01/20	153	3	19/02/22	184
4	31/01/20	152	4	26/02/22	188
5	08/02/20	142	5	05/03/22	195

c. Application of Artificial Neural Network method with *Rapidminer*
From data processing with Rapidminer, the following results were obtained.

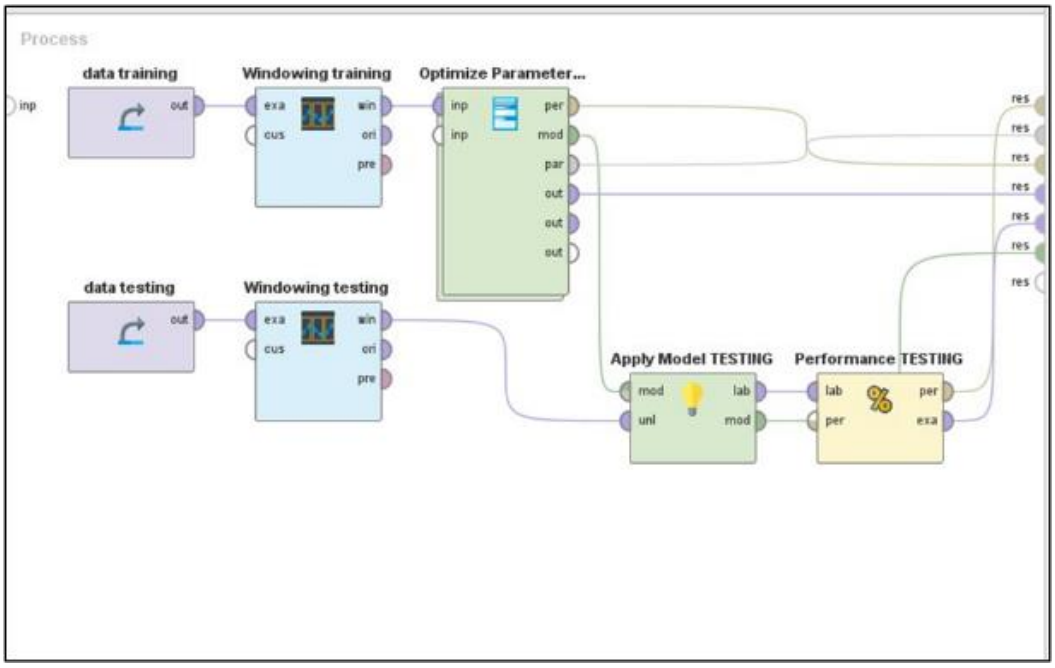

Figure 1. Stages of Artificial *Neural Network Implementation*

In Figure 1, it can be seen that the implementation stages using *Software RapidMiner*. The initial step involves a training process, where the data used for training undergoes a process *windowing* to set the forecast distance. After that, the next step is to go to the operator *optimize parameter* (*grid*). In the operator *optimize parameter* (*grid*), parameters such as learning rate (*learning rate*) and momentum are set, both have values

between 0.1 to 0.9, as well as the maximum number of iterations or epochs. Operator *optimize parameter* (*grid*) also includes subprocesses *cross-validation*, where the data *training* (as much as 70% of the total data) divided into k subsets with the same amount.

From each subset, the average value is calculated, and one subset is selected as a reference for forecasting and testing the data. Process *cross-validation* Involving Subprocesses *training* and *testing*. On the subprocess *training*, operator *neural net* used, while on the subprocess *testing*, operator *apply model* and *performance* Used. After the process *optimize parameter* (*grid*) is done, the next step is the process of *testing*. Data *testing* will experience a process *windowing*, and the model will be implemented using the *apply model*. So that in the future, there will be a value *root mean square error* (RMSE).

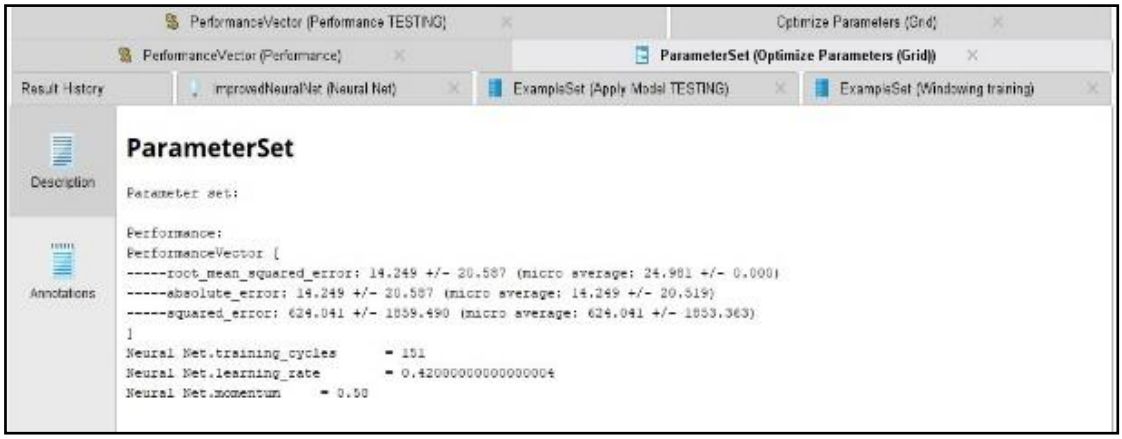

Figure 2. RMSE Results

From figure 2. above, the root mean square error (RMSE) value of 14.249, with the training *cycles* parameter of 151, with *the learning rate* parameter of 0.42 and the *momentum* parameter of 0.58.

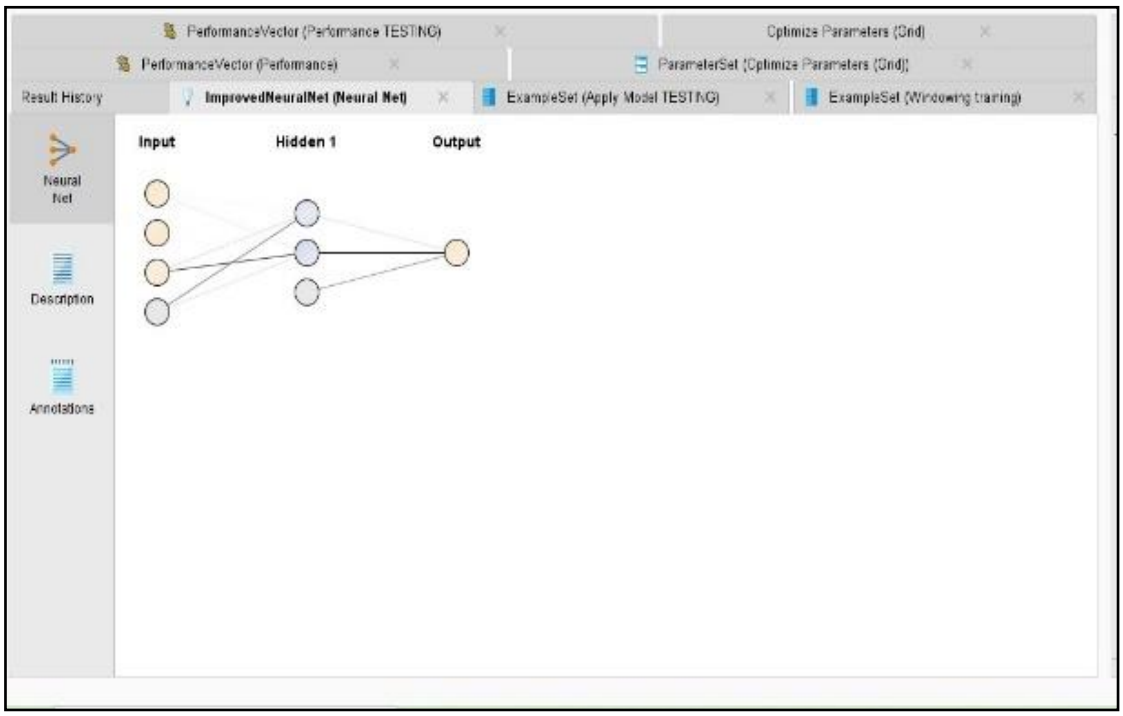

Figure 3. *Neural Net Operator*

In Figure 3, it can be seen that the operator *neural net* produce *output* in the form of a model architecture design from the input data. In addition, this model also gets an activation function, namely *sigmoid*. Models formed through the process *windowing* Generate a structure with 4 *layer* on the layer *input*, 3 *layer* on the hidden layer, and 1 *layer* on the layer *Output*. Every *layer* There are 2 *Node* with the *Sigmoid* each.

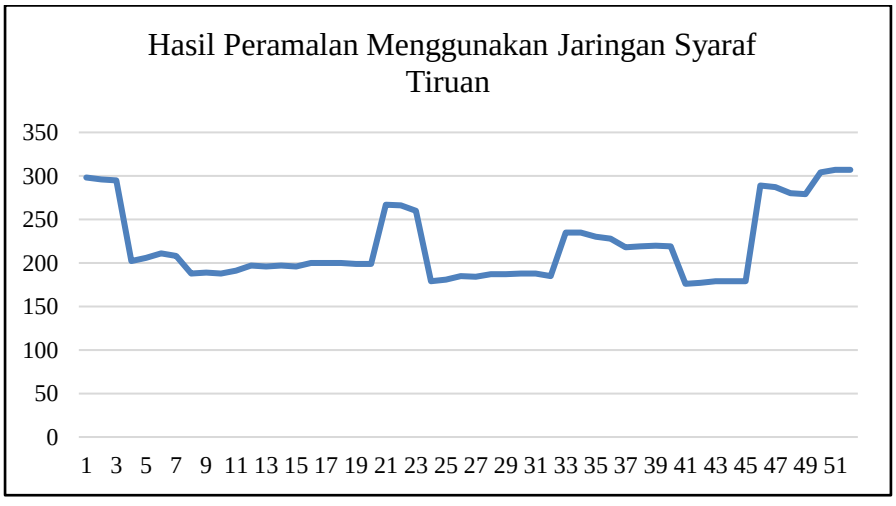

Figure 4. Graph of Forecasting Results Using Artificial Neural Network Method

Based on figure 4, the forecast results using the artificial neural network method were obtained, namely, in January 2023 the forecast results were obtained of 1091 pcs,

in February 2023 the forecast results were obtained of 813 pcs, in March 2023 the forecast results were obtained of 765 pcs, in April 2023 the forecast results were obtained of 989 pcs, in May 2023 the forecast results were obtained of 865 pcs, in June 2023 the forecast results were 886 pcs, in July 2023 the forecast results were 931 pcs, in August 2023 the forecast results were 843 pcs, in September 2023 the forecast results were 1115 pcs, in October 2023 the forecast results were 751 pcs, in November 2023 the forecast results were 934 pcs, in December 2023, 1477 pcs were obtained. The highest demand was in December which was 1477 pcs due to the large number of orders for wedding souvenirs.

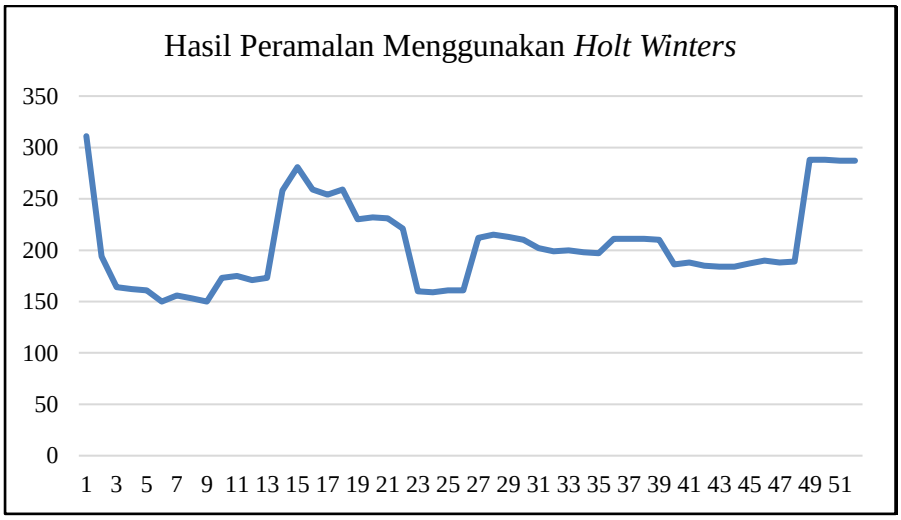

Figure 5. Graph of Forecasting Results Using *the Holt Winters Method*

Based on figure 5, the RMSE result is 39.110, forecasting using the multiplication method *holt winters* namely, in January 2023 the forecast results were obtained of 831 pcs, in February 2023 the forecast results were obtained of 620 pcs, in March 2023 the forecast results were obtained of 669 pcs, in April 2023 the forecast results were obtained of 1225 pcs, in May 2023 the forecast results were obtained of 952 pcs, in June 2023 the forecast results were obtained of 701 pcs, in July 2023 the forecast results were obtained of 1011 pcs, in August 2023 the forecast results were obtained of 799 pcs, in September 2023 the forecast results were obtained of 1040 pcs, in October 2023 the forecast results were obtained of 743 pcs, in November 2023 the forecast results were obtained of 749 pcs, in December 2023 the forecast results were obtained of 1339 pcs. The highest demand was in December which was 1339 pcs due to the large number of orders for wedding souvenirs.

Based on the results of the comparison of RMSE values from the artificial neural network method and *holt winters*, the artificial neural network method because it has a lower RMSE value compared to the *holt winters* Because in the artificial neural network method, it has the capacity to extrapolate and adjust data to patterns that develop over time. This ability makes artificial neural network methods more flexible in responding to complex seasonal trends or patterns [17]. From the comparison of RMSE values, the

artificial neural network method has a lower value of 14.249, while the *holt winters* has an RMSE value of 39,110. Based on the results of the comparison, it can be concluded that the artificial neural network method is better if applied, because it has a lower RMSE and a higher level of accuracy when compared to *holt winters*.

CONCLUSION

Fundamental Finding: This study demonstrated that the Artificial Neural Network (ANN) method significantly outperformed the Multiplicative Holt-Winters method in forecasting wallet product demand for UMKM Pengerajin Dompet Khas Tanggulangin (PDKT), achieving a lower Root Mean Square Error (RMSE) of 14.249 compared to 39.110. This finding underscores the ANN's superior capacity for extrapolating and adapting to complex seasonal trends, making it a more effective tool for demand forecasting in fluctuating markets. **Implication:** The results suggest that PDKT MSMEs can enhance inventory management and optimize resource allocation by implementing ANN for demand forecasting, ultimately leading to reduced costs associated with raw material shortages and excesses. **Limitation:** However, this study is limited by its reliance on historical demand data from only three years, which may not capture long-term trends or shifts in consumer behavior that could impact future demand patterns. **Further Research:** Future studies could expand the dataset to include a more extended period or incorporate additional variables, such as economic indicators or consumer trends, to improve forecasting accuracy. Additionally, exploring the integration of hybrid forecasting models that combine the strengths of both ANN and Holt-Winters methods may yield even more robust predictive capabilities.

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