**Holt-Winters Forecast**

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Simulation Modeling and Methods – 002

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**1.0 Introduction**

The Holt-Winters Forecasting Method is a simulation to predict the behavior of a sequence of values over a time series. Holt-Winters is a way to model 3 specific aspect of the time series. This includes the level (current de-seasonalized demand), trend over a specific amount of time (growth or decline in demand), and cyclical patterns called seasonality, which is predictable seasonal fluctuation. This method uses the technique of exponential smoothing to review values from the past and use them to predict values for the future. The three aspects of the time series model are expressed as the three types of exponential smoothing. This explains why the Holt-Winters model is called the triple exponential smoothing. The predicted values are computed by a combined effect of values, trend, and seasonality. Due to the 3 aspects of the time series behavior, there are 3 parameters. This model contains a parameter for each smoothing. These parameters are listed as α, β, and γ.

* 1. This type of forecasting is important because the future is always uncertain. Forecasting drives many types of planning decisions for companies all over the world. There is randomness in future demand and there can be randomness in sales. This type of forecasting is a short-term time series. Using past demand to forecast future demand has been a historical forecasting technique. Time series assumes that past demand history is a good indicator of future demand. This is appropriate when there is not significant variation year to year.
  2. There are variations of the Holt-Winters Model. The **multiplicative model** looks as such:

**S = level trend seasonal factor**. This method is preferred when the seasonal variations are changing proportional to the level of the series. The **additive model** looks as such: **S = level + trend + seasonal factor**. This method is preferred when the seasonal variations stay constant through the series. Lastly, there is a **mixed model** which includes:**S=(level+trend) seasonal factor**. In this model, I will be using the additive variation.

**2.0 Model Explanation**

**2.1** The variables for the Winters model include:

= demand in period t

**=** estimated level in period t

**=** estimate of seasonal factor for period t

**=** estimated trend (level change) in period t

**=** forecast made in period t for period t+n

**2.2** Simple Exponential Smoothing

No trend or seasonality:

**=**

is a smoothing constant parameter which is chosen by the user. In this report, I will first start with a value of 0.1. A lower smoothing constant parameter is more stable and less responsive.

**2.3** The Winter’s Model Initialization requires a full season of data:

– the level in period *p* is average of first *p* demands

**-** find seasonality factors for first cycle

**2.4** Once initialization step is complete, these formulas are used to determine estimates of level, trend, and seasonality components in each remaining period for which you have demand data.

Level: **/ ) + )**

Trend:  **β** (**-) + (1- β)**

Seasonality: **γ(/) + (1- γ)**

Forecast:  **=**

In my model, I have used excel Solver to find optimal smoothing parameters.

**3.0 Procedure for Rolling Forecast**

1. Identify number of seasons or years and smoothing constants. In the initial problem, smoothing constants of 0.1 are used. Excel Solver then finds optimal constants. Smoothing parameters must be between 0 and 1.
2. Initialization
3. Compute the forecast for period *p* + 1:

1. From step 2.4, find
2. **Repeat steps above for *p+2***
3. **Repeat steps above for p+3**

**4.0 Forecast Errors**

Forecast error in period *t, :*

Mean Absolute Deviation:

=

Mean Squared Error:

=

1. **Objectives and Dataset**

The dataset used is UC\_SCM Corporation Demand Set. This set contains 5 full years of sales data, broken down by month.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Dataset** |  |  |
| **Sales** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** |
| **JAN** | 300 | 400 | 300 | 600 | 600 |
| **FEB** | 400 | 500 | 600 | 500 | 300 |
| **MAR** | 400 | 400 | 600 | 500 | 400 |
| **APR** | 400 | 600 | 400 | 300 | 300 |
| **MAY** | 500 | 600 | 500 | 600 | 800 |
| **JUN** | 700 | 900 | 700 | 800 | 700 |
| **JUL** | 800 | 400 | 800 | 1,100 | 900 |
| **AUG** | 500 | 900 | 1,100 | 1,500 | 1,100 |
| **SEP** | 1,100 | 1,300 | 1,600 | 1,700 | 2,100 |
| **OCT** | 1,300 | 1,300 | 1,600 | 1,700 | 2,100 |
| **NOV** | 1,500 | 1,700 | 1,900 | 2,100 | 2,300 |
| **DEC** | 900 | 1,100 | 900 | 1,300 | 900 |
| **Total** | 8,800 | 10,100 | 11,000 | 12,700 | 12,500 |

**Objectives**

1. I will use Winter’s Method to forecast the sales in Year 6 - 2020 for each individual month.
2. All smoothing parameters in my first model are set to 0.1. In the new model, using Excel Solver, I will find optimal smoothing parameters. Experimenting with various values of parameters can show different fits for the model.
3. I will try to minimize the MAD and MSE values as low as possible. Model 2 will show optimal MSE, while model 3 will show optimal MAD.
4. **Project Steps and Analysis**

**1.** Transpose data and create unique categories for each variable. Label each month as a different period, starting with December of 2015. Once I hit the forecasted periods of 2020, I start the periods over as 1 again.

A screenshot of a cell phone

Description automatically generated

**2.** Initializing the forecast. The first step in initialization is to find the estimated level in period 0. To do this, I averaged the sales from 2015. Next, I found the estimate of the seasonal factor for 2015. To find the estimate of the seasonal factor for each month of 2015, the amount of sales for that specific month is taken, divided by the average found from 2015 sales. Below is the output:

A screenshot of a cell phone

Description automatically generated

3. Next is to find the estimated level for all periods before the 2020 forecast. To do this, the alpha value of 0.1 is multiplied by the sales amount for the same period, being divided by the seasonality value for the same month the prior year. This is being added to 1 minus the alpha value multiplied by level and trend from the previous period.

A screenshot of a cell phone

Description automatically generated The same formula is copied down for each period.

4. Then the trend and seasonality for each period must be found. To find trend, the beta value of 0.1 is multiplied by the level of the current period minus the previous period. This is added to 1 minus the beta value multiplied by the trend of the previous period.

Seasonality is found by multiplying the gamma value by sales divided by level for the same period. This is added to 1 minus gamma multiplied by the seasonality of the same month in the previous year.

Below is the Excel Output with level, trend, and seasonality computed:

A screenshot of a cell phone

Description automatically generated

5. Next is the most important part, predicting the forecast. Forecast for the given data periods is level plus trend multiplied by seasonality of the previous year same period. For forecasting the year of 2020, the level from the most recent period is added to most recent period times trend. All of this is being multiplied with the seasonality of the same month of the previous year. Below is my forecast for the 2020 year.

A screen shot of a social media post

Description automatically generated

6. Next the error is examined, followed by the absolute value of error (MAD) and the MSE. Initial error is found by taking forecast minus sales of the same period. Original model statistics:

Mean Absolute Deviation: **186.56**

Mean Squared Error: **58,031.67**

7. Below is a visualization of sales compared to forecast in the initial model.

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**7.0 Excel Solver for Optimal Smoothing Parameters**

I next wanted to use the Excel Solver tool to find my optimal alpha, beta, and gamma numbers for my forecast. I have set my objective as minimizing the MSE value by changing my variable cells of alpha, beta, and gamma. Two constraints are set to not allow my parameters to be more than 1 or less than 0. When the solver tool is used I now have new values:

**Alpha = 0.0069**

**Beta = 1**

**Gamma = 0.5211**

My forecast numbers are now changed:

A screen shot of a social media post

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I now have new values for MAD and MSE:

**MAD: 167.81**

**MSE: 40,181.06**

Both my values have decreased, however my objective in this scenario was set to minimize MSE.

Next, I use solver again, but the objective is set to my initial MAD value. All the previous steps are followed just as my initial model. My new values become:

**Alpha = 0.0067**

**Beta = 1**

**Gamma = 0.3043**

My new forecast numbers are now as such:

A close up of a screen

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**MAD: 165.31**

**MSE: 42,279.74**

**8.0 Table Comparison and Graphs**

|  |  |  |  |
| --- | --- | --- | --- |
| **Model** | **Forecast (12/12/20)** | **MAD** | **MSE** |
| Original – 0.1 parameters | 1,266.78 | 186.56 | 58031.67 |
| Model 2 - MSE Optimization | 1,077.88 | 167.81 | 40181.06 |
| Model 3 - MAD Optimization | 1,186.21 | 165.31 | 42279.74 |

**Original Model MSE Optimized**

A close up of text on a white background

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**MAD Optimized**

**A picture containing text

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**Full output:**

**A screenshot of a cell phone

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**Conclusion –** Using solver in both cases lowered both the MSE and MAD in the other models. The MSE model (model 2) contains a slightly higher MAD value but a lower MSE value. Model 3 contains a lower MAD value but a higher MSE value.

**9.0 Bibliography**

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