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# TEMPORAL DYNAMICS OF THE ATTRACTIVENESS OF ARAB COMMERCIAL PORTS: A QUANTITATIVE ANALYSIS BASED ON MARITIME PERFORMANCE INDICATORS 2009-2024

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## ABSTRACT

*This study aims to analyze the temporal and spatial efficiency of Arab ports during the past 15 years (2009-2024). The study included 19 ports and evaluated them based on 11 indicators covering operational, logistical, security, and infrastructure dimensions. GIS tools were used to conduct spatial analyses, in addition to quantitative descriptive analyses such as correlation and linear regression, to interpret the relationships between indicators. The results showed the superiority of Jebel Ali, Tanger Med, and Hamad ports in terms of performance. The temporal analysis also highlighted a wave of growth between 2009 and 2014, followed by relative stability, and then sharp variations from 2019 to 2024. Meanwhile, Moran's analysis revealed spatial clusters of efficiency in the Gulf and Morocco. The study concludes that measuring port efficiency cannot be limited to operational indicators alone but requires integrating them with the geospatial dimension to provide a more comprehensive and accurate picture of port reality analyses.*

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**KEYWORDS:** Port Efficiency; Geography of Maritime Transportation; Spatio-Temporal Analysis; Geographic Information Systems (GIS); Maritime Performance Indicators; Port Competitiveness; Arab Ports.

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## 1. INTRODUCTION

Arab ports reflect over a century of construction and development. The historical emergence and growth of local and regional economic and commercial activities are closely tied to the foundations of these ports, which have continued to strengthen their role by adapting to expanding and evolving trade flows. Today, international trade is a primary driver of economic development and the main channel for exchanges between countries.

Port attractiveness depends on multiple factors. One primary way to assess it is by examining port performance over time; this analysis focuses on the period 2009–2024. The maritime performance indicators selected for Arab commercial ports during this interval were chosen according to data availability and serve as benchmarks for maritime governance, providing a preliminary quantitative evaluation of regional port attractiveness.

Over the past two decades, Arab seaports have experienced a notable improvement in navigational performance and a corresponding increase in attractiveness within maritime trade dynamics (Berggren, 2015). Ports are essential components of heavy transport infrastructure and constitute a major engine of global trade and goods movement (Kosowska-Stamirowska, 2020; UNCTAD, 2020). Enhancements in port infrastructure and operations strengthen a country's competitive position in maritime transport and can improve its economic and geostrategic standing, with measurable effects on maritime connectivity, container throughput, the number of shipping lines, and operational efficiency indicators (UNCTAD, 2020).

Maritime transport accounted for nearly 70% of global trade by value and over 80% of goods traded by volume in 2021 (Yagci & Noordali, 2024). Consequently, assessing commercial port attractiveness offers key insights into countries' logistical capabilities and regional and international competitiveness (Wilmsmeier & Monios, 2020). At the same time, some ports remain vulnerable to geopolitical, economic, and regulatory challenges that can undermine performance.

The UNCTAD (2024) report indicates that the strategic importance of Arab commercial ports shifted substantially between 2019 and 2024, influenced by a range of maritime performance indicators that reflect both regional and global shipping dynamics. As trade volumes and shipping technologies have advanced, improvements in accessibility and operational efficiency have become critical determinants of a port's attractiveness to international shipping and logistics networks. These

advances are evident in upgraded infrastructure and higher performance on indicators such as maritime connectivity and container-handling efficiency.

### 1.1. Study Problem and Questions

The study identifies a critical gap: there is no systematic temporal and spatial analysis of changes in the attractiveness of Arab commercial ports, and global quantitative indicators are underutilized for tracking these changes. This deficiency undermines the formulation of effective, evidence-based development strategies informed by long-term performance data. The literature review further reveals a marked scarcity of geographical studies that integrate temporal and spatial dimensions with quantitative analysis, leaving an unresolved knowledge gap regarding the resulting spatial patterns and the relative positioning of ports.

This study seeks to answer the following questions:

Q1: What are the temporal and spatial trends in the attractiveness of Arab ports during the study period?

Q2: How can ports be categorized according to their levels of efficiency and navigational attractiveness, and what are the similarities and differences between Arab maritime regions?

Q3: What spatial patterns emerge from the port efficiency analysis, and how do they reflect the position of Arab ports in the global maritime transportation network?

### 1.2. Significance Of the Study

The study examines temporal and spatial variations in the attractiveness of commercial ports across the Arab world between 2009 and 2024, situating the analysis within maritime transport geography. Using a quantitative, analytical methodology, it assesses port performance beyond operational metrics by incorporating infrastructure, logistics, security, and institutional stability to deliver a comprehensive evaluation of port dynamics in the Arab context.

This research contributes by identifying regional disparities among Arab ports and linking those differences to temporal and spatial determinants, thereby clarifying the mechanisms that facilitate or impede regional integration.

### 1.3. Study Objectives and Research Questions

The study aims to analyze the spatio-temporal changes in the efficiency and attractiveness of Arab commercial ports during the period 2009–2024, tracing their development trajectories and identifying differences among the various maritime regions.

- To classify Arab ports and map the dynamic patterns of maritime attractiveness using quantitative and spatial analytical tools, thereby highlighting pivotal ports and the variability of their competitiveness within the global maritime context.

#### 1.4. Theoretical Framework and Literature Review

Maritime transportation underpins international trade: more than 80% of global trade is carried by sea, with some estimates approaching 90% (UNCTAD, 2024; ICS; EMSA). Ports are critical nodes that connect local economies to global maritime networks, and their efficiency directly influences supply chain costs, reliability, and competitiveness. In the Arab context, the strategic locations of commercial ports on sea lanes such as the Red Sea and the Arabian Gulf provide substantial logistical advantages but also increase vulnerability to geopolitical shifts, changing trade patterns, and evolving maritime sustainability requirements (Arab Center Washington, 2021; Al-Obeidi, 2021; Youvan, 2024; Alexandre, 2021; World Bank, 2024). The geographic and economic specifics of Arab ports necessitate assessing temporal changes in their attractiveness to evaluate both current performance and adaptive capacity within a dynamic maritime environment.

This study integrates theoretical frameworks that explain spatial and temporal variation in port attractiveness. The navigational-attractiveness framework, grounded in the gravity model of spatial economics, posits that maritime flow volumes correlate positively with factors such as geographic location, infrastructure quality, competitive costs, and market demand. Navigational interactions depend on characteristics of origin and destination centers and decline with spatial barriers; empirical studies indicate that ship movements broadly conform to gravity-model predictions (Rodrigue, 2024; Kaluza et al., 2010; Huang et al., 2012).

The network model conceptualizes ports as interconnected nodes within the global maritime transport network, with importance measured by connectivity and centrality metrics. The Container Port Connectivity Index (CPCI), derived from LSCI components, captures a port's centrality, while measures such as betweenness centrality identify key transit hubs in the network (Jarumaneiroj et al., 2022; Kaluza et al., 2010).

Quantitative performance indicators—such as

LSCI, number of services, and container throughput (TEUs)—are increasingly used to assess port competitiveness (UNCTAD, 2024; Ji, 2025). Port resilience, defined as the capacity to adapt to and recover from crises including political conflict, natural disasters, and economic shocks, is also critical. Combining these theoretical frameworks with quantitative indicators converts descriptive measures into analytical tools that reveal the complex interrelations among infrastructure, network dynamics, and political, economic, and institutional factors (Rodrigue, 2019; Tsoulfas, 2025).

Studies on port performance assessment have witnessed a remarkable development, with Data Envelopment Analysis (DEA)<sup>1</sup> being a prominent tool in measuring productivity and operational efficiency and identifying performance gaps (Trujillo et al., 2020; Chen et al., 2016; Salameh et al., 2021; Ji et al., 2024), but these studies noted the absence of a standardized framework for assessing performance, given the different port characteristics and operating methods. Maritime network analysis has expanded substantially due to wider access to Automatic Identification System (AIS) data and advances in computing. Research has examined the structure and evolution of global shipping networks—focusing on connectivity, centralization, and resilience—which has enhanced understanding of maritime distribution dynamics and inter-port relationships (Ducruet et al., 2019; Mou et al., 2020).

Spatial analysis in transportation geography has become essential for assessing ports' locational advantages and the spatio-temporal development of shipping networks. Improvements to port infrastructure strengthen maritime connectivity and stimulate regional economic growth (Rodrigue, 2020). Several studies have specifically analyzed ports on strategic corridors, such as the Maritime Silk Road, to evaluate how location affects navigational competitiveness and access to internal markets.

Recent scholarship has broadened to include the environmental and social dimensions of port operations under the green-ports agenda. These works emphasize emissions reductions, enhanced waste management, and greater energy efficiency in alignment with global environmental objectives (Taljaard, 2024; Su, 2024; ResearchGate review, 2025).

Literature has also explored the influence of external shocks—including the COVID-19 pandemic, climate change, and geopolitical unrest—on port resilience and operational sustainability. Findings

outputs, and is one of the prominent tools in efficiency and productivity studies.

<sup>1</sup> DEA is an acronym for Data Envelopment Analysis, a mathematical method used to measure the relative efficiency of similar units (such as ports or airports) by comparing inputs and

demonstrate the value of institutional preparedness, resilient infrastructure, and multimodal integration for maintaining port functionality (Liu, 2023; Couñago-Blanco et al., 2024; Song, 2025).

Despite the breadth of maritime transportation research, there is a relative scarcity of studies that comprehensively examine temporal changes in the attractiveness of Arab commercial ports within a transportation geography framework for 2009–2024. Previous work often covers limited temporal or spatial dimensions (Alamouh et al., 2021; Sakib et al., 2018; Zhou & Luo, 2023) and lacks integrated temporal–spatial analyses based on a comprehensive set of maritime performance indicators. This study addresses that gap by conducting a long-term, multi-indicator analysis of Arab port attractiveness and linking the results to theoretical frameworks in transportation geography to deepen understanding of the region’s maritime dynamics.

This study will utilize theoretical frameworks in transportation geography to provide a deeper understanding of maritime dynamics in the region.

### 1.5. Methodology And Research Tools

This study adopts a descriptive-analytical approach by tracing temporal changes in the maritime performance indicators of Arab commercial ports during the period 2009–2024. The analysis employs both statistical time-series methods and spatial analysis techniques based on Geographic Information Systems (GIS) in order to identify the temporal and spatial patterns of port attractiveness and to interpret the factors influencing its transformations. The methodological framework includes time series analysis to capture trends and changes, spatial analysis to generate dynamic maps and detect spatial patterns, classification of ports according to attractiveness indicators, and correlation and multiple regression analyses to determine the factors affecting port attractiveness.

**To achieve the objectives of the research, the study examined 11 indicators grouped into the following categories:**

- Maritime performance indicators: Liner Shipping Connectivity Index (LSCI), container throughput (TEUs).
- Operational efficiency indicators: vessel waiting time, Logistics Performance Index (LPI).
- Cost indicators: port charges (USD).
- Infrastructure indicators: berth length and number, infrastructure quality, storage capacity.
- Safety and security indicators: Global Peace

Index (GPI), number of maritime accidents.

The Incremental Spatial Autocorrelation tool was applied to determine the optimal analysis distance for measuring the spatial autocorrelation of container throughput (TEU) values among the studied ports. The analysis was performed on a point layer projected in a metric coordinate system (WGS 1984 World Mercator), using a Fixed Distance Band and Row Standardization. The tool was executed for the average of each five-year reference period separately (2009, 2014, 2019, 2024), with both the Start Distance and Increment set to approximately 150 km, following an initial calibration using the average nearest neighbor. The distance at which the highest statistically significant z-score was recorded was then adopted as the reference distance in subsequent analyses (Moran’s I), ensuring consistency in comparison across years.

**The mathematical expression of Moran’s I is given as:**

$$I = \frac{n}{W} \cdot \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^n (x_i - \bar{x})^2}$$

**Where:**

- $n$  = number of spatial units (ports).
- $x_i$  = value of the variable (TEU) at location  $i$ .
- $\bar{x}$  = mean of all values.
- $w_{ij}$  = spatial weight between locations  $i$  and  $j$  (based on the chosen distance band).
- $W = \sum_i \sum_j w_{ij}$  sum of all spatial weights.

A comprehensive database was constructed covering a set of Arab ports during the period 2009–2024, with the aim of measuring and analyzing their operational efficiency and maritime attractiveness. This database included both quantitative and qualitative fields representing the main dimensions of port performance, namely: container throughput (TEU), number of port calls, port charges (USD per container), average waiting time (days), berth length (meters), number of berths, Global Peace Index (GPI), Logistics Performance Index (LPI), storage/handling capacity, number of maritime accidents, and infrastructure quality (measured on a scale from 1 to 3). These data were employed to build composite indicators and were subsequently transformed into spatial and temporal maps reflecting the development of ports across the studied periods.

The study also employed a Multiple Linear Regression (MLR) model designed to explain variations in the Liner Shipping Connectivity Index (LSCI) of Arab ports based on a set of operational variables. The LSCI, published by UNCTAD, is the

international benchmark for measuring the degree of integration of ports and countries into the global liner shipping network. It is built upon five core dimensions: the number of direct shipping services, the number of active shipping companies, the size of the deployed fleet, vessel capacity, and the number of connected ports. Globally, the index is used as a key measure of maritime attractiveness and logistical competitiveness. In this study, due to limited availability of detailed data for some of these elements, container throughput (TEUs) and number of port calls were adopted as the explanatory variables (X) most strongly associated with port attractiveness, while the LSCI served as the dependent variable (Y) in the regression model.

**The multiple linear regression equation is expressed as:**

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$$

**Where:**

- Y= Liner Shipping Connectivity Index (LSCI).
- $\beta_0$ = intercept (constant).
- $X_1$ = container throughput (TEUs).
- $X_2$ = number of port calls.
- $\beta_1, \beta_2$ = regression coefficients representing the effect of each explanatory variable.
- $\varepsilon$ = error term capturing unexplained variation.

The data were processed using SPSS software, where multiple linear regression was conducted to identify the quantitative relationship among the variables, and the coefficient of determination ( $R^2$ ) was calculated to estimate the proportion of variance explained by the model. The study relied on open-access international data sources that provide reliable quantitative information on the performance of commercial ports.

**These sources included databases and periodic reports issued by international organizations and specialized maritime platforms, most notably:**

- Liner Shipping Connectivity Index (LSCI): UNCTAD reports.
- Container throughput (TEUs): official port reports and UNCTAD databases.

- Monthly vessel calls: MarineTraffic and FleetMon platforms.
- Vessel turnaround time: logistics reports available from ports and open research sources.
- Annual reports from the UNCTAD Maritime Connectivity Index platform.
- Infrastructure quality and technological updates: port reports and publicly available technical sources.
- Safety, security, and management indicators: data published on the official websites of governmental bodies and international maritime organizations.

## 2. STUDY AREA

This study examines the navigational attractiveness of a selected set of major Arab commercial ports chosen using geographic and methodological criteria to ensure comprehensive and balanced representation. The sample covers the primary maritime regions of the Arab world—the Arabian Gulf, the Red Sea, the eastern and southern Mediterranean, and the Atlantic coast of North Africa—to capture temporal shifts in attractiveness across diverse economic and geopolitical contexts.

Selected ports were chosen for their strategic and functional importance in international trade and for their representation in datasets from UNCTAD, the World Bank, and maritime traffic platforms, enabling precise temporal and spatial analysis. The sample reflects varied development trajectories, including rapid expansion (e.g., Hamad Port and Jebel Ali) and contraction driven by political or security challenges (e.g., Beirut, Hodeidah, and Latakia).

To introduce an institutional perspective, the study also includes ports with different governance and operational models (governmental, private, and hybrid), allowing assessment of the relationship between management structure and maritime attractiveness (Figure 1).

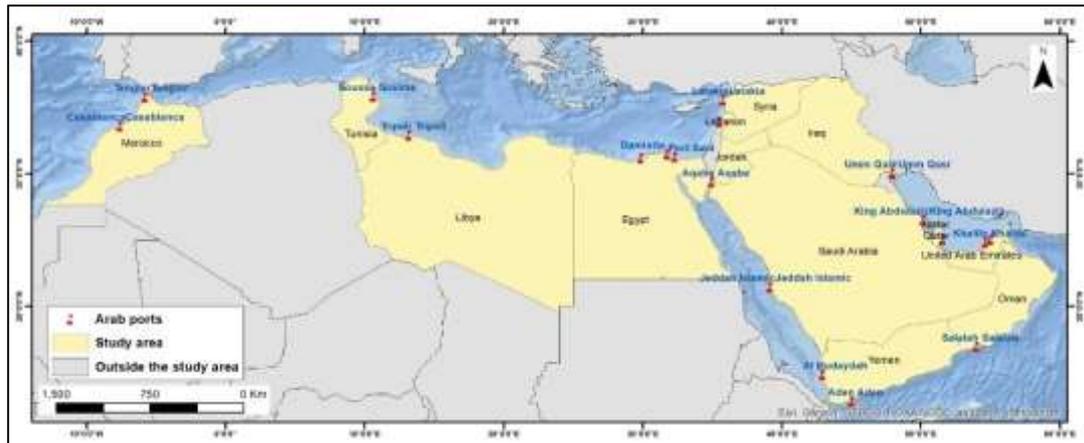


Figure 1: The Study Area.

The study examined 19 seaports across 13 Arab countries, covering the Arabian Gulf, the Red Sea, the southern and eastern Mediterranean, and the Atlantic coast. The ports included Port Said, Alexandria, and Damietta in Egypt; King Abdulaziz and Jeddah Islamic ports in Saudi Arabia; Rabia, Jebel Ali, and Khalifa in the United Arab Emirates; Salalah in Oman; Hamad in Qatar; Aden and Hodeidah in Yemen; Umm al-Qasr in Iraq; Aqaba in Jordan; Tangier and Casablanca in Morocco; Latakia in Syria; Beirut in Lebanon; Tripoli in Libya; and Sousse in Tunisia.

The strategic geographic positions of these ports make them key nodes in the global trade network, shaping international shipping routes. Extending from the Red Sea to the Arabian Gulf, they serve as vital transit points for goods and fuel and help facilitate trade within the Arab region as well as between Europe, Asia, and Africa. Regional conflicts and shifting geopolitical dynamics have further reinforced their importance as gateways for economic and diplomatic engagement (Kotait & Ismail, 2018).

Understanding the historical development of Arab commercial ports is essential to explain changes in navigational performance and attractiveness over time. These ports have historically operated as pivotal centers in intercontinental trade networks and therefore remain sensitive to geopolitical shifts, technological advances, and regional and international economic policies. As global trade patterns evolve, the ports' capacity to adapt to new demands has become a defining factor, with some coastal cities experiencing a notable maritime resurgence.

Targeted investments in infrastructure and advanced technologies have improved operational efficiency at several ports, particularly in the Arabian Gulf. This progress is reflected in the Container Port

Performance Index 2023 ship dwell-time rankings, where ports such as Salalah, Hamad, Khalifa, and Damman performed strongly (World Bank, 2024). These developments intersect with port sustainability frameworks that emphasize social, environmental, and institutional dimensions as drivers of regional growth (Alamouh et al., 2021). Additionally, the geostrategic location of Arab ports and ongoing dynamics in the Red Sea and Bab al-Mandeb underscore the complex challenges and opportunities that affect development and competitiveness (Koshaimah & Zou, 2023; OECD/ITF, 2024).

### 3. RESULTS AND DISCUSSION

#### 3.1. Analysis Of Navigation Performance Indicators for Arab Ports (2009-2024)

Maritime performance indicators are essential for assessing the operational efficiency and competitive appeal of Arab commercial ports over time. In this analysis, these indicators encompass the factors that drive temporal changes in port efficiency. We examine fifteen-year trends in navigation performance metrics, evaluate key measures and their influence on port attractiveness, analyze time-series patterns for each indicator, assess port efficiency from both temporal and spatial perspectives, and classify ports based on these results.

#### 3.2. Evolution Of Arab Port Performance Indicators Between 2009 And 2024

The evolution of maritime and port performance indicators over the past fifteen years demonstrates a shift from traditional operational measures to a broader analytical framework that captures recent research and objective trends in performance, efficiency, and sustainability (Kishore et al., 2024).

The integration of AIS data and route analysis techniques has contributed to the generation of accurate performance indicators (such as dock<sup>2</sup>/waiting<sup>3</sup> time and actual port limits) in a real-time and comparable manner (Wijaya et al., 2024). The econometric literature also shows that improving port efficiency is associated with clear quantitative outcomes on shipping costs and competitiveness, supporting the shift from mere measurement to data-driven decision-making (Suárez-Alemán et al., 2016). Modern institutional measurement tools—such as the World Bank’s Container Port Performance Index (CPPI) and UNCTAD reports—confirm the widespread use of data, including AIS, to compare performance across ports and countries and track vessel dwell time improvements (World Bank, 2024; UNCTAD, 2024).

The evolution of maritime navigation performance indicators from 2009 to 2024 highlights significant improvements in maritime navigation efficiency and competitiveness, particularly with regard to Arab commercial ports. Over the decades, technological developments have transformed these indicators from mere basic metrics into sophisticated data-driven analyses that impact operational decision-making. Improved systems have facilitated real-time monitoring and analysis of vessel movements, leading to improved operational performance and reduced response times. The evolution of maritime navigation performance indicators is essential for enhancing port operational efficiency in the context of global trade dynamics (Table 1).

**Table 1: Comparison Of the Rate of Change Between 2009 And 2024 For Arab Ports.**

Port Region	Indicator	2009	2024	Rate of Change (%)
Arabian Gulf Ports	Container Throughput (TEUs)	6,175,000	71,433,333	15.52
Red Sea Ports		425,000	1,859,000	30.46
Mediterranean Ports		705,812.5	1,131,850	60.36
Arabian Gulf Ports	Waiting Time (Days)	2.15	1.13	-47.29
Red Sea Ports		5.50	4.47	-18.79
Mediterranean Ports		3.95	2.96	-25.00
Arabian Gulf Ports	Logistics Performance Index (LPI)	3.40	2.96	-14.22
Red Sea Ports		2.32	2.62	12.95
Mediterranean Ports		2.44	3.01	23.59
Arabian Gulf Ports	Global Peace Index (GPI)	1.95	1.43	-26.50
Red Sea Ports		3.77	3.23	-14.16
Mediterranean Ports		2.61	1.95	-25.36

The regional analysis of temporal indicators highlights clear spatial disparities in maritime development among Arab ports. The Mediterranean has emerged as the fastest-growing hub, with handling volumes increasing by more than 60%, confirming its evolution into a strategic node in global trade. The Arabian Gulf continued to lead in physical throughput despite moderate growth, and achieved notable operational efficiency by reducing average waiting time to the region's lowest level (1.13 days). The Red Sea, although slower to reduce waiting times, has demonstrated improving logistics performance and a promising service dynamic.

By contrast, the Global Peace Index (GPI) paints a different picture: Mediterranean ports offer a safer, more investment-friendly environment, while the Arabian Gulf and Red Sea show relatively lower stability, which limits their capacity to fully benefit

from maritime globalization.

Incremental spatial autocorrelation analysis underscores a pronounced regional dimension. A high Moran's I indicates that poor performance clusters spatially rather than occurring at random. This result is statistically significant ( $\alpha = 0.05$ ): the z-score exceeded the critical threshold and the p-value was  $< 0.05$ , confirming that the observed spatial pattern is unlikely to be due to chance. These findings suggest that port competitiveness is strongly linked to integration within cohesive maritime regions, where advanced infrastructure generates clear centers of attraction, while technological and security gaps hinder integration in other areas.

Overall, Arab port competitiveness reflects a complex interaction among economic growth, operational efficiency, and security stability. Spatial mapping of these factors identifies regions of

<sup>2</sup> Dock time = the time a ship remains at the berth.

<sup>3</sup> Waiting time: the time a ship spends waiting for its turn before docking.

strength and weakness and helps direct maritime investment toward areas best positioned for future growth.

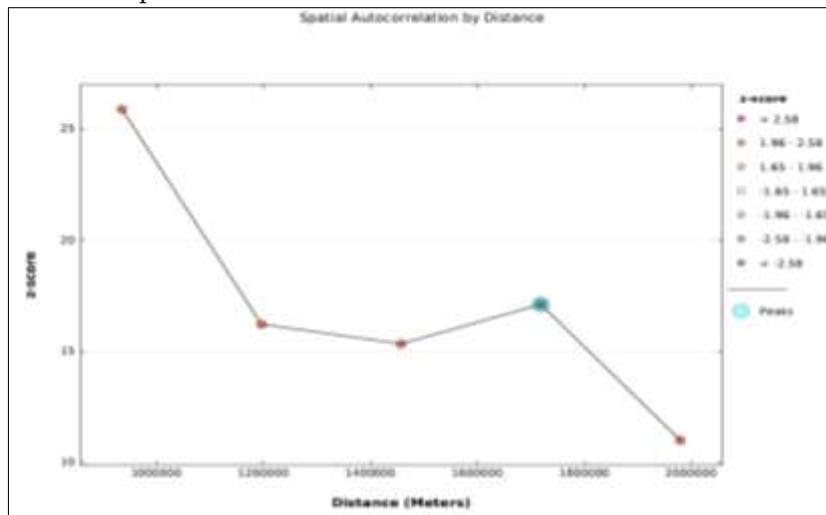


Figure 2: Spatial Incremental Analysis Index for Arab Ports.

**3.3. Key Performance Measures and Their Impact on Port Attractiveness**

Key performance metrics—critical indicators of operational efficiency and competitiveness—substantially influence the attractiveness of Arab commercial ports. These metrics include response

time, storage and handling capacity, navigational performance, and other measures examined in this study; together they evaluate a port’s ability to manage cargo flows efficiently. Working in concert, these indicators enhance overall port performance, a decisive factor for global shipping lines and a catalyst for regional economic growth.

Table 2: Correlation Matrix Between the Different Indicators Measured on Arab Ports.

Indicator	1	2	3	4	5	6	7	8	9	10	11
1. TEU Throughput	1.00										
2. Port Charges (USD)	0.60	1.00									
3. Waiting Time (Days)	-0.39	-0.41	1.00								
4. Berth Length (m)	0.72	0.82	-0.49	1.00							
5. Number of Berths	0.86	0.72	-0.41	0.93	1.00						
6. GPI (Security Stability)	-0.37	-0.39	0.89	-0.45	-0.38	1.00					
7. LPI (Logistics Performance)	0.45	0.56	-0.84	0.57	0.48	-0.78	1.00				
8. Number of Connections	0.87	0.84	-0.48	0.95	0.96	-0.45	0.57	1.00			
9. Storage Capacity	0.64	0.52	-0.60	0.65	0.56	-0.53	0.67	0.65	1.00		
10. Maritime Accidents	-0.28	-0.34	0.73	-0.35	-0.25	0.69	-0.79	-0.34	-0.54	1.00	
11. Infrastructure Quality	0.49	0.66	-0.81	0.64	0.51	-0.74	0.93	0.63	0.77	-0.78	1.00

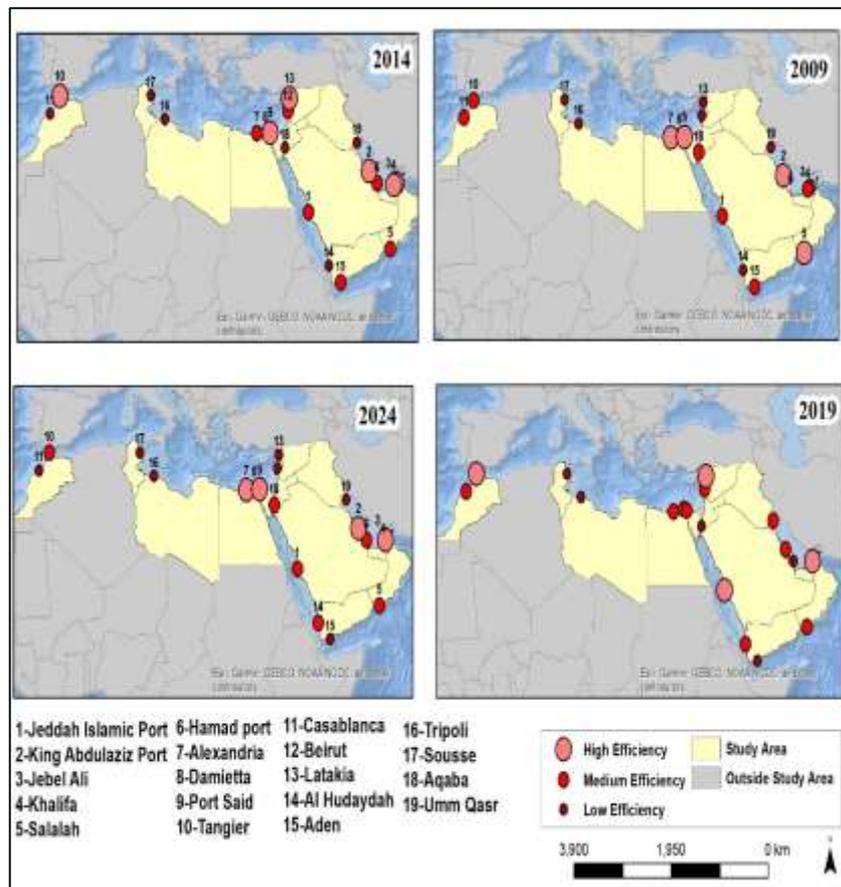
The Pearson correlation matrix reveals a network of relationships that clarify how Arab ports function within their spatial and economic contexts.

Infrastructure—measured by berth length and number—shows a strong positive correlation with operational efficiency, as indicated by the Logistics

Performance Index (LPI) and the number of ship calls. This suggests that structural expansion not only increases physical capacity but also improves logistics flow and attracts greater shipping traffic, consistent with the role of hub ports located near

levels: intensive usage increases the likelihood of accidents, making ports in high-density shipping areas more vulnerable to such risks.

Overall, the correlation matrix provides more than statistical coefficients: it maps how Arab ports



major international shipping routes.

Conversely, waiting time serves as an indicator of port readiness: ports that expanded berths or invested in infrastructure generally experience reduced congestion. In some cases, higher fees are associated with shorter waiting times, implying that charges may reflect the level of service and investment in operational efficiency.

High infrastructure quality does not automatically translate into superior logistics performance in insecure environments. The observed negative relationship between the Global Peace Index (GPI) and infrastructure implies that stability is a prerequisite for converting physical assets into operational capacity; political instability or fragility can undermine a port's competitiveness despite substantial infrastructure.

Additionally, the positive association between storage/handling capacity and maritime accidents highlights operational pressures at high utilization

interact with their economic and spatial environments. Structural expansion tends to enhance efficiency and vessel attraction, security stability improves the returns on infrastructure investment, and political fragility or instability can negate the advantages of otherwise advanced physical assets.

### 3.4. Analysis Of Time Trends for Each Indicator

Using the database described in the methodology, composite indicators were constructed to capture port efficiency across both temporal and spatial dimensions. To reduce the impact of short-term annual fluctuations, consecutive five-year averages were calculated for 2009–2024, providing a more stable assessment of development trends. Figure 3 depicts the repositioning of Arab ports over these intervals, highlighting those that have strengthened their competitive standing and those that have declined within the regional port network.

*Figure 3: Ranking The Spatial Efficiency of Arab Ports From 2009 To 2024 Based on The Study Indicators.*

The data indicate that ports such as Hamad (Qatar) and Jebel Ali (UAE) strengthened their positions through strategic investments that improved efficiency indicators by 32 and 5 points, respectively. Other ports, including Hodeidah, recorded more modest gains (+9 points) despite challenging geopolitical conditions. By contrast, Sousse (-10 points), Jeddah Islamic (-6 points), and Salalah (-4 points) experienced declines, reflecting regional competition and shifting shipping patterns.

Declines at Jeddah Islamic and Port Said are attributable not only to internal operational or investment shortcomings but also to broader geopolitical factors that govern international shipping lanes. Access to these ports requires transiting the Bab al-Mandab Strait, a strategic corridor whose instability—exacerbated by the political situation in Yemen—directly affects maritime traffic. In contrast, Gulf hubs such as Jebel Ali, Khalifa, and King Abdulaziz benefit from more secure sea routes to Asia that do not require passage through this strait, providing a competitive advantage.

This contrast underscores the geostrategic dimension of port efficiency: performance is shaped not only by operational metrics but also by geographic location and the regional stability of sea lanes.

Temporally, the 2009–2014 period experienced the largest collective improvement (Table 3), driven by expansion projects and operational reforms. The 2014–2019 interval was relatively stable. The global downturn associated with the COVID-19 pandemic in 2019–2020 likely contributed to stagnation in growth indicators. The most recent period, 2019–2024, has been more volatile, with some ports consolidating gains while others lost market share.

From a spatial perspective, the results confirm that ports situated on major international sea lanes—particularly those in the Gulf and Morocco—retained a relative advantage over ports on the periphery of these networks, highlighting the important role of geography in shaping port competitiveness.

### ***3.5. Integrated Analysis of Arab Port Efficiency Indicators In Their Temporal And Spatial Dimensions (2009-2024)***

The integrative analysis of Arab port efficiency indicators for 2009–2024 demonstrates that port attractiveness is not determined by a single factor but

by the interaction of throughput, operational capacity, infrastructure, security, and institutional governance. Ports receiving sustained strategic investment—such as Jebel Ali and Tangier—recorded concurrent increases in handling volume (TEU), vessel calls, and improvements in waiting times and the Logistics Performance Index (LPI). By contrast, ports operating in politically unstable environments—such as Beirut and Aden—experienced persistent declines in efficiency despite low tariffs and fees, as instability and security deficits (measured by the Global Peace Index, GPI) undermined competitiveness.

There are pronounced spatial disparities. Ports in the Arabian Gulf and Morocco have emerged as regional hubs within the global maritime network, driven by political stability and strong integration with their hinterlands<sup>4</sup>. Several Eastern Mediterranean and Red Sea ports, however, suffered relative decline due to security challenges and institutional weaknesses. Temporally, the 2014–2019 period corresponds to waves of expansion and modernization of berths and equipment, while the post-2019 downturn aligns with renewed political and security disruptions that eroded earlier gains.

These findings indicate that geographic location alone is insufficient to secure port attractiveness. Competitive performance results from a composite of structural investment, effective governance, political stability, and seamless integration into global transport networks. Ports that successfully align these dimensions consolidate their roles as pivotal nodes in international trade; those that do not remain vulnerable to decline notwithstanding their geographic or material advantages.

Accordingly, building and sustaining port competitiveness in the region requires an integrative strategy that addresses both spatial and temporal dimensions—combining targeted capital investment, institutional reform, security stabilization, and improved connectivity to global and regional supply chains.

It is clear from the integrative analysis that the attractiveness of Arab ports is not the product of a single element, but rather the result of a complex interaction between structural investment, operational efficiency, security stability, and network integration. The results showed that ports that were able to harmonize these dimensions consolidated their position as pivotal centers in global trade, while

<sup>4</sup> Hinterland: The inland area connected to the port, rather than the foreland: the maritime domain facing the port and its associated shipping lanes.

ports that lacked one of these elements remained hostage to decline, despite their geographical location or material capabilities, which confirms that building port competitiveness in the region requires an integrative vision that addresses both spatial and temporal dimensions at the same time.

**3.6. Dynamics Of Temporal and Spatial Change in The Efficiency of Arab Ports (2009-2024)**

The study analyzes the temporal and spatial

changes in the efficiency of Arab ports, revealing a divergent trend between rising and falling ports; the average efficiency of all ports increased from 29.3 points in 2009 to a peak of 32 points in 2014, then gradually declined to 30.8 by 2024. This trend reflects the dual impact of investment waves and subsequent pressures, while the standard deviation indicates a relative convergence in performance levels from 2009 to 2019, before the gap widens again in 2024, highlighting the growing disparity between pivotal ports and those that are less prepared (Figure 4).

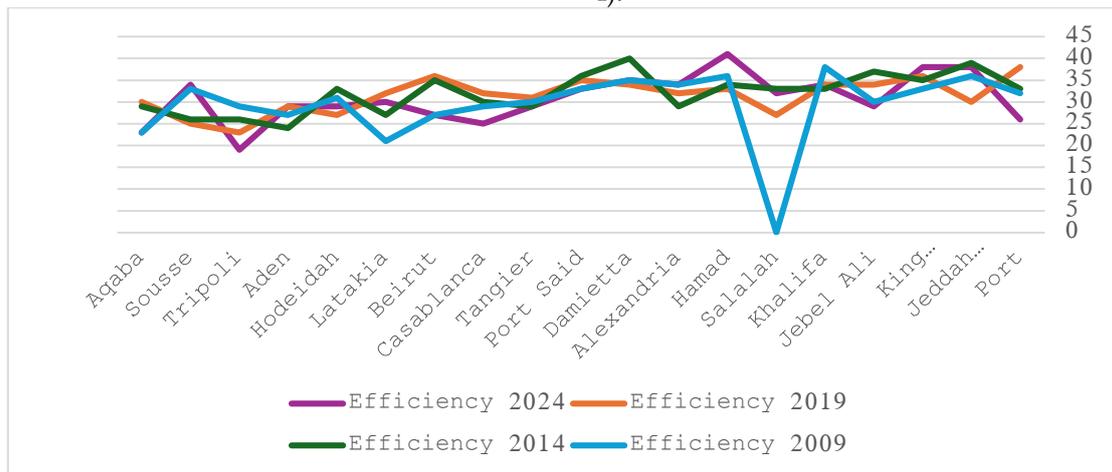


Figure 4: Average Efficiency of Arab Ports From 2009 To 2024.

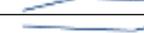
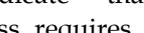
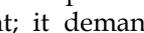
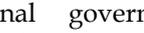
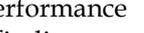
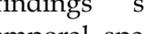
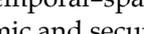
The data show that ports such as Hamad (Qatar) and Jebel Ali (UAE) strengthened their positions through strategic investments that improved efficiency indicators by 32 and 5 points, respectively. Other ports, such as Hodeidah, recorded a modest improvement (+9 points) despite difficult geopolitical conditions. In contrast, declines in Sousse (-10 points), Jeddah Islamic (-6 points), and Salalah (-4 points) reflect the impact of regional competition and shifting shipping patterns.

Notably, the declines in efficiency at both Jeddah Islamic Port and Port Said are driven not only by internal operational or investment factors but also by geopolitical dynamics that govern international shipping lanes. Access to these ports requires transit through the Bab al-Mandab Strait, a strategic corridor whose stability or disruption directly affects maritime trade. The unstable political situation in Yemen has heightened this corridor’s vulnerability and reduced ship flows. By contrast, Gulf ports such as Jebel Ali, Khalifa, and King Abdulaziz benefit

from more secure sea routes to Asia that avoid this strait, providing an additional competitive advantage. This contrast highlights the geostrategic aspect of port efficiency, where operational indicators and geographic exposure to regional sealane stability shape performance.

Temporally, the 2009–2014 period saw the largest collective improvements (Table 3), driven by expansion projects and operational reforms. The 2014–2019 interval was comparatively stable. The global economic downturn associated with the COVID-19 pandemic in 2019–2020 likely contributed to stagnating growth indicators. Finally, the 2019–2024 period was more volatile, with some ports strengthening their positions while others lost market share. From a spatial perspective, the findings confirm that ports located on major sea lanes—particularly in the Gulf and Morocco—retained a relative advantage over more peripheral ports, highlighting the significant role of geography in shaping port competitiveness.

Table 3: Average Efficiency of Arab Ports Over 15 Years.

Country	Port	Port Performance Development Index	Efficiency 2009	Efficiency 2014	Efficiency 2019	Efficiency 2024
Saudi Arabia	Jeddah Islamic		32	33	38	26
Saudi Arabia	King Abdulaziz – Dammam		36	39	30	38
UAE	Jebel Ali		33	35	36	38
UAE	Khalifa		30	37	34	29
Oman	Salalah		38	33	34	34
Qatar	Hamad		0	33	27	32
Egypt	Alexandria		36	34	33	41
Egypt	Damietta		34	29	32	34
Egypt	Port Said		35	40	34	35
Morocco	Tangier		33	36	35	33
Morocco	Casablanca		30	29	31	29
Lebanon	Beirut		29	30	32	25
Syria	Latakia		27	35	36	27
Yemen	Hodeidah		21	27	32	30
Yemen	Aden		31	33	27	29
Libya	Tripoli		27	24	29	29
Tunisia	Sousse		29	26	23	19
Jordan	Aqaba		33	26	25	34
Iraq	Umm Qasr		23	29	30	23

These dynamics indicate that achieving sustainable competitiveness requires more than a single wave of investment; it demands long-term policies that integrate infrastructure, logistics systems, and institutional governance while reducing regional performance disparities. Consequently, these findings support the development of dynamic temporal-spatial maps that link spatial shifts to economic and security variables, thereby informing more precise maritime transportation planning across the region.

The results indicate that Arab port efficiency followed a non-linear trajectory, marked by fluctuations driven by investment, political, and spatial factors. Ports that consolidated their positions did so by investing in infrastructure and integrating services with global transportation networks, while ports that remained unstable or underinvested experienced measurable declines. These patterns illustrate the value of adopting a continuous, dynamic approach to port planning and development.

### 3.7. Interpretation And Analysis of the LSCI

The linear regression analysis of the LSCI reveals spatial and temporal dimensions that go beyond the mere quantitative correlation between operational indicators, as the model was built based on two main variables: handling volume (TEUs) and port calls, as they represent the most capable elements of port dynamism in the maritime transportation network. The results showed that the relationship between LSCI and handling volume is somewhat negatively linear, indicating that higher handling volume alone does not always reflect greater integration into maritime networks. This feature is explained in light of the different nature of some ports; there are ports characterized by high cargo volumes but that mainly operate as terminal ports to serve limited local

markets, which reduces the value of their connectivity index compared to smaller ports that are denser in shipping lines.

The number of ship visits was found to be the most decisive factor in explaining the variation in LSCI, as this variable directly reflects the level of the port's network connectivity with other maritime centers. This highlights the important role played by hub ports located on global trade routes, as the density of regular cruises confers them an advanced position in the connectivity index, even if they do not achieve the highest values in handling volume, which shows how LSCI is not just a reflection of operational capacity but a strategic indicator of the degree of integration into the international maritime system.

The high coefficient of determination ( $R^2 = 0.94$ ) shows the strong coherence between the model and the field, reflecting that most of the variation in the LSCI can be explained by these two variables. But the results' true value is in their geography, not just their statistics. They confirm that ports that are located at the nodes of major trade corridors and succeed in attracting multiple shipping companies have a much higher attractiveness than those that rely on expanding berths or increasing storage capacities without achieving a similar network presence.

This analysis leads to the fundamental conclusion that strengthening the position of Arab ports in the global maritime system is not achieved by focusing only on increasing handling volume but also by enhancing network connectivity and integration with global transportation networks. A port that can be a link between different regions and attract a larger number of flights and shipping lines increases its geographical and strategic value at the same time. Thus, the LSCI represents an important analytical tool to understand how Arab ports interact with the dynamics of maritime globalization, making its

results of direct importance in the field of transportation geography and research infrastructure planning.

#### 4. CONCLUSION AND RECOMMENDATIONS

This study demonstrates that the attractiveness of Arab ports is not determined solely by geographic location or throughput; rather, it results from a complex interaction among infrastructure quality, operational efficiency, security and political stability, and institutional governance. The findings indicate that ports that adopt long-term strategies—such as investing in berth capacity, enhancing logistics services, and strengthening connectivity with global shipping lines—can become pivotal nodes within the international maritime system. By contrast, ports affected by geopolitical instability or deficiencies in corporate governance lose competitive standing despite having physical capacity or strategic location. **The results can be summarized in the following points:**

Between 2009 and 2014, the average efficiency of Arab ports experienced a relative increase, which was followed by periods of sharp divergence between ports until 2024.

- Gulf ports (Jebel Ali, Khalifa, Hamad, and King Abdulaziz) and Morocco (Tanger Med and Casablanca) have emerged as leading regional hubs, thanks to ongoing investments in expansion and digitization.
- Eastern Mediterranean ports (Beirut, Latakia) and Yemen (Hodeidah, Aden) have seen a significant decline due to conflicts and political instability.
- Jeddah Islamic Port and Port Said's dependence on traffic through Bab al-Mandab made them more vulnerable to geopolitical fluctuations in Yemen, which negatively impacted their attractiveness.
- Up until 2019, there was a relative convergence in the efficiency levels between the ports, but

by 2024, the differences widened again.

The best relationship is between infrastructure factors (like the length and number of berths) and the amount of cargo handled (TEU), while weak security measures (GPI) directly hinder performance.

**The study divided the recommendations into three axes:**

##### 1. Geospatial Recommendations:

- Strengthening the security and stability of the Bab al-Mandab Strait as a geographical fulcrum that affects the efficiency of all Red Sea ports.
- Investing in the development of Red Sea and Eastern Mediterranean ports to reduce the gap with Gulf and Moroccan ports, thus achieving a spatial balance in port attractiveness.
- Activating the role of peripheral ports by integrating them with land and rail transportation networks to expand their regional reach.

##### 2. Operational Logistics Recommendations:

- Invest in digitization and automation to reduce waiting times and enhance the efficiency of handling operations.
- Adopt risk management and maritime safety systems to reduce accident rates.
- Developing flexible pricing policies that balance competitive attractiveness and financial return.

##### 3. Strategic-Developmental Recommendations

- Build regional partnerships to enhance security stability in vital sea lanes.
- Develop long-term national and regional strategies that adopt time-series analyses to monitor shifts in efficiency.
- Direct investments in port infrastructure integrated with land and air transportation to ensure the competitive position's sustainability.

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