

**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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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 the 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**: The challenge in this prediction problem is to develop an accurate forecasting model that can effectively predict future values based on historical data. The goal is to minimize the forecasting error and improve the accuracy of the forecasts. The problem statement involves selecting the most appropriate forecasting model that can capture the underlying patterns, trends, and seasonality in the data, while also adapting to changes and variations over time and optimizing its parameters to achieve the best possible accuracy. The problem arises from the uncertainty and variability present in the data.

Furthermore, the problem statement involves addressing the limitations of the chosen forecasting model. It requires understanding and mitigating issues such as the inability to capture complex relationships, lack of trend and seasonality detection, and inflexibility to changes in the data.

The problem statement also highlights the importance of evaluating and comparing different forecasting models based on relevant parameters such as Mean Squared Error (MSE), Mean Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE), and Tracking Signal (TS). These parameters serve as standards to measure the performance and effectiveness of the forecasting model.

Addressing this prediction problem requires a combination of statistical analysis, mathematical modeling, and optimization techniques. It involves exploring and comparing different forecasting methods, fine-tuning their parameters, and evaluating their performance to select the most suitable model. The goal is to provide reliable and accurate forecasts that can help organizations optimize their operations, anticipate demand fluctuations, and enhance overall efficiency.

***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**: The 3-period moving average forecasting model calculates the average of the past three observations to generate forecasts. Using this model, we can forecast the values for year 6 from January to December.

The 3-period moving average model provides a simple and straightforward approach to forecasting by considering the average of the most recent observations. However, it is important to note that this model assumes a constant trend and does not capture more complex patterns or seasonality in the data. Although simple and easy to implement, this model has several limitations that can affect its accuracy and reliability. Some of the key limitations of the moving average model include:

* The moving average model assumes a constant trend and does not account for seasonality in the data. This can lead to inaccurate forecasts when the data exhibit trend or seasonality patterns.
* The moving average model assumes a linear relationship between past and future observations. However, in the case of nonlinear relationships, the moving average model may not capture these complex relationships accurately. This can lead to significant forecasting errors, especially when the data exhibits nonlinear patterns.

In conclusion, the 3-period moving average model, after calculating the forecasting error parameters, does not provide accurate and reliable forecasts. The model's performance is suboptimal, with significant errors, deviation, and bias in the forecasts. To improve forecasting accuracy, more advanced forecasting methods that consider additional factors such as seasonality and trends should be considered.

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

**Answer**:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Reported | LOWEST | HIGHEST |
| MSE | 27974658.9 | 111111.111 | 27974658.9 |
| MAD | 4380.11696 | 333.333333 | 4380.11696 |
| MAPE | 74.7721682 | 11.1111111 | 78.095927 |
| Ts | -5.4032043 | -8.5850914 | 0.24540902 |

The reported forecasting error parameters indicate the performance of the model and the accuracy of the forecasts:

Mean Squared Error (MSE): The MSE value of 27,974,658.87 indicates that, on average, the squared differences between the predicted values and the actual values are quite large. This suggests that the 3-period moving average model is not accurately capturing the underlying patterns and variations in the data, resulting in significant errors in the forecasts.

Mean Absolute Deviation (MAD): The MAD value of 4,380.116959 represents the average absolute difference between the predicted values and the actual values. This indicates that, on average, the forecasts have a considerable deviation from the actual values, suggesting that the model may not be capturing the underlying trends and patterns effectively.

Mean Absolute Percentage Error (MAPE): The MAPE value of 74.77% indicates that, on average, the percentage difference between the predicted values and the actual values is quite high. This suggests that the forecasts have a substantial relative error, indicating the limitations of the 3-period moving average model.

Tracking Signal (TS): The negative TS value of -5.403204272 indicates that the forecasts tend to have a systematic bias, consistently overestimating or underestimating the actual values. This suggests that the 3-period moving average model may not be effectively adapting to changes in the underlying patterns and trends in the data.

**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. Briefly discuss these forecasts (*Discussion NOT to exceed 500 words)*

**Answer**: Using the smoothing factor α of 0.2. value, we generated forecasts using the simple exponential smoothing model for year 6 from January to December. This approach assumes that the recent past is a good indicator of the future behavior of the variable being forecasted. The forecasts generated by this model for year 6 are based on historical data and the chosen smoothing factor. The reported forecasting error metrics indicate that the model's performance is not optimal. The relatively high values of MSEt, MADt, and MAPEt suggest that the forecasts generated by the model have a considerable amount of error or deviation from the actual values.

Mean Squared Error (MSE): The MSE value of 27,525,821 indicates that, on average, the squared differences between the predicted values and the actual values are quite large. This suggests that the model is not accurately capturing the patterns and trends in the data, resulting in significant errors in the forecasts.

Mean Absolute Deviation (MAD): The MAD value of 4,364.83499 represents the average absolute difference between the predicted values and the actual values. This indicates that, on average, the forecasts have a considerable deviation from the actual values, suggesting that the model may not be capturing the underlying patterns and variations effectively.

Mean Absolute Percentage Error (MAPE): The MAPE value of 81.56% indicates that, on average, the percentage difference between the predicted values and the actual values is quite high. This suggests that the forecasts have a substantial relative error, indicating the limitations of the simple exponential smoothing model in accurately capturing the dynamics of the data.

Tracking Signal (TS): The negative TS value of -5.2873268 indicates that the forecasts tend to have a systematic bias, consistently overestimating or underestimating the actual values. This suggests that the model is not effectively adapting to the underlying patterns and trends in the data.

In conclusion, the simple exponential smoothing model with α = 0.2, as reported by the given forecasting error metrics, does not provide accurate and reliable forecasts. The model's performance is suboptimal, with significant errors, deviation, and bias in the forecasts. To improve the forecasting accuracy, alternative forecasting methods or more advanced models should be considered, considering the specific characteristics and patterns of the data.

Bottom of Form

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

**Answer**:

Alpha α = 0.2

|  |  |  |  |
| --- | --- | --- | --- |
|  | Reported | Lowest | Highest |
| MSEt | 27525821 | 9688538.35 | 38646944.4 |
| MADt | 4364.83499 | 2575.86275 | 6216.66667 |
| MAPEt | 81.5597676 | 67.2402127 | 310.833333 |
| TSt | -5.2873268 | -6.7148976 | 5.22342932 |

**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**:

|  |  |  |  |
| --- | --- | --- | --- |
| Alpha α = 1 |  |  |  |
|  | Reported | Lowest | Highest |
| MSEt | 17010782.4 | 5830868.06 | 38646944.4 |
| MADt | 3003.61111 | 1527.08333 | 6216.66667 |
| MAPEt | 53.4253247 | 45.8549784 | 310.833333 |
| TSt | 0.07213539 | -4.8925098 | 2.89145497 |

**Discussion:** The optimization process aimed to minimize the MSE, which is a measure of the average squared difference between the predicted values and the actual values. By optimizing the value of α, the forecasting model achieved significant improvements in the forecasting error parameters compared to the reported values.

MSE: The optimized model achieved an MSE of 17,010,782.4, which is considerably lower than the reported value of 27,525,821. This indicates that the optimized model has reduced the average squared difference between the predicted values and the actual values, resulting in improved accuracy.

MAD: The MAD for the optimized model is 3,003.61111, which is lower than the reported value of 4,364.83499. This indicates that the optimized model has reduced the average absolute difference between the predicted values and the actual values, indicating improved forecasting reliability.

MAPE: The MAPE for the optimized model is 53.43%, which is lower than the reported value of 81.56%. This indicates that the optimized model has reduced the percentage difference between the predicted values and the actual values, resulting in improved accuracy in terms of relative errors.

Tracking Signal (TS): The optimized model achieved a TS of 0.07213539, which is considerably closer to zero than the reported value of -5.2873268. A TS close to zero indicates a more unbiased forecast. Therefore, the optimized model shows significant improvement in reducing bias compared to the reported model.

Overall, the optimization process has greatly improved the forecasting error parameters MSE, MAD, MAPE, and TS for the model developed in Question 4. In conclusion, the optimization process successfully improved the forecasting error of the model by minimizing the MSE. The optimized model with α=1 provided better accuracy, precision, and reduced bias compared to the reported model with α=0.2. Optimized forecasts can be considered more reliable and can precise decision-making.

**Question 7 (6 points):** Develop 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**: Holt's model provides a forecasting method that considers both the level and trend in the data. The forecasts generated using the provided values of α=0.3 and β=0.1 for year 6 can be discussed as follows:

* Accuracy Assessment: The accuracy of the forecasts can be evaluated by comparing them with the actual values of year 6 once they become available. This will allow us to calculate metrics such as Mean Squared Error (MSE), Mean Absolute Deviation (MAD), and Mean Absolute Percentage Error (MAPE) to assess the accuracy and performance of Holt's model.
* Level: The level component in Holt's model represents the average value of the time series. The forecasts for year 6 will reflect the estimated level for each respective month. By capturing the underlying level, the model can provide insights into the expected overall magnitude of the data.
* Trend: The trend component in Holt's model captures the direction and rate of change in the time series. The forecasts will consider the estimated trend to project future values, allowing us to anticipate whether the series is expected to increase or decrease over time.
* Model Flexibility: Holt's model provides flexibility in adjusting the values of α and β to capture different patterns and trends in the data. If the current values of α=0.3 and β=0.1 do not adequately represent the underlying patterns, it may be necessary to experiment with different parameter values to improve the forecast accuracy.

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

**Answer**:

|  |  |  |  |
| --- | --- | --- | --- |
| Alpha ⍺ | 0.3 |  |  |
| Beta β | 0.1 |  |  |
|  | Reported | Lowest | Highest |
| MSEt | 23314646.3 | 2372512.154 | 23314646.27 |
| MADt | 3960.52201 | 1252.01769 | 3960.52201 |
| MAPEt | 69.0318156 | 40.39796453 | 145.6284153 |
| Tst | -10.082759 | -12.07361667 | 4.666216286 |

**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 and provide a Discussion of how optimization improved the forecasting error (*Discussion NOT to exceed 500 words)*

**Answer**:

|  |  |  |  |
| --- | --- | --- | --- |
| Alpha ⍺ | 1 |  |  |
| Beta β | 0.00757918 |  |  |
|  |  |  |  |
|  | Reported | Lowest | Highest |
| MSEt | 16370765.3 | 1949650.36 | 16370765.3 |
| MADt | 2934.53011 | 980.98339 | 2934.53011 |
| MAPEt | 50.8105995 | 30.5736757 | 145.628415 |
| Tst | 0.30149027 | -5.3605067 | 2.47099409 |

The optimized values for the parameters are as follows:

Alpha (⍺): 1

Beta (β): 0.00757918

**Discussion:** The optimization process aimed to minimize the MAD, which is a measure of the average absolute difference between the predicted values and the actual values. By optimizing the values of α and β, the forecasting model achieved improvements in the forecasting error parameters compared to the reported values.

MAD: The optimized model achieved a MAD of 2,934.53011, which is lower than the reported value of 3,960.52201. This indicates that the optimized model provides more accurate forecasts, with a reduced average absolute difference between the predicted values and the actual values.

MSE: The MSE for the optimized model is 16,370,765.3, which is lower than the reported value of 23,314,646.27. The lower MSE indicates that the optimized model has reduced the average squared difference between the predicted values and the actual values, resulting in improved accuracy on forecasts.

MAPE: The MAPE for the optimized model is 50.81%, which is lower than the reported value of 69.03%. The lower MAPE suggests that the optimized model has reduced the percentage difference between the predicted values and the actual values, indicating improved accuracy.

Tracking Signal (TSt): The optimized model achieved a TSt of 0.30149027, which is closer to zero than the reported value of -10.08275893. A TSt close to zero indicates a more unbiased forecast. Therefore, the optimized model shows improvement in reducing bias compared to the reported model.

Overall, the optimization process has improved the forecasting error parameters, including MAD, MSE, MAPE, and TS. This implies that the optimized value provides more accurate and unbiased forecasts compared to the reported model. These improvements can lead to better decision-making based on the forecasts.

**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. Briefly discuss these forecasts (Discussion NOT to exceed 500 words)

**Answer**: Winter's model for forecasting is a popular forecasting method that can effectively capture seasonality in time series data. By incorporating the level, trend, and seasonal components, the model can provide accurate forecasts for future periods.

Based on the provided parameters (⍺=0.2, β=0.3, Y=0.1), we generated forecasts for year 6. However, it's important to note that these forecasts assume that the historical data follows the same patterns and relationships as in the previous years.

The forecasts can be analyzed and discussed based on their potential implications and accuracy:

* Accuracy Assessment: The accuracy of the forecasts can be evaluated by comparing them with the actual values of year 6 once they become available. This will allow us to calculate metrics such as Mean Squared Error (MSE), Mean Absolute Deviation (MAD), and Mean Absolute Percentage Error (MAPE) to assess the accuracy and performance of the Winter's model.
* Seasonal Patterns: The Winter's model considers the seasonal factor which captures the seasonal patterns in the data. The forecasts for year 6 will reflect these patterns, enabling us to anticipate the seasonal variations and make informed decisions accordingly.
* Level and Trend: The level and trend components in the Winter's model help capture the overall level and direction of the time series. The forecasts will consider these components to anticipate the future values, underlying trends, and changes in the series.
* Model Flexibility: Winter’s model provides flexibility in adjusting the values of α, β, and Y to capture different patterns, trends, and seasonality in the data. If the current values of α=0.2 and β=0.3 and Y=0.1 do not adequately represent the underlying patterns, it may be necessary to experiment with different parameter values to improve the forecast accuracy.

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

**Answer**:

|  |  |  |  |
| --- | --- | --- | --- |
| ⍺ | 0.2 |  |  |
| β | 0.3 |  |  |
| Y | 0.1 |  |  |
|  | Reported | Lowest | Highest |
| MSE | 3844547.963 | 161289.882 | 3844547.963 |
| MAD | 1423.751852 | 347.638173 | 1423.751852 |
| MAPE | 24.72795514 | 12.5187479 | 29.42249623 |
| TSt | -3.770027009 | -6.049583 | 9.719779822 |

**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**:

|  |  |  |  |
| --- | --- | --- | --- |
| ⍺ | 0.14425295 |  |  |
| β | 0 |  |  |
| Y | 0 |  |  |
|  | Reported | Lowest | Highest |
| MSE | 2329261.91 | 139052.455 | 2329261.91 |
| MAD | 1132.37756 | 302.1247 | 1132.37756 |
| MAPE | 21.1596653 | 11.5507213 | 29.4224962 |
| TSt | 0.9999998 | -4.493405 | 9.12266535 |

The optimized values for the parameters are as follows:

* Alpha (⍺): 0.14425295
* Beta (β): 0
* Gamma (γ): 0

**Discussion:** The optimization process aimed to minimize the MAPE, which is a commonly used metric to evaluate forecasting accuracy. By optimizing the values of the parameters ⍺, β, and γ, the forecasting model achieved improvements in the forecasting error parameters compared to the reported values.

MAPE: The optimized model achieved a MAPE of 21.16%, which is lower than the reported value of 24.73%. This indicates that the optimized model provides more accurate forecasts, with the percentage difference between the predicted values and the actual values being reduced.

MSE: The MSE for the optimized model is 2,329,261.91, which is lower than the reported value of 3,844,547.963. The lower MSE indicates that the optimized model has reduced the average squared difference between the predicted values and the actual values, resulting in improved accuracy.

MAD: The MAD for the optimized model is 1,132.37756, which is lower than the reported value of 1,423.751852. The lower MAD suggests that the optimized model has reduced the average absolute difference between the predicted values and the actual values, indicating improved accuracy.

Tracking Signal (TS): The optimized model achieved a TSt of 0.9999998, which is closer to zero than the reported value of -3.770027009. A TS close to zero indicates a more unbiased forecast. Therefore, the optimized model shows improvement in reducing bias compared to the reported model.

Overall, the optimization process has improved the forecasting error metrics, including MAPE, MSE, MAD, and TS. This indicates that the optimized model provides more accurate and unbiased forecasts compared to the reported model. These improvements can lead to enhanced performance and better decision-making based on the forecasts.

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

**Answer**: I developed Holt’s method in Question 7 and Winter’s model in Question 10

Holt's Method:

* Components: Holt's method considers two components: level and trend.
* Level Component: It represents the smoothed value of the series at a given time point. It is updated using the weighted average of the current observed value and the smoothed level of the previous time point.
* Trend Component: It represents the rate of change in the series. The trend is updated using the weighted average of the current estimated trend and the previous estimated trend.
* Smoothing Parameters: Holt's method typically involves two smoothing parameters, one for the level component (alpha) and one for the trend component (beta). These parameters control the amount of weight given to the current observed values and the previous estimates.

Winter's Method:

* Components: Winter's method extends Holt's method by adding a third component for seasonality in addition to the level and trend components.
* Seasonality Component: It captures the repeating patterns or seasonal variations in the data. The seasonality component is updated using the weighted average of the currently observed value and the smoothed seasonality of the corresponding season in the previous year.
* Smoothing Parameters: Winter's method involves three smoothing parameters: one for the level component (alpha), one for the trend component (beta), and one for the seasonality component (gamma). These parameters control the weights assigned to the current values and the previous estimates for each component.

**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)*

**Answer:** Holt's method and Winter's method are both exponential smoothing techniques commonly used for time series forecasting. The choice between the two depends on the characteristics of the data and the specific forecasting problem.

Holt's method, also known as double exponential smoothing, extends simple exponential smoothing by incorporating a trend component in addition to the level component. It is suitable for data with a trend but no seasonality. Holt's method is useful when the trend in the data is relatively stable over time.

Winter's method, also known as triple exponential smoothing, extends Holt's method by including a seasonality component along with the level and trend components. It is appropriate for data with both trend and seasonality. Winter's method is useful when the trend and seasonality in the data exhibit stability over time.

In terms of minimizing error, both methods aim to make accurate predictions, but their effectiveness can vary depending on the characteristics of the data.

* Holt's method may be more effective when the data has a relatively stable trend without significant seasonality. By capturing the trend, it can provide accurate forecasts for data with gradual changes over time.
* Winter's method is more suitable when the data exhibits both trend and seasonality. It captures both components, allowing for accurate forecasts in situations where the patterns repeat over specific seasonal periods.

Holt's Method:

Mean Squared Error (MSEt): 23,314,646.27

Mean Absolute Deviation (MADt): 3,960.52201

Mean Absolute Percentage Error (MAPEt): 69.03%

Tracking Signal (TSt): -10.08275893

Winter's Method:

Mean Squared Error (MSEt): 3,844,547.963

Mean Absolute Deviation (MADt): 1,423.751852

Mean Absolute Percentage Error (MAPEt): 24.73%

Tracking Signal (TSt): -3.770027009

Comparing the dataset, we can observe the following:

MSE: Holt's method has a higher MSE (23,314,646.27) compared to Winter's method (3,844,547.963). Since lower MSE values indicate better accuracy, Winter's method performs better in terms of minimizing the mean squared error (MSE).

MAD: Holt's method has a higher MAD (3,960.52201) compared to Winter's method (1,423.751852). Lower MAD values indicate better accuracy, so Winter's method performs better in terms of minimizing the mean absolute deviation (MAD).

MAPE: Holt's method has a higher MAPE (69.03%) compared to Winter's method (24.73%). Lower MAPE values indicate better accuracy, therefore, Winter's method performs better in terms of minimizing the mean absolute percentage error. (MAPE)

TSt: Holt's method has a lower TSt (-10.08275893) compared to Winter's method (-3.770027009). A TSt value close to zero indicates a more unbiased forecast, so Holt's method performs better in terms of the tracking signal.

Based on the reported data, Winter's method consistently outperforms Holt's method in terms of MSE, MAD, and MAPE. However, Holt's method has a better performance in terms of the tracking signal.

Considering the overall performance and a focus on accuracy metrics, Winter's method appears to be a better choice based on the data. However, it's important to note that while choosing the forecasting method, we should also consider other factors such as the nature of the data, underlying patterns, and specific requirements of the forecasting problem.

Optimization can be used to compare and select the best model among different alternatives. By evaluating the performance of multiple models, optimization helps in identifying the model that provides the most accurate forecasts for a given dataset. Optimization aims to minimize the errors between the predicted values and the actual values. By iteratively adjusting the model parameters, optimization works towards reducing forecast errors such as mean squared error (MSE), mean absolute deviation (MAD), or mean absolute percentage error (MAPE). This results in more accurate forecasts and improved overall forecasting performance.