Short-term Forecasting of Spring Production Volume with Small Data Using Double Exponential Smoothing and Winters' Method

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Abstract

Springs are a crucial part of suspension systems for vehicles. One of the largest companies that produce springs is PT Indospring Tbk that is located in Indonesia. In the last two years, sales volume in PT Indospring Tbk has continuously declined. PT Indospring Tbk needs to take action to prevent further production problems due to inconsistent sales volume. The action that can be taken to prevent production problems, either overproduction or below the customer's demand, is forecasting the production volume of their product. This paper discussed three forecasting methods which are Double Exponential Smoothing, Additive Winters', and Multiplicative Winters' method to determine the number of products that need to be manufactured in the future. Data is gathered from the company's annual report and processed using Minitab 18. By using the same value of parameters, the results show that Winters' Multiplicative method is the most suitable method for the company with the least estimation of errors (MAPE, MAD, and MSD) compared to others.

Keywords
Spring production, Forecasting, Double Exponential smoothing, and Winters' method.

1. Introduction
Springs, alongside tire and shock absorber, is one of the most important parts of suspension systems in the vehicle. It is an elastic part that can adjust itself when the vehicle is loaded and unloaded (Poojari et al. 2021). PT Indospring Tbk is a company that manufactures springs located in Indonesia. This company produces two types of springs, leaf springs, and coil springs. In 2020, this company produced 60,759 springs, 19% lower than the previous year. In the last two years, the production and sales volume growth in this company has been declining. If this trend continues for the next few years, the company will gain lower profit and overproduce its product. That can be prevented by forecasting the number of products that will be manufactured.

Forecasting is an important preparation step to determine the number of items that will be produced based on past data. It refers to a preliminary process of production planning, as the company cannot arbitrarily determine that (Arnold et al. 2008). If the number of productions that the company sets exceeds the customer demand, it would be wasteful for the company. On the other hand, if the number of productions that the company sets is less than the customer demand, it would decrease the company's customer satisfaction. The dissatisfied customer could decrease the competitiveness of the company and it could possibly disrupt the business climate with a change of demand and external stakeholders (Nurcahyo et al. 2020). Those effects lead to declining company profits, whereas the objective of the company is to gain optimum profit. To achieve that, forecasting can be applied to develop better plans to meet customer demands in the future (Arnold et al. 2008). Making a forecast could increase 2% of a company's shareholder value by increasing profit and decreasing capital investment and optimize production (Mentzer 1999).

Generally, there are three techniques of forecasting to meet customer demands in the future, which are qualitative, extrinsic, and intrinsic techniques (Arnold et al. 2008). Qualitative techniques are subjective predictions that are based on intuitions of decision-makers. Then, extrinsic techniques are predictions based on external indicators that correlate with customer demand for a product. An example of extrinsic techniques is gasoline companies that could predict the demand of the product from numbers of vehicles over a year because they have a positive correlation. Lastly, intrinsic techniques are predictions using the company's historical data. These techniques could be performed using moving average, exponential smoothing, Winters' method, or advanced techniques with complex computational methods such as Artificial Neural Network (ANN). There is research that discusses various methods in intrinsic techniques to provide a good production plan.

It is necessary for every company to choose the right forecasting techniques according to company and market conditions. The right forecasting techniques can lead to reaching a company's objective effectively and efficiently. A previous study from Yuniastari and Wirawan (2014) shows that forecasting using the exponential smoothing method in silver production provides a smaller error value than the moving average method. However, Siregar et al. (2017) conducted a study to compare the Double Exponential, Winters' Multiplicative, and Winters' Additive method in palm oil production and shows that Winters' Additive method provides optimum results with a small error value compared to others. In this paper, Double Exponential and both multiplicative and additive Winters' method is used to determine the better forecasting result with the least error values in PT Indospring Tbk to predict the demand of the company's product.

1.1 Objectives

The objective of this study is to forecast the production of springs in PT Indospring Tbk for the next five years. Forecasting is done by comparing several exponential smoothing methods such as the Double Exponential smoothing and both multiple and additive Winters' methods. Several methods are used to find the best prediction of spring production.

2. Literature Review

2.1. Double Exponential Smoothing

The Double Exponential Smoothing (DES) method, also known as Holt's linear exponential method, is appropriately used to forecast the data which show the trend (Holt 2004). The exponential smoothing method is proposed by Robert G.Brown who considers the circumstance of time arrangement as of stability and normality. In the DES method, the smoothed trend component separately uses different parameters, namely α (levels) and γ (trends) (Siregar, et al. 2017). For the determination of the constants, α and γ were released between the range 0-1. Calculation of stationary data can be done using Equation 1, trend data can be done by using Equation 2, and we use Equation 3 to determine the forecast of the production.

$$S_t = \alpha X_t + (1-\alpha)(S_{t-1} + T_{t-1})$$

$$T_t = \gamma(S_t - S_{t-1}) + (1-\gamma)T_{t-1}$$

$$F_{t+m} = S_t + T_t \cdot m$$

where :

S_t : Smoothed observation

X_t : The raw data sequence of observations

T_t : Estimated trend

F_{t+m} : Forecast value

Huang et al. (2012) conducted a study using the DES method to predict resource models in Cloud computing. The results show that the DES method has better performance than other methods. However, it needs good present and past data to make a better prediction. Furthermore, another study by Rani and Raza (2012) used the DES method to predict the price of major pulses in Pakistan. They compare the DES method with the Trend Analysis method, which results that the DES method has a lower error value than the Trend Analysis method. Therefore, this paper uses the DES method and compares it with Winters' method to find the optimum forecast volume of spring production.

2.2. Winters' Method

Winters' method is a Triple Exponential Smoothing (TES) method that is usually used in forecasting by identifying patterns based on time series data (Jafari, et al. 2020). In 1960, Peter R. Winters, an American researcher, extended the DES method to capture the seasonality of the data (Hyndman et al, 2013). The method then has three aspects in the calculations and becomes the triple exponential smoothing method or called the Winters' method.

There are three aspects of the time series that are used in this method, such as levels (α), trends (γ), and seasonality (δ) (Siregar, et al. 2017). Except for seasonality, both levels and trend aspects are used in the DES method. Seasonality is an aspect that is used to see the repeating pattern of the data and subsequently used to forecast the production volume for the following year.

This method can be divided into two groups, such as additive and multiplicative. The Additive Winters' method is suitable for processing constant data that has low fluctuation between one and another, while the Multiplicative Winters' method is more suitable for processing high fluctuation data that are changing proportionally to the level of the series. (Hyndman et al, 2013). Calculation of the Winters' method is described by the following equations:

- Additive methods:

$$S_t = \alpha(X_t - I_{t-L}) + (1-\alpha)(S_{t-1} + T_{t-1})$$

$$T_t = \gamma(L_t - L_{t-1}) + (1-\gamma)T_{t-1}$$

$$I_t = \delta(X_t - S_t) + (1-\delta)I_{t-L}$$

- Multiplicative methods:

$$S_t = \alpha\frac{X_t}{I_{t-L}} + (1-\alpha)(S_{t-1} + T_{t-1})$$

$$T_t = \gamma(L_t - L_{t-1}) + (1-\gamma)T_{t-1}$$

$$I_t = \delta\frac{X_t}{S_t} + (1-\delta)I_{t-L}$$

- The forecast can be found by using the following equation:

$$F_{t+m} = (S_t + T_t m)I_{t-L+m}$$

Where equation 4 and 7 is the calculation of the level value at time *t* with α is smoothing factor for level, equations 5 and 8 is the calculation of the trend value at time *t* with γ is smoothing factor for trend, and equations 6 and 9 is the calculation of the seasonal value at time *t* with δ is smoothing factor for a seasonal value. Equation 10 is used for calculating the forecast using all three parameter values that have been obtained from the previous calculation.

The study by Tratar and Strmcnik (2016) shows that Winter's methods are the most appropriate method for long-term prediction compared to other methods that they used. The objective of their study is to compare the most suitable method in forecasting short-term and long-term heat load. Additionally, Rossi and Brunelli (2015) conduct a study to solve forecasting power usage by comparing the traditional forecasting method and Winters' method. This study shows interesting results with an error percentage level of Winters' method is below 2%. Hence, this paper uses Winters' method to identify whether there is a seasonality of data and predict spring production volume compared with the DES method.

3. Methods

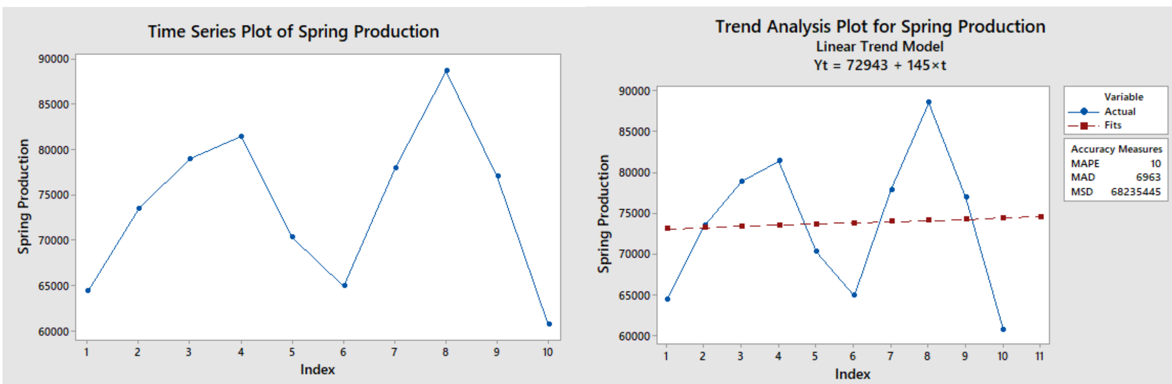
Data that is stored in Microsoft Excel is imported to Minitab 18 to be processed. After that, time series plot and trend analysis is conducted by clicking the 'Stat' tab, 'Time Series' section, and 'Time Series Plot' or 'Trend Analysis'. This paper uses a simple time series plot and linear model type of trend analysis. Next, forecasting can be done by clicking the 'Stat' tab, 'Time Series' section, and 'Double Exp. Method' or 'Winters' Method'. The dialog box will open, then variable, level value, trend value, and the number of forecasts need to be inserted. In Winters' method dialog box, there are the seasonal length and seasonal parameters that must be filled and method type (additive/multiplicative) that must be chosen. Last, the result of the forecast can be shown by clicking 'Result' in the dialog box of both methods then tick 'Summary table and result table'. Then, click 'OK' to generate a forecast and analyze the results.

4. Data Collection

The data that is used is collected from the annual report of the company. The company provides the reports from 2012 to 2020 on their websites. In this study, the report that is used is from 2013 to 2020. The report in 2012 is ignored since it does not show the required data. The required data is a total spring production from each year. After the required data is found, the data is gathered and stored in Microsoft Excel.

5. Results and Discussion

Figure 1.a is a time series plot of the data and Figure 1.b is a trend analysis plot of data. From that, the spring production volume over time is fluctuating. Although the data is fluctuating, there is a slight upward trend of the data. However, because of the small amount of data, the seasonality of the data cannot be determined. Therefore, forecasting using double exponential and winters' methods can be conducted. The parameters, levels (α), trends (γ), and seasonal (δ), of all methods that are used in this paper, are adapted based on a study conducted by Siregar, et al. (2017). However, this paper used the same value of (α), (γ), and (δ) which are 0.6, 0.02, and 0.02 respectively.



(a) (b)

Figure 1. Time series plot and trend analysis plot of data

5.1 Numerical Results

Table 1 shows a model summary of the Double Exponential, Additive Winters', and Multiplicative Winters' methods. The spring production is based on historical data and the production is in tonnes. In table 1, smooth shows the level component of the model, predict shows a predicted value from the data, and error is the difference between the predicted value and real data. From the model summary, forecasts in the next five years can be computed and shown in table 2. Lower and upper in table 2 shows the interval of forecast value.

Table 1. Summary of Double Exponential, Additive Winters', and Multiplicative Winters' method

Time	Spring Production	Double Exponential Method			Additive Winters' Method			Multiplicative Winters' Method		
		Smooth	Predict	Error	Smooth	Predict	Error	Smooth	Predict	Error
2011	64340	67838.9	73087.4	-8747.4	58926.4	60898.6	3441.37	59438.8	61168.8	3171.15
2012	73475	71236.5	67878.7	5596.3	73868.7	75882.2	-2407.18	73816.5	75885.8	-2410.79
2013	78934	75897.8	71343.4	7590.6	82402.6	84387.2	-5453.22	82371.2	84629.0	-5694.99
2014	81393	79274.1	76095.8	5297.2	76378.5	78297.7	3095.30	76729.0	78797.5	2595.46

2015	70242	73959.5	79535.7	-9293.7	66282.1	68238.4	2003.57	66392.9	68127.8	2114.23
2016	64891	68578.4	74109.6	-9218.6	69207.7	71188.0	-6297.02	68670.2	70412.1	-5521.06
2017	77856	74160.8	68617.9	9238.1	78268.3	80173.0	-2317.05	78478.7	80438.4	-2582.41
2018	88616	82894.0	74311.1	14304.9	86723.2	88600.2	15.82	87268.7	89402.3	-786.27
2019	76973	79470.2	83216.0	-6243.0	83941.3	85818.5	-8845.47	84090.3	86098.9	-9125.87
2020	60668	68287.7	79717.3	-19049.3	66629.7	68400.7	-7732.73	66613.8	68182.9	-7514.87

Table 2. Forecast in the next 5 years

Period	Double Exponential Method			Additive Winters' Method			Multiplicative Winters' Method		
	Forecast	Lower	Upper	Forecast	Lower	Upper	Forecast	Lower	Upper
2021	68306.2	45134.7	91478	65140.0	54946.1	75334	64413.0	54241.5	74585
2022	68324.6	40678.4	95971	77708.5	66007.0	89410	77077.3	65401.6	88753
2023	68343.1	35786.5	100900	87345.8	73813.0	100879	87173.7	73670.6	100677
2024	68361.6	30628.7	106094	84284.8	68710.6	99859	84148.6	68608.7	99688
2025	68380.0	25300.7	111459	72090.4	54337.3	89844	71001.3	53287.2	88715

To determine the most appropriate methods, estimated errors in each method can be analyzed. Table 3 shows an estimated error using the Mean Absolute Percentage Method (MAPE), Mean absolute deviation (MAD), and Mean Squared Deviation (MSD) from each method. MAPE is used to measure the appropriateness of the model's estimated value that is expressed in terms of mean absolute percentage of error, MAD is used to measure the accuracy of the model's estimated value which expressed in terms of the absolute mean error, and MSD is used to measure the accuracy of the model's estimated value which expressed as the average of the squares of the errors (Junaidi 2014). The method which has the lowest value of MAPE, MAD, and MSD is the most suitable method.

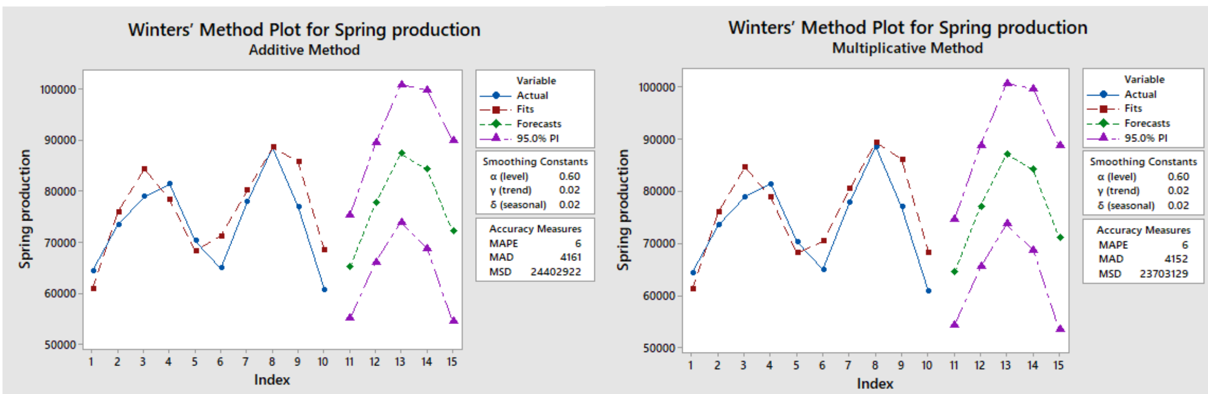
Table 3. Estimated error using MAP, MAD, MSD

Data	Exponential Smoothing	Estimated Error		
		MAPE	MAD	MSD
Spring Production	Double (α=0.6, γ=0.02)	13	9458	105668969
	Additive Winters' Method (α=0.6, γ=0.02, δ=0.02)	6	4161	24402922
	Multiplicative Winters' Method (α=0.6, γ=0.02, δ=0.02)	6	4152	23703129

There is a significant difference in estimated error value between the Double Exponential method and Winters' method. The estimated error value of the Double Exponential method is higher than Winters' method. This implies that the Double Exponential method is not suitable for the data and it means that there is a seasonality in the data. Based on Figure 1.a the season length of data is five years because the sixth year is the turning point and indicates the new season.

5.2 Graphical Results

Figure 2.a shows the plot of Additive Winters' method while figure 2.b shows the plot of Multiplicative Winters' method. The plot shows that both models fit with the data indicated by the turning point of the actual and smoothed data at the same point location. The value of MAPE from both methods is the same but the value of MAD and MSD of the multiplicative method is lower than the additive method. From that, the fluctuation of data is unconstant and follows a multiplicative time series.



(a) (b)

Figure 2. The Plot of Additive Winters' method and Multiplicative Winters' method

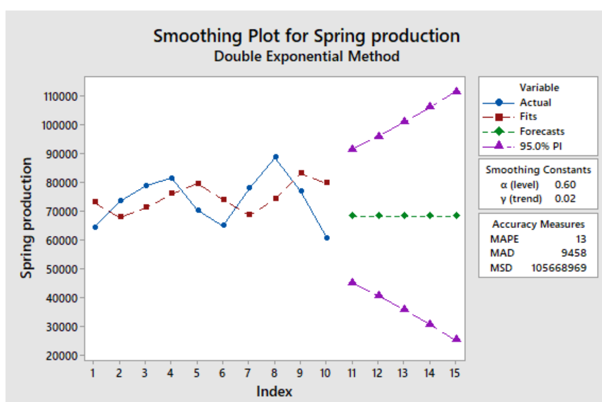


Figure 3. The Plot of double exponential method

Figure 3 shows the plot of the Double Exponential method. From that, the model tends to not fit the data by the difference of the several turning point locations. It is in accordance with the big MAPE value and indicates that the Double Exponential method is not suitable.

6. Conclusion

From this discussion, it can be concluded that Winters' Multiplicative method is the most suitable method for the company with the least estimation of errors (MAPE, MAD, and MSD) compared to others. The spring production volume for 2021 until 2025 is 64413.0, 77077.3, 87173.7, 84148.6, and 71001.3 tonnes respectively. By using Winters' Multiplicative method, it shows that there is a multiplicative seasonality in spring production volume. The company could investigate the cause of seasonality of production volume to improve their production planning and utilization of the company's resources. After that, the company is expected to satisfy customers' demands and obtain optimized profit. Further research can be done by using more complete data and optimized method parameters.

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Biography

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