Comparing The Accuracy of Holt's and Brown's Double Exponential Smoothing Method in Forecasting The Coal Demand Of Company X

Ajeng Rahmawati, Charisma Nur Ramadhanti, Firda Hanna Ismia, Rahmat Nurcahyo
Department of Industrial Engineering
Faculty of Engineering, Universitas Indonesia
Kampus UI Depok, 16424, Indonesia
ajeng.rahmawati@ui.ac.id, charisma.nur@ui.ac.id, firda.hanna@ui.ac.id, rahmat@eng.ui.ac.id

Abstract

Coal is a fossil fuel that is commonly used throughout the world. Nowadays, the demand for coal is fluctuating because of several factors. These changes and uncertainties on the demand level of coal requires more attention from the companies because they must determine the accurate level of production in a certain period of time. The accuracy in predicting how much is needed and how much is produced will be very necessary, because it helps the company to fulfill the market needs and to retain customer loyalty. In this paper, we estimate the demand for coal production for the next 6 years in Company X using Brown's and Holt's Double Exponential Smoothing Method then determine which method is the most accurate. With Brown's method, the result obtained is that the maximum value of α parameter is 0.4 and the MAPE value is 6.74. On the other hand, with Holt's method we got the value of MAPE is 5.8157, with alpha 0.5867, and gamma 0.14754. By comparing the two methods, we conclude that Holt's method is more accurate in predicting the demand level in the next 6 years than Brown's method, as Holt's method has a smaller value of forecast error.

Keywords
Coal, Forecasting Demand, Exponential Smoothing Method, Holt's DES, Brown's DES.

1. Introduction
Coal is a fossil fuel that is commonly used throughout the world. The definition of coal, according to Undang Undang No. 3 Tahun 2020, is a deposit of organic carbon compounds that are naturally formed from plant debris. In Indonesia, the number of sediment areas is scattered from Sumatra to Papua, with the largest source of coal being in Kalimantan. As stated by the Indonesian Ministry of Energy and Mineral Resources (ESDM Ministry) in their 2019 annual performance report, it was written that the amount of coal in Indonesia reached 149 billion tonnes. This amount does not include the amount of coal reserves of 37.6 billion tonnes, according to a study by the Badan Geologi. In the following year, the ESDM Ministry said that the realization of coal production reached 561 million, which is equivalent to 102% of the previous target of 550 million tons. Meanwhile, the realization of domestic coal utilization reached 85% of the target, namely 155 million tons.

Nowadays, the demand for coal is fluctuating because of several factors including the increasing number of public demands for energy and coal as a more affordable choice than any other energy source. It is also influenced by the demand of the electricity industry, where coal is mostly used for electricity generation, which reaches 70% of the total domestic coal demand. Meanwhile, other needs are for the processing and refining industry at 11%, for the cement industry at 10%, for the paper industry at 4%, for the textile industry at 4%, and for the fertilizer industry at 1% (Arif 2014). In 2018, the ESDM Ministry explained that the use of coal in Indonesia has increased every year. In an interval of 5 years, since 2005, the use of coal has increased to 67 million tonnes, previously only 41 million tonnes. During this period, the proportion of coal in energy units also increased by 4% and this value is also predicted to continue to increase up to 33% in 2025.

Moreover, in a bigger scope, the demand for coal could also be affected by the export price of coal, GDP per capita, the total population, and the real exchange rate of the exported country. On the other hand, currently there is a shift in the society lifestyle, where they tend to be more aware of their environment which drives them to choose a more environmentally friendly source of energy to fulfill all needs.

These changes and uncertainties on the demand level of coal requires more attention from the companies, because they must determine the accurate level of production in a certain period of time. The accuracy in predicting how much is needed and how much is produced will be very necessary, because it helps the company to fulfill the market needs and to retain customer loyalty. In addition, forecasting the demand will be helpful for the company to figure out the best strategy that affects the cost and revenue, business growth, inventories, as well as manpower and natural resources utilization. Therefore, it is important to choose the appropriate modelling approaches as the first step for accurate demand forecasting (Chen et al. 2019).

1.1 Objectives

This research aims to help coal companies to fulfill the customer demand despite the uncertainties and the fluctuating demand level in order to avoid losses on the shortage or excess production of an item, and to maximize the revenue of their business. Moreover, this paper also takes notice of the accuracy of the forecast result to be able to determine the right amount of products needed.

2. Literature Review

2.1 Demand Forecasting

Demand forecasting includes the process of estimating customer demand within a time period. It utilizes historical data or previous trends to project future revenue and production planning which affects business strategies. Moreover, to increase the accuracy level of forecast, it requires supply chain collaboration (Raghunathan 1999). The purpose of doing demand forecasting is to reduce loss, increase customer satisfaction and retention, form better management, and to optimize the supply chain process. Eventually, the optimization of the whole process will lead to a bigger revenue. There are several methods to estimate the demand in production process, namely qualitative techniques, moving average, and exponential smoothing. In this paper, our focus is to use Holt’s and Brown’s Double Exponential Smoothing, which the result and discussion of the upcoming 6 years forecast will be explained in the following section.

2.2 Qualitative Techniques

Qualitative techniques are techniques that are most in line with the accuracy of a company's actual data. The output obtained by using this method will be different for each company, this is due to the subjective influence of a person. The results of qualitative techniques can be influenced by one's emotions, intuition, or even experiences. Qualitative techniques can be done by several methods, namely:

1. Executive opinion or judgment, a method that results from the judgment submitted through the opinion of a manager or other stakeholder.
2. Delphi technique, this technique is done by distributing questionnaires to the target. The data obtained from the survey is processed into statistical data to be used as a reference for further forecasting forecasts. The Delphi technique is proven to be the most accurate technique.
3. Combined sales force, this technique requires multiple sales reports in several regions, the results of these reports are combined into a report level.
4. Market survey, a market survey technique conducted by directly involving potential buyers by providing a survey of criticism and suggestions or interviews.

2.3 Extrinsic Techniques

Extrinsic forecasting technique is a forecast based on external indicators; it is continuous with the product needs of a company. On demand, one division is closely related to the activities of other divisions. Examples of correlation are sales of bricks are proportional to housing starts, or sales of automobile tires are proportional to gasoline consumption.

Usually, extrinsic forecasting techniques are more precise in the long-term forecasting process so that they can predict the significant changes that will occur in the future with a causal review. However, extrinsic techniques usually require expensive application development costs, this occurs due to the difficulty of providing information (information on changes in measurable external factors).

Extrinsic forecasting is most useful in forecasting the total demand for a firm's products or the demand for families of products. As such, it is used most often in business and production planning rather than the forecasting of individual end items.

2.4 Intrinsic Techniques

Intrinsic technique forecasting is a forecast that uses historical data. This technique is based on an assumption that what happened in the past is likely to happen in the future. There are two intrinsic techniques that are often used in forecasting, there are Moving Average and Exponential Smoothing techniques.

2.4.1 Moving Average

Moving Average is a simple business forecasting method which is often used to estimate possible situations in the future using a collection of data from the past period (historical data). This method is usually used to forecast things such as demand forecasting, technical analysis of stock and forex movements, and predicting future business trends. This Moving Average method is better used to calculate data that is stable or data that form a horizontal pattern (does not fluctuate too sharply). The reason is that the data in each period is given the same weight so that it cannot represent certain specific periods or the last period data which is usually considered the best data in describing the current condition. With the formula:

$$MA = \Sigma X \text{ / Number of Periods}$$

where:
MA = Moving Average
ΣX = the sum of all calculated time period data
Number of periods = Number of Periods Moving average

2.4.2 Exponential Smoothing

Exponential smoothing analysis is a time series analysis and is a method of forecasting by giving weight to a series of previous observations to predict future values (Trihendradi 2005). This method has a few techniques which are Single Exponential Smoothing (SES), Double Exponential Smoothing (DES), etc. The formula for Exponential Smoothing is:

$$F_t = F_{t-1} + \alpha \left(D_{t-1} - F_{t-1}\right)$$

where:
F_t = Current Demand Forecast
F_{t-1} = Past Demand Forecast
α = Exponential Constants
D_{t-1} = Actual Demand

a. Single Exponential Smoothing (SES)

Single Exponential Smoothing is usually used when the data trend tends to form horizontally or relatively stable. In this method, the data is weighted by an exponential function (Fachrurrazi, 2015). The equation for this method is as follows:

$$F_{t+m} = \alpha y_t + (1 - \alpha)F_t$$

Where:
F_{t+m} = Forecast value in period t+m
y_t = Actual value in period t
α = Unknown smoothing constant to be determined (with the value between 0 and 1)
F_t = Forecasted value for period t

b. Double Exponential Smoothing (DES)

This method is similar to the Single Exponential Smoothing, used when the data shows a trend, except that the level and trend from the data must be updated according to each period (Kalekar 2004). With the equation as follows:

$$F_{t+1} = S_t + b_t$$

- Holt

Holt is one of the derived methods from Double Exponential Smoothing (DES). However, this method does not use DES's formula directly, rather smoothes the data trend with a different parameter than the one used in the original sequence (Makridakis 1993). Holt method is also known as the two-parameter linear method. The formula for this method is as follows:

- Brown

While Holt uses two different parameters in its calculation, Brown only uses one, hence this method is also known as the one parameter method. The aim of this method is also to make a linear trend, similar to Linear Moving Average, except that the brown method does not add a supplementary parameter.

2.5 Forecasting Error

Forecasting error is a difference between the actual estimate and the estimated future period. Forecasting error is a measure of the accuracy of an estimate. Forecasting errors can be divided into standard and relative error measures. The standard error size usually results in an error in the same unit as the data presented, while the relative error size is usually based on a percentage which makes it easier to understand the quality of the forecast error. The most commonly used error measures are MAPE, MAD, MSE, and so-on (Subagyo 1984).

2.5.1 Mean Absolute Deviation (MAD)

The mean absolute deviation (MAD) is used to estimate the number of errors in the same unit as the actual data (Moon and Yao 2011). Based on the formula, MAD tests the accuracy of the forecast result by finding the average of the absolute value of each error. While using this measurement, it is believed that the smaller MAD results in a more accurate and suitable model.

$$\text{MAD} = \frac{1}{n}\sum_{i=1}^{n} |x_i - \text{m(X)}|$$

Where,
m(x) = average value of the data set
n = number of data values
x_i = data values in the set

2.5.2 Mean Squared Error (MSE)

Mean Square Error (MSE) calculates the mean of the sum of squared difference between the forecasted and the original value. The MSE can be estimated by the formula (Hansun 2013),

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n} (Y_i - \hat{Y_\iota})^2$$

Where MSE as the mean squared error, n indicates the total number of data, Yi represents the observed value, and Ŷi represents the forecasted values.

2.5.3 Mean Absolute Percentage Error (MAPE)

The Mean Absolute Percent Error (MAPE) is a measure of the predictive accuracy of statistical forecasting. This statistical prediction calculation is usually used in the loss function of model registration and evaluation problems, this occurs because there is an intuitive interpretation of the relative error.

$$\text{M} = \frac{1}{n}\sum_{i=1}^{n} |\frac{A_t - F_t}{A_t}|$$

Where,
M = mean absolute percentage error
n = number of times the summation iteration happens
A_t = actual value
F_t = forecast value

For example, if the MAPE is 6, on average, the forecast is off by 6%. However, if sometimes the MAPE value looks very large and the model with the data looks suitable, it is necessary to look again at the plot section. This needs to be done to see if there is a data value that is close to the value 0. Because MAPE is closely related to the actual data so that the value of 0 makes the MAPE value high.

In measuring the accuracy of MAPE, it is usually necessary to base the residual data from one period ahead. This is because the model will be used to predict the Y value of the future time period. The difference in the predicted and actual Y values is the residual for the next period. Therefore, a measure of an accuracy will provide an indication of what allows a good value at one period from the end of the data. This also supports that this accuracy does not indicate the accuracy of forecasting which is more than one period. In this case, it is necessary to look again at the suitability of the model to ensure that the estimates and models follow the data correctly.

3. Methods

In this paper, the forecast data were estimated with Holt's and Brown's Double Exponential Smoothing method using statistical data processing software. First, the trend analysis is carried out to determine whether the historical data has a trend pattern. After that, using the same software, we also check for any seasonality in the data. After we obtain the results, we proceed to find the optimal smoothing parameters which are alpha and gamma and use those parameters to forecast the demand in the upcoming years. It is also necessary to compute the forecast error with MAPE, MSD and MSE. Lastly, we compare the MAPE value between Holt's and Brown's method to determine which method is more accurate and suits the data.

4. Data Collection

The demand data was obtained from Company X's annual report from 2009 to 2020 which seems fluctuating over time. With this study, the data was assessed in order to determine the predicted demand level for the next 6 years. Afterwards, the authors implement the Double Exponential Smoothing Method using statistical data processing software to visualize and forecast the demand level until 2026.

Table 1. The Coal Demand in Million Tons from 2009 until 2020

Year	Demand (in Million Tons)
2009	41.4
2010	43.8
2011	50.8
2012	48.6
2013	53.5
2014	57.0
2015	53.1
2016	54.1
2017	51.82
2018	54.39
2019	59.19
2020	54.14

5. Results and Discussion

5.1 Trend Analysis

We test the trend analysis to determine whether the historical data has a trend pattern. By using the software, it is proved that the data forms a linear trend with positive gradient, which results in the equation Y(t) = 44,60 + 1,111t. It can also be seen in the graph visualization that the historical data tends to increase over time. The points that are close to the linear equation line show that the data in those years are approaching the normal line. Besides, the further the points are from the trend line indicate that there were shifts or changes in the demand level pattern. Due to the fact that the data has trends, it is possible to implement the Double Exponential Smoothing method in accordance with the research paper written by Yulitasari in 2011. Furthermore, the authors forecast the demand level using Brown's and Holt's Double Exponential Smoothing method and compare the MAPE values as the forecast error parameter to determine which method suits best.

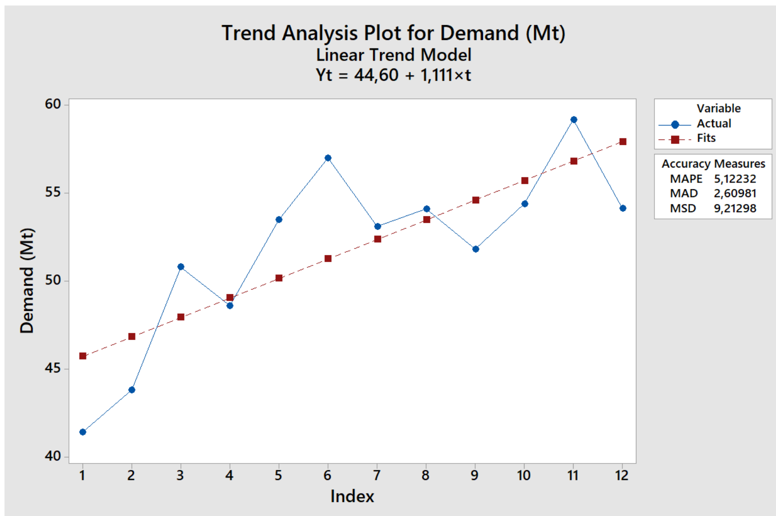
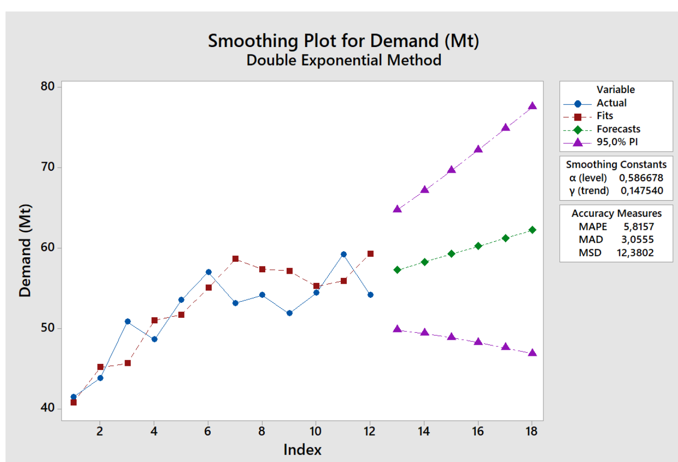


Figure 1. Trend Analysis Plot of Historical Data

5.2 Forecasting Coal Demand Using Holt's Double Exponential Smoothing Method

Using the software, the authors project the forecast data of demand for the next 6 years using Holt's method and optimized ARIMA. The obtained results are the value of alpha = 0.5867 and gamma = 0.14754, as stated in the following figure.



Forecasts

Period	Forecast	Lower	Upper
13	57,2420	49,7561	64,7280
14	58,2308	49,3627	67,0988
15	59,2195	48,8331	69,6059
16	60,2083	48,2190	72,1975
17	61,1970	47,5502	74,8438
18	62,1858	46,8443	77,5273

Figure 2. Forecast of Demand Level using Holt's DES Method

Based on the calculation, it is proved by 95% confidence level, that the demand will be between approximately 57.242 mT and 62.1858 mT for the next 6 years, with MAPE value of 5.8157, MAD value of 3.0555, and MSD value of 12.3802. These value of accuracy measures indicate that the forecast error is passable, and the model fits the actual data.

5.3 Forecasting Coal Demand Using Brown's Double Exponential Smoothing Method

To calculate the forecast using Brown's Double Exponential Smoothing method, it is necessary to find the maximum value of α parameter which results in the minimum MAPE value, which ranges between 0.1 and 0.9. An example of this method with $\alpha = 0.1$ for $t = 3$ is stated below.

First, we calculate,
$S'_3 = a_p X_3 + (1 - a_p)(S'_{3-1})$
$S'_3 = (0.1 \times 50.8) + (1 - 0.1)(41.64)$
$S'_3 = 42.556$

$S''_3 = a_p S'_3 + (1 - a_p)(S''_{3-1})$
$S''_3 = (0.1 \times 42.556) + (1 - 0.1)(41.424)$
$S''_3 = 41.537$

$a_3 = 2S'_3 - S''_3$
$a_3 = 2(42.556) - 41.537$
$a_3 = 43.575$

$b_3 = a_p \times (S'_3 - S''_3) / (1 - a_p)$
$b_3 = 0.1 \times (42.556 - 41.537) / (1 - 0.1)$
$b_3 = 0.113$

Then, to forecast the demand level of the next one period, we use m =1,
$F_{3+1} = a_3 + (b_3 \times m)$
$F_4 = 43.575 + (0.113 \times 1)$
$F_4 = 43.688$

After we get the forecast value, we compare between the original data and the forecast result to acknowledge the forecast value error which is represented by MAPE,
$PE_3 = [(X_3 - F_3) \times 100] / F3$
$PE_3 = [(50.8 - 41.88) \times 100] / 50.8 = 17.559$

Furthermore, the next step is to summarize the total forecast error value of each alpha using the equation below.

$$MAPE = \frac{1}{n}\sum_{t-1}^{M} |\mathrm{PE}_t|$$

After calculating the MAPE value, we find the minimum MAPE among all alpha variation.

Table 2. MAPE Value for Each Alpha Parameter

Value of Alpha	MAPE
0.1	9.408
0.2	6.861
0.3	6.767
0.4	**6.740**
0.5	7.073
0.6	7.338
0.7	7.776
0.8	8.496
0.9	9.301

From Table 2, we can infer that the maximum value of α parameter is 0.4 as it has the smallest MAPE value of 6.74. Hence, the authors calculate the forecast for the next 6 years with the value α of 0.4. The forecasted demand level is obtained as follows.

Table 3. Forecast of Demand Level using Brown's DES Method

Years	Demand level
2021	56.324
2022	56.823
2023	57.322
2024	57.820
2025	58.319
2026	58.818

Moreover, to make a clear comparison between actual data, forecast data with Brown's method, and forecast data with Holt's method, the results are presented in the figure below.

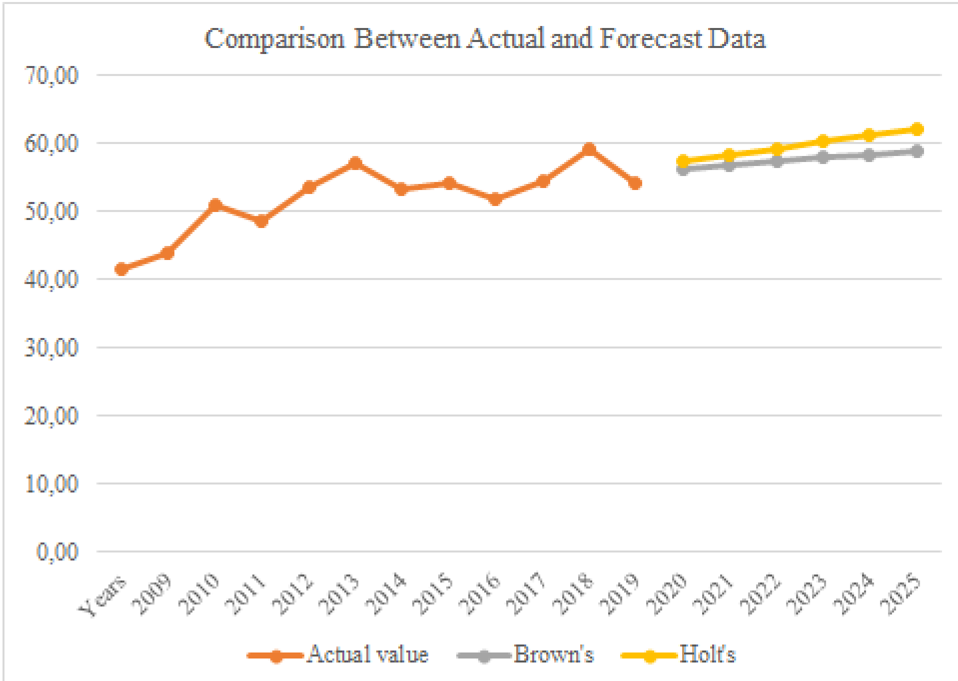


Figure 3. Comparison Between Actual and Forecast Data

6. Conclusion

From this paper, the forecasting of coal demand is done based on the historical data from the past 11 years. This will help the business owner to be prepared to produce at the same level with the predicted numbers. Using Brown's method, the result obtained is that the maximum value of α parameter is 0.4 and the MAPE value is 6.74. On the other hand, with Holt's method we got the value of MAPE is 5.8157, alpha = 0.5867, and gamma = 0.14754. By comparing the two methods, we conclude that Holt's method is more accurate in predicting the demand level in the next 6 years than Brown's method, as Holt's method has a smaller value of forecasting error. Our suggestion for future research is to implement and optimize this method to achieve a higher accuracy so that it will be more beneficial for the company in producing the coal in order to meet the customer demand.

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Biography

Ajeng Rahmawati is an undergraduate student of Industrial Engineering at Universitas Indonesia. Ajeng was born in Jakarta on January 19th, 2001. She has been actively involved in various student community activities and organizations. She is currently a member of BEM FTUI's Social and Environment Division as their expert staff, and she is also the Assistant Manager of Company Visit Division in Industrial and System Engineering Competition or ISEEC 2021. Her field of interest includes Supply Chain Management, Sustainability, and Industrial Psychology.

Charisma Nur Ramadhanti is an undergraduate student of Industrial Engineering at the Universitas Indonesia. She actively participated in various study communities and organizations. She is currently working in the Research and Development Division in F&B Start-up Company and Deputy Director in ISEEC 2021 Industrial Engineering, University of Indonesia. Her field of interest is in Job Design, Industrial Psychology, and Organizational Design.

Firda Hanna Ismia is studying Industrial Engineering at Universitas Indonesia. She has been actively participating in various study communities and organizations. She is currently serving as the Director in the Institute of Industrial and System Engineers in Universitas Indonesia and as working as an assistant in Management Information System and Decision Support Laboratory. Her fields of interest in research are Information System, Project Management, and Engineering Economics.

Rahmat Nurcahyo is currently active as academic staff in the Industrial Engineering Department, Universitas Indonesia. Mr. Rahmat was born in Jakarta, June 2nd 1969. He started his higher education in Mechanical Engineering, Universitas Indonesia and graduated in 1993. Then, he continued his study in University of New South Wales and earned his master degree (M.Eng.Sc.) in 1995 and doctoral degree in Faculty of Economics, Universitas Indonesia. Mr. Rahmat has taught several courses in Industrial Engineering UI, including Industrial Psychology, Industrial Economy, and Total Quality Management. Mr. Rahmat is International Register of Certificated QMS Auditors.