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Beyond Infrastructure Institutional Enablers as the Missing Link in Container Terminal Competitiveness- A Mixed Methods Study from Egypt

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Abstract: What makes a container terminal competitive in a fast-growing emerging economy? Conventional wisdom emphasises physical assets such as quay length, berth depth, crane capacity and yard area. This study challenges that view by examining the Alexandria Container and Cargo Handling Company (ACCHCO) in Egypt. Using an explanatory sequential mixed-methods design, the research combines PLS-SEM on survey data from 366 stakeholders, output-oriented VRS DEA with 2020-2025 operational data, and Fuzzy AHP to elicit stakeholder priorities, together with semi-structured interviews of ten executives and academic experts. The findings reveal that Institutional and Strategic Enablers are the strongest determinant of terminal competitiveness (beta = 0.482, f-squared = 0.626) and significantly moderate the infrastructure-competitiveness relationship. The newer Dekheila Terminal consistently underperforms the older Alexandria Terminal, with unrealised throughput reaching 963,805 TEUs in 2022 despite superior physical assets. Stakeholder priorities assign the highest weights to Landside Logistics (0.34) and ISE (0.33), compared with Infrastructure (0.14). The structural model explains 87.7 percent of the variance in perceived competitiveness (R-squared = 0.877). The paper provides a validated strategic roadmap centred on a Unified Operational Control Center and demonstrates that governance reform can yield higher returns than infrastructure investment in emerging-economy ports.

Keywords: *Container Terminal Competitiveness; Institutional Enablers; Port Governance; PLS-SEM; DEA; Fuzzy AHP; Egypt.*

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I. INTRODUCTION

Container terminals are vital nodes in global trade and economic growth. Over 80% of international merchandise trade by volume moves by sea [29], and the efficiency of container terminals directly affects national logistics costs, trade competitiveness and regional development. For emerging economies, ports are not merely gateways but engines of industrialisation and foreign direct investment.

For decades, terminal development has focused on physical infrastructure such as berth depth, crane numbers and yard area, following the Resource-Based View of the firm [5]. Consequently, many developing countries have invested heavily in port infrastructure, assuming that better equipment automatically drives efficiency and competitiveness. Egypt, for example, has spent billions on port expansion, including the Suez Canal Corridor project and new terminals at Sokhna and Port Said.

Yet many newer or upgraded terminals underperform relative to expectations. This suggests that more is at stake than physical resources. A growing body of research emphasises institutional factors, including governance quality,

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inter-organisational coordination, regulatory efficiency and strategic alignment of stakeholders [16], [7]. However, empirical evidence from emerging economies, particularly the Middle East and North Africa region, remains scarce. Most studies focus on Asian or European ports, leaving a contextual gap.

This study fills that gap by analysing the Alexandria Container and Cargo Handling Company (ACCHCO) in Egypt, a major state-owned operator running two terminals: Alexandria, opened in 1984, and Dekheila, opened in 1996. Their different infrastructure ages provide a natural comparison to test whether newer physical assets automatically yield better performance.

The research asks: (1) What are the key competitiveness factors for a container terminal in a developing economy such as Egypt? (2) How do stakeholder perceptions relate to actual operational efficiency? and (3) Which institutional and strategic enablers matter most for creating value from infrastructure, digitalisation and performance?

Using PLS-SEM, DEA, Fuzzy AHP and qualitative interviews, the study shows that institutional quality is not merely another driver but a fundamental moderator that determines the returns from physical and digital assets. The paper provides a validated strategic roadmap for reform, moving beyond an infrastructure-centric model.

II. THEORETICAL FRAMEWORK AND HYPOTHESES

➢ *Theoretical Perspectives*

The study builds on four complementary theoretical lenses. Resource-Based View (RBV) argues that a firm's unique, valuable and inimitable resources, including physical assets, human capital and organisational routines, provide sustained competitive advantage [5]. In ports, infrastructure such as cranes and berths is often considered a key resource; however, RBV also emphasises that resources alone are insufficient without effective organisational capabilities.

Network Theory views ports as embedded in logistics networks. Competitiveness depends not only on the terminal but also on hinterland connectivity, multimodal integration and relationships with shipping lines, logistics providers and customs [9], [26].

Service-Dominant Logic proposes that value is co-created through services, information exchange and relational interactions [30]. Digitalisation, real-time data sharing and customer service quality are therefore central to modern port competitiveness.

Transaction Cost Economics holds that governance structures, coordination mechanisms and contractual arrangements affect efficiency by reducing or increasing transaction costs [12], [31]. In ports, fragmented governance, procurement delays and weak accountability can raise transaction costs and erode competitiveness.

➢ *Key Competitiveness Determinants*

From the systematic literature review, five constructs are operationalised: Infrastructure Condition, Landside Logistics Efficiency, Digitalisation Adoption, Institutional and Strategic Enablers, and Competitiveness/Productivity.

➢ *Research Hypotheses*

- H1: Infrastructure Condition is positively associated with terminal competitiveness/productivity.
- H2: Landside Logistics Efficiency is positively associated with competitiveness/productivity.
- H3: Digitalisation Adoption is positively associated with competitiveness/productivity.
- H4: Institutional and Strategic Enablers are positively associated with competitiveness/productivity.
- H4a-H4c: Institutional and Strategic Enablers positively moderate the relationships between Infrastructure, Landside Logistics, Digitalisation and Competitiveness.

➢ *Conceptual Model*

The conceptual model contains three independent variables, Infrastructure Condition, Landside Logistics Efficiency and Digitalisation Adoption, one moderator, Institutional and Strategic Enablers, and the dependent construct Competitiveness/Productivity. The model tests direct effects and interaction effects.

➢ *Systematic Literature Review Highlights*

A systematic review of more than 40 studies from 2010-2025 identified substantial differences in automation, rail connectivity and crane productivity between leading global ports and Egyptian ports, while institutional fragmentation repeatedly appears as a barrier in developing-country ports [2], [25], [17], [8], [32]. The manuscript identifies a contextual gap in applying a hybrid PLS-SEM, DEA and Fuzzy AHP framework to an Egyptian terminal and explicitly testing institutional moderation.

III. METHODOLOGY

➢ *Research Design*

An explanatory sequential mixed-methods design [14] was used. Phase 1 comprised PLS-SEM on survey data from 366 respondents to test the hypotheses, output-oriented VRS DEA to benchmark efficiency, and Fuzzy AHP to derive stakeholder-prioritised weights for the four competitiveness dimensions. Phase 2 comprised semi-structured interviews with ten executives and academic experts to explain the quantitative findings.

➢ *Quantitative Data and Sample*

PLS-SEM used a 26-item, five-point Likert questionnaire developed from validated port competitiveness scales [28], [15], [3]. The questionnaire was reviewed by academic supervisors and five maritime experts for content validity. It was distributed to all ACCHCO employees (N = 2,327) between January and March 2025. A total of 366 usable responses were obtained, yielding a response rate of 15.7%. This exceeds the minimum required by the finite-population calculation and the a priori power analysis.

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Inclusion criteria required at least one year of experience at ACCHCO and direct involvement in terminal operations or management. Port authority staff were included because ACCHCO operates as a state-owned enterprise under the umbrella of the Egyptian Ports Authority and these staff work regularly with ACCHCO. The sample comprised 44.0% operational staff, 26.8% port authority staff, 23.2% managers and 6.0% other stakeholders. In total, 77.3% had more than ten years of experience.

Non-response bias was assessed by comparing early and late respondents. No significant differences were found in age, experience or role composition. Role-composition bias was also assessed by rerunning analyses with and without the port-authority subgroup; the pattern of results remained consistent.

Common-method bias was assessed using Harman's single-factor test and a marker-variable analysis. The single factor accounted for 31.2% of total variance, below the 50% threshold [27]. The marker variable showed a non-significant correlation with CP ($r = 0.04$, $p = 0.38$).

Measurement-model assessment showed Cronbach's alpha values above 0.78, composite reliability above 0.85 and AVE above 0.53, meeting recommended thresholds [21]. Discriminant validity was confirmed using the Fornell-Larcker criterion [20].

DEA used an output-oriented Variable Returns to Scale model [4]. Inputs were total operating hours and net operating hours; output was annual throughput in TEUs. Data for Alexandria covered 2020-2025 and data for Dekheila covered 2022-2025. The matched 2022-2025 period was used for direct comparison. Sensitivity analyses produced consistent rankings (Spearman rho = 0.91-0.94).

Fuzzy AHP used triangular fuzzy numbers to handle uncertainty in pairwise comparisons [10]. The 366 respondents provided pairwise comparisons of the four dimensions. Consistency ratios were below 0.10 and weights were defuzzified using the centre-of-area method.

- *Qualitative Data*

Ten semi-structured interviews were conducted with the CEO, COO, CFO, Head of Engineering, Heads of Operations at Alexandria and Dekheila, HR Manager, IT Manager and two external academics. Interviews were recorded, transcribed verbatim and analysed using thematic analysis [6]. Themes were developed deductively from quantitative findings and inductively from emerging patterns.

IV. RESULTS

- *Descriptive Statistics*

Mean scores were INF = 3.40, LL = 3.82, DIG = 4.15, ISE = 3.87 and CP = 3.74. The lowest-rated infrastructure item was the statement that overall infrastructure condition supports high terminal productivity (3.12). The highest-rated digitalisation item concerned documentation and approvals (4.40), indicating that digital tools for paperwork are well adopted while integration and strategic use lag.

- *PLS-SEM Results*

The structural model explained 87.7% of the variance in CP (R-squared = 0.877; adjusted R-squared = 0.875). The Stone-Geisser Q-squared for CP was 0.645, confirming predictive relevance. ISE was the strongest direct driver (beta = 0.482, f-squared = 0.626). The significant INF x ISE interaction (beta = 0.074, p = 0.039) means that the positive association between infrastructure and competitiveness is stronger when institutional quality is high. LL and DIG had significant direct effects but non-significant interactions with ISE.

- *Fuzzy AHP Results*

Stakeholders prioritised human and process factors over physical assets. Landside Logistics received a weight of 0.34 and ISE 0.33, while Digitalisation received 0.19 and Infrastructure 0.14. The combined weight of LL and ISE was 0.67 compared with 0.14 for infrastructure.

- *DEA Results*

Alexandria reached full efficiency in 2023 and 2025. The worst year was 2022, with efficiency 0.805 and unrealised throughput of 102,825 TEUs. Dekheila never achieved full efficiency. Its 2022 efficiency was 0.293, corresponding to 963,805 TEUs of unrealised throughput. The older Alexandria terminal consistently outperformed the newer Dekheila terminal, contradicting an infrastructure-centric explanation of performance.

- *Qualitative Findings*

Seven themes emerged: governance fragmentation; procurement delays; weak KPI accountability; process misalignment; digitalisation without organisational transformation; human-capital gaps; and strategic consensus around a Unified Operational Control Center (UOCC). Participants reported overlapping mandates, three-to-six-month delays for critical spare parts, metrics not linked to management incentives, berth-yard desynchronisation, reactive planning and poor shift handovers. Existing systems often digitise paperwork rather than transform decision-making.

The CFO highlighted procurement delays as a vicious cycle of underutilisation: equipment breakdowns lead to reactive maintenance, which increases costs and reduces throughput. Bureaucratic processes and limited delegated spending authority, rather than financial constraints, were identified as key barriers. These findings explain the DEA slack and reinforce the PLS-SEM result that ISE is the primary determinant of competitiveness.

V. DISCUSSIONS

- *Theoretical Contributions*

First, institutional enablers emerge as both a primary driver and a moderator. ISE has a larger direct association with competitiveness (beta = 0.482, f-squared = 0.626) than infrastructure (beta = 0.264), and significantly moderates infrastructure returns (beta = 0.074, f-squared = 0.017). This is consistent with TCE because better governance can reduce transaction costs and amplify capital productivity.

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Second, the findings challenge infrastructure-centric development. The newer Dekheila Terminal underperforms the older Alexandria Terminal, with nearly one million TEUs of unrealised capacity in a single year. This cannot be adequately explained by physical assets alone and points to coordination and governance failure.

Third, stakeholder prioritisation confirms the theoretical argument. Fuzzy AHP weights of LL = 0.34 and ISE = 0.33 align with the PLS-SEM results, indicating that practitioners place greater importance on landside processes and institutional quality than on physical assets.

Fourth, digitalisation acts as an enabler rather than a panacea. Digitalisation has a significant but modest direct association with competitiveness (beta = 0.095). Its potential is constrained by organisational readiness, siloed systems and limited data-driven decision-making [22].

➢ *Practical Implications for Port Managers and Policymakers*

The findings translate into a phased strategic roadmap grounded in DEA gaps, path coefficients and qualitative constraints. Phase I focuses on establishing a UOCC, delegating limited procurement authority for critical spares, standardising SOPs, implementing real-time KPI dashboards and strengthening shift-handover tools. Phase II focuses on KPI-based accountability, expanded procurement delegation, yard redesign, berth-yard synchronisation, integration of terminal operating systems with commercial and financial systems, predictive congestion analytics and workforce multi-skilling. Phase III focuses on executive performance contracts, strategic partnerships, AI-based optimisation, digital-twin capability and a full Port Community System.

The single most critical recommendation, unanimously supported by stakeholders, is the UOCC. It addresses governance fragmentation, data silos and coordination failures simultaneously without requiring massive capital investment. The CFO’s involvement is important because procurement delegation, financial-system integration and performance contracts require financial governance alignment.

➢ *Comparison with Previous Studies*

The findings are consistent with work on port-cluster governance and port devolution [16], [7]. However, unlike studies that treat institutional factors mainly as a background condition, this study explicitly models and tests the moderating role of ISE. The large direct effect size suggests that governance reform may yield higher returns than infrastructure investment in emerging-economy ports.

PLS-SEM competitiveness and DEA efficiency are distinct but complementary measures. CP captures stakeholder perceptions of service quality, reliability, customer satisfaction and competitive positioning, whereas DEA provides an objective output-oriented measure of how effectively operating-hour inputs are converted into TEUs. Convergence across the two measures strengthens the conclusion that institutional quality is central.

VI. CONCLUSION, LIMITATIONS AND FUTURE RESEARCH

➢ *Conclusion*

This study demonstrates that for container terminals in emerging economies, institutional quality can be more important than physical infrastructure. At ACCHCO, fragmented governance, procurement delays, weak accountability and poor coordination reduce the returns from capital investments. Convergent evidence from PLS-SEM, DEA, Fuzzy AHP and interviews points to systemic governance reform as the path to competitiveness. The paper provides a validated phased roadmap centred on a Unified Operational Control Center and offers actionable guidance for port managers and policymakers in Egypt and similar contexts.

➢ *Limitations*

The study has four main limitations. First, it is a single-case study, which limits statistical generalisability, although the depth of mixed-methods evidence supports analytical generalisability [33]. Second, the cross-sectional survey design precludes causal inference; reported relationships should therefore be interpreted as associations rather than causal effects. Third, external shocks, including the COVID-19 pandemic and the 2023-2024 Red Sea disruptions, may have affected throughput. Fourth, although Harman’s single-factor test and marker-variable analysis suggest that common-method bias is not a significant concern, the cross-sectional design remains a limitation.

➢ *Future Research Directions*

Future research should longitudinally track implementation of the strategic roadmap; compare multiple Egyptian ports with Mediterranean ports; test the generalisability of the institutional moderation effect across emerging economies; incorporate sustainability metrics such as carbon emissions and energy efficiency into DEA models; and examine organisational change during the transition from digitised processes to data-driven decision-making.

Table 1 Key Competitiveness Constructs and Their Theoretical Anchors

Construct	Definition	Theoretical Anchor
Infrastructure Condition (INF)	Physical assets: berth depth, crane quality, yard layout, equipment reliability	RBV
Landside Logistics Efficiency (LL)	Gate operations, customs clearance, hinterland connectivity, truck turnaround	Network Theory
Digitalisation Adoption (DIG)	Digital platforms, real-time data sharing, process automation	SDL
Institutional and Strategic Enablers (ISE)	Governance quality, coordination, regulatory efficiency, KPI accountability, strategic alignment	TCE

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Competitiveness/Productivity (CP)	Perceived terminal competitiveness across operational efficiency, service quality, reliability and positioning	Multi-theoretical

Table 2 PLS-SEM Path Coefficients and Hypothesis Testing Results

Hypothesis	Path	Beta	t-statistic	p-value	Support
H1	INF -> CP	0.264	5.670	<0.001	Supported
H2	LL -> CP	0.178	4.400	<0.001	Supported
H3	DIG -> CP	0.095	2.605	0.009	Supported
H4	ISE -> CP	0.482	11.846	<0.001	Strongly supported
H4a	INF x ISE -> CP	0.074	2.075	0.039	Supported
H4b	LL x ISE -> CP	-0.022	0.496	0.620	Not supported
H4c	DIG x ISE -> CP	-0.031	0.891	0.373	Not supported

Table 3 Fuzzy AHP Priority Weights for Competitiveness Dimensions

Dimension	Weight
Landside Logistics Efficiency	0.34
Institutional and Strategic Enablers	0.33
Digitalisation Adoption	0.19
Infrastructure Condition	0.14

Table 4 Alexandria Terminal Efficiency Scores 2020-2025

Year	Throughput (TEUs)	Total Hours	Net Hours	Efficiency
2020	455,976	17,398	17,180	0.914
2021	468,194	17,614	17,046	0.931
2022	425,358	14,467	14,388	0.805
2023	413,262	17,582	17,562	1.000
2024	517,108	19,953	19,743	0.921
2025	439,494	15,492	13,594	1.000

Table 5 Comparative Efficiency Alexandria Versus Dekheila 2022-2025

DMU	Year	Throughput (TEUs)	Efficiency	Unrealised TEUs
Alexandria	2022	425,358	0.805	102,825
Alexandria	2023	413,262	1.000	0
Alexandria	2024	517,108	0.921	44,071
Alexandria	2025	439,494	1.000	0
Dekheila	2022	400,362	0.293	963,805
Dekheila	2023	407,373	0.848	72,886
Dekheila	2024	509,067	0.832	102,470
Dekheila	2025	484,457	0.763	150,817

Table 6 Integrated Strategic Roadmap for ACCHCO 2026-2031

Phase / Timeframe	Governance and Operations	Digital and Human Capital	Expected Impact
I. Stabilisation 0-12 months	Establish UOCC; delegate limited procurement authority; daily cross-functional meetings; standardise SOPs	Real-time KPI dashboards; digital shift handover; KPI-linked incentives; document critical knowledge	5-10% productivity increase
II. Optimisation 1-3 years	KPI accountability; expand procurement delegation; yard redesign; berth-yard synchronisation	Integrate TOS with commercial and financial systems; predictive congestion analytics; multi-skilling; mentoring	15-20% efficiency improvement
III. Strategic Positioning 3-5 years	Executive performance contracts; strategic partnerships; position ACCHCO as regional benchmark	AI-based optimisation; digital twin; blockchain documentation; full Port Community System	Sustainable competitive advantage

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APPENDIX

➢ *Appendix A. Survey Measurement Model*

Table A1 Infrastructure Condition (INF)

Item	Loading
INF1: Sufficient berth depth for large vessels	0.782
INF2: Crane quality and availability meet requirements	0.801
INF3: Yard layout supports efficient handling	0.745
INF4: Equipment reliability is satisfactory	0.763
INF5: Adequate storage capacity	0.718
INF6: Infrastructure supports high productivity	0.694
Composite Reliability / AVE / Alpha	0.891 / 0.581 / 0.851

Table A2 Landside Logistics Efficiency (LL)

Item	Loading
LL1: Gate operations are efficient and fast	0.784
LL2: Customs clearance is streamlined	0.756
LL3: Hinterland connectivity is adequate	0.791
LL4: Truck turnaround times are acceptable	0.742
LL5: Coordination with logistics providers is effective	0.718
LL6: Container release processes are efficient	0.703
Composite Reliability / AVE / Alpha	0.882 / 0.560 / 0.842

Table A3 Digitalisation Adoption (DIG)

Item	Loading
DIG1: Digital platforms are used for documentation and approvals	0.815
DIG2: Real-time data sharing occurs	0.782
DIG3: Digital systems support operational decisions	0.754
DIG4: TOS is effectively utilised	0.738
DIG5: Predictive analytics are used	0.693
DIG6: Digitalisation improved visibility	0.677
Composite Reliability / AVE / Alpha	0.895 / 0.582 / 0.861

Table A4 Institutional and Strategic Enablers (ISE)

Item	Loading
ISE1: Governance structures are clear and effective	0.795
ISE2: Inter-organisational coordination is efficient	0.771
ISE3: Regulatory processes are efficient	0.748
ISE4: KPI accountability is enforced	0.732
ISE5: Strategic planning aligns with operations	0.715
ISE6: Management responsiveness is satisfactory	0.689
ISE7: Cross-functional collaboration is effective	0.673
Composite Reliability / AVE / Alpha	0.904 / 0.572 / 0.873

Table A5 Competitiveness/Productivity (CP)

Item	Loading
CP1: Terminal is competitive relative to regional peers	0.802
CP2: Operational efficiency meets expectations	0.784
CP3: Service quality is consistently high	0.756
CP4: Reliability of operations is satisfactory	0.738
CP5: Terminal has a good reputation among shipping lines	0.721
CP6: Productivity levels are acceptable	0.693
CP7: Overall terminal competitiveness is high	0.671
Composite Reliability / AVE / Alpha	0.899 / 0.563 / 0.858

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A.2 Discriminant Validity HTMT Values

Construct	INF	LL	DIG	ISE	CP
INF	-				
LL	0.682	-			
DIG	0.451	0.483	-		
ISE	0.573	0.594	0.512	-	
CP	0.641	0.612	0.523	0.738	-

All HTMT values are below 0.85, confirming discriminant validity [21].

A.3 Collinearity Diagnostics VIF Values

Predictor	VIF
INF	1.872
LL	1.934
DIG	1.513
ISE	2.456

All VIF values are below 5, indicating no problematic collinearity [21].

A.4 Construct-Level Effect Sizes

Effect	f-squared	Interpretation
INF -> CP	0.231	Medium
LL -> CP	0.112	Small-Medium
DIG -> CP	0.035	Small
ISE -> CP	0.626	Large
INF x ISE -> CP	0.017	Small
LL x ISE -> CP	0.002	Negligible
DIG x ISE -> CP	0.004	Negligible

Interpretation follows Cohen [13]: f-squared >= 0.02 = small, >= 0.15 = medium, and >= 0.35 = large.

A.5 Bootstrap Settings

Parameter	Setting
Resampling Method	Bootstrapping
Number of Resamples	5,000
Confidence Interval Method	Bias-corrected and accelerated bootstrap
Confidence Level	95%
Significance Levels	*p < 0.05, **p < 0.01, ***p < 0.001