Desa-Kota
JURNAL PERENCANAAN WILAYAH, KOTA, DAN PERMUKIMAN

Volume 8, Nomor 1, 2026, 119 - 130
http://jurnal.uns.ac.id/jdk/article/view/92729
DOI: https://doi.org/10.20961/desa-kota.v8i1.92729.119-130

E-ISSN: 2656-5528

Forecasting Passenger Numbers at Sri Bintan Pura Tanjungpinang Harbor: An Application of Double Exponential Smoothing

Dwi Rosida[1*]
[1]Urban and Regional Planning, School of Architecture, Planning and Policy Development, Institut Teknologi Bandung, Bandung, Indonesia
**e-mail*: rosidadwi10@gmail.com

(Received: 27 August 2024; Reviewed: 19 December 2024; Accepted: 23 January 2025)

Abstract

The maritime transportation sector is vital for managing the movement of people and goods, especially in coastal and island regions. Accurate passenger forecasting is essential for optimizing port operations and enhancing service delivery. This study applies Double Exponential Smoothing (DES) method to forecast passenger numbers at Sri Bintan Pura Tanjungpinang Harbor in Riau Islands Province. This method, known for its effectiveness in capturing trends and seasonality, has been utilized to predict passenger volumes based on historical data from 2015 to 2023 in this research. Secondary data were sourced from the Central Statistics Agency (BPS) of Riau Islands Province, encompassing domestic and international passenger statistics. Results indicate that DES provides highly accurate forecasts for domestic passengers, with Mean Absolute Percentage Errors (MAPE) of 4.53% for departures and 5.10% for arrivals, and good accuracy for international passengers, with MAPE values of 14.68% for departures and 16.14% for arrivals. Forecasts for 2034 suggest a significant increase in passenger numbers, with domestic departures reaching 1,430,393 and arrivals reaching 1,564,647, while international departures are projected reaching 747,056 and arrivals reaching 768,125. These projections highlight a substantial growth trajectory, emphasizing the need for strategic infrastructure development at the port. Recommendations include optimizing existing facilities, expanding terminal buildings, and enhancing transport infrastructure to accommodate forecasted increase. This study contributes to the literature by demonstrating the application of DES in maritime contexts, offering valuable insights for port management and regional planning.

Keywords: Double Exponential Smoothing (DES); maritime transportation; passenger forecasting

1. INTRODUCTION

The maritime transportation industry plays a crucial role in facilitating the movement of people and goods, particularly in regions with a significant coastal and island population. As the demand for maritime transportation continues to grow, the need for accurate forecasting techniques becomes paramount to ensure efficient resource allocation and effective service delivery (Andini & Sunyoto, 2018; Mahkya et al., 2020; Tando et al., 2016). In the context of the Sri Bintan Pura Tanjungpinang Harbor, in Riau Islands province, understanding and predicting the number of passengers is essential for optimizing the harbor's operations, improving infrastructure, and enhancing the overall passenger experience.

The Double Exponential Smoothing (DES) method, a powerful time series forecasting technique, has been widely used in various transportation-related applications (Alhindawi et al., 2020; Fauziah et al., 2017, Habsari et al., 2020; Prakosa & Satiawan, 2019, Yaqin et al., 2022). It is particularly adept at capturing trends and seasonality, making it a suitable approach for forecasting the number of passengers at the Sri Bintan Pura Tanjungpinang Harbor. Its effectiveness can be quantitatively assessed through the Mean Absolute Percentage Error (MAPE), which helps evaluate the accuracy of the forecasts and ensures that predictions remain close to actual observed values (Febrian et al., 2019; Habsari et al., 2020; Xu et al., 2020).

For instance, Double Exponential Smoothing (DES) method was applied in a study on prediction of the number of passengers at Djuanda Airport in Surabaya, using linear programming techniques. The study highlighted that the identification of problems related to the mismatch between the number of available aircraft and the number of passengers can be overcome through a designed prediction (Prakosa & Satiawan, 2019). Moreover, this research shows that the Double Exponential Smoothing method is more effective than Triple Exponential Smoothing method in predicting the number of airplane passengers. The forecasting accuracy using the Double Exponential Smoothing method is better than Triple Exponential Smoothing method based on the error evaluation measured in the study (Ramadiani et al., 2019).

This research is situated within the context of the application of the Double Exponential Smoothing method to forecast the number of passengers at Sri Bintan Pura Tanjungpinang Harbor in Riau Islands Province. This research fills a significant void in the literature that pertains to the application of passenger forecasting methods at Sri Bintan Pura Tanjungpinang Port. Up to now, no study has explicitly used the Double Exponential Smoothing method to forecast the volume of passengers at this port. By utilizing this forecasting method in the context of Sri Bintan Pura Tanjungpinang Port, this study gives fresh insights that can be applied to enhance operational management and planning at the port in addition to providing a forecasting method that is pertinent to the port's circumstances.

The objective of this study is to apply the Double Exponential Smoothing method to forecast the number of passengers at Sri Bintan Pura Tanjungpinang Harbor. By leveraging this time series forecasting technique, the study aims to provide accurate and reliable passenger forecasts that can assist harbor management and stakeholders in optimizing operational planning, resource allocation, and overall service delivery. Additionally, the research seeks to contribute to the existing body of knowledge by demonstrating the effectiveness of Double Exponential Smoothing method in a maritime context where it has not previously been applied, thus filling a notable gap in the literature. The problem statement of this study is: (1) How accurate is the Double Exponential Smoothing method in forecasting passenger numbers at Sri Bintan Pura Tanjungpinang Harbor for domestic and international travel from 2015 to 2023? and (2) What are the forecasted results for 2034?

2. THEORETICAL FRAMEWORK

The existing literatures highlight various approaches to predicting vessel and cargo volumes in port operations, with a particular emphasis on the application of advanced forecasting techniques. For instance, Rao et al. (2025) explored container terminal operations using machine learning and deep learning algorithms to forecast vessel arrivals and the duration of container barge stays at the port. Similarly, Tengecha & Zhang (2021) examined the challenges faced by the Dar es Salaam port in Tanzania, identifying issues such as prolonged container waiting times, vessel clearance delays, and low traffic flow as significant constraints to maritime efficiency. These studies underscore the critical need for effective forecasting methods to enhance operational performance in port settings.

Recent research also demonstrates the effectiveness of the Double Exponential Smoothing method in forecasting passenger numbers across various transportation contexts. Ramadiani et al. (2019) found that the method consistently outperforms other forecasting techniques, establishing its reliability for generating accurate predictions. Prakosa & Satiawan (2019) further illustrated its practical benefits in improving operational efficiency at Juanda International Airport by aligning aircraft availability with passenger demand. Additionally, Amalia et al. (2020) emphasized the importance of forecasting systems in optimizing service delivery and capacity planning, confirming the method's reliability in predicting passenger volumes across different classes. These insights are directly applicable to enhance operational management at Sri Bintan Pura Tanjungpinang Harbor, suggesting the implementation of similar forecasting systems could significantly improve planning and efficiency in maritime transport.

This recent research aligns with the research goal of leveraging Double Exponential Smoothing method for more accurate and effective passenger forecasting. This research explores the utilization of the Double Exponential Smoothing method for forecasting passenger numbers at this port, marking a significant advancement in the application of time series forecasting techniques within the maritime sector. The research contributes to filling a notable gap in the existing literature by focusing specifically on Sri Bintan Pura Tanjungpinang Harbor.

3. RESEARCH METHODS

This research employs a quantitative approach, utilizing secondary data obtained from the Central Statistics Agency (Badan Pusat Statistik or BPS) of the Riau Islands Province. This research focuses on the number of passengers departing and arriving for both domestic and international ships from 2015 to 2023 at Sri Bintan Pura Tanjungpinang Harbor, Riau Islands province. The analysis begins with a descriptive examination of passenger trends, followed by the application of the Double Exponential Smoothing method to enhance forecasting accuracy. This research evaluates the reliability of the forecasting model using accuracy metrics such as Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and Standard Deviation of Error.

3.1. DATA

This research uses secondary data obtained from BPS of Riau Islands Province. The number of people departing and arriving for both domestic and international ships from 2015 to 2023 is included in the statistics used. The information for year 2016–2024 was taken from the Riau Islands Province paper. The first set of data, which was collected from the BPS website, shows the number of passengers entering and leaving the Riau Islands Province by district or city, together with columns that show the kind of shipping. Subsequently, data were sorted so that the number of passengers in Tanjungpinang, which is where Sri Bintan Pura Harbor is located, was the main emphasis. The following are the data that were used in this research: 1) number of passengers departing for domestic cruises in 2015-2023; 2) number of passengers arriving on domestic cruises in 2015-2023; 3) number of passengers departing for international shipping in 2015-2023; and 4) number of passengers arriving on international shipping in 2015-2023.

3.2. DATA ANALYSIS

This research begins with a descriptive analysis to provide an overview of passenger trends for both domestic and international voyages between 2015 and 2023 at Sri Bintan Pura Tanjungpinang Harbor. This initial analysis sets the stage for a more detailed quantitative approach, which involves utilizing statistical methods to analyze historical data. Subsequently, to enhance the forecasting accuracy, the study employs the Double Exponential Smoothing method, as proposed by Brown (Dharmawan & Indradewi, 2020; Hansun & Subanar, 2016). This technique, which includes both single and double levels of smoothing, builds upon the insights gained from the descriptive analysis (Alhindawi et al., 2020; Anamisa et al., 2024; Febrian et al., 2020).

3.2.1. Time Series Forecasting Techniques

Time series forecasting techniques analyze historical data to predict future values (Habsari et al., 2020; Xu et al., 2020). These methods are essential in scenarios where past patterns and trends are indicative of future occurrences (Adamuthe et al., 2015; Hansun et al., 2021; Krisma et al., 2019; Yousuf et al., 2022). The Double Exponential Smoothing method is defined by the following equations. First, Single Exponential Smoothing is calculated using Equation 1.

$$S'_t = \alpha X_t + (1-\alpha) S''_{t-1} \quad (1)$$

where S'_t is the single exponential smoothing value for period t, α is the smoothing constant $(0 < \alpha < 1)$, X_t is the actual value for period t, and S'_{t-1} is the forecast value for period $t-1$ (Bose et al., 2020; Febrian et al., 2020; Sidqi & Sumitra, 2019).

Next, Double Exponential Smoothing is computed as shown in Equation 2.

$$S''_t = \alpha X_t + (1-\alpha) S''_{t-1} \quad (2)$$

where S''_t represents the Double Exponential Smoothing value for period t, and S''_{t-1} is the value for period $t-1$ (Amalia et al., 2020b; Habsari et al., 2020; Yaqin et al., 2022a).

Constants a_t and b_t are calculated as:

$$a_t = 2S'_t - S''_{t-1} \quad (3)$$

$$b_t = \frac{\alpha}{1-\alpha}(S'_t - S''_{t-1}) \quad (4)$$

Finally, the forecast value is given by Equation 5.

$$F_t = a_t + b_t m \quad (5)$$

where F_t is the forecast value for period t, a_t and b_t are constants, and m is the number of periods to forecast (Alhindawi et al., 2020; Febrian et al., 2020; Hansun & Subanar, 2016; Ramadiani et al., 2020a; Sidqi & Sumitra, 2019).

The process begins with determining the optimal smoothing parameters for the forecasting model. Once these parameters are identified, they are used to apply exponential smoothing, which helps in developing the forecasting model (Alhindawi et al., 2020; Febrian et al., 2020; Habsari et al., 2020) (Febrian et al., 2019; Habsari et al., 2020). Finally, this model is applied to the actual data to generate forecasts and calculate error metrics.

3.2.2. Forecast Accuracy

Forecast accuracy is crucial for assessing the reliability and effectiveness of forecasting models. The Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and Standard Deviation of Error (Unbiased) are three measures used to assess forecast accuracy (Alhindawi et al., 2020; Habsari et al., 2020; Hansun & Subanar, 2016; Xu et al., 2020). Various metrics are used to measure how well a forecasting model predicts future values compared to actual outcomes.

One of the primary metrics used to measure forecasting accuracy is the Mean Absolute Error (MAE). MAE is a widely used metric that quantifies the average magnitude of forecast errors. It does this without considering the direction of the errors, meaning it does not differentiate between overestimates and underestimates (Adamuthe et al., 2015; Anamisa et al., 2024; Bose et al., 2019). The MAE is calculated as the average of the absolute differences between the forecasted and actual values. Lower MAE values signify better forecast accuracy, as they reflect smaller errors between predicted and actual outcomes (Bakar et al., 2022).

Additionally, the Mean Absolute Percentage Error (MAPE) offers a perspective on forecast accuracy relative to the actual values. It measures the average absolute percentage error between forecasted and actual values, providing a scale-independent accuracy assessment. Because MAPE can give a percentage-based measure of forecasting accuracy, it is selected. It is computed with the following formula (Habsari et al., 2020; Mahkya et al., 2020).

$$MAPE = \frac{1}{n}\sum_{t=1}^{n} \left|\frac{y_i - \hat{y}_i}{y_i}\right| \times 100\% \quad (6)$$

where y_i represents the actual value and $\hat{y}_i$ the forecasted value.

MAPE is categorized into different accuracy ranges. MAPE less than 10% indicates that the forecasting model is highly accurate, with minimal prediction errors, making its results very reliable. MAPE between 10% and 20% reflects a good level of accuracy, suggesting that while there are some prediction errors, the forecasts are still sufficiently reliable for planning and decision-making purposes. MAPE between 21% to 50% denotes a fair level of accuracy where the forecasts are acceptable, but may contain more significant errors, potentially requiring adjustments to the model. MAPE exceeding 50% signifies poor accuracy, with large prediction errors that render the forecasts unreliable for accurate decision-making. In conclusion, greater MAPE values suggest that model improvements are necessary to improve accuracy, whereas lower MAPE values imply better predicting accuracy and reliability (Habsari et al., 2020; Sidqi & Sumitra, 2019).

Table 1. MAPE Value Range

Percentage	Forecasting Accuracy
<10%	High
10%-20%	Good
21%-50%	Fair
>50%	Poor

Source: (Habsari et al., 2020)

Another key metric is the Standard Deviation of Error measures the variability of forecast errors, offering insight into the consistency of the forecasts. This metric assesses how spread out the forecast errors are from the mean error. A lower standard deviation indicates that forecast errors are more consistent and less variable, which is desirable for reliable forecasting (Habsari et al., 2020; Ramadiani et al., 2019).

4. RESULTS AND DISCUSSION

4.1 DESCRIPTIVE ANALYSIS

Descriptive analysis plays a critical role by systematically summarizing passenger trends at Sri Bintan Pura Tanjungpinang Harbor from 2015 to 2023. It provides comprehensive overview through visualizations and statistical summaries, including mean, median, standard deviation, minimum, and maximum values to identify patterns and variations in passenger numbers.

Table 2 presents data on the number of domestic departing passengers from 2015 to 2023, showing a general trend of growth interrupted by the COVID-19 pandemic. Passenger numbers increased from 481,226 in 2015 to a peak of 929,592 in 2019, indicating robust growth in domestic travel. The pandemic caused a significant drop in 2020 to 580,465 due to travel restrictions and reduced demand. Recovery began in 2021 with a rise to 461,625, and continued into 2022 with 746,686 passengers, reflecting a resurgence as restrictions eased. By 2023, the number of departing passengers reached 864,330, nearing pre-pandemic levels and suggesting a strong recovery and ongoing growth in domestic travel.

Table 2. The Number of Domestic Departing Passengers

Year	Number of Passengers
2015	481,226
2016	504,767
2017	636,587
2018	830,372
2019	929,592
2020	580,465
2021	461,625
2022	746,686
2023	864,330

Source: (BPS of Riau Islands Province, 2024)

Table 3. Statistical Description of The Number of Domestic Departing Passengers

Statistics	Value
Mean	670,628
Median	636,587
Standard Deviation	177,567
Minimum	461,625
Maximum	929,592

Based on Table 3, the average number of domestic departing passengers at Sri Bintan Pura Tanjungpinang Harbor from 2015 to 2023 is 670,328 passengers. This indicates a growing demand for maritime transportation services over the years. The standard deviation of 177,567 suggests a high level of variability in the data. The highest and lowest passenger numbers during this period were 929,592 and 461,625 respectively.

Table 4. The Number of Domestic Arriving Passengers

Year	Number of Passengers
2015	410,274
2016	515,471
2017	595,803
2018	905,765
2019	905,765
2020	640,684
2021	460,290
2022	773,719
2023	895,911

Source: (BPS of Riau Islands Province, 2024)

Table 4 illustrates the fluctuations in domestic arriving passengers from 2015 to 2023, revealing a general trend of growth interrupted by a significant decline during the COVID-19 pandemic. Passenger numbers rose steadily from 410,274 in 2015 to a peak of 905,765 in 2019. However, in 2020, the number dropped to 640,684 due to pandemic-related travel restrictions and reduced consumer confidence. The subsequent years saw a gradual recovery, with 2021 witnessing a partial rebound to 460,290 and a more substantial increase to 773,719 in 2022. By 2023, the passenger counts nearly approached pre-pandemic levels at 895,911, reflecting a strong recovery in domestic travel. This pattern underscores the resilience of the domestic travel sector amid significant disruptions and highlights the ongoing resurgence in travel activity.

Table 5. Statistical Description of The Number of Domestic Arriving Passengers

Statistics	Value
Mean	662,369
Median	640,684
Standard Deviation	182,776
Minimum	410,274
Maximum	905,765

Table 5 provides a comprehensive summary of key statistical measures for domestic arriving passengers at Sri Bintan Pura Tanjungpinang Harbor from 2015 to 2023. The mean of 662,369 reflects the average annual passenger count over the study period, indicating a general trend in passenger volume. The median value of 640,684 represents the midpoint of the data set, offering insight into the central tendency and ensuring that the average is not unduly influenced by extreme values. The standard deviation of 182,776 quantifies the variability or dispersion in passenger numbers, highlighting the extent of fluctuation around the mean. The minimum value of 410,274 and the maximum value of 905,765 define the range of observed passenger counts, illustrating the highest and lowest levels recorded.

Table 6. The Number of International Departure Passengers

Year	Number of Passengers
2015	205,565
2016	251,292
2017	231,794
2018	248,676
2019	229,646
2020	35,410
2021	0
2022	55,605
2023	117,069

Source: (BPS of Riau Islands Province, 2024)

Table 6 shows the number of international departure passengers at Sri Bintan Pura Tanjungpinang Harbor from 2015 to 2023. In 2015, there were 205,565 passengers, which increased to 251,292 in 2016 before slightly decreasing to 231,794 in 2017. The numbers rose again to 248,676 in 2018 but dropped to 229,646 in 2019. A significant decline occurred in 2020, with only 35,410 passengers, likely due to the COVID-19 pandemic's impact on travel. The following year 2021, saw the number of passengers fall to zero possibly due to ongoing travel restrictions. In 2022, the number of passengers increased to 55,605 as restrictions began to ease and by 2023, the figure further rose to 117,069, indicating a gradual recovery in international travel.

Table 7. Statistical Description of The Number of International Departure Passengers

Statistics	Value
Mean	152,784
Median	205,565
Standard Deviation	101,041
Minimum	0
Maximum	251,292

Table 7 provides a statistical description of the number of international departure passengers at Sri Bintan Pura Tanjungpinang Harbor. The mean number of passengers is 152,784, indicating the average level of passenger traffic over the years. The median value is 205,565, representing the middle point of the data when arranged in order. The standard deviation is 101,041, reflecting a high degree of variability in passenger numbers. The minimum recorded number of passengers is 0, while the maximum is 251,292, highlighting the range of passenger traffic extremes during the period.

Table 8. The Number of International Arriving Passengers

Year	Number of Passengers
2015	216,786
2016	266,740
2017	234,087
2018	239,881
2019	242,956
2020	42,718
2021	312
2022	54,147
2023	118,409

Source: (BPS of Riau Islands Province, 2024)

Table 8 shows the number of international arriving passengers at Sri Bintan Pura Tanjungpinang Harbor from 2015 to 2023. In 2015, there were 216,786 arriving passengers, which increased to 266,740 in 2016. The following years saw varying numbers, with 234,087 passengers in 2017, 239,881 in 2018, and a peak of 242,956 in 2019. In 2020, there was a significant drop to 42,718 passengers, likely due to the COVID-19 pandemic's impact on travel. The number further decreased to 312 in 2021, possibly due to continued restrictions. Passenger numbers began to recover in 2022 with 54,147 and continued to rise to 118,409 in 2023, indicating a gradual resurgence in international arrivals.

Table 9. Statistical Description of The Number of International Arriving Passengers

Statistics	Value
Mean	157.337
Median	216.786
Standard Deviation	103.378
Minimum	312
Maximum	266.740

Table 9 provides a statistical summary of the number of international arriving passengers at Sri Bintan Pura Tanjungpinang Harbor. The mean number of passengers is 157,337, reflecting the average level of arrivals over the period. The median is 216,786, which is the middle value of the dataset when arranged in ascending order. The standard deviation is 103,378, indicating a high degree of variability in the passenger numbers. The minimum number of arriving passengers recorded is 312, while the maximum is 266,740, representing the range of passenger traffic extremes during the period.

4.2. TIME SERIES PATTERN IDENTIFICATION

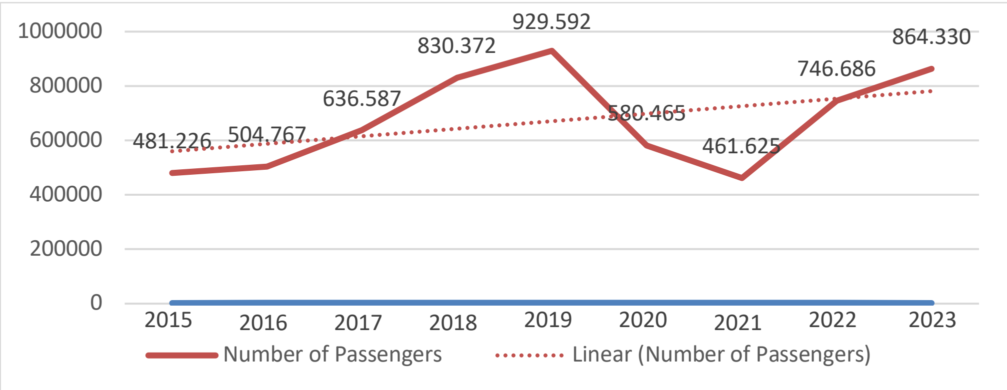

Figure 1. Plot of Domestic Departure Passenger Data

Figure 1 presents a graphical representation of the number of domestic departure passengers at Sri Bintan Pura Tanjungpinang Harbor from 2015 to 2023. The plot reveals a pattern of fluctuations over the years with significant variations in passenger numbers from year to year. Despite these fluctuations, an overall upward trend is evident. This indicates that, while there are yearly oscillations in the data, there is a general increase in the number of domestic passengers over the observed period. The fluctuations could be attributed to various factors such as seasonal travel demands, economic conditions, or other local influences, but the prevailing trend suggests a growing demand for domestic travel through the harbor.

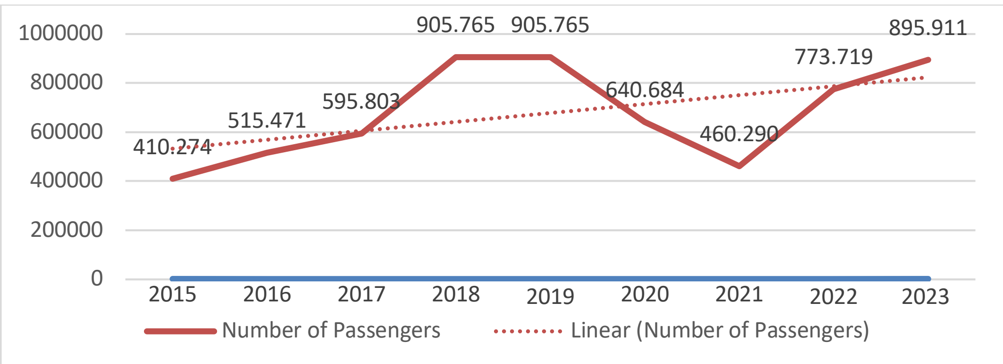

Figure 2. Plot of Domestic Arrival Passenger Data

Figure 2 illustrates the number of domestic arriving passengers at Sri Bintan Pura Tanjungpinang Harbor from 2015 to 2023. The plot shows notable year-to-year fluctuations in passenger numbers, reflecting periods of both increase and decrease. Despite these variations, there is a discernible upward trend over the years. This suggests that, although there are yearly variations likely influenced by factors such as seasonal travel patterns, economic conditions, or local events the overall number of domestic arrivals has been increasing. The trend indicates a growing interest or demand for domestic travel through the port, even though the data reveals periods of significant fluctuation.

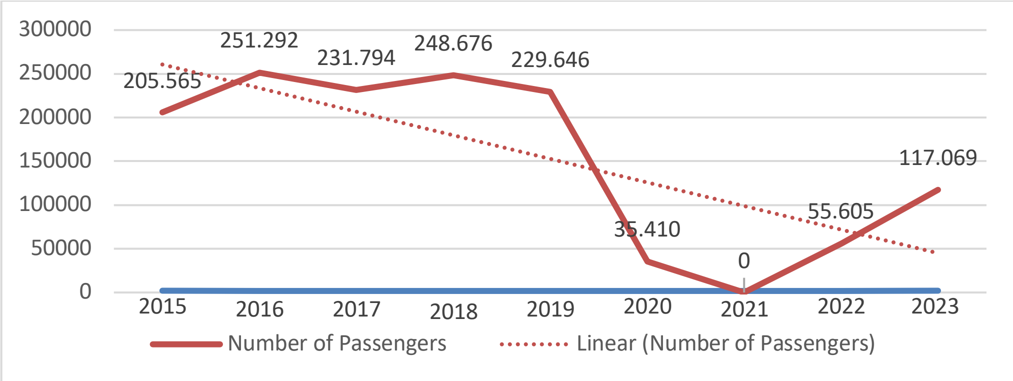

Figure 3. Plot of International Departure Passenger Data

Figure 3 presents the data on the number of international departure passengers at Sri Bintan Pura Tanjungpinang Harbor from 2019 to 2023. The plot highlights considerable year-to-year fluctuations in passenger numbers with some periods showing significant increases or decreases. However, the overarching trend is a marked decline.

From 2019 to 2023, there is a clear decrease in the number of passengers departing internationally. This downward trend is especially noticeable when compared to the pre-pandemic year of 2019, suggesting a substantial drop in international travel. Several factors could be contributing to this decline, including the impact of the COVID-19 pandemic, which led to widespread travel restrictions and changes in international travel behavior. Other possible influences might include changes in airline routes, economic conditions, or shifts in travel policies. Despite occasional fluctuations in the data, the general trend points to a reduced level of international departures from the port over the observed period.

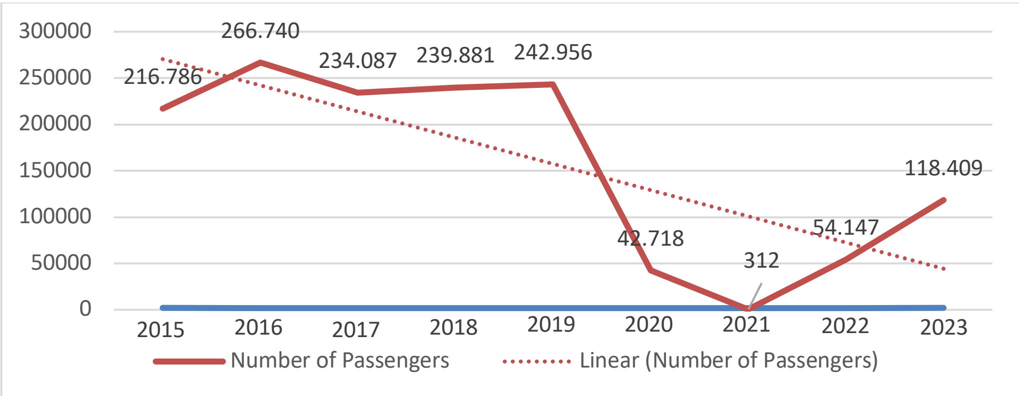

Figure 4. Plot of International Arrival Passenger Data

Figure 4 illustrates the number of international arriving passengers at Sri Bintan Pura Tanjungpinang Harbor from 2015 to 2023. The graph demonstrates a clear and significant downward trend throughout the period. The data shows a steady decrease in the number of international arrivals with notable reductions in passenger numbers over the years. Starting from a relatively high figure in 2015, the numbers appear to drop consistently, reaching much lower levels by 2023. This decline is particularly evident when comparing the peak years, such as 2016 with the subsequent years showing a pronounced reduction.

Several factors could contribute to this significant decrease. The COVID-19 pandemic, which led to widespread travel restrictions and reduced international travel, is likely a major factor. Additionally, changes in travel policies, economic conditions, or shifts in international travel patterns might have influenced this trend. The consistent downward trajectory in the data suggests a substantial impact on international travel to and from the port, reflecting broader global travel challenges and disruptions experienced over the years.

4.3. FORECASTING WITH DOUBLE EXPONENTIAL SMOOTHING

4.3.1. Determination of Smoothing Parameters

The smoothing parameters for forecasting using the Double Exponential Smoothing method are crucial for accurate predictions. The optimal alpha values obtained are 0.5 for both domestic departure and arrival passengers and 0.9 for international departure and arrival passengers, as they provide the smallest forecasting errors. The forecast coefficients derived from this smoothing process are presented in Table 10.

Table 10. Forecast Coefficients

Forecast Coefficient	Domestic		International	
	Departure	Arrival	Departure	Arrival
a	819,228	852,233	116.788	118.073
b	55,560	64,765	57.297	59.096

In Table 10, the coefficient a represents the level component, while coefficient b represents the trend component. For domestic passengers, the level coefficients are 819,228 for departures and 852,233 for arrivals with trend coefficients of 55,560 for departures and 64,765 for arrivals. For international passengers, the level coefficients are 116,788 for departures and 118,073 for arrivals with trend coefficients of 57,297 for departures and 59,096 for arrivals. These coefficients are used in the Double Exponential Smoothing equations to generate forecasts and assess the model's performance.

4.3.2. Error Testing

The error testing of the passenger forecasting results for Sri Bintan Pura Tanjungpinang Harbor is presented in Table 11, which shows the error metrics.

Table 11. Error Values

Criterion	Domestic		International	
	Departure	Arrival	Departure	Arrival
MAE	34.772	39.189	42.098	41.962
MAPE	**4,53**	**5,10**	**14,68**	**16,14**
UNBIASED	39.290	36.114	48.682	50.675

Table 11 presents three criteria for measuring forecasting error: Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and Standard Deviation of Error (Unbiased). MAE measures the average magnitude of errors in forecasts without considering their direction, with lower values indicating better forecast accuracy. For domestic passengers, MAE is 34,772 for departures and 39,189 for arrivals, while for international passengers, it is 42,098 for departures and 41,962 for arrivals. MAPE provides the average absolute percent error of forecasts, offering a relative measure of accuracy as a percentage. The MAPE values are 4.53% for domestic departures, 5.10% for domestic arrivals, 14.68% for international departures, and 16.14% for international arrivals where lower percentages suggest higher accuracy.

Unbiased Error, or the standard deviation of errors, assesses the variability of forecast errors with lower values indicating less variability and better forecast consistency. The unbiased error values are 39,290 for domestic departures, 36,114 for domestic arrivals, 48,682 for international departures, and 50,675 for international arrivals. The MAPE values indicate that the Double Exponential Smoothing method provides high forecasting accuracy for domestic departure and arrival passengers, and good accuracy for international departure and arrival passengers, based on the MAPE ranges shown in Table 1.

4.3.3. Forecast Results

The forecast results for the number of passengers at Sri Bintan Pura Tanjungpinang Harbor using the Double Exponential Smoothing method for the year 2034 are presented in Table 12.

Table 12. Forecast Results

Year	Domestic		International	
	Departure	Arrival	Departure	Arrival
2015	481.226	410.274	205.565	216.786
2016	504.767	515.471	251.292	266.740
2017	636.587	595.803	231.794	234.087
2018	830.372	905.765	248.676	239.881
2019	929.592	905.765	229.646	242.956
2020	580.465	640.684	35.410	42.718
2021	461.625	460.290	-	312
2022	746.686	773.719	55.605	54.147
2023	864.330	895.911	117.069	118.409
2034	**1.430.393**	**1.564.647**	**747.056**	**768.125**

Table 12 presents the forecasted number of passengers at Sri Bintan Pura Tanjungpinang Harbor using the Double Exponential Smoothing method for the year 2034. The forecast includes estimates for both domestic and international departures and arrivals. The table shows substantial projected increases in passenger numbers for 2034 compared to historical data. For domestic travel, the forecasted number of departures is 1,430,393, and arrivals are 1,564,647. These figures represent a significant growth from earlier years, such as 2015 when the numbers were 481,226 for departures and 410,274 for arrivals. This increase suggests a robust upward trend in domestic travel demand.

Similarly, for international travel, the forecasted figures are 747,056 for departures and 768,125 for arrivals in 2034, up from 205,565 and 216,786 respectively in 2015. This growth indicates a substantial recovery and expansion in international travel, reflecting improved travel conditions and increased global connectivity. Overall, the forecast results indicate a positive trend in passenger traffic at the port, with substantial increases projected for both domestic and international travel. This growth is likely driven by factors such as economic development, population growth, and enhanced transport infrastructure, suggesting that Sri Bintan Pura Tanjungpinang Harbor will experience significant growth in passenger volume over the next decade.

5. CONCLUSION

Based on the forecast results, it is projected that in 2034, Sri Bintan Pura Tanjungpinang Harbor will experience significant increases in passenger numbers. Specifically, the forecasted number of domestic departures is 1,430,393 and arrivals are 1,564,647. For international travel, the projections are 747,056 departures and 768,125 arrivals. The optimal alpha values for forecasting, chosen based on the best standard error, are 0.5 for domestic passenger numbers with high accuracy MAPE values of 4.53 for departures and 5.10 for arrivals, and 0.9 for international passenger numbers with good accuracy MAPE values of 14.68 and 16.14 for departures and arrivals, respectively.

The projected increase in passenger traffic at Sri Bintan Pura Harbor underscores the need for strategic development policies. To accommodate this growth, it is crucial to optimize the use of existing facilities and infrastructure, make efficient use of available land according to needs, and invest in the expansion of passenger terminal buildings, parking areas, and transport facilities. Implementing these strategies will help ensure the port can handle the anticipated increase in passenger volume and continue to support regional and international travel effectively.

6. RESEARCH LIMITATION AND RECOMMENDATION

This research has several limitations that may affect the interpretation and generalizability of the findings. First, it relies on secondary data from the Central Statistics Agency (BPS) of the Riau Islands Province, which may contain reporting biases or inaccuracies. The analysis focuses on historical trends from 2015 to 2023, potentially overlooking sudden changes in external factors such as economic fluctuations or unforeseen events like natural disasters and pandemics that could significantly influence passenger numbers. While the Double Exponential Smoothing method effectively captures trends, it assumes that future patterns will closely follow historical data, which may not hold true in rapidly changing environments. Additionally, the research does not explore qualitative factors that influence passenger behavior, such as changes in consumer preferences or competition from alternative transportation modes.

To enhance the robustness and applicability of future research, several recommendations should be considered. Researchers should incorporate primary data collection methods, such as surveys or interviews, to gather firsthand insights from passengers and stakeholders in the transportation sector, there by mitigating potential biases in secondary data. Expanding the analysis to include a broader time frame and assessing the impact of significant external factors, such as economic conditions and global events, will provide a more comprehensive understanding of passenger trends. Additionally, integrating qualitative research methods can enrich the analysis by exploring traveler motivations and preferences. Finally, employing advanced forecasting techniques, such as machine learning models, can improve the adaptability of predictions to changing patterns and incorporate a wider range of variables, leading to more accurate and actionable insights in the maritime transport sector.

REFERENCES

Adamuthe, A. C., Gage, R. A., & Thampi, G. T. (2015). Forecasting Cloud Computing Using Double Exponential Smoothing Methods. *ICACCS 2015 - Proceedings of the 2nd International Conference on Advanced Computing and Communication Systems*, 3–7. https://doi.org/10.1109/ICACCS.2015.7324108

Alhindawi, R., Abu Nahleh, Y., Kumar, A., & Shiwakoti, N. (2020). Projection of Greenhouse Gas Emissions for the Road Transport Sector Based on Multivariate Regression and the Double Exponential Smoothing Model. *Sustainability*, *12*(21), 9152. https://doi.org/10.3390/su12219152

Amalia, E. L., Harijanto, B., & Santoso, A. (2020). Passenger Volume Forecasting Information System for PT KAI Daop 2 Bandung Using Double Exponential Smo othing Method. *IOP Conference Series: Materials Science and Engineering*, 1–7. https://doi.org/10.1088/1757-899X/732/1/012080

Anamisa, D. R., Mufarroha, F. A., Jauhari, A., Khotimah, B. K., Hariyawan, M. Y., & Haq, A. F. (2024). Forecasting Ginger Harvest Yields: A Comparative Study of Double Exponential Smoothing and Long Short-Term Memory Models. *Academic Journal*, *11*(6), 1481. https://doi.org/10.18280/mmep.110609

Andini, T. D., & Sunyoto, R. M. (2018). Sistem Peramalan Jumlah Penumpang Kapal Laut di Pelabuhan Tanjung Perak Surabaya Menggunakan Triple Eksponensial Smoothing Berbasis Android. *Positif : Jurnal Sistem Dan Teknologi Informa*, *4*(2), 113–124. https://doi.org/10.31961/positif.v4i2.582

Badan Pusat Statistik Provinsi Kepulauan Riau. (2024). *Provinsi Kepulauan Riau Dalam Angka 2024*.

Bakar, N. N. A., Bazmohammadi, N., Çimen, H., Uyanik, T., Vasquez, J. C., & Guerrero, J. M. (2022). Data-Driven Ship Berthing Forecasting for Cold Ironing in Maritime Transportation. *Applied Energy*, *326*, 119947. https://doi.org/10.1016/j.apenergy.2022.119947

Bose, R., Dey, R. K., Roy, S., & Sarddar, D. (2019). Time Series Forecasting Using Double Exponential Smoothing for Predicting the Major Ambient Air Pollutants. *Information and Communication Technology for Sustainable Development*, 603–613. https://doi.org/10.1007/978-981-13-7166-0_60

Dharmawan, P. A. S., & Indradewi, I. G. A. A. D. (2020). Double Exponential Smoothing Brown Method Towards Sales Forecasting System with a Linear and Non-Stationary data Trend. *Journal of Physics: Conference Series*, *1810*, 1–9. https://doi.org/10.1088/1742-6596/1810/1/012026

Fauziah, F. N., Gunaryati, A., & Komala Sari, R. T. (2017). Comparison Forecasting with Double Exponential Smoothing and Artificial Neural Network to Predict the Price of Sugar. *Academic Journal*, *18*(4), 13–1.

Febrian, D., Idrus, S. I. Al, & Nainggolan, D. A. J. (2019). The Comparison of Double Moving Average and Double Exponential Smoothing Methods in Forecasting the Number of Foreign Tourists Coming to North Sumatera. *Journal of Physics: Conference Series*, *1462*, 1–10. https://doi.org/10.1088/1742-6596/1462/1/012046

Habsari, H. D. P., Purnamasari, I., & Yuniarti, D. (2020). Forecasting Uses Double Exponential Smoothing Method and Forecasting Verification Uses Tracking Signal Control Chart (Case Study: Ihk Data of East Kalimantan Province). *BAREKENG: Jurnal Ilmu Matematika Dan Terapan*, *14*(1), 13–22. https://doi.org/10.30598/barekengvol14iss1pp013-022

Hansun, S., & Subanar. (2016). H-WEMA: A New Approach of Double Exponential Smoothing Method. *TELKOMNIKA*, *14*(2), 772–777. https://doi.org/10.12928/TELKOMNIKA.v14i1.3096

Hansun, S., Wicaksana, A., & Kristanda, M. B. (2021). Prediction of Jakarta City Air Quality Index: Modified Double Exponential Smoothing Approaches. *International Journal of Innovative Computing, Information and Control*, *17*(4), 1363–1371. https://doi.org/10.24507/ijicic.17.04.1363

Krisma, A., Azhari, M., & Widagdo, P. P. (2019). Perbandingan Metode Double Exponential Smoothing dan Triple Exponential Smoothing dalam Parameter Tingkat Error Mean Absolute Percentage Error (MAPE) dan Means Absolute Deviation (MAD). *Prosiding Seminar Nasional Ilmu Komputer Dan Teknologi Informasi*, 81–87.

Mahkya, D. Al, Anggraini, D., Fitriawati, A., & Siahaan, R. M. (2020). Pemodelan dan Prediksi Jumlah Penumpang Pelabuhan Bakauheni selama Periode Tsunami Selat Sunda Menggunakan Autoregressive Integrated Moving average. *Journal of Science and Applicative Technology*, *4*(1), 32–37. https://doi.org/10.35472/jsat.v4i1.266

Prakosa, A. N. Y., & Satiawan, P. R. (2019). Kajian Keterkaitan Faktor-Faktor yang Mempengaruhi Ketersediaan Ruang Terbuka Hijau di Kota Madiun. *Teknik ITS*, *8*(2), 41–46. https://doi.org/10.12962/j23373539.v8i2.49256

Ramadiani, Syahrani, R., Astuti, I. F., & Azainil. (2019). Forecasting the Number of Airplane Passengers Uses the Double and the Triple Exponential Smoothing Method. *Journal of Physics: Conference Series*, *1524*, 1–11. https://doi.org/10.1088/1742-6596/1524/1/012051

Rao, A. R., & Gupta, H. W. and C. (2025). Predictive Analysis for Optimizing Port Operations. *Applied Sciences*, *15*(6), 1–20.

https://doi.org/10.3390/app15062877

Sidqi, F., & Sumitra, I. D. (2019). Forecasting Product Selling Using Single Exponential Smoothing and Double Exponential Smoothing Methods. *IOP Conference Series: Materials Science and Engineering*, *662*(3), 1–6. https://doi.org/10.1088/1757-899X/662/3/032031

Tando, J., Komalig, H., & Nainggolan, N. (2016). Prediksi Jumlah Penumpang Kapal Laut di Pelabuhan Laut Manado Menggunakan Model ARMA. *D'Cartesian*, *5*(2), 95–99.

Tengecha, N. A., & Zhang, X. (2021). Status, Constraints and Strategies of Marine Traffic Flow on Dar es Salaam Port, Tanzania. *2020 2nd International Conference on Robotics Systems and Vehicle Technology*, 54–59. https://doi.org/10.1145/3450292.3450314

Xu, Z., Dun, M., & Wu, L. (2020). Prediction of Air Quality Based on Hybrid Grey Double Exponential Smoothing Model. *Complexity*, *2020*(1), 1–13. https://doi.org/10.1155/2020/9427102

Yousuf, M. U., Al-Bahadly, I., & Avci, E. (2022). Wind Speed Prediction for Small Sample Dataset Usinghybrid First-Order Accumulated Generating Operation-Based Double Exponential Smoothing Model. *Energy Science & Engineering*, *10*(3), 726–739. https://doi.org/10.1002/ese3.1047