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Analysis of Movement Patterns and Recovery Rates of Sea Transport Passengers in Indonesia for the 2019–2024 Period Using Trend Analysis and Recovery Index Approach

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Abstract

Sea transportation is a strategic mode of transportation that supports regional connectivity in Indonesia as an archipelagic country. The COVID-19 pandemic that began in 2020 caused a significant decrease in passenger numbers because of restrictions on population mobility. Although marine transportation activity increased after the pandemic, national-scale evaluations of the recovery trajectory remain limited. This study analyzes the movement patterns of Indonesian sea transportation passengers during 2019–2024 by identifying three phases: the pre-pandemic phase (2019), the contraction phase (2020–2021), and the recovery phase (2022–2024). The research uses a quantitative approach with secondary data from the Central Statistics Agency (BPS) Sea Transportation Statistics for 2019–2024. The analysis uses descriptive statistics, Annual Growth Rate (AGR), Compound Annual Growth Rate (CAGR), Recovery Index (RI), simple linear regression, and the Mann–Kendall test. Passenger numbers fell to 44.6% of the 2019 baseline in 2020 and then increased to a Recovery Index of 106.0% in 2024. Regression and Mann–Kendall results indicate a statistically significant upward trend during 2020–2024. The study contributes a national-level analytical framework that combines growth, baseline-relative recovery, and complementary trend tests to characterize post-pandemic maritime passenger recovery. The findings provide an empirical basis for capacity planning and adaptive national sea transportation policy.

Keywords: Sea Transportation, Passengers, Recovery Index, Trend Analysis, COVID-19 Pandemic

1. INTRODUCTION

Indonesia is the largest archipelagic country in the world with more than 17,000 islands, so sea transportation is the backbone of connectivity between regions [1]. The performance of the sea transportation sector not only affects population mobility, but also logistics distribution, regional economic growth, and equitable development [2]. Therefore, monitoring of port activities including ship visits, freight flows, and passenger movements is an important indicator in national transportation planning [3]. The Central Statistics Agency (BPS) routinely publishes the publication of Sea Transportation Statistics [4], [5], [6], [7], [8], [9]which contains data on commercial and non-commercial port activities throughout Indonesia, thus becoming a reliable source of official data for evaluating the performance of this sector.

In 2020, the COVID-19 pandemic caused the government to impose restrictions on population mobility on a large scale [10] . These policies have an impact on the lives of people whose mobility and movement are limited due to the quarantine policy due to the trade-off between the health and economic sectors [11] . This policy also has a direct impact on the transportation sector, mostly business activities related to population movement , and sea transportation which has a drastic decrease in the number of passengers [12] . The decline was followed by a gradual recovery process in line with the easing of travel restrictions and the recovery of national economic activities in 2022 to 2024 [12] . However, most previous research still focused on evaluating the performance of specific ports [13] , analysis of passenger forecasting using the ARIMA/SARIMA method [13], [14], or operational studies at the local level [15], [16]. This study comprehensively analyzes the dynamics of the movement of sea transportation passengers nationally using official statistical data in a time span that includes pre-pandemic conditions, contraction periods, and recovery phases is still limited.

The novelty of this study lies in integrating national-scale passenger movement analysis with a baseline referenced Recovery Index and two complementary trend testing approaches over a complete shock and recovery observation

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window. Unlike previous studies that primarily focus on individual ports, local operational conditions, or passenger forecasting using ARIMA/SARIMA models [13], [14] , this study uses the official Central Bureau of Statistics (BPS) national aggregate dataset to capture the combined response of Indonesia maritime passenger system. The framework also differentiate annual changes (AGR), compounded growth (CAGR), recovery relative to the 2019 baseline (RI), and overall trends using linear regression and the Mann–Kendall test.. This combination allows the study to evaluate not only whether passenger demand increased after the pandemic, but also whether the aggregate system exceeded its pre-pandemic level and what that result implies for capacity planning and adaptive transportation policy. Therefore, the contribution is analytical and planning-oriented rather than a replacement for detailed port level forecasting.

This study aims to: (1) analyze the trend in the number of Indonesian sea transportation passengers during 2019–2024; (2) identify the contraction and post-pandemic recovery phases; (3) measure the recovery rate using the Recovery Index with 2019 as the pre-pandemic baseline; and (4) test the statistical significance of the upward passenger trend. The study is intended to provide an empirical analytical basis for port capacity planning and adaptive national marine transportation policies in response to external shocks.

2. METHODS

2.1. Research Object

The research object is the national sea transportation passenger sector in Indonesia, represented by the total number of passengers arriving and departing at ports throughout Indonesia. The study uses secondary data from the Sea Transportation Statistics published by the Central Statistics Agency (BPS) for the 2019–2024 period [4], [5], [6], [7], [8], [9] . The 2019 data represents the pre-pandemic baseline, 2020–2021 represents the pandemic phase, and 2022–2024 represents the recovery phase after pandemic. The data cover domestic and foreign shipping at commercial and non commercial ports.

2.2. Treatment Of Research Object

The main research variable is the number of sea transportation passengers, measured annually at the national level. The year of observation is treated as the independent temporal variable, while passenger volume is the dependent variable. No experimental treatment is applied to the research object because the study uses secondary observational data. Variations are examined through different periods of transportation activity, namely pre-pandemic (2019), pandemic phase (2020–2021), and recovery phase (2022–2024).

2.3. Method and Research Procedures

The study applies a descriptive quantitative approach to evaluate the development and recovery of national sea transportation passenger mobility. The analysis consists of descriptive analysis, Annual Growth Rate (AGR), Compound Annual Growth Rate (CAGR), Recovery Index (RI), simple linear regression, and the Mann–Kendall trend test. The annual passenger series is treated as an observational time series; no experimental treatment is applied.

AGR is used to measure annual changes in passenger volume, while CAGR measures the average annual growth over a specified period. The Recovery Index compares passenger activity in each year with the 2019 pre-pandemic baseline, allowing the level of post-pandemic recovery to be quantitatively evaluated. A value above 100% indicates that passenger activity has exceeded the pre-pandemic level, whereas a value below 100% indicates that recovery has not yet reached the baseline.

Simple linear regression is used to identify the direction and magnitude of the passenger trend. The Mann–Kendall test, a widely used non-parametric method for detecting monotonic trends in time-series and environmental data, is applied to verify the statistical significance of the observed trend. Its main advantage is that it does not require normally distributed data and is relatively robust to outliers. However, its interpretation is limited to monotonic trends and may be less informative for very short time series or data containing strong autocorrelation.

The research procedure consists of data collection, data alignment and validation, descriptive analysis, AGR and CAGR calculation, Recovery Index calculation, linear regression, Mann–Kendall testing, and interpretation through tables and graphical visualization.

Stage Of Analysis Method :

1. Data Collection: Collecting total passenger data for 2019–2024 from BPS publications.
2. Data Alignment and Validation: Ensure consistency of data definitions and coverage.

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3. Descriptive analysis: Presenting data in the form of tables and graphs.
4. Calculation of AGR:

$$AGR_t = [(P_t - P_{t-1}) / P_{t-1}] \times 100\% \quad (1)$$

where P_t is passenger volume in year t and P_{t-1} is passenger volume in the preceding year.

$$AGR = \left(\frac{P_t - P_{t-1}}{P_{t-1}}\right) \times 100\% \quad (2)$$

5. Calculation of CAGR:

$$CAGR = [(P_n / P_0)^{(1/n)} - 1] \times 100\% \quad (3)$$

where P_0 is the initial passenger volume, P_n is the final passenger volume, and n is the number of annual intervals.

$$CAGR = [\left(\frac{P_n}{P_0}\right)^{\frac{1}{n}} - 1] \times 100\% \quad (4)$$

6. Recovery Index Calculation

$$RI_t = (P_t / P_{2019}) \times 100\% \quad (5)$$

where P_{2019} is the pre-pandemic baseline passenger volume. RI = 100% indicates recovery to the 2019 level; RI > 100% indicates that passenger volume has exceeded the 2019 baseline.

$$RI_t = \left(\frac{P_t}{P_{2019}}\right) \times 100\% \quad (6)$$

as a pre-pandemic baseline.P_{2019}

Regression model:

$$Y_t = \beta_0 + \beta_1 t + \varepsilon_t \quad (7)$$

For reproducibility, t is coded sequentially for the recovery/contraction series (2020 = 1, 2021 = 2,.., 2024 = 5) , Y_t is passenger volume in million passengers, β_0 is the intercept, β_1 is the annual trend coefficient, and ε_t is the residual. The slope is tested at $\alpha = 0.05$ and R^2 is reported as the coefficient of determination.

7. Parametric trend test: Simple linear regression.$Y = \beta_0 + \beta_1 t + \varepsilon$
8. Non-parametric trend test: Mann–Kendall test for trend significance verification.

Interpretation and visualization: Structure tables and graphs to support discussion

2.4. Tools and Materials

The main research material is the BPS Sea Transportation Statistics dataset for 2019–2024 [4], [5], [6], [7], [8], [9]. Microsoft Excel is used for data compilation, validation, descriptive analysis, growth calculations, Recovery Index calculations, and visualization. R statistical software is used primarily to perform the Mann–Kendall trend test and verify the statistical significance of the observed trend.

Implementation and reproducibility: the BPS annual passenger totals were compiled in Microsoft Excel and checked for consistent year coverage and passenger definitions before analysis. AGR and CAGR were calculated from consecutive annual observations and the selected period endpoints, respectively. RI was calculated for each year using 2019 as the fixed baseline. For regression, the recovery-period year labels were coded as t = 1–5 (2020–2024), and ordinary least-squares estimation was used to obtain the slope, intercept, R^2, and slope significance. The Mann–Kendall test was conducted in R on the same 2020–2024 series using a

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5% significance level. Because only five observations are available for the trend test, the results are interpreted as evidence of an upward/monotonic association rather than as a high-precision forecasting model.

3. RESULTS AND DISCUSSION

3.1. Passenger Growth (2019-2024)

Table 1 presents the dynamics of Indonesian sea transportation passenger volumes during 2019–2024. The results indicate a clear three-phase pattern consisting of pre-pandemic conditions, pandemic-induced contraction, and post-pandemic recovery. Overall, passenger mobility experienced a substantial decline in the early stage of the COVID-19 pandemic, followed by a continuous recovery from 2021 onward and ultimately exceeded the pre-pandemic level in 2024.

In 2019, the total number of sea transportation passengers reached 56.65 million people, representing the baseline condition before the COVID-19 pandemic. In 2020, the number of passengers decreased by 31.36 million people or 55.37% compared to the previous year, caused by the COVID-19 pandemic. This decline is in line with social distancing policies that reduce inter island mobility, Passenger volume therefore declined to less than half of the pre-pandemic level. In 2021, there was a small increase (14.89%) in line with the easing of restrictions, but the number of passengers was still below 50% of 2019 conditions.

Starting in 2022, growth increased rapidly (39.21%) in line with the end of most travel restrictions and the recovery of economic activity. The positive trend continues until 2024, where the total number of passengers reaches 60.07 million, an increase of 11.10 million passengers or 22.68% compared with 2023. More importantly, the 2024 passenger volume exceeded the 2019 baseline by approximately 3.42 million passengers, or 6.04%. This result indicates that, in terms of aggregate passenger volume, Indonesian sea transportation had not only recovered from the pandemic shock but had also surpassed its pre-pandemic level by 2024.

Table 1. Total Indonesian Sea Transportation Passengers in 2019–2024

Year	Total Passengers (million)	Change (million)	AGR (%)
2019	56.65	—	—
2020	25.29	-31.36	-55,37%
2021	29.05	+3.76	+14,89%
2022	40.44	+11.39	+39,21%
2023	48.97	+8.53	+21,08%
2024	60.07	+11.10	+22,68%

Figure 1 illustrates the development of Indonesian sea transportation passenger volumes and the corresponding Recovery Index during the 2019–2024 period. The results reveal a clear V-shaped recovery pattern, characterized by a sharp contraction at the onset of the COVID-19 pandemic, followed by a sustained and relatively rapid recovery in the subsequent years.

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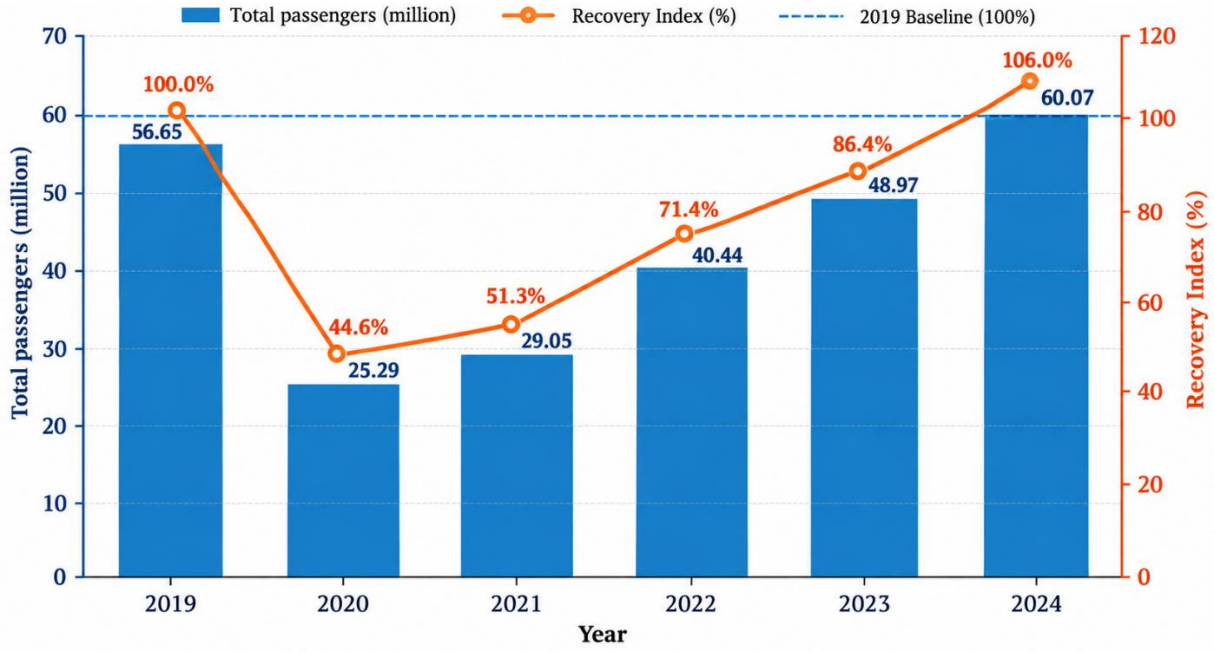


Figure 1. Passenger Development and Recovery Index of Indonesia's Sea Transportation (2019–2024)

This pattern reflects the high sensitivity of the marine transportation sector to external disturbances, as well as showing the sector's ability to recover when economic conditions and mobility policies return to normal. These findings indicate the importance of increasing the resilience of the marine transportation system through strengthening infrastructure, adaptive policies, and service management capable of maintaining essential connectivity during future disruptions, because sea transportation plays a strategic role in maintaining connectivity among geographically dispersed islands and supporting the continuity of national economic activity.

3.2. Compound Annual Growth Rate (CAGR)

To provide a clearer perspective on long-term growth and the pace of post-pandemic recovery, the Compound Annual Growth Rate (CAGR) is calculated over two different time frames.

1. CAGR 2019–2024 (including crisis years):

$$\text{CAGR} = \left(\frac{60{,}07}{56{,}65}\right)^{1/5} - 1 = 1{,}18\% \tag{8}$$

The first period, 2019–2024, represents the overall development of passenger mobility from the pre pandemic baseline to the end of the observation period. The CAGR for this period is approximately 1.18% per year. Although passenger volume increased from 56.65 million in 2019 to 60.07 million in 2024, the relatively low CAGR reflects the substantial contraction experienced in 2020. Therefore, the long-term growth rate appears modest because the calculation incorporates the severe pandemic shock into the observation period. This result indicates that the sector's overall passenger volume in 2024 was only moderately higher than its pre-pandemic level despite the strong recovery after 2020.

2. CAGR 2020–2024 (recovery period):

2020–2024 CAGR is approximately 24.10% per year, indicating a substantially faster rate of growth during the recovery period. This high CAGR reflects the increase in passenger volume from the pandemic-induced low point of 25.29 million in 2020 to 60.07 million in 2024.

The difference between the two CAGR values shows that the low 2019–2024 CAGR of 1.18% does not indicate weak sectoral growth, but is mainly influenced by the sharp contraction in 2020. In contrast, the 2020–2024 CAGR of 24.10% demonstrates the rapid recovery of passenger mobility from the pandemic-induced

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low point. Therefore, CAGR should be interpreted together with the Recovery Index and annual growth rates to provide a more comprehensive assessment of both long-term growth and post-pandemic recovery.

3.3 Recovery Index (RI) Based on 2019

Table 2 presents the Recovery Index (RI) of the number of Indonesian sea transportation passengers during the period 2020–2024 using 2019 as the baseline (RI = 100%). This index is used to measure the recovery rate of the marine transportation sector after the COVID-19 pandemic by comparing the number of passengers each year to pre-pandemic conditions. Recovery Index value below 100% indicates that passenger mobility has not fully recovered, while a Recovery Index above 100% indicates that passenger activities have exceeded normal conditions before the pandemic.

Table 2. Passenger Recovery Index 2020–2024

Year	Total Passengers (million)	Recovery Index (%)	Status
2019	56.65	100,0%	Baseline
2020	25.29	44,6%	Severe decline
2021	29.05	51,3%	Early recovery
2022	40.44	71,4%	Advanced recovery
2023	48.97	86,4%	Close to normal
2024	60.07	106,0%	Full recovery

The results indicate that Indonesian sea transportation passenger mobility followed a V-shaped recovery trajectory. By 2024, the Recovery Index reached 106.0%, meaning that aggregate passenger volume was approximately 6% above the 2019 pre-pandemic baseline. Importantly, RI > 100% should be interpreted as recovery beyond the selected baseline, not as evidence that every Indonesian port or region recovered equally. At the national level, the result signals that the demand shock has been absorbed and that the maritime passenger system has entered a post-recovery growth condition. The increase may be associated with population growth, economic expansion, restoration or opening of routes, and changes in passenger mode preferences; however, these factors are not causally estimated in the present study.

3.4 Trend Analysis of Sea Transportation Passenger Recovery

To determine whether the increase in sea transportation passenger numbers during the recovery period occurred consistently and was statistically significant, the study employed simple linear regression and the Mann–Kendall trend test. The analysis focused on the 2020–2024 period, representing the contraction and subsequent recovery phases following the COVID-19 pandemic.

Simple Linear Regression

The simple linear regression analysis produced the following results:

Regression equation:

1. Fitted regression equation: $Y = 13.92 + 8.948t$, where t = 1 for 2020, 2 for 2021, …, 5 for 2024, and Y is passenger volume (million).
2. Slope coefficient: approximately 8.95 million passengers per year.
3. Coefficient of determination (R^2): approximately 0.980, indicating that about 98.0% of the variation in passenger volume in the 2020–2024 series is associated with the linear time trend.
4. Significance test: the slope coefficient is statistically significant at the 5% level (two-sided $p \approx 0.0012$).

The regression results indicate that the number of Indonesian sea transportation passengers increased by approximately 8.95 million passengers annually during the 2020–2024 period. The high R^2 value of approximately 0.98 indicates a very strong linear relationship between time and passenger volume. The statistically significant slope further confirms that the observed increase was unlikely to have occurred by random variation alone. Therefore, the null hypothesis (H_0) of no significant linear trend is rejected, indicating a statistically significant upward trend in passenger numbers during the recovery period.

Because the regression is based on only five annual observations in 2020–2024, the high R^2 should not be interpreted as evidence of a stable forecasting relationship. It primarily describes the strong upward relationship within this short recovery-period series.

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Mann–Kendall Trend Test

To verify the regression results using a non-parametric approach, the Mann–Kendall test was subsequently applied. This method is appropriate for trend analysis because it does not require the data to follow a normal distribution.

1. The passenger data for 2020–2024 were 25.29, 29.05, 40.44, 48.97, and 60.07 million, respectively. All observations increased sequentially, resulting in 10 possible data pairs, with all 10 pairs showing a positive direction.
2. the Mann–Kendall statistic was S=10, with a variance of approximately 16.67 and a standardized test statistic of approximately Z=2.21.
3. The one-sided p-value was approximately 0.014, which is below the 5% significance level ($p<0.05$).
4. The Mann–Kendall results therefore lead to the rejection of the null hypothesis (H_0), indicating the presence of a statistically significant upward trend in Indonesian sea transportation passenger numbers during 2020–2024.

The consistency between the linear regression and Mann–Kendall results strengthens the evidence that passenger mobility experienced a sustained recovery following the pandemic-induced contraction.

Overall, the results from linear regression, the Mann–Kendall test, and the Recovery Index provide consistent evidence of a significant recovery in Indonesian sea transportation passenger mobility. Passenger numbers increased continuously from 25.29 million in 2020 to 60.07 million in 2024, while the Recovery Index reached 106.04% in 2024. These findings indicate that the marine transportation sector is experiencing a continuous recovery process after contracting due to the COVID-19 pandemic, until it reaches a full recovery condition in 2024.

The findings of this study identify three phases in the development of national sea transportation passenger mobility in Indonesia:

1. Pre-Pandemic Phase (2019). Passenger volume reached 56.65 million, representing the baseline condition of normal sea transportation activity before the COVID-19 pandemic.
2. Contraction Phase (2020–2021). The pandemic caused a substantial decline in passenger mobility, with passenger volume falling by 55.37% in 2020. Although mobility began to recover in 2021, the Recovery Index (RI) was only 51.3%, indicating that passenger activity remained approximately half of the pre-pandemic level. This contraction reflects the effects of mobility restrictions, reduced transportation operations, and uncertainty in passenger travel behavior.
3. Recovery Phase (2022–2024). Passenger mobility recovered rapidly from 2022 onward, with sustained annual growth through 2024. The Recovery Index reached 106.0% in 2024, indicating that passenger activity had exceeded the 2019 pre-pandemic baseline. This recovery provides evidence of the sector capacity to restore aggregate passenger mobility following the pandemic-induced disruption.

Compared with international evidence, Indonesia's recovery trajectory is broadly consistent with patterns observed in several developing countries, particularly in Southeast Asia, where transportation demand experienced a sharp pandemic-induced contraction followed by a relatively rapid recovery. However, Indonesia's recovery may be particularly influenced by its geographical characteristics and high dependence on sea transportation for inter-island connectivity. Unlike countries with more integrated land based transportation networks, Indonesia archipelagic structure makes sea transportation an essential component of passenger mobility that cannot be fully substituted by other modes.

The achievement of RI > 100% has direct implications for transport system planning. First, for port capacity planning, the national result indicates that passenger demand should no longer be treated as a temporary post-pandemic recovery effect alone. Port authorities should reassess design and operational capacity against current and expected demand, including berth and terminal throughput, passenger processing areas, landside access, vessel scheduling, and peak-period congestion. Because RI is an aggregate indicator, capacity decisions should be supported by port- and province-level demand analysis rather than by national RI alone. Second, adaptive transportation policy should use phased and flexible interventions: capacity expansion where sustained demand pressure is confirmed, service and route adjustments where recovery is weaker, and targeted accessibility measures for underserved regions. This reduces the risk of both premature investment and capacity shortages. Third, the sustained recovery suggests that long-term maritime resilience requires more than restoring pre-pandemic operations. Infrastructure redundancy, flexible operating procedures, digital passenger and traffic monitoring, contingency planning, and coordination among ports, operators, and government agencies can help maintain essential inter-island connectivity during future shocks. Thus, the 106.0% RI is best viewed as a planning signal: the national system has recovered in aggregate, but resilience depends on whether infrastructure and policy can adapt to uneven demand and future disruptions.

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4. STUDY LIMITATIONS

This study has several limitations that should be considered when interpreting the results. First, the analysis uses only six annual observations (2019–2024), and the statistical trend analysis after the baseline uses five observations (2020–2024). Such a short series limits statistical power, reduces the ability to distinguish persistent structural trends from post-pandemic rebound effects, and makes the regression unsuitable as a stand-alone forecasting model. Second, the data are nationally aggregated, combining passenger activity across Indonesia's ports and regions. National aggregation can conceal substantial regional differences in the speed and level of recovery; a national RI above 100% therefore does not imply that all provinces or ports have exceeded their 2019 levels. Third, annual data do not capture seasonal or monthly fluctuations, route-specific dynamics, or differences between domestic and international services. Finally, the study is descriptive and trend-oriented and does not estimate the causal effects of economic, demographic, policy, or operational variables. These limitations define the appropriate scope of the findings and motivate more granular future research.

5. CONCLUSIONS

This study developed and applied a national-level analytical framework to characterize the contraction and recovery of Indonesia's sea transportation passenger system during 2019–2024 using official BPS data. By combining AGR, CAGR, a 2019-based Recovery Index, simple linear regression, and the Mann–Kendall test, the framework separates the magnitude of annual change from baseline-relative recovery and statistical trend evidence. This provides a compact diagnostic approach for evaluating post-pandemic maritime passenger recovery and translating aggregate mobility trends into planning signals.

1. Passenger mobility experienced a substantial contraction in 2020, declining by 55.37% from 56.65 million passengers in 2019 to 25.29 million passengers. Passenger volume subsequently increased each year, reaching 60.07 million passengers in 2024, exceeding the pre-pandemic level.
2. The Compound Annual Growth Rate (CAGR) during the 2020–2024 recovery period reached 24.10% per year, indicating a strong and rapid rebound in passenger mobility following the pandemic-induced decline.
3. Based on the Recovery Index (RI) using 2019 as the baseline, passenger mobility reached 106.0% in 2024. This indicates that sea transportation passenger activity had fully recovered and exceeded the pre-pandemic level by approximately 6%.
4. Simple linear regression and the Mann–Kendall test both confirm a statistically significant upward trend in passenger numbers during the 2020–2024 period ($p<0.05$). These results strengthen the evidence that the observed recovery represents a consistent upward trend rather than random annual fluctuations.

Overall, the findings provide empirical evidence of the resilience and recovery of Indonesia's sea transportation sector following the COVID-19 shock. The broader contribution of the framework is its ability to connect national passenger recovery measurement with practical decisions on capacity, resource allocation, route development, and adaptive policy, while explicitly recognizing that aggregate recovery may mask regional disparities. Future research should extend the framework to provincial and port level analyses, distinguish domestic and international shipping categories. use monthly or quarterly data to capture seasonality, integrate forecasting methods such as ARIMA/SARIMA or other time-series and machine learning approaches and incorporate socio-economic, demographic, infrastructure, and policy variables. These extensions would improve spatial resolution, explanatory power, and forecasting capability and would support more targeted and resilient maritime transportation planning in Indonesia.

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