Port Logistics Efficiency, Multi-modal Connectivity and Regional GDP in South-Western Bangladesh: Evidence from Mongla Port, 2015–2025

Ефективність портової логістики, мультимодальна транспортна сполученість та регіональний валовий внутрішній продукт на південному заході Бангладеш: результати дослідження порту Монгла за 2015–2025 роки

Md Sohel Rana [A]
Assistant Professor, Department of Business Administration, e-mail: msohel@nwu.ac.bd, ORCID ID: https://orcid.org/0009-0000-8644-729X

Sabit Al Farabi [A]
BBA in Finance, e-mail: farabisabit8@gmail.com, ORCID ID: https://orcid.org/0009-0004-6596-078X

Shaikh Taufikul Islam [B]
Assistant Professor, Department of Business Administration, e-mail: taufikulislam@bauet.ac.bd, ORCID ID: https://orcid.org/0009-0009-8983-1348

R. H. M. Aftabuzzaman [C]
B.Sc. in Textile Engineering Graduate, e-mail: rhmaftab@gmail.com, ORCID ID: https://orcid.org/0009-0009-6700-7657

Tanbir Hossain [A]
Corresponding author: BSS, MSS in Economics, MA in Sustainable Development Management, Head and Senior Lecturer, Department of Economics, Assistant Professor, e-mail: tanbir.nwustu@yahoo.com, ORCID ID: https://orcid.org/0000-0003-1935-3001

Мд Сохел Рана [A]
доцент кафедри бізнес-адміністрування, e-mail: msohel@nwu.ac.bd, ORCID ID: https://orcid.org/0009-0000-8644-729X

Сабіт Аль-Фарабі [A]
бакалавр бізнес-адміністрування за спеціалізацією "Фінанси", e-mail: farabisabit8@gmail.com, ORCID ID: https://orcid.org/0009-0004-6596-078X

Шайх Тауфікул Ісламм [B]
доцент кафедри бізнес-адміністрування, e-mail: taufikulislam@bauet.ac.bd, ORCID ID: https://orcid.org/0009-0009-8983-1348

Р. Х. М. Афтабуззаман [C]
бакалавр наук у галузі текстильної інженерії, e-mail: rhmaftab@gmail.com, ORCID ID: https://orcid.org/0009-0009-6700-7657

Танбір Хоссейн [A]
Corresponding author: Бакалавр соціальних наук та магістр соціальних наук за спеціалізацією "Економіка", магістр із менеджменту сталого розвитку, доцент e-mail: tanbir.nwustu@yahoo.com, ORCID ID: https://orcid.org/0000-0003-1935-3001

[A] North Western University, Khulna, Bangladesh
[B] Bangladesh Army University of Engineering & Technology (BAUET), Bangladesh
[C] Primeasia University, Bangladesh

[A] Північно-Західний університет, м. Кхулна, Бангладеш
[B] Армійського університету інженерії та технологій Бангладеш (BAUET), Бангладеш
[C] Університету Праймасія, Бангладеш

Received: September 1, 2026 | Revised: October 10, 2026 | Accepted: October 31, 2026

UDC 656.615:656.025.4:332.1(549.3)

DOI: https://doi.org/10.33445/sds.2026.16.5.51

Purpose. To examine the relationships between port logistics efficiency, multimodal transport connectivity and regional gross domestic product (GDP) in south-western Bangladesh, using Mongla Port as a case study for 2015–2025.

Methodology. The study employs quantitative analysis of annual secondary data (n = 11) obtained from the Mongla Port Authority and Bangladesh Bureau of Statistics. Two ordinary least squares (OLS) regression models assess the associations between navigational depth, technological adaptation, administrative delays, vessel turnaround time, cargo throughput, post-Padma Bridge connectivity and regional GDP. Diagnostic tests and alternative specifications assess the robustness of the estimates.

Findings. Both regression models demonstrate joint statistical significance ($p = 0.0302$ and $p = 0.0013$, respectively). However, none of the individual explanatory coefficients is statistically significant at the 5% level. Channel depth is negatively associated with vessel turnaround time, while cargo throughput and post-bridge connectivity exhibit positive associations with regional GDP. Including a linear time trend reverses the estimated post-bridge coefficient, indicating specification sensitivity.

Мета дослідження. Оцінити взаємозв'язки між ефективністю портової логістики, мультимодальною транспортною сполученістю та регіональним ВВП південно-західного Бангладеш на прикладі порту Монгла у 2015–2025 роках.

Методи дослідження. Проаналізовано 11 річних спостережень за даними Адміністрації порту Монгла та Статистичного бюро Бангладеш. Побудовано дві регресійні моделі методом найменших квадратів (OLS). Перша характеризує зв'язок тривалості обслуговування суден із глибиною каналу, технологічною адаптацією персоналу й адміністративними затримками; друга — зв'язок регіонального ВВП із вантажообігом, тривалістю обслуговування суден та індикатором періоду після відкриття мосту Падма. Проведено діагностичні тести й перевірку стійкості оцінок.

Результати дослідження. Обидві моделі статистично значущі загалом (p = 0,0302 та p = 0,0013 відповідно), проте жоден окремий коефіцієнт не є значущим на рівні 5 %. Виявлено від'ємний зв'язок глибини каналу з тривалістю обслуговування суден і додатні зв'язки вантажообігу та післямостового періоду з регіональним ВВП. Додавання часового тренду змінює знак коефіцієнта післямостового періоду.

Практична значущість. Підтримання портової інфраструктури,

Practical implications. The findings identify port infrastructure maintenance, administrative efficiency and multimodal connectivity as potential policy priorities, although their economic effects require further empirical verification.

Limitations. The small sample, trending GDP series and absence of a comparison region restrict statistical inference and prevent causal interpretation.

Paper type. Original research article.

Обмеження дослідження. Мала вибірка, трендовість номінального ВВП і відсутність контрольного регіону не дозволяють встановити причинність.

Тип статті. Оригінальна наукова стаття.

Keywords: logistics efficiency, secondary ports, Mongla Port, vessel turnaround time, channel draft, multimodal connectivity, regional GDP, Padma Bridge, OLS regression.

Ключові слова: ефективність логістики; другорядні морські порти; порт Монгла; тривалість обслуговування суден; глибина судноплавного каналу; мультимодальна транспортна сполученість; регіональний валовий внутрішній продукт; міст Падма; регресія методом найменших квадратів.

Introduction

In the contemporary global economy, the development of secondary maritime gateways may contribute to more balanced regional development and greater trade competitiveness. In developing maritime economies, secondary ports increasingly serve not only as shipping facilities but also as potential catalysts for regional economic diversification. Concentrating maritime traffic in primary gateway ports can exacerbate congestion, while insufficient investment may leave secondary coastal regions with underused facilities and persistent infrastructure constraints.

In Bangladesh, congestion at major ports and vessel waiting times can increase logistics costs and disrupt trade. Earlier policy assessments, including the Asian Development Bank (2011), highlighted the importance of infrastructure investment and institutional improvements at alternative ports in responding to changes in international shipping.

The relationship between maritime logistics efficiency and regional economic performance is particularly relevant to Mongla Port. Islam and Haider (2016) reported substantial inefficiencies in its operations, associating underutilized capacity with hinterland constraints and fragmented management. Earlier work by Farleigh (1984) and the Center for Research and Training Services (2015) also identified channel siltation and navigational restrictions as obstacles to accommodating larger, more heavily loaded vessels and maintaining reliable port operations.

Monios (2017) noted that ports with navigational draft restrictions may remain dependent on feeder services unless dredging and channel improvement programs are sustained. Efficient supply chains also require adequate terminal equipment and support vessels. Hasan and Khondoker (2022) identified limitations in Mongla Port's service fleet and supporting infrastructure, including pilotage services, cargo-handling equipment and tugboat capacity, as potential contributors to longer vessel turnaround times.

Reducing operational delays can lower inventory holding costs and improve supply-chain reliability. Limão and Venables (2001) emphasized that inadequate transport infrastructure increases trade costs and limits access to markets. At a broader scale, road, rail, and inland waterway connections extend a port's economic hinterland. The Japan International Cooperation Agency (2017) likewise highlighted the importance of intermodal connectivity for trade flows and the effective reach of port services.

The opening of the Padma Bridge and the development of south-western transport corridors have altered the accessibility of Mongla Port. Ali et al. (2022) discussed the bridge's potential contribution to mobility and connectivity. Improved access may make Mongla more attractive for cargo moving to and from Dhaka, although the extent of any resulting shift in traffic requires empirical verification. More generally, Lakshmanan (2011) argued that transport infrastructure can generate wider economic benefits through improved market access and related activity.

Previous research has frequently examined logistics performance at the national level, while evidence linking port-specific operating indicators to regional economic outcomes remains limited, particularly for secondary ports such as Mongla. This study addresses that gap by combining annual

data on channel draft, the Human–Technology Gap, administrative clearance delays, vessel turnaround time and cargo throughput with regional GDP and an indicator for the period following the opening of the Padma Bridge. The dataset covers 2015–2025. Given the small sample and pronounced trend in regional GDP, the analysis focuses on statistical associations and their sensitivity to alternative specifications rather than causal identification.

This study aims to examine the associations among port-specific logistics indicators, cargo throughput, vessel turnaround time, the period following the opening of the Padma Bridge, and regional GDP in the Khulna Division of southwestern Bangladesh.

A. **How are port operating conditions and navigational characteristics associated with logistics efficiency at Mongla Port?**

The first research question examines whether navigable channel depth, delays associated with technological adaptation and administrative clearance time are related to vessel turnaround time. These indicators represent physical, organizational and procedural dimensions of port operations.

B. **How are port logistics indicators and the post-Padma Bridge period associated with the level of regional GDP?**

Додано примітку [1]: Post-Padma Bridge Construction Period

Multimodal hinterland connectivity involves the integration of road, rail, and inland waterway networks with port facilities. Improved connections may reduce travel times and transport costs. In this study, however, connectivity is represented only by an indicator for the years following the Padma Bridge's opening; it is not measured directly. The second research question therefore concerns the statistical associations between cargo throughput, vessel turnaround time, the post-bridge period and GDP in the Khulna Division.

Literature Review

The trade and transport literature identifies port logistics as an important component of market access and economic activity. Maritime transport can reduce trade frictions and support participation in global value chains (Notteboom & Rodrigue, 2009). Conversely, administrative and technical constraints at secondary ports such as Mongla may raise local transaction costs and limit the economic opportunities available to surrounding regions.

Port performance depends not only on physical capacity but also on institutional arrangements and administrative procedures. Documentation requirements, customs processes and limited information sharing can prolong vessel clearance and turnaround times (Mkocha & Mwisila, 2025). Infrastructure deficiencies and weak administrative coordination may reinforce one another. Oberhofer et al. (2021) described border-related delays as a barrier to trade, while Kumari and Bharti (2021) examined the role of bureaucracy in logistics performance. Unpredictable clearance procedures may also complicate scheduling and operational planning (Smith, 2021).

Introducing digital platforms, electronic port systems and integrated databases requires corresponding workforce capabilities. A Human–Technology Gap may arise when employees lack the training needed to use new systems effectively (Brunila et al., 2021). Investment in human capital is therefore an important complement to technological upgrading. The resource-based perspective emphasizes the value of organizational capabilities (Barney, 1991), while Neugebauer et al. (2024) discussed challenges associated with digital technologies in port settings. Recent research also highlights the need to align digitalization with organizational readiness and employee skills (Pavat et al., 2026).

Secondary ports may also face competitive disadvantages when tariffs and administrative charges are opaque or unpredictable. Such uncertainty can complicate long-term contracting and investment decisions (Brooks et al., 2022). Transparent governance, accountability and performance measurement can help improve port administration. Results-based management

approaches link operational objectives to measurable indicators, such as crane productivity and clearance times (Wudhikarn et al., 2018). Clear tariff rules can reduce discretionary practices and transaction costs (Pomfret & Sourdin, 2010), while single-window systems may simplify documentation and coordination across agencies (World Bank, 2013).

Environmental compliance has also become increasingly relevant to port competitiveness and market access. The green-port literature emphasises the need to balance trade facilitation with responsible environmental management (Acciaro et al., 2014). Potential measures include staff training, emissions monitoring and greener supply-chain practices (Mahmud et al., 2024). When supported by transparent governance, environmental management may strengthen the resilience of port operations and regional supply chains (Tanjung, 2026).

Materials and Methods

1. Research Design

This study uses a quantitative design based on secondary annual time-series data to examine associations among port logistics efficiency, the post-Padma Bridge period and regional economic performance in south-western Bangladesh.

The analysis covers 2015–2025 and comprises 11 annual observations. This period includes years before and after the opening of the Padma Bridge in 2022.

The empirical analysis comprises two complementary ordinary least squares (OLS) regression models.

Model 1 examines associations between port infrastructure, technological adaptation, administrative procedures and vessel turnaround time.

Model 2 examines associations between cargo throughput, vessel turnaround time, the post-Padma Bridge period and regional gross domestic product (GDP).

Given the small sample and the pronounced trend in regional GDP, the analysis is exploratory. Coefficients are interpreted as conditional statistical associations, not causal effects.

2. Data Sources and Variables

The study draws on secondary data from institutional sources, including the Mongla Port Authority (MPA) and the Bangladesh Bureau of Statistics (BBS).

Port indicators are drawn from MPA administrative records, operational reports and hydrographic information. Regional GDP figures are sourced from the BBS national accounts statistics.

The dataset includes the following variables:

- Regional GDP: GDP of the Khulna Division, measured in billions of Bangladeshi taka (BDT) at current market prices.
- Cargo Throughput: Annual cargo volume handled at Mongla Port, measured in millions of metric tonnes.
- Vessel Turnaround Time (VT): Average time required to complete vessel-related port operations, measured in hours.
- Channel Draft (CD): Navigable depth of the port access channel, measured in metres.
- Human–Technology Gap (HTG): Operational delays attributed to workforce adaptation to digital port-management systems, measured in hours.
- Administrative Friction (AF): Time associated with administrative and customs-clearance procedures, measured in days.
- Hinterland Connectivity (HC): A binary indicator distinguishing the periods before and after the opening of the Padma Bridge.

The post-bridge indicator distinguishes the following periods:

$$HC_t = 0 \text{ for 2015–2021;}$$
$$HC_t = 1 \text{ for 2022–2025.}$$

This variable identifies the post-bridge period; it does not directly measure the quality or intensity of multimodal connectivity. Its coefficient must therefore not be interpreted as the causal effect of the Padma Bridge.

Each variable has 11 annual observations. Table 1 presents the dataset.

3. Model 1: Port Logistics Efficiency

Model 1 examines associations between navigational conditions, technological adaptation, administrative procedures and vessel turnaround time.

The model is specified as follows:

$$VT_t = \beta_0 + \beta_1 CD_t + \beta_2 HTG_t + \beta_3 AF_t + \varepsilon_t. \quad (1)$$

where: VT_t – average vessel turnaround time in year t, hours;
β_0 – intercept term;
$\beta_1, \beta_2, \beta_3$ – regression coefficients;
CD_t – navigable channel depth in year t, metres;
HTG_t – Human–Technology Gap in year t, hours;
AF_t – Administrative Friction in year t, days;
ε_t – random error term.

The dependent variable, vessel turnaround time, serves as an operational indicator of port logistics efficiency.

The explanatory variables represent physical infrastructure, technological adaptation and administrative procedures.

Each estimated coefficient describes a conditional association with vessel turnaround time, holding the other included variables constant.

A negative coefficient for channel draft would indicate an association between greater navigable depth and shorter turnaround times. Positive coefficients for technological and administrative delays would be consistent with longer turnaround times.

The directions and statistical significance of these associations are determined empirically.

4. Model 2: Regional Economic Performance

Model 2 examines associations among port logistics indicators, the post-Padma Bridge period and regional GDP.

The model is specified as follows:

$$GDP_t = \alpha_0 + \alpha_1 TP_t + \alpha_2 VT_t + \alpha_3 HC_t + \mu_t. \quad (2)$$

where: GDP_t – regional GDP of the Khulna Division in year t, billion BDT at current market prices;
α_0 – intercept term;
$\alpha_1, \alpha_2, \alpha_3$ – regression coefficients;
TP_t – annual cargo throughput, million metric tonnes;
VT_t – average vessel turnaround time, hours;
HC_t – binary indicator for the post-Padma Bridge period;
μ_t – random error term.

Regional GDP represents the level of regional economic activity, not its growth rate.

Cargo throughput measures the scale of cargo operations, while vessel turnaround time captures an operational dimension of port efficiency.

The post-bridge indicator distinguishes observations from after the opening of the Padma Bridge from those of earlier years.

The model tests for statistical associations with regional GDP; it does not establish that changes in port operations or connectivity caused changes in regional economic performance.

5. Econometric Estimation

Both models are estimated using ordinary least squares (OLS).

The analysis reports regression coefficients, standard errors, t-statistics and corresponding p-values.

Model fit is assessed using R^2 and adjusted R^2.

The joint significance of the explanatory variables is assessed using the F-test.

Individual coefficients are evaluated using t-tests, with particular attention to the 5% significance level.

With 11 observations and three explanatory variables in each model, there are seven residual degrees of freedom.

Consequently, estimates may be sensitive to individual observations, correlations among regressors and alternative model specifications.

6. Diagnostic Tests

Diagnostic procedures are used to examine the statistical properties of the estimated models.

The Durbin–Watson statistic is reported to assess possible first-order serial correlation in the residuals.

Variance inflation factors (VIFs) are used to examine multicollinearity among the regressors.

The Breusch–Pagan test assesses heteroskedasticity, and the Shapiro–Wilk test assesses residual normality.

Dickey–Fuller unit-root tests are used to examine the stationarity of the continuous time-series variables.

The level-series tests include specifications with an intercept and with an intercept plus a linear trend; first-difference tests include an intercept.

No lagged differences are included because the sample is small.

Monte Carlo simulations are used to obtain critical values for the short series.

With only 11 observations, however, unit-root tests have limited power. Failure to reject the unit-root null hypothesis is therefore inconclusive rather than proof of non-stationarity.

7. Robustness Checks

Alternative specifications are estimated to assess the sensitivity of the associations in Model 2.

First, a linear time trend is added to examine the influence of the upward trend in regional GDP.

Second, a specification with log-transformed regional GDP is estimated to assess sensitivity to the dependent variable's functional form.

The alternative models are compared in terms of coefficient direction, magnitude and statistical significance.

Particular attention is paid to the post-bridge indicator because it is correlated with time and may reflect other developments after 2021.

Changes in coefficient signs or significance across specifications are interpreted as evidence of sensitivity to model specification.

8. Methodological Limitations

The analysis has several methodological limitations.

First, the dataset contains only 11 annual observations, limiting the power of regression estimates and diagnostic tests.

Second, regional GDP is measured at current prices and therefore reflects changes in both output and the price level.

Third, the post-bridge indicator captures the period after the infrastructure project rather than an independently measured change in connectivity.

Fourth, the models omit potentially relevant determinants of regional GDP, including

investment, inflation, national economic conditions and other infrastructure projects.

Finally, the construction of the Human–Technology Gap and Administrative Friction indicators requires more detailed documentation to ensure reproducibility.

These limitations inform the interpretation of the findings. The study is exploratory and does not identify causal effects.

Results

Table 1 presents the annual dataset for Mongla Port, combining operational indicators with regional macroeconomic data for 2015–2025. It provides the basis for the subsequent regression analysis.

Table 1. Annual port logistics indicators and regional GDP, 2015–2025

Fiscal Year	Regional GDP (Billion BDT)	Cargo Throughput (Million Metric Tons)	Vessel Turnaround (Total Hours)	Channel Draft (Meters)	Human-Tech Gap (Delay Hours)	Admin Friction (Clearance Days)	Hinterland Connectivity
2015	1,649.82	4.923	106.8	4	13.8	12	0
2016	1,888.82	5.798	117.36	4	14.9	11	0
2017	2,153.64	7.514	122.16	4.2	17.5	10	0
2018	2,453.02	9.716	125.04	4.2	21.2	9	0
2019	2,771.23	11.315	106.56	4.5	23.6	8	0
2020	3,455.81	11.037	107.76	4.5	25	13	0
2021	3,847.90	11.945	98.88	4.8	22.1	7	0
2022	4,329.17	11.392	87.6	5	18	6	1
2023	4,894.72	9.905	79.2	6.5	14.2	5	1
2024	5,481.00	10.868	88.8	7.5	11.5	4	1
2025	6,011.38	8.531	79.68	7.5	9.8	3	1

Source: Authors' compilation based on Mongla Port Authority operational reports and Bangladesh Bureau of Statistics data (2026).

Table 2 reports the Model 1 OLS estimates for associations between channel draft, workforce adaptation delays, administrative clearance time and vessel turnaround time. The estimates describe conditional relationships rather than established causal effects.

Table 2. OLS estimates for Model 1: Vessel turnaround time

Variable	Parameter	Coefficients	Standard Error	t Stat	P-value
Intercept	β_0	132.329839	49.9466727	2.649423	0.032969
Channel Draft (Meters)	β_1	-7.4968391	5.521845902	-1.35767	0.216708
Human-Tech Gap (Delay Hours)	β_2	-0.1325707	0.870444199	-0.1523	0.883245
Admin Friction (Clearance Days)	β_3	1.30321698	2.021414821	0.644705	0.539663
Model Diagnostics					
R Square	0.699685593				
Adjusted R Square	0.570979418				
Standard Error	10.68094598				
Observations	11				
F-Statistic	5.436 (p = 0.0302)				

Source: Authors' calculations (2026). Note: The F-test evaluates the joint null hypothesis that all slope coefficients equal zero. The intercept p-value refers only to the intercept.

Table 3 presents the Model 2 OLS estimates of the associations between cargo throughput, vessel turnaround time, and the post-Padma Bridge period and regional GDP. The coefficients should not be interpreted as causal effects.

Table 3. OLS estimates for Model 2: Regional GDP

Variable	Parameter	Coefficients	Standard Error	t Stat	P-value
Intercept	α_0	5139.61502	3179.708917	1.616379	0.150046
Cargo Throughput (Million Metric Tons)	α_1	167.410032	88.79190498	1.88542	0.101355
Vessel Turnaround (Total Hours)	α_2	-35.915679	25.69190988	-1.39794	0.204833
Hinterland Connectivity	α_3	1346.675	806.7688887	1.66922	0.139004
Model Diagnostics					
R Square	0.879091245				
Adjusted R Square	0.827273208				
Standard Error	622.4197064				
Observations	11				
F-Statistic	16.965 (p = 0.0013)				

Source: Authors' calculations (2026). Note: The F-test evaluates the joint null hypothesis that all slope coefficients equal zero. None of the individual slope coefficients is significant at the 5% level.

Results for Model 1

In Model 1, a one-meter increase in channel draft is associated with a 7.497-hour decrease in vessel turnaround time, holding the other variables constant. The coefficient has the expected negative sign but is not statistically significant at the 5% level ($p = 0.217$). Accordingly, the estimate does not establish that deeper channels reduce turnaround times. Greater navigable depth could reduce tidal restrictions, but this mechanism cannot be confirmed from the present results.

The Human–Technology Gap coefficient is −0.133, suggesting a negative conditional association between reported adaptation delays and turnaround time. This direction is contrary to the expected positive association, but the estimate is not statistically significant ($p = 0.883$). Potential explanations include measurement overlap, the construction of the indicator and correlations among regressors; these possibilities cannot be evaluated reliably with 11 observations.

The administrative friction coefficient is 1.303, implying an estimated 1.303-hour increase in vessel turnaround time for each additional day of clearance time, holding other variables constant. The coefficient is expressed in hours per day because the dependent variable and regressor use different units. The estimate is not statistically significant ($p = 0.540$), so it provides insufficient evidence of an independent association between clearance delays and turnaround time.

Model 1 accounts for approximately 70% of the sample variation in vessel turnaround time ($R^2 = 0.6997$; adjusted $R^2 = 0.5710$). The joint F-test rejects the null hypothesis that all three slope coefficients are zero ($F = 5.436, p = 0.0302$). However, none of the individual coefficients is significant at the 5% level. With seven residual degrees of freedom and VIF values of up to 4.89, individual estimates remain imprecise.

Results for Model 2

In Model 2, an additional million tonnes of cargo throughput is associated with an estimated 167.410 billion BDT higher regional GDP, holding the other included variables constant. This coefficient is not statistically significant at either the 5% or 10% level ($p = 0.101$), so the data do not establish a reliable association.

An additional hour of vessel turnaround time is associated with an estimated 35.916 billion BDT lower regional GDP. However, the coefficient is not statistically significant ($p = 0.205$).

Although its sign is consistent with the expectation that longer port stays increase trade costs, the evidence is insufficient to establish a relationship with regional economic activity.

The post-bridge indicator has a coefficient of 1,346.675 billion BDT. Conditional on the other regressors, the model estimates a higher level of regional GDP in 2022–2025 than in 2015–2021. This coefficient is not statistically significant ($p = 0.139$) and must not be interpreted as the effect of the Padma Bridge. The indicator applies only to the final four observations, while GDP rises throughout the sample and the model omits several potential determinants of economic activity. Improved road and rail access could reduce transport frictions, but this study does not establish that mechanism.

Model 2 has $R^2 = 0.8791$ and adjusted $R^2 = 0.8273$; its joint F-test is significant ($F = 16.965$, $p = 0.0013$). Nevertheless, none of the three slope coefficients is individually significant at the 5% level. The high R^2 may partly reflect the common time trend in GDP and the post-bridge indicator rather than a stable structural relationship, as the robustness checks suggest.

Diagnostic tests and robustness checks

The Durbin–Watson statistics are 1.195 for Model 1 and 1.410 for Model 2. With 11 observations and three regressors, the results are inconclusive under conventional 5% bounds; positive serial correlation cannot be ruled out. Model 1 VIFs are 4.89 for channel draft, 1.69 for the Human–Technology Gap and 3.94 for administrative friction. Model 2 VIFs are 1.15 for throughput, 4.53 for turnaround time and 4.28 for the post-bridge indicator, indicating some collinearity but no VIF above five in the baseline models. The Breusch–Pagan tests do not reject homoskedasticity ($p = 0.697$ and $p = 0.162$), and the Shapiro–Wilk tests do not reject residual normality ($p = 0.775$ and $p = 0.772$). These tests have limited power in such a small sample. Dickey–Fuller tests using simulated critical values do not reject a unit root in any of the six level series at the 5% level (critical values: −3.23 with an intercept and −4.00 with an intercept and trend). The regional GDP test statistic is 2.785. In first differences, only administrative friction rejects the unit-root null at 5% (statistic −4.549; critical value −3.27). Vessel turnaround time and log regional GDP yield test statistics of −3.193 and −2.924, respectively, which are below the reported 10% critical value of −2.78. Given the small sample, these findings remain inconclusive regarding stationarity.

Regional GDP is strongly correlated with time ($r = 0.991$), and a linear time trend alone accounts for 98.2% of its sample variation. Adding a time trend to Model 2 raises R^2 to 0.997 and changes the post-bridge coefficient from 1,346.675 to −70.011 billion BDT ($p = 0.680$). The turnaround coefficient remains statistically insignificant ($p = 0.364$), while the throughput coefficient becomes negative (−93.656; p = 0.006). These estimates warrant caution because the trend is correlated with the other regressors, the reported VIF reaches 9.54 and only six residual degrees of freedom remain. In a log-GDP specification, the post-bridge coefficient is 0.356 ($p = 0.138$), while the throughput coefficient is 0.079 ($p = 0.012$), corresponding to approximately an 8% difference in GDP per additional million tonnes of throughput, conditional on the model. Taken together, these checks demonstrate substantial specification sensitivity. The coefficients are descriptive associations, not evidence that transport infrastructure has—or lacks—a causal economic effect. The Dickey–Fuller results also warrant caution when interpreting the level regressions: regional GDP does not reject a unit root in levels ($t = 2.785$) or first differences ($t = -2.025$).

Discussion

Comparison with previous studies

Several coefficient signs are consistent with the literature, although most estimates are not statistically significant. Navigational restrictions and siltation have been discussed as constraints at Mongla Port (Farleigh, 1984; Center for Research and Training Services, 2015; Monios, 2017). The

negative channel-draft coefficient is consistent with this account, but its uncertainty prevents a firm conclusion. The positive coefficient for administrative clearance time is consistent with research on trade-related delays (Oberhofer et al., 2021; Kumari & Bharti, 2021). Conversely, the negative Human–Technology Gap coefficient differs from expectations based on studies of digital adoption (Brunila et al., 2021; Neugebauer et al., 2024). Because the result is statistically insignificant and the indicator's construction is insufficiently documented, it should not be interpreted as evidence against those studies.

For Model 2, the positive baseline coefficients for throughput and the post-bridge period are broadly consistent with arguments that transport connectivity can support regional economic activity (Limão & Venables, 2001; Lakshmanan, 2011; Japan International Cooperation Agency, 2017). However, the present dataset supports substantially weaker inference, and the post-bridge coefficient changes sign after a time trend is introduced. Unlike Islam and Haider (2016), who evaluated Mongla Port's operational performance, this study relates port indicators to a regional macroeconomic outcome. The findings are therefore not directly comparable.

Limitations and directions for further research

This study has several limitations. First, 11 annual observations provide few degrees of freedom and limited statistical power, making the estimates sensitive to specification. Second, OLS regressions involving trending annual series may yield spurious associations; unit-root tests are underpowered, and a reliable cointegration analysis is not feasible with this sample. Third, the post-bridge indicator captures all changes after 2021, not solely those attributable to the Padma Bridge. The models also lack a comparison region and omit relevant determinants of GDP. Fourth, GDP is measured in current prices and therefore incorporates inflation; a constant-price series would be preferable. Fifth, the Human–Technology Gap and Administrative Friction indicators require more detailed documentation. Future studies could use longer or higher-frequency port series, panel data covering several ports or regions, and suitable designs such as ARDL, error-correction models or difference-in-differences with an appropriate comparison group. Constant-price GDP, GDP growth and productivity indicators would also be useful outcomes.

Conclusion

Secondary ports receive less attention in policy debates than major gateway ports, despite their potential relevance to regional development. This study examines Mongla Port, Bangladesh, using an annual time-series dataset for 2015–2025 ($n = 11$).

Both baseline models are jointly significant at the 5% level (Model 1: $p = 0.0302$; Model 2: $p = 0.0013$). The regressors jointly account for substantial variation in vessel turnaround time and regional GDP, respectively. However, no individual slope coefficient is significant at the 5% level, and the throughput coefficient in Model 2 also fails to reach the 10% threshold ($p = 0.101$).

The results do not establish that the Padma Bridge or improved hinterland connectivity increased regional GDP: the baseline post-bridge coefficient is not statistically significant ($p = 0.139$) and changes sign when a time trend is included. The estimated associations between channel draft, technological adaptation, administrative delays, and turnaround time are likewise too imprecise to support firm conclusions.

Maintaining navigable channels, streamlining administrative procedures and improving multimodal connections remain plausible policy priorities. However, their economic effects should be evaluated using longer datasets and research designs that support causal inference.

Funding

This study received no specific financial support.

Competing interests

The authors declare that they have no competing interests.

Use of Artificial Intelligence

The authors must disclose whether and how artificial intelligence tools were used in preparing the manuscript.

References

Acciaro, M., Ghiara, H., & Cusano, M. I. (2014). Energy management in seaports: A new role for port authorities. Energy Policy, 71, 4–12. https://doi.org/10.1016/j.enpol.2014.04.013

Ali, M. Y., Suma, S. A., Islam, M. R., & Hadiuzzaman, M. (2022). The Padma Multipurpose Bridge: A link towards a prosperous future through connectivity and mobility. *MIST International Journal of Science and Technology*, 10(2), 1–7. https://doi.org/10.47981/j.mijst.10(02)2022.385(01-07)

Asian Development Bank. (2011). South *Asia regional cooperation strategy (2011–2015). Asian Development Bank.* https://www.adb.org/documents/south-asia-regional-cooperation-strategy-2011-2015

Bangladesh Bureau of Statistics. (2025). National accounts statistics 2025. https://bbs.gov.bd/pages/static-pages/6922deda933eb65569e1dd83

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17(1), 99–120.* https://doi.org/10.1177/014920639101700108

Brooks, M. R., Knatz, G., Pallis, A. A., & Wilmsmeier, G. (2022). Transparency in port governance: Setting a research agenda. *Journal of Shipping and Trade, 7, Article 1.* https://doi.org/10.1186/s41072-021-00103-4

Brunila, O.-P., Kunnaala-Hyrkki, V., & Inkinen, T. (2021). Hindrances in port digitalization? Identifying problems in adoption and implementation. *European Transport Research Review,* 13, Article 62. https://doi.org/10.1186/s12544-021-00523-0

Center for Research and Training Services. (2015). *Hydrographic Dynamics and Siltation Modeling of the Passur River Channel. CRTS Technical Studies Series*, No. 42, Dhaka.

Farleigh, D. R. P. (1984). *Navigational Constraints and Dredging Requirements for the Passur Channel*, Mongla Port. Report prepared for the United Nations Development Programme (UNDP) and the Government of Bangladesh, Dhaka.

Hasan, K. R., & Khondoker, M. R. H. (2022). A feasibility study for the procurement of support, service and utility vessels for Mongla Port. *Bangladesh Maritime Journal*, 5(1), 83–96. https://doi.org/10.70279/bmj-v5-i1-1080

Islam, M. A., & Haider, M. Z. (2016). Performance assessment of Mongla Seaport in Bangladesh. *International Journal of Transportation Engineering and Technology*, 2(2), 15–21. https://sciencepublishinggroup.com/article/10.11648/j.ijtet.20160202.11

Japan International Cooperation Agency. (2017). Data collection survey on the comprehensive transport plan between Dhaka and Chittagong: Final report. JICA. https://openjicareport.jica.go.jp/pdf/12300331.pdf

Kumari, M., & Bharti, N. (2021). Does bureaucracy affect the outcome of logistics performance? Empirical evidence from South Asia. *American Journal of Business*, 36(1), 84–102. https://doi.org/10.1108/AJB-08-2020-0134

Lakshmanan, T. R. (2011). The broader economic consequences of transport infrastructure investments. *Journal of Transport Geography*, 19(6), 1325–1333. https://doi.org/10.1016/j.jtrangeo.2011.08.001

Limão, N., & Venables, A. J. (2001). Infrastructure, geographical disadvantage, transport costs, and trade. *The World Bank Economic Review*, 15(3), 451–479. https://doi.org/10.1093/wber/15.3.451

Mahmud, K. K., Chowdhury, M. M. H., & Shaheen, M. M. A. (2024). Green port management practices for sustainable port operations: A multi method study of Asian ports. *Maritime Policy & Management, 51*(8), 1902–1937. https://doi.org/10.1080/03088839.2023.2258125

Mkocha, D., & Mwisila, L. (2025). Assessment of the impact of Tanzania Electronic Single Window System on cargo congestion in Tanzania: A case of Dar Es Salaam Port. *Social Science and Humanities Journal*, 9(10), 9219–9228. https://doi.org/10.18535/sshj.v9i10.2063

Mongla Port Authority. (n.d.). Annual reports. https://mpa.gov.bd/pages/annual-reports?page=2&page_size=10#

Mongla Port Authority. (n.d.). Cargo handling. https://mpa.gov.bd/pages/static-pages/6922dd7d933eb65569e153b7

Monios, J. (2017). Cascading feeder vessels and the rationalisation of small container ports. *Journal of Transport Geography*, 59, 88–99. https://doi.org/10.1016/j.jtrangeo.2017.02.001

Neugebauer, J., Heilig, L., & Voß, S. (2024). Digital twins in the context of seaports and terminal facilities. *Flexible Services and Manufacturing Journal*, 36, 821–917. https://doi.org/10.1007/s10696-023-09515-9

Notteboom, T., & Rodrigue, J.-P. (2009). The future of containerization: Perspectives from maritime and inland freight distribution. *GeoJournal*, 74(1), 7–22. https://doi.org/10.1007/s10708-008-9210-4

Oberhofer, H., Pfaffermayr, M., & Sellner, R. (2021). Revisiting time as a trade barrier: Evidence from a panel structural gravity model. *Review of International Economics*, 29(5), 1382–1417. https://doi.org/10.1111/roie.12547

Pavat, C., Pavlić Skender, H., & Zaninović, P. A. (2026). The analysis on sustainable maritime supply chains and port operations in main European ports. Pomorski zbornik, 66(1), 133–150. https://hrcak.srce.hr/346315

Pomfret, R., & Sourdin, P. (2010). Trade facilitation and the measurement of trade costs. Journal of International Commerce*, Economics and Policy*, 1(1), 145–163. https://doi.org/10.1142/S1793993310000010X

Smith, D. (2021). *Big data insights into container vessel dwell times*. *Transportation Research Record: Journal of the Transportation Research Board, 2675*(10), 1222–1235. https://doi.org/10.1177/03611981211015248

Tanjung, I. A. (2026). Sustainable port development: Balancing economic growth and environmental stewardship in Indonesian hub ports. *Marine Transport Management and Logistics Journal*, 2(1), 18–27. https://jurnal.poltekpelsulut.ac.id/index.php/Transport/article/view/276

World Bank. (2013). Single window systems: What we have learned. World Bank. https://blogs.worldbank.org/en/trade/single-window-systems-what-we-have-learned

Wudhikarn, R., Chakpitak, N., & Neubert, G. (2018). A literature review on performance measures of logistics management: An intellectual capital perspective. *International Journal of Production Research*, 56(13), 4490–4520. https://doi.org/10.1080/00207543.2018.1431414

This is an open access journal and all published articles are licensed under a Creative Commons «Attribution» 4.0.