

**BUSA 511: Project Assignment cover page**

Assignment for Course:      BUSA 511: Business Analytics for Managers

Submitted to:                 Dr. Syed A. Raza

Submitted by:

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| **Student Name** | **CWID** |
| **Tazeen Rashid** | **50368366** |

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Title of Assignment: **Time Series Forecasting Group Project**

CERTIFICATION OF AUTHORSHIP: I certify that I am the author of this paper and that any assistance received in its preparation is fully acknowledge and disclosed in the paper. I have also cited any sources from which we used data, ideas of words, whether quoted directly or paraphrased.  I also certify that this paper was prepared by me specifically for this course

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**Time Series Forecasting Project Instructions**

***Instructions***

This is an individual assignment and therefore must be completed by an individual student without outside assistance of any type. Follow the instructions below in order to complete the assignment:

* **Step 1**: Download and read the project statement for the *on the Forecasting problem* stated in the Microsoft Word file “**project\_description.docx**”. Read carefully this document
* **Step 2**: Download the Excel file “**project\_data.xlsx**”. Use the data in the file to perform timeseries forecasting analyses.
* **Step 3**: Based on your analytics performed and use of the models in Step 2, answer the questions and provide a short (*not exceeding 500 words*) recommendation/explanation

***Submittals***

1. Submit your answers to this assignment using this Microsoft Word document and post to the assignment drop box before the required deadline. Be sure to complete the above first page cover sheet. Enter your answers in the pages below to include all of your answers and results of your interpretations of calculations for the assignment questions. Your answers must be entered directly into this Word document below each question. Use as much space as needed.
2. Submit your Excel spreadsheet(s) with calculations/ visualizations to the assignment drop box before the required deadline. Your Excel model calculations will be used to substantiate your answers to the assignment questions herein.

***Grading***

This is an individual assignment. A total of 100 percentage points is possible for this assignment. This includes the point values which are assigned to each question - point values are noted next to each question below. Use APA 7 writing style as a guide for answers that require a written explanation. Up to 10 points will be deducted from the combination of written explanation answers that are poorly written. The percentage points earned on this assignment will be 20% weight obtain the final assignment grade.

Please answer following Question with reference to the project file: “**Project\_description.docx**”

***Question 1*** (6 points): Define a problem statement that reflects the challenge faced in this prediction problem (*Do not exceed 500 words*)

**Answer**:

ABC Corporation has the last five years' monthly demand data stored and they want to forecast the demand for Year Six; all months. Having a sense of predicted (forecast) demand would help them manage their inventory levels, production planning, and resource allocation as well as put profit projections in place. The management must make predictions using various methods and try to understand level, trend, seasonality as well as random errors in the demand to figure out which model is projecting most accurately based on their demand data.

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Description automatically generated

Based on the chart of the data, we can see a rising trend in demand over the years and there’s clear seasonality in the demand where it goes at higher levels in Q4, especially peaking around the 11th month. This shows that during the holiday season esp. Thanksgiving, the demand rises every year.

***Question 2*** (6 points): Develop a 3-period moving average forecasting model. Report the forecasts for year 6 from months January through December inclusive. Discuss briefly these forecasts (*Discussion NOT to exceed 500 words*)

**Answer**:

Check the ‘Moving Average’ sheet from the workbook for reference.

***Method 1 for forecasts:***

Since we have actual demand values till period 60 (i.e. Year 5 Dec), we can only do predictions for January of year 6 and all the remaining forecasts would be the same value until we get the actual demand values for new months. So, based on this, our Moving average Forecasts would be:

|  |  |
| --- | --- |
| **Period** | **Forecasts** |
| 61 | 16666.6667 |
| 62 | 16666.6667 |
| 63 | 16666.6667 |
| 64 | 16666.6667 |
| 65 | 16666.6667 |
| 66 | 16666.6667 |
| 67 | 16666.6667 |
| 68 | 16666.6667 |
| 69 | 16666.6667 |
| 70 | 16666.6667 |
| 71 | 16666.6667 |
| 72 | 16666.6667 |

***Method 2 for forecasts:***

Another way of having 3-period moving averages is to take the average of the last three years’ respective months. This way, the forecasts show better seasonality and trend and so the values would be:

|  |  |
| --- | --- |
| **3-period moving avg:** | |
| **Year 6 Months** | **Forecasted Demand** |
| Jan | 4000.00 |
| Feb | 3666.67 |
| Mar | 4000.00 |
| Apr | 2333.33 |
| May | 5333.33 |
| Jun | 6333.33 |
| Jul | 8333.33 |
| Aug | 11333.33 |
| Sep | 17000.00 |
| Oct | 17000.00 |
| Nov | 20000.00 |
| Dec | 9333.33 |

In summary, Method 1 failed to capture the seasonality of the given dataset whereas, the Method 2 can capture seasonality better although the deviations are high given the upward trend of the seasonality.

***Question 3*** (6 points): Compute for the model developed in Question 2, compute the error parameters MAD, MSE, MAPE, and TS. Explain these error computations (*Explanation NOT to exceed 500 words*)

**Answer**:

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Reported** | **Min** | **Max** |
| **MAD** | 4380.11696 | 333.3333333 | 4380.11696 |
| **MSE** | 27974658.9 | 111111.1111 | 27974658.9 |
| **MAPE** | 74.7721682 | 11.11111111 | 78.095927 |
| **TS** | 5.40320427 | -0.245409015 | 8.58509142 |

Based on error parameters, we can gauge that:

1. **Mean Absolute Deviation (MAD)**:
   * Reported: 4380.116959
   * Min: 333.3333333
   * Max: 4380.116959
   * MAD represents the measure of variability in a set of data points based on absolute error points in each observation. The reported MAD value is the maximum value of the past data. This suggests that there is a wide range of deviation from the mean in the dataset. The minimum value indicates the lowest deviation observed, while the maximum value corresponds to the highest deviation. The discrepancy between the minimum and maximum values suggests variability in the deviation across the dataset.
2. **Mean Squared Error (MSE)**:
   * Reported: 27974658.87
   * Min: 111111.1111
   * Max: 27974658.87
   * MSE represents the measure of variability in a set of data points based on the sum of squared error points in each observation. The reported MSE value is substantially higher than the minimum value but consistent with the maximum value. This indicates that while there may be fluctuations in the prediction errors, the overall magnitude of the errors remains relatively consistent across the dataset.
3. **Mean Absolute Percentage Error (MAPE)**:
   * Reported: 74.77216822
   * Min: 11.11111111
   * Max: 78.09592703
   * MAPE measures the average absolute percentage difference between the forecast and the actual value. The reported MAPE value falls within the range defined by the minimum and maximum values. This suggests that while there may be variations in the percentage difference between predicted and actual values, the reported MAPE value is relatively consistent with the range observed in the dataset.
4. **Tracking Signal (TS)**:
   * Reported: 5.403204272
   * Min: -0.245409015
   * Max: 8.585091421
   * Tracking signal helps understand whether the forecast model has a systematic bias and how much it is. The reported tracking signal value falls within the range defined by the minimum and maximum values. This suggests that the reported value is typical of the overall variability observed in the dataset, with fluctuations occurring within the defined range.

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Description automatically generated

The moving avg forecast maps the seasonality of the data removing the extreme variations and smoothening the seasonality of the given data. The absolute errors i.e. MAD and the MSE show high deviations of errors representing the weakness in this methodology to accurately capture the data variations.

***Question 4*** (6 points): Develop a simple exponential smoothing forecasting model, assume, α=0.2. Report the forecasts for year 6 from months January through December inclusive. Discuss briefly these forecasts (*Discussion NOT to exceed 500 words)*

**Answer**:

Check the ‘Exponential Smoothing’ sheet from the workbook for reference.

Since we have actual demand values till period 60 (i.e. Year 5 Dec), we can only make predictions for January of year 6 and all the remaining forecasts would be the same value until we get the actual demand values for new months. So, based on alpha of 0.2, our Exponential Smoothing Forecasts would be:

|  |  |
| --- | --- |
| **Period** | **Forecast** |
| 61 | 8000 |
| 62 | 8000 |
| 63 | 8000 |
| 64 | 8000 |
| 65 | 8000 |
| 66 | 8000 |
| 67 | 8000 |
| 68 | 8000 |
| 69 | 8000 |
| 70 | 8000 |
| 71 | 8000 |
| 72 | 8000 |

***Question 5*** (6 points): For the model developed in Question 4, compute the error parameters MAD, MSE, MAPE, and TS.

**Answer**:

Exponential smoothing is a technique used for forecasting time series data by assigning exponentially decreasing weights to past observations. Considering the given value of alpha as 0.2, here are comments on each error metric:

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Given Value** |  |  |
| **Alpha** | 0.2 |  |  |
|  | **Reported** | **Min** | **Max** |
| **MSE** | 27525821.03 | 9688538.348 | 38646944 |
| **MAD** | 4364.834986 | 2575.862747 | 6216.667 |
| **MAPE** | 81.55976758 | 67.24021274 | 310.8333 |
| **TS** | 5.287326801 | -5.22342932 | 6.714898 |

1. **Mean Squared Error (MSE)**:
   * Reported: 27525821.03
   * Min: 9688538.348
   * Max: 38646944.44
   * The reported MSE value falls within the range defined by the minimum and maximum values. While it is higher than the minimum value, it is lower than the maximum value. This indicates that the forecasting model with an alpha of 0.2 produces errors that are consistent with the observed range. A lower MSE value suggests better accuracy in forecasting, but it's essential to further analyze the forecast performance relative to other metrics.
2. **Mean Absolute Deviation (MAD)**:
   * Reported: 4364.834986
   * Min: 2575.862747
   * Max: 6216.666667
   * The reported MAD value falls within the range defined by the minimum and maximum values. This suggests that the average deviation of individual data points from the mean is consistent with the variability observed in the dataset. However, a lower MAD value would indicate better accuracy in forecasting, as it represents smaller deviations from the actual values.
3. **Mean Absolute Percentage Error (MAPE)**:
   * Reported: 81.55976758
   * Min: 67.24021274
   * Max: 310.8333333
   * The reported MAPE value falls within the range defined by the minimum and maximum values. However, it is relatively high compared to the minimum value, indicating potential variability in the accuracy of the forecast. A lower MAPE value indicates better accuracy in forecasting, as it represents smaller percentage differences between predicted and actual values.
4. **Tracking Signal (TS)**:
   * Reported: 5.287326801
   * Min: -5.223429323
   * Max: 6.714897584
   * The reported tracking signal value falls within the range defined by the minimum and maximum values. This suggests that the reported value is typical of the overall variability observed in the dataset. However, a value closer to zero would indicate better accuracy in forecasting, as it represents smaller differences between predicted and actual values.

In summary, as per error parameters, we can observe high deviations in the smoothening of the given dataset whereas, the exponential smoothing shows better data capturing as compared to the moving average. The exponential smoothing method failed to capture the seasonality and the upward trend of the data for the forecasted values in year 6.

***Question 6*** (6 points): For the model developed in Question 4, using Excel Solver optimize the value of α with and objective to minimize MSE. Report your results provide a discussion how optimization improved the forecasting error (*Discussion NOT to exceed 500 words)*

**Answer**:

Using Solver, the optimal value of alpha comes as 1. Here are some comments on the error values for exponential smoothing, considering the context of the optimal value of alpha:

1. **Mean Squared Error (MSE)**:
   * Reported: 17010782.41
   * Min: 5830868.056
   * Max: 38646944.44
   * The reported MSE value is higher than the minimum value but lower than the maximum value. This suggests that while the forecast accuracy may vary, the overall magnitude of the squared errors is within the observed range. It's important to note that the MSE measures the average squared difference between predicted and actual values, so a lower value indicates better accuracy.
2. **Mean Absolute Deviation (MAD)**:
   * Reported: 3003.611111
   * Min: 1527.083333
   * Max: 6216.666667
   * The reported MAD value falls within the range defined by the minimum and maximum values. This indicates that the average deviation of individual data points from the mean is consistent with the variability observed in the dataset. A lower MAD value indicates better accuracy in forecasting.
3. **Mean Absolute Percentage Error (MAPE)**:
   * Reported: 53.42532468
   * Min: 45.85497835
   * Max: 310.8333333
   * The reported MAPE value falls within the range defined by the minimum and maximum values. However, the maximum value is considerably higher than the reported value, indicating potential outliers or extreme errors in the forecast. MAPE measures the average percentage difference between predicted and actual values, so a lower value indicates better accuracy.
4. **Time Series (TS)**:
   * Reported: -0.072135393
   * Min: -2.891454965
   * Max: 4.892509776
   * A graph with blue and orange lines

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     Description automatically generatedThe reported time series value falls within the range defined by the minimum and maximum values. This suggests that the reported value is typical of the overall variability observed in the dataset, with fluctuations occurring within the defined range. TS measures the difference between predicted and actual values, so a value closer to zero indicates better accuracy.

Before optimization, the exponential smoothening failed to capture the extremes of the seasonalities and to show the deviations between the dataset whereas, after optimization, the exponential smoothening captured the lowest and the highest variability for each season. The optimal value of alpha came out to be 1 which means the highest weight given to recent actual values of demand brings the lowest MSE.

However, both methods of exponential smoothing failed to capture the seasonality for the forecasting of year 6 until we got the new actual values of the demand each month.

***Question 7*** (6 points): Develop a Holt’s model for forecasting, assume, α=0.3, and β =0.1. Report the forecasts for year 6 from months January through December inclusive. Discuss briefly these forecasts (*Discussion NOT to exceed 500 words)*

**Answer**:

Refer to the Holts Method sheet in the workbook. The forecasts are:

|  |  |
| --- | --- |
| **Periods** | **Forecasts** |
| 61 | 8271.25847 |
| 62 | 8383.2618 |
| 63 | 8495.26514 |
| 64 | 8607.26847 |
| 65 | 8719.2718 |
| 66 | 8831.27514 |
| 67 | 8943.27847 |
| 68 | 9055.28181 |
| 69 | 9167.28514 |
| 70 | 9279.28848 |
| 71 | 9391.29181 |
| 72 | 9503.29514 |

The holt’s method forecasts failed to capture the seasonality of the given dataset but successfully captured the upward trend.

***Question 8*** (6 points): For the model developed in Question 7, compute the error parameters MAD, MSE, MAPE, and TS.

**Answer**:

Analyzing the provided Holt's method numbers with α = 0.3 and β = 0.1, let's comment on each error metric:

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Given Value** |  |  |
| **α** | 0.3 |  |  |
| **β** | 0.1 |  |  |
|  | **Reported** | **Min** | **Max** |
| **MSE** | 28910358.5 | 2177755 | 28910359 |
| **MAD** | 4531.928372 | 1180.616 | 4531.928 |
| **MAPE** | 83.06880973 | 40.8882 | 145.6284 |
| **TS** | 2.713923217 | -4.03528 | 6.592165 |

1. **Mean Squared Error (MSE)**:
   * Reported: 28910358.5
   * Min: 2177755.496
   * Max: 28910358.5
   * The reported MSE value is consistent with the maximum value but significantly higher than the minimum value. This indicates variability in the accuracy of the forecast. A lower MSE value is desired as it reflects better accuracy in predicting future values.
2. **Mean Absolute Deviation (MAD)**:
   * Reported: 4531.928372
   * Min: 1180.615798
   * Max: 4531.928372
   * The reported MAD value falls within the range defined by the minimum and maximum values. However, a lower MAD value indicates better accuracy in forecasting, as it represents smaller deviations from the actual values.
3. **Mean Absolute Percentage Error (MAPE)**:
   * Reported: 83.06880973
   * Min: 40.88819792
   * Max: 145.6284153
   * The reported MAPE value falls within the range defined by the minimum and maximum values. However, it is relatively high compared to the minimum value, indicating potential variability in the accuracy of the forecast. A lower MAPE value indicates better accuracy in forecasting, as it represents smaller percentage differences between predicted and actual values.
4. **Tracking Signal**:
   * Reported: 2.713923217
   * Min: -4.035277525
   * Max: 6.592165068
   * The reported tracking signal value falls within the range defined by the minimum and maximum values. A tracking signal close to zero indicates that the forecasting model is accurately predicting future values. Positive values indicate overestimation, while negative values indicate underestimation. Thus, a tracking signal close to zero is desired for an accurate forecast.

The given parameter values for Holt’s Method are better than the moving average but exponential smoothing gave better MSE values.

***Question 9*** (6 points): For the model developed in Question 7, using Excel Solver optimize the values of α and β with an objective to minimize MAD. Report your results provide a Discussion how optimization improved the forecasting error (*Discussion NOT to exceed 500 words)*

**Answer**:

1. Using Solver, the optimal values of alpha and beta comes out to be 0.9886 and 0 respectively. Based on these we now get:  
   **Mean Squared Error (MSE)**:
   * Reported: 16526363.13
   * Min: 1958390.942
   * Max: 16526363.13
   * The reported MSE value is consistent with the maximum value but significantly higher than the minimum value. This indicates variability in the accuracy of the forecast. A lower MSE value is desired as it reflects better accuracy in predicting future values.
2. **Mean Absolute Deviation (MAD)**:
   * Reported: 2937.887787
   * Min: 973.9726825
   * Max: 2937.887787
   * The reported MAD value falls within the range defined by the minimum and maximum values. However, a lower MAD value indicates better accuracy in forecasting, as it represents smaller deviations from the actual values.
3. **Mean Absolute Percentage Error (MAPE)**:
   * Reported: 51.11095581
   * Min: 30.45141131
   * Max: 145.6284153
   * The reported MAPE value falls within the range defined by the minimum and maximum values. However, it is relatively high compared to the minimum value, indicating potential variability in the accuracy of the forecast. A lower MAPE value indicates better accuracy in forecasting, as it represents smaller percentage differences between predicted and actual values.
4. **Time Series (TS)**:
   * Reported: -1.157272439
   * Min: -3.220064626
   * Max: 5.358988008
   * The reported time series value falls within the range defined by the minimum and maximum values. A tracking signal close to zero indicates that the forecasting model is accurately predicting future values. Positive values indicate overestimation, while negative values indicate underestimation. Thus, a tracking signal close to zero is desired for an accurate forecast.

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Before optimization, Holt’s Method failed to capture the extremes of the seasonalities and to show the deviations between the dataset whereas, after optimization, it captured the lowest and the highest variability for each season. The optimal value of alpha and beta came out to be 0.988 and 0 respectively which means the higher weight given to recent actual values of demand brings the lower MAD.

However, both methods of Holts failed to capture the seasonality for the forecasting of year 6 until we got the new actual values of the demand each month.

***Question 10*** (6 points): Develop a Winter’s model for forecasting, assume, α=0.2, β =0.3, and γ =0.1. Report the forecasts for year 6 from months January through December inclusive. Discuss briefly these forecasts (*Discussion NOT to exceed 500 words)*

**Answer**:

|  |  |
| --- | --- |
| **Periods** | **Forecasts** |
| 61 | 4295.14786 |
| 62 | 4789.41581 |
| 63 | 4708.57614 |
| 64 | 4067.34742 |
| 65 | 6420.37481 |
| 66 | 8664.83223 |
| 67 | 8937.99554 |
| 68 | 12158.2352 |
| 69 | 18428.2617 |
| 70 | 19023.5005 |
| 71 | 22868.6582 |
| 72 | 11851.8819 |

A graph of a graph showing the results of a forecast

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Winter’s methodology successfully captures the upward trend as well as the seasonality.

***Question 11*** (6 points): For the model developed in Question 10, compute the error parameters MAD, MSE, MAPE, and TS.

**Answer**:

Analyzing the error parameters generated using Winters' method with the given values of Period, Alpha, Beta, and Gamma, we can say that:

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Given Value** |  |  |
| **Period** | 12 |  |  |
| **Alpha** | 0.2 |  |  |
| **Beta** | 0.3 |  |  |
| **Gamma** | 0.1 |  |  |
|  |  |  |  |
|  | **Reported** | **Min** | **Max** |
| **MSE** | 3828266.433 | 173424.3 | 3828266 |
| **MAD** | 1420.883066 | 348.8325 | 1420.883 |
| **MAPE** | 24.70064584 | 12.75887 | 32.59923 |
| **TS** | 3.418389818 | -9.59675 | 5.708757 |

1. **Mean Squared Error (MSE)**:
   * Reported: 3828266.433
   * Min: 173424.2793
   * Max: 3828266.433
   * The reported MSE value falls within the range defined by the minimum and maximum values. While it is higher than the minimum value, it is consistent with the maximum value. This indicates variability in the accuracy of the forecast. A lower MSE value is desired as it reflects better accuracy in predicting future values.
2. **Mean Absolute Deviation (MAD)**:
   * Reported: 1420.883066
   * Min: 348.8324732
   * Max: 1420.883066
   * The reported MAD value falls within the range defined by the minimum and maximum values. However, a lower MAD value indicates better accuracy in forecasting, as it represents smaller deviations from the actual values.
3. **Mean Absolute Percentage Error (MAPE)**:
   * Reported: 24.70064584
   * Min: 12.75886926
   * Max: 32.59922557
   * The reported MAPE value falls within the range defined by the minimum and maximum values. However, it is relatively high compared to the minimum value, indicating potential variability in the accuracy of the forecast. A lower MAPE value indicates better accuracy in forecasting, as it represents smaller percentage differences between predicted and actual values.
4. **Tracking Signal**:
   * Reported: 3.418389818
   * Min: -9.596752598
   * Max: 5.708757472
   * The reported tracking signal value falls within the range defined by the minimum and maximum values. A tracking signal close to zero indicates that the forecasting model is accurately predicting future values. Positive values indicate overestimation, while negative values indicate underestimation. Thus, a tracking signal close to zero is desired for an accurate forecast.

***Question 12*** (6 points): For the model developed in Question 10, using Excel Solver optimize the values of α, β, and γ with an objective to minimize MAPE. Report your results provide a Discussion how optimization improved the forecasting error (*Discussion NOT to exceed 500 words)*

**Answer**:

Using Solver, the optimal values of alpha, beta and gamma come out to be 0, 0.0224 and 0 respectively. Based on these, error parameters becomes:

1. **Mean Squared Error (MSE)**:
   * Reported: 1897224.192
   * Min: 128542.5929
   * Max: 1897224.192
   * The reported MSE value falls within the range defined by the minimum and maximum values. While it is higher than the minimum value, it is consistent with the maximum value. This indicates variability in the accuracy of the forecast. A lower MSE value is desired as it reflects better accuracy in predicting future values.
2. **Mean Absolute Deviation (MAD)**:
   * Reported: 1046.789359
   * Min: 247.601445
   * Max: 1046.789359
   * The reported MAD value falls within the range defined by the minimum and maximum values. However, a lower MAD value indicates better accuracy in forecasting, as it represents smaller deviations from the actual values.
3. **Mean Absolute Percentage Error (MAPE)**:
   * Reported: 19.64237369
   * Min: 10.17489791
   * Max: 32.59922557
   * The reported MAPE value falls within the range defined by the minimum and maximum values. However, it is relatively high compared to the minimum value, indicating potential variability in the accuracy of the forecast. A lower MAPE value indicates better accuracy in forecasting, as it represents smaller percentage differences between predicted and actual values.
4. **Tracking Signal**:
   * Reported: 0.432081856
   * Min: -4.749982776
   * Max: 6.143092604
   * The reported tracking signal value falls within the range defined by the minimum and maximum values. A tracking signal close to zero indicates that the forecasting model is accurately predicting future values. Positive values indicate overestimation, while negative values indicate underestimation. Thus, a tracking signal close to zero is desired for an accurate forecast.

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Although before optimization, the winter’s method successfully captured the seasonality and the upward trend, after optimization this method captured the movement of the data more successfully with better smoothening. As shown in the charts above, the errors have reduced after optimization.

***Question 13*** (6 points): Discuss the model developed in Question 10 is how different from model developed in Question 7, (*Discussion NOT to exceed 500 words)*

**Answer**:

**Key Differences:**

1. **Level and Trend Smoothing**:
   * Winters' method allows for separate smoothing of level, trend, and seasonality components, whereas Holt's method only incorporates level and trend smoothing. This difference in the modeling approach may result in variations in the level of smoothing applied to the data, impacting the forecast accuracy and error metrics.
2. **Seasonality Handling**:
   * Winters' method explicitly incorporates seasonality smoothing (controlled by the parameter γ), which can be beneficial for capturing recurring patterns in the data. In contrast, Holt's method does not directly address seasonality, making it less suitable for datasets with pronounced seasonal variations.
3. **Error Metrics**:
   * The error metrics (MSE, MAD, MAPE, Tracking Signal) provide insights into the accuracy and performance of the forecasting models. The differences in these error metrics between the two methods reflect variations in the forecast accuracy, potentially influenced by the modeling assumptions and parameter values.

In summary, the choice between Winters' method and Holt's method depends on the specific characteristics of the time series data and the forecasting objectives. Winters' method may be preferred for datasets with pronounced seasonality, while Holt's method is more suitable for capturing linear trends in the absence of strong seasonal patterns. Since our data has significant seasonality, Winter’s method was able to make more accurate predictions.

***Question 14*** (22 points): Which model you will select and Why and how does the optimization improve the forecasting performance of the methods? (*1 to 2-page discussion recommend*)

Forecasting demand is a critical task for businesses across various industries. Accurate demand forecasts enable organizations to make informed decisions regarding production, inventory management, and resource allocation. To achieve reliable forecasts, businesses often employ various time series forecasting methods, each with its own strengths and limitations.

In this project, we compared the performance of four commonly used forecasting methods: 3-month moving averages, exponential smoothing, Holt's method, and Winters' method, in forecasting demand data over a six-year period. By evaluating key error metrics and analyzing the results, we aim to identify the most effective forecasting approach for demand forecasting.

The results synopsis is:

1. **3-Month Moving Averages**:
   * MAD: 4380.116959
   * MSE: 27974658.87
   * MAPE: 74.77216822
   * Tracking Signal: 5.403204272
   * The 3-month moving averages method yields relatively high error metrics across all parameters, indicating limited accuracy in forecasting demand. The high MAD, MSE, and MAPE values suggest significant deviations between the forecasted and actual demand values, while the positive tracking signal indicates a consistent overestimation of demand.
2. **Exponential Smoothing**:
   * Optimal Alpha (α): 1
   * MAD: 3003.611111
   * MSE: 17010782.41
   * MAPE: 53.42532468
   * Tracking Signal: -0.072135393
   * Exponential smoothing with an optimal alpha value of 1 performs moderately well in forecasting demand. The error metrics, although lower compared to the 3-month moving averages method, still indicate room for improvement. The negative tracking signal suggests a tendency to underestimate demand, which may lead to inventory shortages.
3. **Holt's Method**:
   * Optimal Alpha (α): 0.988697827
   * Optimal Beta (β): 0
   * MAD: 2937.887787
   * MSE: 16526363.13
   * MAPE: 51.11095581
   * Tracking Signal: -1.157272439
   * Holt's method with optimal alpha and beta values performs comparable to exponential smoothing. The error metrics show moderate accuracy in forecasting demand, with a slight improvement over exponential smoothing. However, the negative tracking signal indicates a tendency to underestimate demand, similar to exponential smoothing.
4. **Winters' Method**:
   * Optimal Alpha (α): 0
   * Optimal Beta (β): 0.022463563
   * Optimal Gamma (γ): 0
   * Period: 12
   * MAD: 1046.789359
   * MSE: 1897224.192
   * MAPE: 19.64237369
   * Tracking Signal: 0.432081856
   * Winters' method with optimal alpha, beta, and gamma values performs the best among the four forecasting methods. The error metrics indicate significantly lower deviations from actual demand values compared to the other methods, with the lowest MAD, MSE, and MAPE values. Additionally, the tracking signal close to zero suggests accurate forecasting with minimal underestimation or overestimation of demand.

**Conclusion:**

Based on the comprehensive analysis of error metrics, Winters' method emerges as the most effective forecasting technique for demand data in our dataset. The optimal parameter values for alpha, beta, and gamma, combined with the seasonal component captured by the method, contribute to its superior performance in forecasting accuracy. Businesses seeking to improve their demand forecasting processes should consider adopting Winters' method, especially when dealing with datasets exhibiting seasonal patterns.