Analysis Of Forecasting For Bottled Drinking Water In Gallons At Pt Abc

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Abstract

Background : Inaccurate production planning can result in excess inventory, material accumulation, and imbalances between incoming and outgoing stock in manufacturing companies. These issues were identified in the production of 19-liter bottled drinking water at PT ABC, highlighting the need for a forecasting method capable of providing more accurate demand estimates

Purpose : This study aims to determine the most appropriate demand forecasting method for 19-liter bottled drinking water by comparing several quantitative forecasting techniques based on historical demand data.

Methodology : A quantitative time-series approach was employed using monthly demand data for 19-liter gallons collected throughout 2022. Three forecasting methods—Single Exponential Smoothing, Linear Regression, and Double Exponential Smoothing with Trend—were evaluated. Model performance was assessed using Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Tracking Signal analysis to determine forecasting accuracy and model validity

Findings : The historical demand data exhibited an increasing trend, indicating that Linear Regression was the most suitable forecasting method. Among the evaluated models, Linear Regression produced the lowest forecasting errors, with a MAPE of **0.41%**, a MAD of **4,062.611**, and an MSE of **26,179,663.49**. Based on this model, the projected demand for the following six months was **1,001,833.2; 1,004,232.5; 1,006,631.9; 1,009,031.2; 1,011,430.5; and 1,013,829.9 gallons**, respectively.

Implications : The findings provide a reliable basis for improving production planning, inventory management, and decision-making processes by reducing the risk of overstock and enhancing the efficiency of manufacturing operations. Future studies are recommended to incorporate longer historical datasets and compare conventional forecasting techniques with advanced machine learning or hybrid forecasting models to improve prediction accuracy under dynamic market conditions.

Originality : This study contributes by systematically comparing multiple quantitative forecasting methods to identify the most appropriate technique for the demand pattern of 19-liter bottled drinking water in a real industrial setting. The proposed approach offers a practical framework for selecting forecasting models based on demand characteristics, thereby supporting more effective production planning in the bottled water industry.

Keywords: *Demand, Forecasting, Linear Regression, MAPE, bottled water, production planning*

INTRODUCTION

Every company needs to plan its future operational activities, the plans developed by managers are sometimes fraught with uncertainty. To address this issue, managers must be adept at handling such

situations. Extensive knowledge, sufficient experience, and accurate data can lead to sound decisions. Decisions made by managers influence the company's future success (Yildirim Ozmutlu & Arun, 2026). For example, estimating the amount of raw material inventory needed to meet next month's demand is one of the issues that must be resolved to ensure the continuity of a company's production. When making decisions, managers always strive to make good estimates of what will happen in the future. Making good estimates is the primary goal of forecasting (Nafisah et al., 2025).

PT. ABC is a company engaged in the bottled water production industry, with the overall goal of maximizing profits. However, in its efforts to achieve this goal, the company sometimes still faces obstacles. These issues arise because the company produces more 19-liter gallon containers than the market demands. This is evident from the accumulation of gallon containers in the storage warehouse and the buildup of raw material inventory in the materials warehouse, when inventory is held for too long, it causes an imbalance between gallon container output and raw material intake.

In previous studies, such as Rizaldy et al. (2024) discussed ARIMA, Holt-Winters, and hybrid ARHOW models for the pharmaceutical industry (in the context of demand forecasting and supply chain optimization), but these models have limitations when dealing with nonlinear patterns or when external variables have a strong influence. Furthermore, Abdillah et al. (2023), Dinanti & Suryati, (2023) which tested Single Exponential Smoothing (SES) for sales/demand forecasting in MSMEs or retailers, showed that SES can provide reasonable predictions for the short term if the data patterns are not too volatile or exhibit low random variation. However, if there are consistent trends or nonlinearities, or external factors (such as promotions, prices, or weather) that influence demand, a single SES model is often insufficient without modifications (e.g., applying an adaptive SES or combining SES with other components).

However, the studies reviewed in this research reveal three issues that still require attention. First, comparisons between forecasting methods are often reported primarily as comparisons of numerical errors, while the fit between observed data patterns and the structural assumptions of each method is not always explicitly explained. Second, model selection is often based on a single accuracy metric, even though different error measures capture different aspects of forecasting deviation. Third, models with small mean errors may still exhibit systematic bias, therefore, additional verification procedures are necessary before forecasts are used for operational planning (Nurmayanti & Sudrajat, 2021). These issues are particularly relevant to the production of 19-liter gallons, where seemingly small percentage error can represent thousands of physical units and directly affect warehouse utilization and material flow. Having identified the potential problem, the author will address it using forecasting methods, as these methods allow us to predict or plan the number of gallons to be produced in the coming period, thereby preventing excessive product buildup.

The forecasting process influences a company's inventory levels. Forecasting predicts future demand or the quantity of products that must be produced in the future, thus by conducting the forecasting process, a company can estimate its future inventory needs. Forecasting minimizes the occurrence of inventory shortages or surpluses that could result in losses for the company (Mitra et al., 2022). Forecasting also affects service levels, if a company can accurately predict demand, it will be able to fulfill customer orders quickly and accurately. Customers no longer need to wait for goods to be produced, as they are already available in inventory, which improves the company's service level to customers. Forecasting is also useful in determining production schedules, these schedules are important for managing productivity levels over a specific period (Panda & Mohanty, 2023).

This study develops and demonstrates an integrated, decision-making-oriented model selection procedure for real-world large-scale production cases. This procedure combines: the identification of historical demand patterns as the basis for selecting candidate methods, simultaneous evaluation using

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MAPE, MAD, and MSE so that relative error, mean absolute deviation, and sensitivity to large errors are considered together, verification of tracking signals to assess forecasting bias and stability, and application of the selected model to six-month production demand forecasting. This integration distinguishes this study from a simple comparison of three conventional methods because the selected model is evaluated in terms of both statistical accuracy and operational reliability. Therefore, PT ABC creates product forecasts so that, within a given timeframe, the company can meet consumer demand, avoid losses resulting from overproduction, and better develop its products. Therefore, this study aims to determine the most appropriate demand forecasting method based on historical production data for 19-liter gallons.

METHODOLOGY

This study uses the time series method, which is a quantitative forecasting method that uses time as the basis for forecasting. In general, future demand is influenced by time. To make a forecast, historical (past) demand data is required. Forecasting is a technique used in planning systems to determine future production activities based on historical data, with the aim of developing better and more profitable systems and policies for the relevant company or organization.

1. Types of Forecasting

Based on their nature, forecasting methods are classified into two categories (Vandeput, 2021):

a. Qualitative Forecasting

This is a forecasting technique used when historical data is unavailable or available but limited in quantity.

b. Quantitative Forecasting

This is a forecasting technique in which historical data patterns are used to predict future conditions. There are three conditions for applying this forecasting method: the availability of information about the past, the ability to quantify that information in the form of numerical data, and the assumption that certain aspects of past patterns will continue into the future. There are two main quantitative techniques: time series analysis and structural models (or causal models) (Shmueli & Polak, 2024).

The following are the steps in developing a forecast using quantitative forecasting:

1. Determine the forecasting objective
2. Create a scatter plot
3. Select at least two forecasting methods deemed appropriate
4. Calculate the parameters of the forecasting functions.
5. Calculate the error for each method, select the best one that is, the one with the smallest error
6. Select the best method that is, the one with the smallest error.
7. Verify the forecast.

Based on the nature of its formulation, forecasting is classified into two types, namely:

a. Subjective forecasting, which is based on the forecaster's feelings or intuition.
b. Objective forecasting, which is based on relevant historical data, using techniques and methods to analyze that data.

Meanwhile, based on the forecast time horizon, forecasting is classified as follows:

a. Long-term forecasting, which is conducted to produce forecasts with a time horizon of more than one and a half years.
b. Short-term forecasting is forecasting conducted to produce forecast results with a time horizon of less than one and a half years. Thus, short-term forecasting uses relationship analysis techniques in which the only influencing variable is time.

2. Quantitative Methods

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Quantitative methods are methods based on the analysis of numerical relationships in data or on statistical methods. Quantitative methods are grouped into two main categories, namely(Ganestyani & Suryaningrum, 2026):

a. **Intrinsic Quantitative Methods (Time Series Models)**

Time series model is a method that uses a series of observations of a variable in the form of discrete time intervals. The observed time spans the period from the past up to the present. The time series models commonly used in forecasting analysis are as follows.

- **Moving Average Method**

The moving average method uses a set of actual data to generate forecast values for the future. This method is effective when the assumption is that market demand remains stable over time. Mathematically, it is expressed as follows:

$$F_{t+1}=\frac{\sum_{i=1}^{t} di}{t} \quad (1)$$

$$F_{t+2}=\frac{\sum_{i=2}^{t+1} di}{t} \quad (2)$$

Notes:
Ft = Demand forecast for period t
t = Number of periods
di = Demand

- **Weighted Moving Average Method**

The weighted moving average method is more responsive to changes because data from more recent periods are typically given greater weight. Mathematically, this is expressed as follows:

$$Ft=\frac{(P_1\times W_1)+(P_2\times W_2)+\cdots+(P_n\times W_n)}{W_1+W_2+\cdots+W_n} \quad (3)$$

Notes:
Ft = Demand forecast for period t
P = Demand for period t
W = Weight

- **Single Exponential Smoothing Method**

The single exponential smoothing method is an advanced weighted moving average forecasting method, yet it remains easy to use. Mathematically, it is expressed as follows:

$$Ft+1 = S'= \alpha \times Dt + (1-\alpha)\, Ft \quad (4)$$

Notes:
Ft/ S' = Demand forecast for period t
α = Smoothing constant ($0 \leq \alpha \leq 1$)
Dt = Actual demand for the previous period (t – 1)

- **Double Exponential Smoothing**

The double exponential smoothing method is a more complex exponential smoothing method that can adapt to existing trends. Mathematically, it is expressed as follows:

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$$\text{Parameter} = at = S't + (S't - S''_t) \quad (5)$$

$$\text{Trend} = bt = \frac{a}{(1-a)(S't - S''t)} \quad (6)$$

$$DES = S''_t = \alpha \times S't + (1-\alpha)S''_{t-1} \quad (7)$$

$$Ft = at + (bt \times m) \quad (8)$$

Notes:

at = Smoothing constant ($0 \leq \alpha \leq 1$)
bt = Trend constant ($0 \leq \beta \leq 1$)
Ft = Demand forecast for period t
m = period

- **Linear Regression**

Linear regression is a statistical method for predicting the future by drawing a straight line. This line illustrates the relationship between two factors—cause and effect—which is expressed as follows:

$$b = \frac{n\sum_{t=1}^{n}(t\,d_t) - (\sum_{t=1}^{n} d_t)(\sum_{t=1}^{n} t)}{n\sum_{t=1}^{n} t^2 - (\sum_{t=1}^{n} t)^2} \quad (9)$$

$$a = d' - bt' \quad (10)$$

$$Ft = a + b.t \quad (11)$$

Notes:

a = constant
b = regression coefficient
Ft = Demand forecast for period t
t = period

3. Selection of Forecasting Methods

Forecasting accuracy is a fundamental aspect of forecasting, it refers to how to measure the suitability of a particular forecasting method for a given dataset. Accuracy is considered a rejection criterion for selecting a forecasting method. In time series modeling of historical data, future conditions can be forecasted, forecast accuracy is used to test the validity of these forecasts. Some of the criteria used to test forecast accuracy include:

1. Mean Square Error

$$\text{MSE} = \frac{\sum_{1=2}^{n} ei\text{^}2}{n} \quad (12)$$

2. Mean Absolute Error

$$\text{MAE} = \frac{\sum_{1=2}^{n} ei}{n} \quad (13)$$

3. Mean Absolute Percentage Error

$$\text{MAPE} = \frac{\sum_{1=2}^{n} |ei|/dt}{n} \times 100\% \quad (14)$$

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Where:
e = dt− Ft (error in period t)
dt = demand data in period t
Ft = forecast value in period t
n = number of time periods

The forecasting method selected is the one that yields the smallest error value. Validation in a forecasting process is useful for determining whether there are significant differences between the forecast results and historical demand data. Validation tests are conducted using moving range charts, paired t-tests, F-tests, chi-square tests, and tracking signal charts. The following are examples of indicators used to test the validity of data (Anggraeni & Arifin, 2022):

1. Tracking Signal
   A measure of how well a forecast predicts actual values, the forecast is updated weekly, monthly, or quarterly, so that new demand data is compared against the forecast values. The Tracking Signal is calculated as the running sum of the forecast errors using:

$$\text{Tracking Signal} = \frac{\sum_{1=1}^{n} dt-Ft}{\frac{\sum_{1=1}^{n} |dt-Ft|}{n}} \quad (15)$$

Where:
dt = demand data in period t
Ft = forecast value in period t
n = number of time periods

RESULT AND DISCUSSION

This study uses data on demand for 19-liter water gallons over the last 12 months of 2022. Based on the results of mapping the demand data for 19-liter gallons during that 12-month period, it can be seen that the data pattern tends to increase from January to December, as shown in Table 1 and Figure 1. This situation indicates an upward trend, so the forecasting method used must be able to capture the tendency for demand to increase over time. It is important to pay attention to this trend pattern because selecting a forecasting method that does not align with the data characteristics can result in a higher error rate.

Table 1. Data On Demand For 19-Liter Water Gallons In 2022

Period	Month	Demand
1	January	966750
2	February	976300
3	March	974500
4	April	981520
5	Mei	994700
6	June	991950

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7	July	983900
8	August	987950
9	September	987800
10	October	989750
11	November	999860
12	Desember	999870

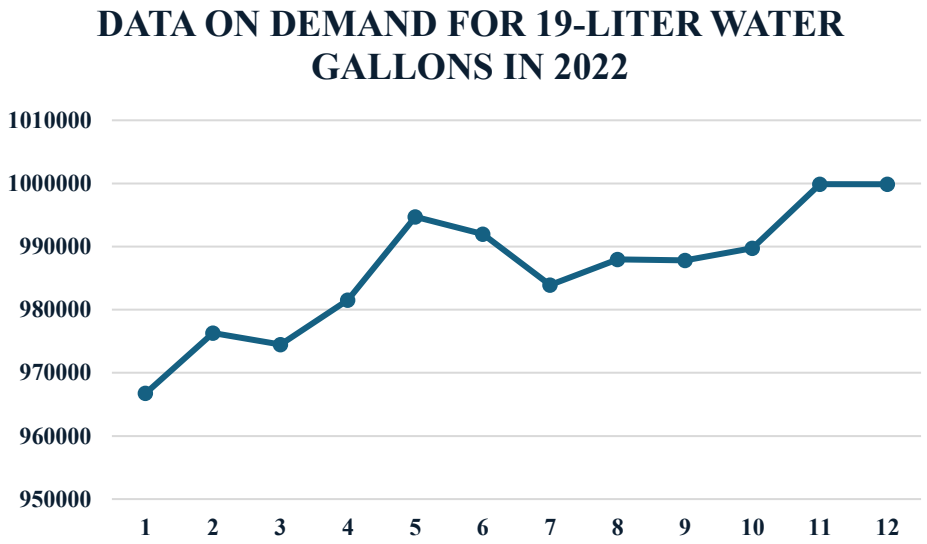


Figure 1. Data On Demand For 19-Liter Water Gallons In 2022

This increased demand indicates that the demand for 19-liter gallon products rose relatively during the observation period. Therefore, the company needs to plan its production more accurately so that the quantity of products produced matches market demand. If production planning is not based on accurate forecasts, the company risked overproduction, inventory congestion in the warehouse, or, conversely, product deficiencies when demand increased.

A. Comparison of Forecasting Methods

This study employed three forecasting methods: Single Exponential Smoothing, Linear Regression, and Double Exponential Smoothing with Trend. These three methods were selected because they are suitable for historical data patterns that show an upward trend. The use of an alpha value of 0.8 in the SES method and an alpha value of 0.4 in the DES method was determined through trial and error with alpha values ranging from 0 to 1, and the values with the smallest error were selected. Each method was then evaluated based on forecasting error metrics, namely Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD), and Mean Square Error (MSE).

Table 2. Comparison of Forecasting Methods

No	Method	MAPE	MAD	MSE

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1	*Single Exponential Smoothing* α = 0,8	0,52%	5173,159	49371791,45
2	*Linear Regression*	0,41%	4062,611	26179663,49
3	*Double Eksponential Smoothing Trend*	0,54%	5327,216	50494230,04

The results in Table 2 show that the Single Exponential Smoothing method with α = 0,8 yields a MAPE of 0.52%, a MAD of 5.173,159, and an MSE of 49.371.791,45. Meanwhile, the Double Exponential Smoothing with Trend method with α = 0,4 yields a MAPE of 0.54%, a MAD of 5.327,216, and an MSE of 50.494.230,04. The Linear Regression method produced the smallest error values, namely a MAPE of 0,41%, a MAD of 4.062,611, and an MSE of 26.179.663,49. Thus, the Linear Regression method is the most appropriate method to use for forecasting demand for 19-liter gallons at PT ABC. The Linear Regression method yields optimal results because its model structure best fits the characteristics of the 19-liter gallon demand data, which exhibits a relatively linear upward trend. Linear regression estimates the relationship between time periods and demand levels by utilizing all observations simultaneously, thereby capturing the general trend of the data and reducing the impact of temporary monthly fluctuations. In contrast, Single Exponential Smoothing does not explicitly include a trend component, so it tends to produce delayed forecasts when demand continues to rise. Although Double Exponential Smoothing accounts for trends, its recursive calculation process makes the results more sensitive to initial values, smoothing parameters, and inter-period changes in demand—especially since the study data only covers 12 months. The alignment between the data pattern and the structure of Linear Regression yields lower MAPE, MAD, and MSE values compared to the other two methods. Therefore, the superiority of Linear Regression is not only based on a comparison of error metrics but also on its ability to depict the trend of increasing demand in a more stable and representative manner.

B. Advantages of the Linear Regression Method

The Linear Regression method is capable of providing better forecasting results because the demand data shows a relatively linear upward trend. This method uses a linear equation to describe the relationship between time periods and demand levels. With parameter values of a = 970.641,8 and b = 2,39933, this method can estimate demand for the next period based on the upward trend of previous data. The MAPE value of 0,41% indicates that the forecasting error rate is very small. This suggests that the forecast results are highly accurate and can therefore be used as a basis for production decision-making. Furthermore, the lower MAD and MSE values compared to other methods indicate that the deviation between actual data and forecast results is also less significant.

Forecasts generated using the linear regression method can help the company determine the production volume of 19-liter gallons for the next period. With more accurate forecasts, the company can reduce the risk of overproduction, which leads to inventory buildup in the warehouse. Additionally, the company can maintain product availability to ensure it continues to meet consumer demand. This contributes to improved operational efficiency, better control of storage costs, and enhanced service levels for customers (Ramos et al., 2020).

C. Verification of Forecast Results

The forecast results were also verified using a tracking signal. Based on the validation results, the tracking signal values remained within the established control limits—that is, between the upper and lower control limits. This indicates that the forecasting method used remains under control and is

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acceptable for use in production planning. This type of verification is important because a method with a small error value is not necessarily suitable for use if its forecast results are unstable. Therefore, the use of a tracking signal is a crucial step in ensuring that the forecasting method does not produce excessive bias. In this study, the Linear Regression method not only produced the smallest error value but also yielded a tracking signal that remained within the control limits (Athallah & Rozi, 2023).

Overall, the research results indicate that the choice of forecasting method must be tailored to the pattern of historical data. Since the demand data for 19-liter gallons exhibits an upward trend, the Linear Regression method is the most appropriate choice compared to Single Exponential Smoothing and Double Exponential Smoothing with Trend. This method produces the lowest error rate and provides forecasting results that can serve as the basis for production planning. Thus, the application of the Linear Regression method can serve as a solution for PT ABC in addressing the imbalance between production and demand. The use of this method is expected to help the company determine more accurate production quantities, minimize inventory buildup, and improve the effectiveness of inventory control.

CONCLUSION

Based on the results of the demand forecast analysis for 19-liter gallons at PT ABC, it can be concluded that historical demand data shows an upward trend. Therefore, the forecasting method used must be able to account for the increasing demand over time to ensure more accurate forecast results. This study compares three forecasting methods: Single Exponential Smoothing, Linear Regression, and Double Exponential Smoothing with Trend. The comparison results show that the Linear Regression method is the best because it produces the smallest error values compared to the other methods. The Linear Regression method yielded a MAPE of 0.41%, a MAD of 4,062.611, and an MSE of 26,179,663.49. Meanwhile, the Single Exponential Smoothing method produced a MAPE of 0.52%, and the Double Exponential Smoothing with Trend method produced a MAPE of 0.54%.

The forecast results using the linear regression method for the next six months are 1,001,833.2; 1,004,232.5; 1,006,6319; 1,009,031.2; 1,011,430.5; and 1,013,829.9 gallons. These results can serve as a basis for the company in developing production plans and inventory control. By using the appropriate forecasting method, the company can reduce the risk of overproduction, minimize inventory buildup in the warehouse, and maintain a balance between production volume and market demand. Therefore, the Linear Regression method is recommended as the forecasting method for 19-liter gallon demand at PT ABC.

AUTHOR'S CONTRIBUTION

Author 1: Conceived and designed the analysis, wrote the paper, and contributed data or analysis
Author 2: Collected the data and performed the analysis

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DECLARATION OF COMPETING INTEREST

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