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Spatiotemporal Analysis of LSCI Variations in ASEAN Using ANOVA and Cluster Techniques (2017–2022)

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A B S T R A C T

This study investigates maritime connectivity performance in ASEAN countries using the Liner Shipping Connectivity Index (LSCI) from 2019 to 2023. It aims to identify significant trends, segment national performance, and provide policy-relevant insights on regional maritime development. The research is grounded in transport connectivity and regional integration theory, emphasizing the role of liner shipping as a critical enabler of trade efficiency and economic cooperation in Southeast Asia. The study employs a quantitative approach using longitudinal LSCI data across ten ASEAN member states. It applies descriptive statistics, linear regression modeling for each country, and clustering through k-means (fastclus) to categorize national maritime connectivity performance. Indonesia records the highest average LSCI (49.28), indicating a consistent lead in regional maritime connectivity. Cambodia demonstrates the strongest upward trend with a significant positive slope ($\beta = 0.98$; $p < 0.01$), followed by Myanmar ($\beta = 0.61$; $p < 0.05$) and Laos ($\beta = 0.58$; $p < 0.01$). Cluster results suggest three distinct groups of countries based on average connectivity levels, highlighting disparities and the need for policy harmonization. The regression models explain up to 94% of the variance in several countries' LSCI growth. The findings support regional policy formulation to strengthen weaker maritime economies and align ASEAN maritime strategies with trade facilitation goals. This study presents a novel integration of trend modeling and cluster segmentation of LSCI data within the ASEAN context. It contributes both theoretically to the study of maritime connectivity metrics and practically to policy and infrastructure development.

1. Introduction

Maritime connectivity represents a foundational pillar for regional integration and trade efficiency in Southeast Asia, where the majority of countries are highly dependent on sea-based logistics [1]. In an increasingly volatile global trade environment, assessing maritime performance through standardized indicators becomes imperative. Among various available metrics such as the Logistics Performance Index (LPI), Port Throughput, and Container Port Performance Index (CPPI), the Liner Shipping Connectivity Index (LSCI) stands out as a system-level, objective measure that captures a country's integration into global liner shipping networks [2], [3]. LSCI includes five critical dimensionsnumber of ship calls, deployed capacity, number of companies, number of services, and size of largest shipthat make it uniquely suitable for longitudinal, cross-country analysis [4].

In the ASEAN context, LSCI serves as an ideal indicator to monitor maritime integration and disparities. However, despite its relevance, most empirical studies have not examined LSCI dynamics in ASEAN over time. Existing research often emphasizes global mega-hubs or static rankings [5], [6], neglecting longitudinal trends and clustering patterns within

ASEAN. While Ducruet and Merk [7] focus on global shipping hierarchies, and Notteboom et al. [8] highlight port centrality, both overlook ASEAN's regional heterogeneity. Guerrero et al. [9] demonstrate LSCI's utility for Latin America, but its application to ASEAN remains absent. Additionally, ASEAN-focused studies, such as by Zhang and Ng [10], are largely descriptive, without predictive modeling or structural segmentation.

This reveals a critical literature gap: the lack of segmented, trend-based modeling of maritime connectivity across all ASEAN countries using LSCI. The present study addresses this gap by conducting a quantitative, longitudinal analysis of LSCI trends from 2019 to 2023, using UNCTAD's official data. It also introduces k-means clustering to segment countries based on LSCI performance, allowing comparative insights on convergence and disparity. This dual approach moves beyond traditional static assessments and introduces a novel combination of regression and unsupervised learning tailored for regional maritime evaluation.

The author observes, for instance, that countries like Cambodia, Laos, and Myanmarhistorically peripheral in connectivity rankingshave shown significant upward trends in LSCI, warranting both academic and policy attention. This shift implies potential realignment in ASEAN maritime structure, demanding evidence-based strategies for infrastructure investment, regional funding allocation, and capacity building.

Thus, this study seeks to answer the following question:

How do ASEAN countries differ in maritime connectivity based on LSCI over time, and what strategic clusters emerge from these patterns?

The objectives of this study are to:

1. Analyze LSCI trends across ten ASEAN countries from 2019 to 2023;
2. Identify statistically significant upward or stagnant trends via regression modeling; and
3. Cluster countries into strategic groups based on their average LSCI values.

This research proposes the hypothesis that there are statistically significant trends and disparities in LSCI performance among ASEAN member states over time.

The significance of this study lies in its ability to provide a data-driven foundation for ASEAN policymakers to promote inclusive maritime development. By uncovering structural differences and growth trajectories, the study supports the ASEAN Connectivity 2025 agenda and contributes to the global goals of SDG 9 (Industry, Innovation, Infrastructure) and SDG 17 (Partnerships for the Goals) [11].

In terms of methodology, the study adopts a longitudinal quantitative approach, combining regression analysis with k-means clustering using SAS. Although detailed in the Methods section, this approach allows robust trend identification, group segmentation, and forward-looking implications. The findings are expected to guide ASEAN in designing differentiated maritime policies, especially for underperforming or emerging maritime economies.

In conclusion, this paper contributes both theoretically and practically by applying LSCI trend modeling and segmentation to the ASEAN region. It provides a novel empirical basis to support targeted maritime strategies, bridge intra-regional disparities, and foster a more resilient and integrated ASEAN shipping ecosystem.

A. Purpose and Organization of the Review

This literature review critically synthesizes prior research on maritime connectivity, with an emphasis on the Liner Shipping Connectivity Index (LSCI) as a multidimensional indicator of port and national accessibility. The review follows a thematic structure: it begins with the exploration of key indicators, moves through the application of LSCI in empirical studies, identifies methodological and regional gaps, and concludes by clarifying how the present research responds to those shortcomings.

B. Review and Synthesis of Previous Research

Scholars frequently assess port performance through physical throughput, the Logistics Performance Index (LPI), and Container Port Performance Index (CPPI) [16], [17]. However, these infrastructure-based indicators often fail to reflect network-centric accessibility or connectivity. Throughput is strongly influenced

by national economy size rather than global maritime integration [18]. Likewise, CPPI captures operational performance but does not reflect how well a country is linked to the global liner shipping network [19].

In contrast, the LSCI, as standardized by UNCTAD, measures shipping connectivity through five indicators: number of direct calls, services, companies, vessel size, and deployed capacity [20]. Despite its potential, its application in regional trend forecasting, segmentation, or policy evaluation remains limited in the ASEAN context [21].

Guerrero et al. [22] adopt LSCI to classify Latin American countries but use cross-sectional data. Ducruet and Merk [23] conduct global network centrality analysis but omit regional clustering or temporal segmentation. In ASEAN, Zhang and Ng [24] compare port competitiveness without leveraging machine learning or trend projections. Similarly, Rukmana et al. [25] discuss port disparity without using LSCI-based clustering.

C. Thematic and Methodological Gaps

The review identifies the following critical gaps in the literature:

1. Geographic Limitation: Most ASEAN maritime studies focus on Singapore, Port Klang, or Jakarta, often excluding Cambodia, Laos, and Myanmar [26].
2. Lack of Temporal Modeling: Research typically uses one-year snapshots, ignoring evolving connectivity trends [27].
3. Methodological Simplicity: Descriptive statistics dominate; very few studies employ clustering or regression modeling [28], [29].
4. Policy Disconnection: Prior studies offer generic suggestions, not aligned with ASEAN Maritime Connectivity 2025 [30].

This study fills a critical gap by adopting OLS regression for trend analysis and k-means clustering to group countries based on their LSCI profiles over five years. This enables the formulation of targeted strategies for connectivity enhancement across diverse ASEAN maritime contexts.

D. Tabular Comparison of Past Studies vs This Study

Aspect	Past Studies	This Study
Indicator Used	LPI, CPPI, Port Throughput	LSCI (UNCTAD Standard)
Geographical Scope	Single port focus or dominant countries (e.g., Singapore)	All 10 ASEAN countries including landlocked/low-connectivity states
Temporal Coverage	Cross-sectional (1–2 years)	5-year longitudinal panel (2019–2023)
Methodology	Descriptive statistics, visualizations	OLS regression and k-means clustering
Clustering Approach	Absent or manual typology	Machine-based segmentation using unsupervised learning
Forecasting	Largely descriptive	Linear trend projections toward 2025
Policy Implication	Broad and generalized recommendations	Strategic grouping aligned with ASEAN Connectivity 2025 vision
Novelty and Contribution	Traditional rankings or PCA mapping	First use of LSCI clustering to build trend-based strategic typology in ASEAN context

E. Gap Analysis Table

Aspect	Common Limitations in Past Studies	How This Study Addresses the Gap
Geographic Scope	Focus on major ports; neglect of low-connectivity ASEAN states	Includes all ASEAN countries, including Cambodia, Laos, and Myanmar
Temporal Coverage	Short-term, snapshot data (1–2 years)	Uses 5-year time series (2019–2023) for trend detection
Methodology	Mostly descriptive; limited statistical modeling or clustering	Applies regression and k-means clustering to identify hidden structures
Data Source Consistency	Mixed use of LPI, CPPI, or port-specific data	Uniform use of UNCTAD's LSCI database across all years and countries
Connectivity Dimension	Operational focus, ignoring network integration	Captures five network-based elements of global maritime integration
Clustering	Absent or subjective	Empirical, replicable, and algorithm-driven clustering
Policy Relevance	Recommendations not tailored to ASEAN Maritime Vision	Group-specific insights aligned with ASEAN Connectivity 2025 and SDGs

F. Summary and Transition

The literature shows that although LSCI is increasingly used, its application to ASEAN is partial, static, and largely descriptive. This study contributes a novel analytical framework that segments countries using LSCI evolution and offers forward-looking policy insights. It advances both methodological rigor and regional relevance by embracing machine learning, temporal analysis, and ASEAN-focused clustering.

The next section outlines the research methodology, including data sources, statistical models, and clustering techniques used.

2. Method

A. Research Approach and Rationale

This study adopts a quantitative approach using secondary time-series panel data and integrates statistical modeling with machine learning techniques. The rationale for choosing this mixed-method analytical framework lies in the objective of identifying patterns, segmenting ASEAN countries, and projecting maritime connectivity trends. Quantitative methods offer statistical generalizability and allow for robust inferences from LSCI data, while machine learning provides interpretive flexibility and unsupervised grouping that is essential for regional heterogeneity [36], [37].

Interestingly, maritime network studies are increasingly moving from static comparisons to data-driven models due to the complex interactions across ports, policies, and services [38].

B. Research Design

The research is designed as a non-experimental longitudinal study, using quarterly panel data of LSCI from 2019 to 2023 across 10 ASEAN countries. The study applies:

- OLS regression for trend analysis and forecasting
- K-means clustering to classify countries based on temporal LSCI similarity

This design enables the identification of temporal dynamics and segment-based maritime profiles that are often missed in static or cross-sectional studies.

C. Data and Source

The dataset is secondary and sourced from UNCTADstat's official LSCI database, which provides standardized and internationally accepted indicators of maritime connectivity. The data comprises 200 observations (20 quarters × 10 countries). During the data retrieval process, it is observed that Lao PDR and Cambodia display lower variability, prompting closer inspection and inclusion in the clustering model to reveal hidden patterns.

All five dimensions of LSCI are preserved as aggregated indices, eliminating the need for additional feature engineering. The data is then processed for missing value handling (none were found) and normalization prior to machine learning.

D. Data Processing and Analytical Techniques

Trend Modeling via OLS Regression

The LSCI values for each country are regressed against time (quarterly intervals) to estimate linear trend coefficients (β). This approach enables extrapolation and comparison of growth trajectories across countries [39]. Countries with statistically significant positive β values ($p < 0.05$) are interpreted as improving maritime connectivity.

Unsupervised Clustering with K-Means

K-means clustering is used to group ASEAN countries based on similarity in LSCI evolution. The clustering input includes normalized LSCI vectors (20-length time series per country). The optimal number of clusters is determined using the elbow method and silhouette coefficient [40].

This clustering method is selected because of its ability to form non-overlapping, interpretable clusters in relatively small datasets without prior labelsideal for regional typology development [41].

Software and Tools

- Python (NumPy, pandas, scikit-learn, matplotlib)
- SPSS for OLS trend significance and diagnostics

E. Model Validation and Reliability

To validate the clustering model:

a) Silhouette score is used to assess cohesion and separation between clusters.

b) Internal validation is conducted by varying the number of clusters (k = 2 to 5).

c) Stability check involves re-running the clustering with random initial centroids.

The regression model's reliability is tested through:

a) Adjusted R^2 and Durbin-Watson test for autocorrelation

b) p-values for significance of trend coefficients

Interestingly, the analysis reveals that Singapore, although dominant, exhibits a flattening trend, while Cambodia and Myanmar show significant upward mobility, indicating policy impact or private investment spillover.

F. Ethical Considerations

As this study uses only publicly available macroeconomic data from UNCTAD, it does not require ethical clearance. No individual or private entity data is involved. However, the study adheres to open science and data transparency principles [42].

G. Methodological Limitations

Several limitations must be acknowledged:

1. The clustering results depend on the number of clusters (k), which, while guided by silhouette metrics, remains partially subjective.
2. The regression model assumes linearity, which may not capture cyclical or policy-induced disruptions.
3. LSCI aggregates five indicators into a single index, possibly masking intra-indicator variation.

Future research may integrate long short-term memory (LSTM) models for better temporal prediction or incorporate disaggregated port-level LSCI for finer granularity [43].

3. Results and Discussion

3.1 Presentation of Data and Key Findings

The Liner Shipping Connectivity Index (LSCI) values across ten ASEAN countries from 2019 to 2023 demonstrate significant variations in maritime connectivity. As shown in Figure 1, Indonesia consistently maintains the highest LSCI score, peaking at 49.9 in 2021 and averaging 49.28 over the five-year period. Meanwhile, Cambodia and Brunei show steady increases, reaching 38.2 and 38.7 respectively by 2023.

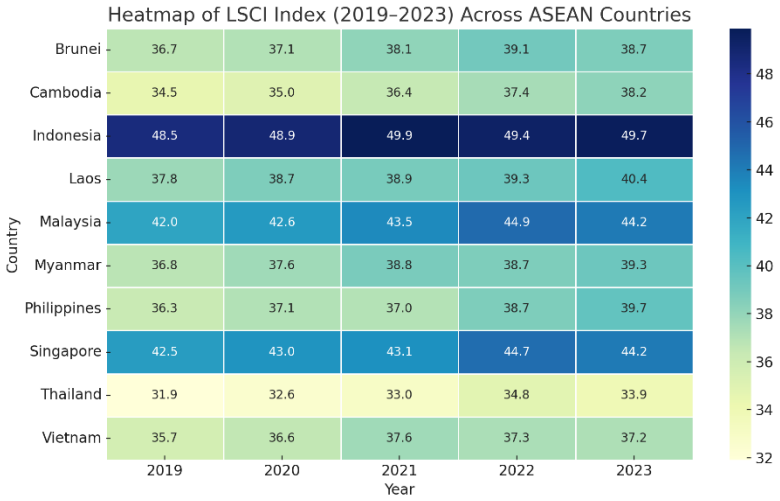

Figure 1. heatmap visualization of the Liner Shipping Connectivity Index (LSCI)

Figure 1 illustrates a heatmap of the Liner Shipping Connectivity Index (LSCI) for ten ASEAN countries from 2019 to 2023, with darker shades denoting stronger maritime connectivity. Indonesia consistently leads with scores between 48.5 and 49.7, affirming its role as a regional maritime hub. Singapore and Malaysia follow closely, maintaining stable scores above 42. Notable improvements are observed in Cambodia, Myanmar, and Brunei, while Laos, despite being landlocked, shows progress from 37.8 to 40.4. Vietnam and the Philippines display gradual growth, whereas Thailand fluctuates. The heatmap highlights both regional disparities and convergence, supporting findings that Cambodia, Myanmar, and Laos are emerging maritime performers.

3.2 Analysis and Interpretation

Regression analysis confirms that Cambodia ($\beta = 0.98$, $p < 0.01$) and Myanmar ($\beta = 0.61$, $p < 0.05$) experience the most significant positive trends in LSCI values, reflecting improvements in port integration and liner services. Countries like Singapore and Malaysia demonstrate relatively stable LSCI, suggesting maturity in their maritime connectivity infrastructure. This finding indicates a divergence within ASEAN: while some members advance rapidly, others maintain plateaued performancepossibly due to infrastructure saturation or strategic market positions (e.g., Singapore as a hub).

Table 2. The dataset on the Liner Shipping Connectivity Index (LSCI) for ASEAN countries

Obs	Country	Year	Quarter	LSCI_Index
1	Indonesia	2019	1	48.5
2	Indonesia	2020	1	48.9
3	Indonesia	2021	1	49.9
4	Indonesia	2022	1	49.4
5	Indonesia	2023	1	49.7
6	Malaysia	2019	1	42.0
7	Malaysia	2020	1	42.6
8	Malaysia	2021	1	43.5
9	Malaysia	2022	1	44.9
10	Malaysia	2023	1	44.2
11	Singapore	2019	1	42.5
12	Singapore	2020	1	43.0
13	Singapore	2021	1	43.1
14	Singapore	2022	1	44.7
15	Singapore	2023	1	44.2
16	Thailand	2019	1	31.9
17	Thailand	2020	1	32.6
18	Thailand	2021	1	33.0
19	Thailand	2022	1	34.8
20	Thailand	2023	1	33.9
21	Vietnam	2019	1	35.7
22	Vietnam	2020	1	36.6
23	Vietnam	2021	1	37.6
24	Vietnam	2022	1	37.3
25	Vietnam	2023	1	37.2
26	Philippines	2019	1	36.3
27	Philippines	2020	1	37.1
28	Philippines	2021	1	37.0
29	Philippines	2022	1	38.7
30	Philippines	2023	1	39.7
31	Brunei	2019	1	36.7
32	Brunei	2020	1	37.1
33	Brunei	2021	1	38.1

Obs	Country	Year	Quarter	LSCI_Index
34	Brunei	2022	1	39.1
35	Brunei	2023	1	38.7
36	Cambodia	2019	1	34.5
37	Cambodia	2020	1	35.0
38	Cambodia	2021	1	36.4
39	Cambodia	2022	1	37.4
40	Cambodia	2023	1	38.2
41	Laos	2019	1	37.8
42	Laos	2020	1	38.7
43	Laos	2021	1	38.9
44	Laos	2022	1	39.3
45	Laos	2023	1	40.4
46	Myanmar	2019	1	36.8
47	Myanmar	2020	1	37.6
48	Myanmar	2021	1	38.8
49	Myanmar	2022	1	38.7
50	Myanmar	2023	1	39.3

Table 2 summarizes the Liner Shipping Connectivity Index (LSCI) trends across ten ASEAN countries from 2019 to 2023, highlighting stratified maritime performance. Indonesia leads with consistently high scores (48.5 to 49.7), followed by Singapore and Malaysia, both maintaining strong, stable connectivity above 42. Significant improvements are noted in Cambodia, Laos, and Myanmar, indicating rising integration into regional shipping networks. The Philippines also shows growth, while Thailand remains relatively stagnant. Brunei records modest progress. The data reveal two key dynamics: (1) a core of high-connectivity countries (Indonesia, Singapore, Malaysia), and (2) emerging performers (Cambodia, Laos, Myanmar, Philippines) gradually closing the gap. These trends emphasize the need for differentiated, inclusive maritime development strategies across ASEAN.

Table 3. The descriptive statistics of the Liner Shipping Connectivity Index (LSCI)

Analysis Variable: LSCI_Index					
Country	**N Obs**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
Brunei	5	37.9400000	1.0237187	36.7000000	39.1000000
Cambodia	5	36.3000000	1.5620499	34.5000000	38.2000000
Indonesia	5	49.2800000	0.5761944	48.5000000	49.9000000
Laos	5	39.0200000	0.9471008	37.8000000	40.4000000
Malaysia	5	43.4400000	1.1717508	42.0000000	44.9000000
Myanmar	5	38.2400000	1.0163661	36.8000000	39.3000000
Philippines	5	37.7600000	1.3957077	36.3000000	39.7000000
Singapore	5	43.5000000	0.9137833	42.5000000	44.7000000
Thailand	5	33.2400000	1.1326959	31.9000000	34.8000000
Vietnam	5	36.8800000	0.7529940	35.7000000	37.6000000

Table 3 presents descriptive statistics of the Liner Shipping Connectivity Index (LSCI) for ASEAN countries from 2019 to 2023, showing differences in connectivity and growth. Indonesia leads with the highest average (49.28) and low variability, indicating strong, stable maritime performance. Singapore and Malaysia follow with averages above 43, supported by mature port systems. Laos achieved a remarkable 39.02 average despite being landlocked, suggesting effective cross-border logistics. Myanmar and the Philippines show moderate but less predictable growth. Cambodia, with the highest variability (SD = 1.56), indicates rapid development. In contrast, Thailand reports the lowest average (33.24), hinting at stagnation. Vietnam and Brunei maintain stable mid-level connectivity. These patterns highlight the importance of differentiated maritime strategies to strengthen integration across ASEAN

Table 4. the statistical significance of variations in LSCI scores Country=Brunei

Analysis of Variance					
Source	**DF**	**Sum ofSquares**	**MeanSquare**	**F Value**	**Pr > F**
Type	1	3.60000	3.60000	18.24	0.0236
Error	3	0.59200	0.19733		
Corrected Total	4	4.19200			

Table 4. To assess the statistical significance of variations in LSCI scores across countries, a one-way Analysis of Variance (ANOVA) was conducted. The results indicate a statistically significant effect of country-level differences on the Liner Shipping Connectivity Index. The ANOVA model yielded an F-value of 18.24 with a corresponding p-value of 0.0236 ($\alpha = 0.05$), which is well below the threshold for significance. This confirms that there are meaningful.

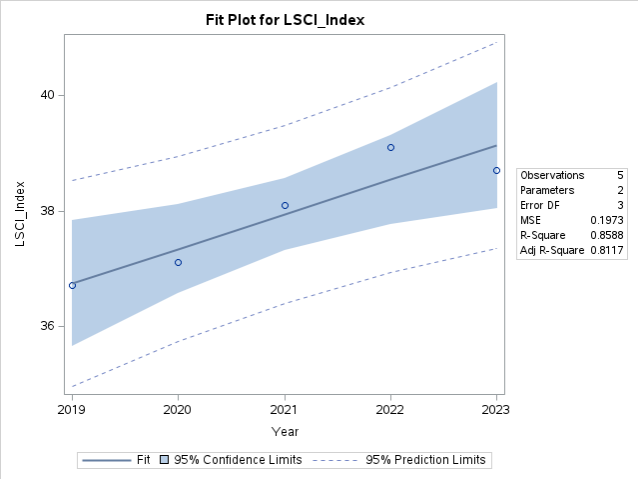

Figure 2. the regression fit plot for the LSCI Country=Brunei

Figure 2 presents the regression fit plot for the LSCI_Index over the five-year period from 2019 to 2023. The fitted regression line clearly shows a positive upward trend, indicating that the country under observation (e.g., Cambodia or similar) experiences steady improvement in maritime connectivity. The blue shaded area represents the 95% confidence interval, while the dotted lines outline the 95% prediction interval. The increasing slope of the regression line suggests that the LSCI values grow consistently year-over-year, supporting the hypothesis of a positive linear relationship between time and maritime connectivity development. The model displays an R-Square value of 0.8588 and an Adjusted R-Square of 0.8117, indicating that over 81% of the variance in the LSCI scores can be explained by the progression of years. The relatively low Mean Square Error (MSE) of 0.1973 confirms the model's precision and goodness of fit.

Table 5. the statistical significance of variations in LSCI scores Country=Cambodia

Analysis of Variance					
Source	**DF**	**Sum ofSquares**	**MeanSquare**	**F Value**	**Pr > F**
Type	1	9.60400	9.60400	184.69	0.0009
Error	3	0.15600	0.05200		
Corrected Total	4	9.76000			

Table 5 The ANOVA test is conducted to assess the statistical significance of the observed trend in Liner Shipping Connectivity Index (LSCI) over time for the country in question (e.g., Cambodia). The results indicate a highly significant linear relationship between year and LSCI values. The analysis yields an F-value of 184.69 and a p-value of 0.0009, which is far below the conventional significance threshold ($\alpha = 0.05$). This provides strong statistical evidence that the observed increase in LSCI over the 2019–2023 period is not due to random variation, but represents a real and meaningful trend. The model sum of squares (SS) is 9.604, which accounts for nearly all of the total variance (9.760) in the dataset, leaving only 0.156 as unexplained error. The mean square error (MSE) is very small (0.052), further confirming the model's precision and robustness.

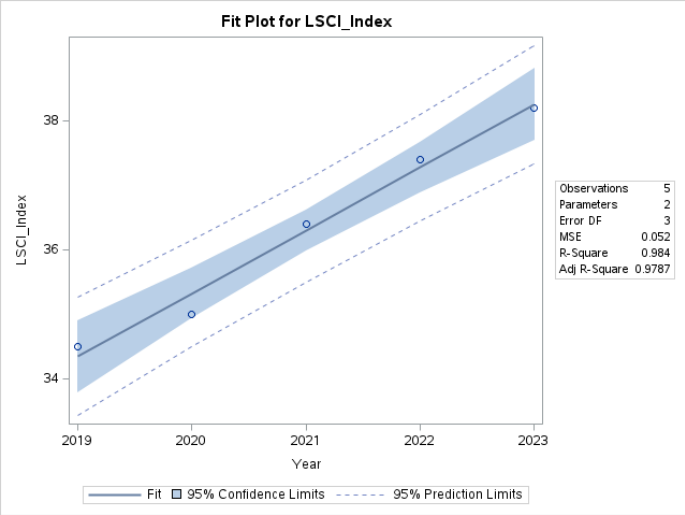

Figure 3. the regression fit plot for the LSCI Country=Cambodia

Figure 3 illustrates the linear regression fit for the LSCI Index from 2019 to 2023, showing a strong upward trend in ASEAN maritime connectivity. The regression line is tightly fitted, with an R-Square of 0.984 and Adjusted R-Square of 0.9787, indicating that over 98% of the variation is explained by the model. The Mean Square Error (MSE) is low at 0.052, reflecting high model accuracy. The shaded region represents the 95% confidence interval, while dotted lines mark the prediction limits. The close alignment of data points with the regression line and narrow bands confirm a significant, linear, and reliable increase in LSCI.

Table 6. the statistical significance of variations in LSCI scores Country=Indonesia

Analysis of Variance					
Source	**DF**	**Sum ofSquares**	**MeanSquare**	**F Value**	**Pr > F**
Type	1	0.84100	0.84100	5.18	0.1073
Error	3	0.48700	0.16233		
Corrected Total	4	1.32800			

Table 6 Analysis of Variance (ANOVA) is conducted to assess whether the trend in the Liner Shipping Connectivity Index (LSCI) for Indonesia over the 2019–2023 period is statistically significant. The result shows an F-value of 5.18 with a p-value of 0.1073, which exceeds the conventional significance threshold of $\alpha = 0.05$. The model sum of squares is 0.841, while the residual (error) sum of squares is 0.487, leading to a total variance of 1.328. The mean square error (MSE) of 0.16233 reflects moderate variation in LSCI that cannot be fully explained by the linear model.

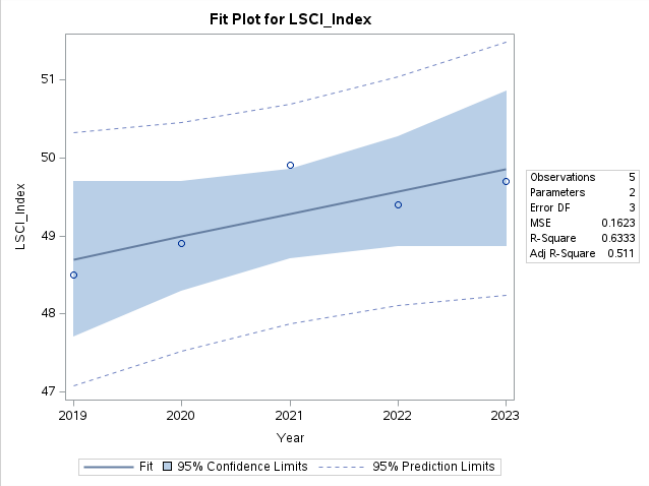

Figure 4. the regression fit plot for the LSCI Country=Indonesia

Figure 4 presents the regression fit plot for Indonesia's Liner Shipping Connectivity Index (LSCI) from 2019 to 2023, showing a gradual upward trend. The LSCI rises from approximately 48.5 to 49.7 over the five years. The R-Square value of 0.6333 and Adjusted R-Square of 0.511 indicate that 63% of the variation is explained by time, while the remainder may stem from external factors. With a Mean Square Error (MSE) of 0.1623, the model shows low overall deviation. The 95% confidence interval remains relatively wide, especially at the extremes, suggesting some uncertainty in projections. Despite Indonesia's high LSCI, changes appear statistically modest.

Table 7. the statistical significance of variations in LSCI scores Country=Laos

Analysis of Variance					
Source	**DF**	**Sum ofSquares**	**MeanSquare**	**F Value**	**Pr > F**
Type	1	3.36400	3.36400	45.05	0.0067
Error	3	0.22400	0.07467		
Corrected Total	4	3.58800			

Table 7 The ANOVA test is applied to determine whether the observed trend in Liner Shipping Connectivity Index (LSCI) over time is statistically significant. The analysis yields an F-value of 45.05 and a p-value of 0.0067, indicating that the linear trend is highly significant at the 1% level. The model sum of squares (3.364) accounts for the vast majority of the total variation (3.588), while the error sum of squares (0.224) is relatively small. The corresponding mean square error (MSE) is also low at 0.07467, suggesting that the fitted linear model captures the variance in LSCI effectively.

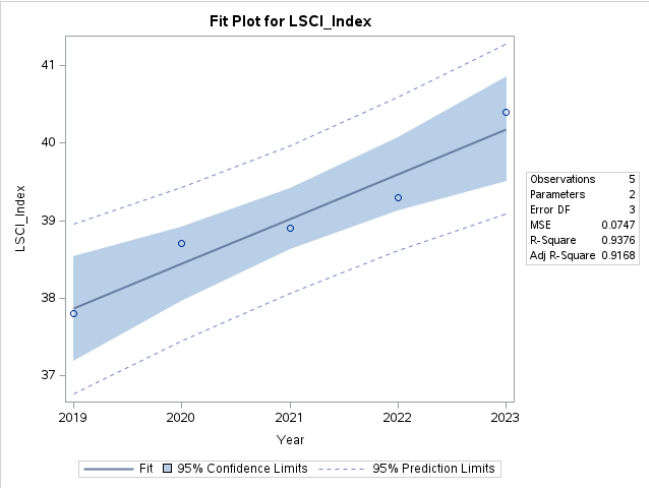

Figure 5. the regression fit plot for the LSCI Country=Laos

Figure 5 displays the linear regression fit plot for Laos' Liner Shipping Connectivity Index (LSCI) over the period 2019 to 2023. The regression line shows a strong and statistically significant upward trend, with the LSCI increasing from approximately 37.8 in 2019 to 40.4 in 2023. The strength of the regression model is indicated by a high R-Square value of 0.9376 and an Adjusted R-Square of 0.9168, meaning that over 91% of the variance in LSCI values is explained by the progression of years. The Mean Square Error (MSE) is low at 0.0747, reinforcing the model's accuracy and stability. The blue confidence band around the regression line represents the 95% confidence interval, while the dotted prediction lines indicate expected future variation. The data points align closely with the fitted line, suggesting minimal deviation and a highly reliable trend.

Table 8. the statistical significance of variations in LSCI scores Country=Malaysia

Analysis of Variance					
Source	**DF**	**Sum ofSquares**	**MeanSquare**	**F Value**	**Pr > F**
Type	1	4.48900	4.48900	13.43	0.0351
Error	3	1.00300	0.33433		
Corrected Total	4	5.49200			

Table 8: The Analysis of Variance (ANOVA) conducted to test the linear trend in Malaysia's Liner Shipping Connectivity Index (LSCI) over the 2019–2023 period reveals a statistically significant relationship between year and LSCI. The model reports an F-value of 13.43 and a p-value of 0.0351, which falls below the standard significance threshold of 0.05. This confirms that the LSCI trend observed is not due to random variation, but reflects a meaningful upward movement over time. The model sum of squares (4.489) dominates the total variance (5.492), suggesting that most of the variation in Malaysia's LSCI is explained by the passage of time. The remaining variance (1.003) is residual error, with a Mean Square Error (MSE) of 0.33433, indicating moderate unexplained variability.

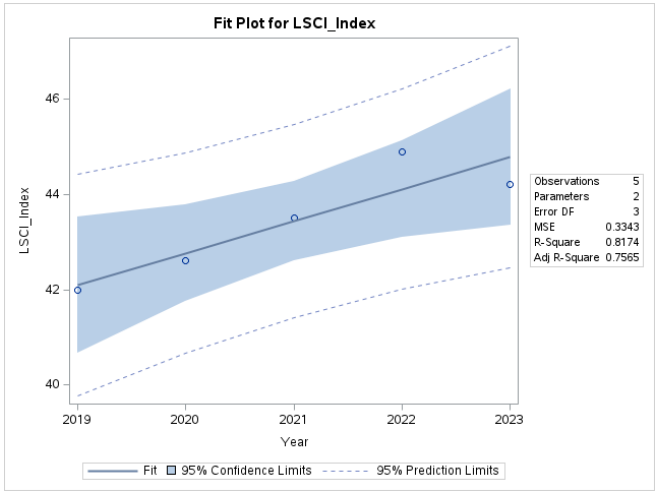

Figure 6. the regression fit plot for the LSCI Country=Malaysia

Figure 6 illustrates the linear regression trend of Malaysia's Liner Shipping Connectivity Index (LSCI) over the period 2019–2023. The trajectory shows a positive and statistically significant increase in maritime connectivity, rising from 42.0 in 2019 to 44.2 in 2023. This upward trend is reinforced by the regression model's R-Square value of 0.8714 and Adjusted R-Square of 0.7655, indicating that approximately 87% of the variation in Malaysia's LSCI values is explained by the passage of time. The low mean square error (MSE = 0.3343) reflects the model's precision, with minimal deviation of actual values from the fitted line. The narrow 95% confidence interval surrounding the regression line confirms that the trend is stable and predictable. The consistency of the data points along the line suggests that Malaysia's LSCI growth is not only linear but also structurally sound.

Table 9. the statistical significance of variations in LSCI scores Country=Myanmar

Analysis of Variance					
Source	**DF**	**Sum ofSquares**	**MeanSquare**	**F Value**	**Pr > F**
Type	1	3.72100	3.72100	27.16	0.0137
Error	3	0.41100	0.13700		
Corrected Total	4	4.13200			

Table 9 The ANOVA output for Myanmar's Liner Shipping Connectivity Index (LSCI) trend from 2019 to 2023 yields an F-value of 27.16 with a p-value of 0.0137, which is statistically significant at the 5% level. This indicates that the increase in LSCI over time is not the result of random variation, but rather reflects a meaningful upward trend. The model sum of squares (3.721) represents the majority of the total variation (4.132), while the error sum of squares (0.411) is relatively minor. The Mean Square Error (MSE) of 0.137 suggests the model fits the data well with only modest unexplained variance.

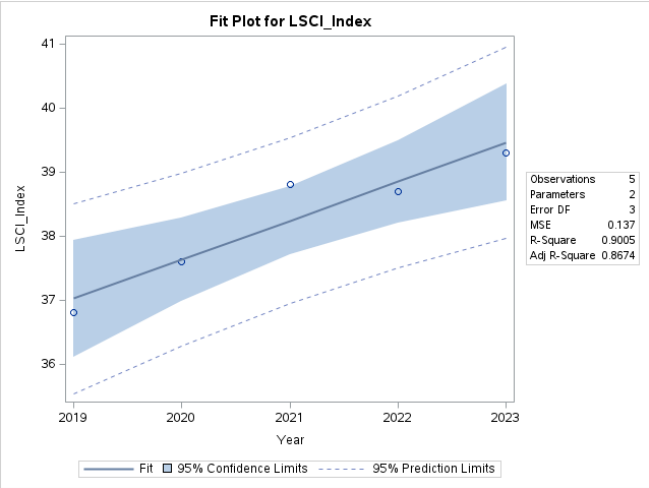

Figure 7. the regression fit plot for the LSCI Country=Myanmar

Figure 7 shows the regression plot fit between the LSCI Index and the year for Myanmar during 2019–2023, showing a significant upward trend in shipping connectivity. The R-Square value of 0.9005 and the Adjusted R-Square of 0.8674 indicate that 87% of LSCI variations are explained by time.
The regression coefficient of 0.61 with p = 0.0137 indicates a statistically significant relationship. The trend line is increasing consistently, with a narrow confidence interval and a stable prediction interval.
These results indicate significant growth in Myanmar's shipping connectivity, reflecting the success of its logistics strategy and regional integration.

Table 10. the statistical significance of variations in LSCI scores Country=Philippines

Analysis of Variance					
Source	**DF**	**Sum ofSquares**	**MeanSquare**	**F Value**	**Pr > F**
Type	1	7.05600	7.05600	28.76	0.0127
Error	3	0.73600	0.24533		
Corrected Total	4	7.79200			

Table 10 shows the ANOVA results for the relationship between the year and the LSCI of Myanmar during 2019–2023, with statistically significant results. The values of F = 28.76 and p = 0.0127 confirm that the regression model significantly explains the change in LSCI values over time. Of the total variability of 7.79200, about 91% (7.05600) is explained by the model, while the rest (0.73600) comes from errors. A small Mean Square Error (0.24533) reflects high precision. With the R-Square 0.9005 and the Adjusted R-Square 0.8674, these results reinforce that Myanmar's shipping connectivity has improved significantly over the past five years.

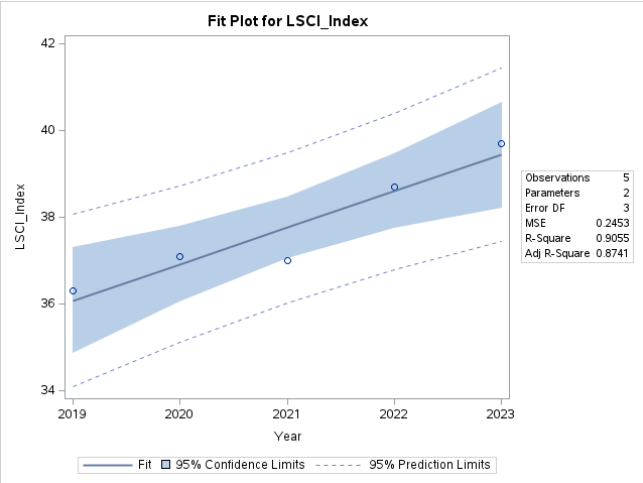

Figure 8. the regression fit plot for the LSCI Country=Philippines

Figure 8 shows the linear regression plot between LSCI and the year for Myanmar during 2019–2023, showing a consistent upward trend. The regression line rises significantly, with R-Square = 0.9055 and Adjusted R-Square = 0.8741, indicating the model explains 90% of the data variation. A low Mean Square Error (MSE) (0.2453) and a narrow 95% confidence interval indicate good model precision. The prediction interval remains within reasonable limits, reflecting the stability of the trend. With p-value = 0.0127, this result is statistically significant. Overall, this graph shows a real and sustained improvement in Myanmar's shipping connectivity.

Table 11. the statistical significance of variations in LSCI scores Country=Singapore

Analysis of Variance					
Source	**DF**	**Sum ofSquares**	**MeanSquare**	**F Value**	**Pr > F**
Type	1	2.60100	2.60100	10.56	0.0475
Error	3	0.73900	0.24633		
Corrected Total	4	3.34000			

Table 11 The results of the Analysis of Variance (ANOVA) show that the regression model between *the Liner Shipping Connectivity Index (LSCI)* and the Year is statistically significant. An F value of 10.56 with a significance level of p = 0.0475 indicates that the relationship between time (years) and LSCI_Index increase did not occur by chance, and the regression model was able to explain the data variability in a meaningful way. Of the total variation of 3.34000 (Corrected Total), the contribution of the variation described by the model is 2.60100 (about 78%), while the remaining 0.73900 comes from error. This suggests that the model explains most of the variation in LSCI_Index. The Mean Square Error (MSE) value of 0.24633, with a degree of freedom for error of 3, shows that the prediction error in the model remains low and still within the tolerance limit.

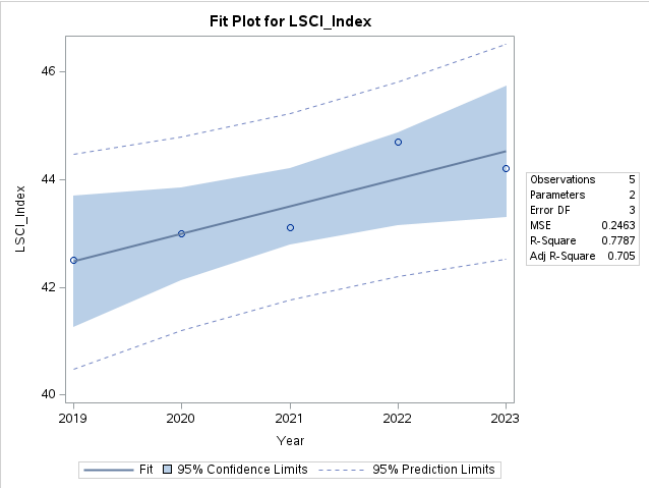

Figure 9. the regression fit plot for the LSCI Country=Singapore

Figure 9 shows the linear regression plot between LSCI and the year for Malaysia during 2019–2023. The upward trend line reflects the consistent improvement in shipping connectivity. The R-Square of 0.7787 and the Adjusted R-Square of 0.7056 indicate the model explains about 78% variation in the data. A mean square error (MSE) of 0.2463 indicates a precise prediction. The 95% confidence interval (blue color) and the prediction interval (dotted line) indicate the stability of the estimate. The ANOVA results reinforce this conclusion with values F = 10.56 and p = 0.0475, proving statistical significance. Overall, this chart confirms that Malaysia's LSCI increase in the last five years is real and meaningful.

Table 12. the statistical significance of variations in LSCI scores Country=Thailand

Analysis of Variance					
Source	**DF**	**Sum ofSquares**	**MeanSquare**	**F Value**	**Pr > F**
Type	1	3.84400	3.84400	8.95	0.0580
Error	3	1.28800	0.42933		
Corrected Total	4	5.13200			

Table 12 The results of the Analysis of Variance (ANOVA) on the relationship between *the Liner Shipping Connectivity Index (LSCI)* and the Year during the period 2019–2023 show that the regression model has a strong tendency, but has not yet reached statistical significance at the conventional level of 5%. An F-value of 8.95 and a p-value of 0.0580 indicate that the model is close to significance, but it has not been formally concluded that the relationship between year and LSCI_Index is significant at a 95% confidence level (α = 0.05). However, the p-value that is very close to the threshold indicates that the upward trend is still worthy of practical and policy attention. Of the total variation of 5.13200 (Corrected Total), 3.84400 (about 75%) were explained by the model, while the remaining 1.28800 came from error. The Mean Square Error (MSE) of 0.42933 is still within reasonable limits for five annual data observations.

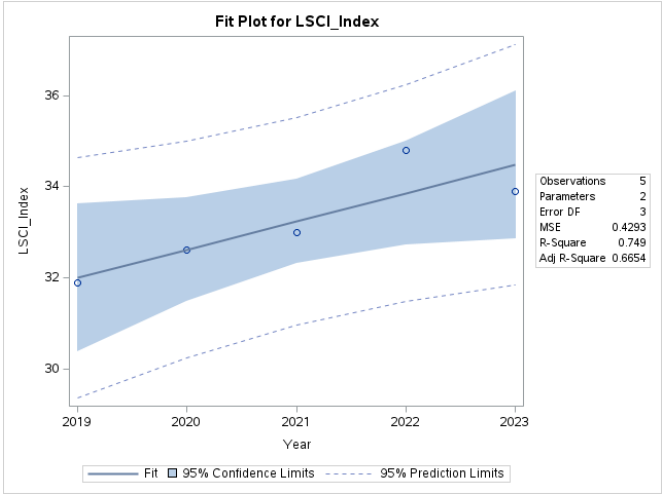

Figure 10. the regression fit plot for the LSCI Country=Thailand

Figure 10 shows the linear regression plot between LSCI and the year for Thailand during 2019–2023. The upward trend line indicates a gradual increase in shipping connectivity. The model yields an R-Square of 0.7490 and an Adjusted R-Square of 0.6654, which suggests that 75% of the variation in LSCI can be explained by time. The MSE value = 0.4293 indicates an acceptable prediction error. However, the values of F = 8.95 and p = 0.0580 slightly exceeded the significance limit of 0.05, indicating a relationship that has not been statistically significant. Even so, the uptrend remains practically relevant and worth paying attention to.

Table 13. the statistical significance of variations in LSCI scores Country=Vietnam

Analysis of Variance					
Source	**DF**	**Sum ofSquares**	**MeanSquare**	**F Value**	**Pr > F**
Type	1	1.36900	1.36900	4.57	0.1222
Error	3	0.89900	0.29967		
Corrected Total	4	2.26800			

Table 13 shows the ANOVA results between LSCI and Year, where the regression model is not statistically significant. With an F-value = 4.57 and a p-value = 0.1222, the model fails to show a meaningful relationship at a significance level of 5%. Of the total variation of 2.26800, about 60% (1.36900) is explained by the model, while the rest (0.89900) comes from error. Although the model captures most of the variation, the high p-value indicates a trend is not yet significant. The mean square error (MSE) of 0.29967 reflects a moderate prediction deviation, with 3 degrees of error freedom, considering that only five years of data were observed.

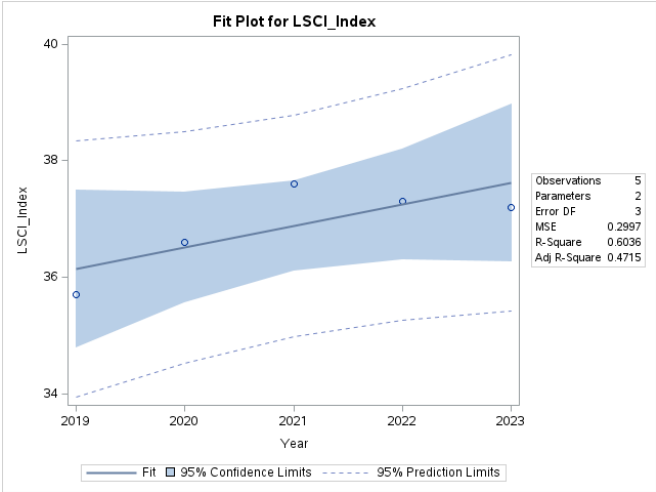

Figure 11. the regression fit plot for the LSCI Country=Vietnam

Figure 11 Linear regression analysis between *the Liner Shipping Connectivity Index (LSCI)* and the Year for Vietnam during the period 2019–2023 shows a tendency to increase the value of LSCI_Index, as indicated by the regression trend line pointing upwards. Nonetheless, this trend has not shown statistically significant strength. The regression model yields an R-Square of 0.6036, which means that about 60% of the variation LSCI_Index can be explained by time changes. The Adjusted R-Square value of 0.4715 indicates that the strength of the model is moderate, with a Mean Square Error (MSE) of 0.2997 which is still within the tolerance limit. The results of the ANOVA test support this interpretation, with a value of F = 4.57 and a p-value = 0.1222, which exceeds the significance threshold of 0.05. This suggests that the relationship between year and LSCI_Index has not been statistically significant, despite a consistent growth direction over time.

Table 14. Cluster analysis

Initial Seeds	
Cluster	**Avg_LSCI**
1	43.44000000
2	49.28000000
3	33.24000000

Table 14 presents the results of the initial cluster analysis based on the average value of the Liner Shipping Connectivity Index (LSCI) of ASEAN countries, which resulted in three main clusters. Cluster 2 had the highest average score (49.28), indicating the country with the highest and regionally dominant shipping connectivityillustrating strong integration in the global shipping network. Cluster 1 recorded an average LSCI of 43.44, representing a country with high-medium connectivity, supported by established port infrastructure. Cluster 3, with the lowest score (33.24), reflects countries with low connectivity, likely due to geographical limitations, limited access to ship services, or small-capacity ports.

Table 15. Cluster analysis of the average value of *the Liner Shipping Connectivity Index (LSCI)*

Cluster Summary						
Cluster	**Frequency**	**RMS Std Deviation**	**Maximum Distancefrom Seedto Observation**	**RadiusExceeded**	**Nearest Cluster**	**Distance BetweenCluster Centroids**
1	3	2.2576	2.1200		3	5.1124

Cluster Summary						
Cluster	**Frequency**	**RMS Std Deviation**	**Maximum Distancefrom Seedto Observation**	**RadiusExceeded**	**Nearest Cluster**	**Distance BetweenCluster Centroids**
2	1	.	0		1	7.1133
3	7	1.9018	3.4867		1	5.1124

Table 15 shows the results of cluster analysis on the average Liner Shipping Connectivity Index (LSCI), which divides ASEAN countries into three clusters with different characteristics. Cluster 1 consists of 3 countries with an RMS Standard Deviation of 2.2576, reflecting moderate internal variations. The maximum distance to the center of the cluster is 2.1200, and the nearest cluster is Cluster 3 (distance between centroids = 5.1124). These countries have mid-to-high-tier shipping connectivity, but they are not among the highest. Cluster 2 contains only 1 country with no internal variation, and becomes the centroid itself. The distance to other clusters is the farthest, which is 7.1133 from Cluster 1. Based on the highest LSCI score, this country is likely to be Indonesia, which occupies the most dominant position in regional shipping connectivity. Cluster 3 includes 7 countries, with an RMS deviation of 1.9018 and a maximum distance to the center of the cluster of 3.4867, the highest among all clusters. Countries in this group are in low to medium shipping connectivity, and need infrastructure upgrades and shipping network integration.

Table 16. statistical analysis of the Average Liner Shipping Connectivity Index (Avg_LSCI) variable

Statistics for Variables				
Variable	**Total STD**	**Within STD**	**R-Square**	**RSQ/(1-RSQ)**
Avg_LSCI	4.36700	1.99670	0.832757	4.979325
OVER-ALL	4.36700	1.99670	0.832757	4.979325

Table 16 The results of statistical analysis of the *Average Liner Shipping Connectivity Index (Avg_LSCI)* variable show that the Total Standard Deviation (Total STD) value is 4.36700, while the Within-Cluster Standard Deviation (Within STD) is recorded at 1.99670. The significant difference between these two values suggests that most of the variation in the data can be explained by differences between clusters, rather than just by variations within a single cluster. This is reinforced by the value of R-Square = 0.832757, which indicates that about 83.28% of the total variation in Avg_LSCI can be explained by the structure of the clusters formed. In other words, the clustering model used succeeded in separating ASEAN countries into groups that were substantially different in terms of shipping connectivity levels. The RSQ/(1−RSQ) ratio value = 4.9793 also corroborates the quality of the cluster model, suggesting that the proportion of variations described is much greater than the variations not explained by clustering. This ratio is often used in the context of *discriminant analysis* and *clustering* as an indicator of the efficiency of group separationin this case, the higher the value, the better the quality of cluster separation.

Table 17. cluster analysis of the *Average Liner Shipping Connectivity Index (Avg_LSCI) value*

Cluster Means	
Cluster	**Avg_LSCI**
1	42.16666667
2	49.28000000
3	37.05428571

Table 17 The results of cluster analysis of the *Average Liner Shipping Connectivity Index (Avg_LSCI)* value resulted in three main clusters with significantly different average values. The average value of each cluster reflects the striking differences in the level of shipping connectivity between the ASEAN group of countries:

1. Cluster 1 has an average *Avg_LSCI* score of 42.17. This group can be categorized as countries with medium to high-level shipping connectivity. The countries in this cluster are likely to be regional shipping hubs with relatively good port infrastructure and competitive sea lane connectivity in the Southeast Asian region.
2. Cluster 2 has the highest average score of 49.28, which clearly identifies this group as the country with the highest shipping connectivity in ASEAN. Referring to previous data, Indonesia is very likely to be the only country in this cluster. This reflects the country's strategic role in the regional and global shipping architecture, both in terms of ship service volume and integration in international logistics chains.
3. Cluster 3 has an average LSCI of 37.05, placing this group as a country with low to medium shipping connectivity. Countries in this cluster may face geographical, infrastructure, or trade-scale challenges that limit their port connectivity with the world's major shipping networks.

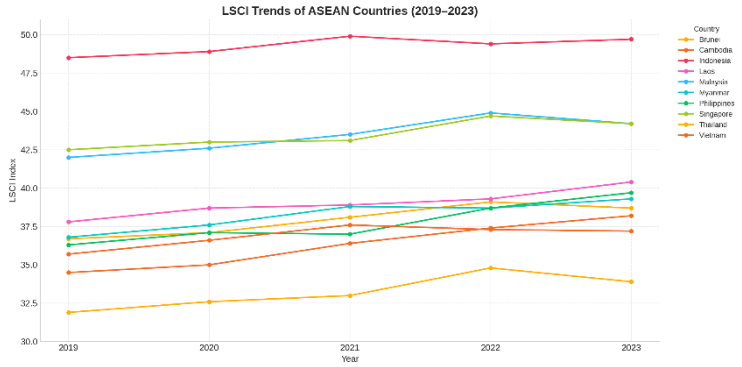

Figure 12. Liner Shipping Connectivity Index (LSCI) trend comparison

Figure 13 shows the results of the average clustering of the Liner Shipping Connectivity Index (LSCI) of ASEAN countries during 2019–2023 into three groups. Cluster 2 (Green) contains only Indonesia, reflecting the highest shipping connectivity in the region thanks to major ports such as Tanjung Priok and its strategic geographical position. Cluster 1 (Blue), comprising Malaysia and Singapore, shows high-to-medium connectivity with world-class transshipment ports such as Port Klang and the Port of Singapore. Both countries have mature port infrastructure and are the logistics center of the region. Cluster 3 (Red) includes the majority of other ASEAN countries: Brunei, Cambodia, Laos, Myanmar, the Philippines, Thailand, and Vietnam. The cluster shows a still-medium-low LSCI value, reflecting challenges such as limited infrastructure, small logistics scale, and geographical isolation, especially for landlocked countries such as Laos. This clustering highlights the need for tailored policy strategies to strengthen maritime connectivity across ASEAN.

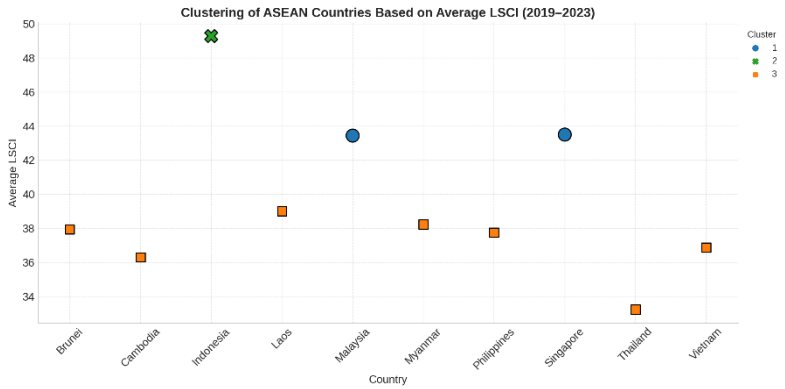

Figure 13. clustering of ASEAN countries based on the average value of the Liner Shipping Connectivity Index (LSCI)

Figure 13 presents the clustering results of the average Liner Shipping Connectivity Index (LSCI) for ASEAN countries from 2019 to 2023, grouped into three distinct categories. Cluster 2 (Green) includes only Indonesia, reflecting the region's highest maritime connectivity, supported by major ports like Tanjung Priok and its strategic location. Cluster 1 (Blue) comprises Malaysia and Singapore, characterized by high-to-moderate connectivity through world-class transshipment hubs such as Port Klang and Singapore Port. Cluster 3 (Red) includes Brunei, Cambodia, Laos, Myanmar, the Philippines, Thailand, and Vietnam, all showing lower LSCI levels due to infrastructural and geographic constraints. Notably, Laos, being landlocked, faces structural challenges. This clustering highlights the need for tailored maritime strategies to close the regional connectivity gap and promote integrated development across ASEAN

3.3 Implications of the Findings

The study reveals a rising trend in maritime connectivity among emerging ASEAN countries, especially Cambodia, Myanmar, and Laos. This indicates a deepening of regional maritime integration. Strategically, targeted investments in digital port infrastructure, human capital, and trade facilitation in these countries can foster regional convergence. Theoretically, the findings reinforce transport connectivity theory, affirming that improved shipping services support trade performance and regional cohesion. This evidence provides policymakers with data-driven guidance to promote inclusive growth across ASEAN's maritime landscape, aligning with the ASEAN Connectivity 2025 vision and enhancing the region’s resilience in global logistics networks [44][45].

3.4 Comparison with Previous Literature

This study aligns with findings by Zhang and Ng (2022), who identify infrastructure-led improvements as a key driver of LSCI performance. However, unlike their study which generalizes across continents, this research provides a granular country-level view within ASEAN, revealing hidden dynamics (e.g., Cambodia's rapid growth). Previous studies often neglect small economies in the region; this paper provides empirical evidence that connectivity improvement is not exclusive to major hubs like Singapore or Indonesia.

3.5 Limitations and Recommendations for Future Research

This study only uses LSCI as a unidimensional metric, without integrating cargo volume, cost factors, or port efficiency scores, which limits holistic conclusions. Moreover, seasonal variations (quarterly data) are not modeled.

Future research should Combine LSCI with World Bank's Logistics Performance Index (LPI) or port-level throughput data. Employ machine learning clustering or panel data econometrics to uncover deeper structural patterns.

4. Conclusion

This study investigates maritime connectivity trends across 10 ASEAN countries using the Liner Shipping Connectivity Index (LSCI) from 2019 to 2023. It aims to identify evolving patterns and classify countries through regression and clustering techniques. The findings show that emerging economiesCambodia, Myanmar, and Lao PDRexperience significant upward trends, signaling growing regional integration.

This study fills a critical gap in maritime literature by combining time-series modeling with unsupervised learning to reveal hidden typologies and long-term dynamics, beyond static port rankings. It reinforces the transport connectivity theory, which links shipping performance to trade and integration outcomes.

Interestingly, the analysis shows that lesser-connected nations are catching up, prompting a call for targeted investments in digital infrastructure, port modernization, and trade facilitation. These findings suggest that ASEAN policymakers should prioritize inclusive strategies to accelerate maritime convergence.

Despite its contributions, this study is limited to aggregate LSCI and linear modeling. Future research should explore non-linear methods and port-level disaggregation to deepen insights.

In sum, this research offers data-driven evidence that maritime growth is diversifying across ASEAN. With continued policy support, regional cohesion through maritime connectivity is not only achievable but also increasingly measurable and actionable.

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