

Analyzing the Impact of Berth Capacity Constraints on Shipping Costs at the Dar es Salaam Container Terminal

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Abstract:

This study investigates how berth capacity constraints at the Dar es Salaam Container Terminal drive up shipping costs and proposes targeted interventions to alleviate this bottleneck. A mixed-methods design combined a structured survey of 90 industry professionals with 18 semi-structured interviews. Quantitative analysis revealed that average berth occupancy stood at 78.4% (SD 9.2), with mean daily demurrage charges of USD 120.50 (SD 25.4). The berth-capacity perception scale demonstrated strong reliability (Cronbach's $\alpha = .81$). Pearson correlation confirmed a robust association between occupancy and demurrage ($r = .68$, $p < .01$), and multiple regression showed berth occupancy as the strongest predictor of demurrage ($\beta = .34$, $p < .001$), explaining 58% of its variance. Qualitative themes excessive vessel queues and manual scheduling inefficiencies corroborated these findings. Building on this evidence, the paper recommends implementing an AI-driven Port Community System, phased quay expansions, and public-private partnerships to optimize berth utilization, reduce vessel waiting times by up to 20%, and substantially lower demurrage costs.

Keywords: Berth Capacity, Shipping Costs, Demurrage, Dar Es Salaam, Port Congestion

1. Introduction:

Port performance serves as a linchpin for the cost efficiency and reliability of global supply chains, with container terminals acting as critical nodes that directly influence shipping schedules and expenses (Notteboom & Rodrigue, 2013). Among the various operational metrics, berth capacity the number of vessels that can be accommodated simultaneously emerges as a key determinant of terminal throughput. High berth utilization often translates into longer vessel waiting times at anchorage, triggering demurrage penalties and elevated bunker fuel consumption, which in turn inflate overall shipping costs. In advanced ports, sophisticated scheduling systems and ample quay

infrastructure help mitigate these pressures; however, in many developing regions, such safeguards remain underdeveloped, magnifying the financial and operational repercussions of berth constraints.

In the context of emerging economies, these challenges are further exacerbated by infrastructure deficits and predominantly manual planning practices. The Dar es Salaam Container Terminal in Tanzania responsible for over 95% of the nation's seaborne trade and serving as the primary gateway for landlocked neighbors such as Uganda, Rwanda, Burundi, and the Democratic

Republic of Congo exemplifies this dynamic. Despite significant modernization efforts under the Dar es Salaam Maritime Gateway Project (DMGP), the terminal continues to contend with limited quay length, outdated slot-allocation procedures, and peak-season spikes in vessel arrivals that overwhelm existing capacity. Such conditions not only hinder the port's ability to handle growing cargo volumes but also generate cascading delays in yard operations and gate processing.

Previous studies have consistently identified berth occupancy as a principal cost driver in containerized trade. Notteboom and Rodrigue (2013) demonstrated that ports operating above 80% quay utilization experience disproportionately higher vessel idle times and bunker surcharges, while Wilmsmeier et al. (2014) documented the downstream effects on yard stacking inefficiencies and gate bottlenecks in European terminals. Yet, scholarship remains scant on the particularities of the East African maritime landscape, where rapid trade growth outpaces infrastructure upgrades and where the operational realities of manual scheduling and stakeholder coordination introduce unique challenges. The interplay between hard metrics such as occupancy rates and turnaround times and the soft factors of planning workflows and data-sharing practices has not been thoroughly explored in this regional setting.

This paper addresses that gap by quantifying the effect of berth capacity constraints on shipping costs specifically demurrage charges at Dar es Salaam. Employing a mixed-methods design, the study integrates quantitative data from 90 structured questionnaires administered to port authority officials, terminal operators, shipping agents, freight forwarders, TASAC representatives, and customs officers, with qualitative insights drawn from semi-structured interviews of 18 key stakeholders. Inferential statistical techniques (Pearson correlation and multiple regression) test hypotheses regarding the strength and significance of occupancy–cost relationships, while thematic analysis of interview

transcripts uncovers the operational mechanisms such as manual slot allocation and coordination bottlenecks that underlie the observed quantitative patterns.

The remainder of the paper is organized as follows. Section 2 synthesizes the literature on berth capacity and its cost implications, highlighting both global findings and regional nuances. Section 3 outlines the methodological framework, detailing sampling strategies, data-collection instruments, and analytical procedures. Section 4 presents the study's results, combining reliability assessments, descriptive and inferential statistics, and thematic summaries of qualitative data. Section 5 discusses these findings in light of existing scholarship and port-management practices, and Section 6 concludes with actionable recommendations and a proposed capacity-enhancement framework. By centering on Dar es Salaam, the paper offers evidence directly pertinent to the DMGP and contributes a replicable model for other high-growth, resource-constrained terminals across Africa and beyond (Cullinane & Wang, 2021).

2. Literature Review:

2.1 Berth Occupancy and Vessel Waiting Times

Berth occupancy rate the proportion of time during which quay lines are actively servicing vessels functions as a fundamental efficiency metric for container terminals (UNCTAD, 2020). High occupancy rates indicate that a terminal's quay infrastructure is nearing its throughput capacity, leaving minimal slack to absorb fluctuations in vessel arrivals or unscheduled maintenance. When berth utilization consistently exceeds 70–75%, the system loses its buffer, resulting in vessels queuing at anchorage until a berth becomes available (Notteboom & Rodrigue, 2013). This queuing not only delays cargo operations but also contributes to cascading inefficiencies across yard stacking and gate processing functions, as ships cannot discharge or load containers until they dock. Consequently, berth occupancy emerges as an early warning indicator: sustained high values portend

downstream congestion and elevated operational costs.

Empirical evidence from European and Asian mega-ports highlights the quantitative relationship between occupancy rates and waiting times. Wilmsmeier et al. (2014) showed that each incremental 5% increase in berth occupancy can translate to an additional 2–3 hours of vessel waiting per call, a ratio that holds across diverse terminal configurations. For ports handling hundreds of weekly calls, these additional waiting hours aggregate to substantial demurrage and fuel-consumption costs. In contexts where carrier alliances adjust rotations to mitigate delays, high berth occupancy also triggers vessel skips, disrupting shipping schedules and undermining service reliability (UNCTAD, 2020). Thus, controlling berth occupancy within optimal thresholds is critical not only for minimizing direct waiting penalties but also for preserving network integrity and contractual performance across liner schedules.

2.2 Demurrage Charges as Cost Penalty:

Demurrage charges constitute the financial penalties imposed on vessel operators or cargo owners when ships remain at berth or containers linger in terminal yards beyond the agreed “free time” allowance (Lun, Lai, & Cheng, 2016). These fees serve a dual purpose: they compensate terminal operators for opportunity costs associated with berth unavailability, and they incentivize cargo interests to expedite loading and unloading processes. In congested ports, demurrage rates can escalate rapidly, often reaching USD 100–200 per container per day, depending on cargo type and contractual terms (Wang & Yap, 2018). Such penalties frequently account for a significant portion of total voyage costs, particularly on short-sea trades or tight intermodal connections where dwell-time buffers are minimal.

Analyses of Mediterranean terminals illustrate how demurrage functions both as a revenue stream and as a penalty mechanism. Wang and Yap (2018) found that, under peak congestion conditions, carriers pass demurrage costs onto

shippers through freight surcharges, thereby externalizing congestion burdens across the supply chain. In severe cases, shippers may seek alternative routings or transshipment hubs to avoid prohibitive detention fees, resulting in volume shifts away from the congested port. This behavior underscores demurrage’s strategic role: it not only recoups missed berth-use fees but also influences cargo flow patterns and competitive dynamics among ports (Lun et al., 2016). As such, managing berth occupancy to minimize demurrage liabilities is both an operational imperative and a commercial necessity for terminal competitiveness.

2.3 Scheduling Practices and Capacity

Utilization:

Berth-allocation practices critically affect how terminal capacity is utilized in real time. Traditional manual scheduling relies on fixed timetables, telephone coordination, and paper-based slot assignments, leaving little room for rapid adjustments when vessels deviate from estimated times of arrival (Li & Panayides, 2020). Such rigidity often results in suboptimal berth utilization: despite apparent high occupancy, actual service may be intermittent, with idle quay sections coexisting alongside vessel queues. Moreover, manual processes are prone to communication lags and human error, compounding delays when unexpected events such as mechanical breakdowns or adverse weather disrupt planned schedules.

In contrast, algorithmic berth-allocation systems harness real-time data feeds (e.g., AIS vessel positions, yard-occupation sensors) and optimization routines to dynamically assign quay windows, balancing competing demands and minimizing cumulative waiting time (Li & Panayides, 2020). Studies show that ports employing such systems achieve 15–20% reductions in average vessel wait times, translating directly into lower demurrage and bunker consumption. However, technology adoption in Sub-Saharan Africa lags behind due to investment constraints, limited IT infrastructure,

and skills gaps among port personnel (Mangan, Lalwani, & Gardner, 2016). Overcoming these barriers requires both capital infusion potentially via public-private partnerships and targeted training programs to build local capacity for digital port management.

2.4 Regional Context: East African Ports:

East African gateway ports share similar berth-capacity challenges, especially during peak agricultural and import seasons. Research on the Port of Mombasa indicates that quay utilization often exceeds 85% during high-demand periods, leading to vessel skips and schedule re-routing by major shipping alliances (Moshi, 2019). This not only imposes direct waiting costs on carriers but also complicates hinterland logistics, as cargo arrival unpredictability strains rail and road transport planning. Similarly, the Port of Durban in South Africa experiences cyclical berth saturation tied to seasonal trade flows, prompting calls for phased quay extensions and enhanced scheduling protocols (Ouma, 2021).

Dar es Salaam, poised for 7–9% annual container growth under the Dar es Salaam Maritime Gateway Project (TPA, 2024), confronts a narrowing margin for operational slack. Without strategic interventions, rising call frequencies will push berth occupancy past critical thresholds more frequently, intensifying vessel waiting times and demurrage exposure. Regional studies recommend a hybrid approach combining incremental quay lengthening with digital berth-allocation and demand-management strategies to spread traffic more evenly and fund capacity upgrades through public-private partnerships. Such measures could provide the flexibility needed to absorb growth while preserving service reliability across the East African corridor.

2.5 Theoretical Framework: Capacity-Cost Linkages:

To conceptualize how berth constraints translate into shipping-cost penalties, this study draws on classical Queuing Theory and Port Throughput Models. In an M/M/1 queue where arrivals follow a Poisson process and service times are

exponentially distributed the expected waiting time (W_e) in the queue can be expressed as:

$$W_q = \rho / \mu (1 - \rho)$$

where ρ represents the traffic intensity (arrival rate λ divided by service rate μ). As ρ approaches unity in other words, as berth utilization nears 100% the denominator ($1 - \rho$) shrinks, causing waiting time to escalate non-linearly (Gupta, Verma, & Singh, 2017). Applied to container berths, this relationship explains why marginal increases in occupancy beyond optimal thresholds can induce disproportionately large vessel delays and demurrage penalties.

Port Throughput Models further extend this framework by incorporating operational factors such as crane productivity, yard dwell dynamics, and gate processing efficiency into capacity-cost analyses. These models demonstrate that berth utilization does not operate in isolation: high quay occupancy often signals upstream yard congestion, which in turn feeds back into quay inefficiencies (Wilmsmeier, Sanchez, & Hoffmann, 2014). Consequently, a holistic view of terminal operations is required, one that recognizes berth, yard, and gate functions as interdependent subsystems. By situating berth capacity within this broader throughput context, the present study grounds its empirical analyses in a robust theoretical foundation, elucidating the mechanisms through which congestion cascades into quantifiable shipping-cost burdens.

3. Methodology:

This study employed a *descriptive quantitative design* supplemented by qualitative insights to examine how berth capacity constraints drive shipping costs at the Dar es Salaam Container Terminal (Creswell, 2014). The quantitative strand centered on a structured questionnaire, administered to 90 industry professionals, which captured both objective operational metrics such as berth-occupancy rate, ship turnaround time, and daily demurrage charges and perceptual ratings of berth-capacity impact. To enrich and contextualize these findings, 18 semi-structured interviews

probed scheduling workflows, data-sharing practices, and perceived cost drivers among key stakeholders. This mixed-method approach ensured that numerical relationships were grounded in the lived experiences of those responsible for vessel planning and quay management.

Sampling followed a purposive strategy designed to include all actors directly involved in berth allocation and vessel operations. Respondents comprised port authority officials, terminal operators, shipping agents, freight forwarders, TASAC representatives, and customs officers, each selected for their first-hand knowledge of berth scheduling and quay utilization challenges. Secondary data covering historical berth-occupancy rates and demurrage-charge records were obtained from Tanzania Ports Authority annual performance reports and UNCTAD port-performance databases (TPA, 2024; UNCTAD, 2020). By integrating primary insights with these authoritative records, the study achieved both depth and breadth in its assessment of berth capacity constraints.

Instrumentation and procedures were rigorously standardized to ensure validity and reliability. The questionnaire incorporated a five-item berth-capacity perception scale (Cronbach’s $\alpha = .81$) alongside fields for actual occupancy percentages and cost figures. Interviews employed an open-

ended guide, allowing participants to elaborate on manual planning inefficiencies, slot-allocation bottlenecks, and coordination breakdowns. All interview sessions were audio-recorded, transcribed verbatim, and coded in NVivo using Braun and Clarke’s (2006) six-step thematic analysis framework. Quantitative data were analyzed in SPSS v27: descriptive statistics (mean, standard deviation) summarized key variables; Pearson’s correlation assessed bivariate linkages; and multiple linear regression quantified berth occupancy’s predictive power on demurrage charges, controlling for yard and gate factors. This comprehensive methodological protocol ensured robust, triangulated evidence on the nexus between berth utilization and shipping-cost penalties.

4. Results and Findings:

This section presents the empirical evidence on how berth capacity constraints at the Dar es Salaam Container Terminal drive shipping costs. It begins with descriptive summaries of the key quantitative variables, assess the reliability of our survey scales, examine bivariate relationships via correlation, estimate the net effects through multiple regression, and conclude with qualitative themes that illuminate the operational mechanisms behind the numbers.

4.1 Descriptive Statistics

Table 1. Descriptive Statistics of Key Variables

Variable	Mean	SD	Min	Max	Skewness	Kurtosis
Berth Occupancy Rate (%)	78.4	9.2	55.0	95.0	-0.45	0.12
Ship Turnaround Time (hrs)	36.7	8.5	22.0	58.0	0.60	0.45
Yard Dwell Time (days)	5.8	1.6	3.0	9.0	0.80	1.20
Truck Gate Turnaround (hrs)	7.4	2.1	4.0	12.0	0.30	-0.10
Daily Demurrage Charge (USD/day)	120.5	25.4	80.0	180.0	0.25	-0.35

Table 1 highlights the central tendency and dispersion of the terminal’s core performance and cost indicators, revealing systemic capacity

pressures. Berth occupancy averages 78.4% (SD = 9.2), indicating that the quay operates close to its maximum throughput capacity on most days; the

slight negative skew (−0.45) suggests occasional dips below this level but no substantial periods of underutilization. Ship turnaround times, with a mean of 36.7 hours (SD = 8.5) and moderate positive skew (0.60), well exceed industry benchmarks (24–30 hours), reflecting frequent anchorage delays when berths are occupied. Yard dwell times averaging 5.8 days (SD = 1.6) and exhibiting right skew (0.80) further underscore stacking backlogs, as containers often remain in the terminal yard well beyond the desired three- to four-day threshold.

On the cost side, truck gate turnaround averages 7.4 hours (SD = 2.1), pointing to persistent

4.2 Scale Reliability

Table 2. Cronbach’s Alpha for Berth-Capacity Perception Scale

Item	Item–Total Correlation	α if Item Deleted
“Quayside is fully utilized >80%”	0.72	0.78
“Vessels often wait >24 hrs”	0.68	0.79
“Slot-allocation is inefficient”	0.65	0.80
“Berth scheduling is manual”	0.74	0.77
“We lack real-time capacity data”	0.69	0.79
Overall Scale		$\alpha = 0.81$

Table 2 demonstrates that the five-item berth-capacity perception scale exhibits strong internal consistency, with an overall Cronbach’s α of 0.81 well above the conventional 0.70 threshold for reliability. Each item contributes meaningfully to the composite measure, as evidenced by item–total correlations ranging from 0.65 to 0.74. Notably, “berth scheduling is manual” and “quayside is fully utilized >80%” show the highest item–total correlations (0.74 and 0.72 respectively), indicating these statements align closely with respondents’ overall perceptions of berth constraints. The “ α if item deleted” values remain below the full-scale α , confirming that no single item unduly inflates or deflates reliability, and that all five questions cohesively measure the underlying construct of berth-capacity concern.

processing bottlenecks at the terminal’s exit points, while daily demurrage charges stand at USD 120.50 (SD = 25.4) with low skewness (0.25), signaling consistently high penalty rates across the respondent pool. These figures collectively paint a picture of a terminal operating with minimal slack: high quay utilization cascades into extended vessel wait times and yard congestion, which in turn trigger hefty demurrage fees and protracted gate processing. The relatively tight standard deviations across all metrics indicate that these challenges are widespread rather than isolated, underscoring the urgency of targeted capacity and process optimizations.

This level of scale reliability ensures that subsequent analyses such as correlating perception scores with actual occupancy rates or demurrage charges are based on a consistent and trustworthy measurement foundation. Because stakeholder perceptions of berth constraints are captured reliably, we can confidently interpret relationships between these subjective ratings and objective performance metrics. Practically, the high α value validates the use of this scale for detecting nuanced shifts in operational sentiment over time or in response to capacity interventions, making it a valuable tool for ongoing monitoring and evaluation at the Dar es Salaam Container Terminal.

4.3 Bivariate Correlation Analysis

Table 3. Correlation Matrix

Variable	1	2	3	4
1. Berth Occupancy (%)	1.00			
2. Ship Turnaround (hrs)	0.72	1.00		
3. Yard Dwell (days)	0.65	0.59	1.00	
4. Daily Demurrage (USD)	0.68	0.75	0.61	1.00

$p < .01$

Table 3 reveals robust, statistically significant relationships among the terminal’s key congestion and cost variables. Berth occupancy rate correlates strongly with ship turnaround time ($r = 0.72, p < .01$), indicating that as quay utilization increases, vessels spend significantly longer at anchorage before docking. Similarly, berth occupancy shows a strong positive association with daily demurrage charges ($r = 0.68, p < .01$), confirming that constrained quay capacity directly translates into greater penalty fees. Yard dwell time also correlates meaningfully with both berth occupancy ($r = 0.65, p < .01$) and demurrage ($r = 0.61, p < .01$), while ship turnaround and demurrage exhibit the highest observed correlation ($r = 0.75, p < .01$). These bivariate coefficients underscore that each operational bottleneck berth, yard, and vessel handling time contributes substantially to elevated demurrage costs.

The pattern of inter-correlations suggests a tightly interwoven congestion dynamic: relieving berth pressure is likely to shorten ship turnaround and reduce yard backlogs, thereby yielding compounding cost savings. However, the moderate correlations among non-berth factors (e.g., ship turnaround vs. yard dwell, $r = 0.59$) also point to feedback loops whereby delays in one area amplify inefficiencies elsewhere. While correlation alone does not establish causation, these findings provide a clear rationale for prioritizing interventions at the quay such as AI-driven berth scheduling to unlock throughput improvements that ripple through yard operations and demurrage liabilities. In practice, addressing the highest-leverage relationships identified here can yield the most immediate and measurable reductions in shipping-cost penalties.

4.4 Multiple Regression Analysis

Table 4. Regression Results (N = 90)

Predictor	B	SE (B)	β	t	p
(Constant)	-45.2	20.7		-2.18	.031
Berth Occupancy (%)	1.02	0.25	0.34	4.08	< .001
Yard Dwell Time (days)	8.75	2.10	0.29	4.17	< .001
Truck Gate Turnaround (hrs)	3.10	0.85	0.24	3.65	< .001
Model Statistics					
R ²	.58				
Adjusted R ²	.56				
F(3,86)	39.80			< .001	

Table 4 presents the multiple regression results predicting daily demurrage charges from three congestion indicators berth occupancy rate, yard dwell time, and truck gate turnaround across 90 observations. The overall model is highly significant ($F(3,86) = 39.80$, $p < .001$) and explains 58% of the variance in demurrage fees ($R^2 = .58$, adjusted $R^2 = .56$), indicating a strong combined effect of these operational factors on penalty costs. The constant term ($B = -45.2$, $p = .031$) suggests that, in the hypothetical absence of congestion delays, demurrage charges would fall below zero underscoring that real-world demurrage is entirely driven by such bottlenecks. Each predictor is statistically significant ($p < .001$): a one-percent increase in berth occupancy adds approximately USD 1.02 to daily demurrage ($\beta = .34$), each additional day of yard dwell contributes roughly USD 8.75 ($\beta = .29$), and every extra hour of gate turnaround tacks on about USD 3.10 ($\beta = .24$).

In standardized terms, berth occupancy exerts the largest individual impact on demurrage ($\beta = .34$), followed by yard dwell time ($\beta = .29$) and gate delays ($\beta = .24$), highlighting quay constraints as the highest-leverage intervention point. The moderate VIFs (< 2.5) and diagnostic checks confirm that multicollinearity is not a concern, and residual analyses indicate homoscedasticity and approximate normality. Practically, these coefficients mean that targeted improvements such as reducing quay utilization through AI-driven scheduling, shortening container dwell via mechanized handling, and streamlining gate processing can each yield quantifiable demurrage savings, with the greatest returns coming from alleviating berth capacity constraints.

4.5 Qualitative Themes: Berth Capacity Constraints

The predominance of *Excessive Vessel Queues*, endorsed by 16 of the 18 interviewees, underscores a systemic bottleneck at the quay that mirrors the quantitative finding of a 36.7-hour average turnaround. As one Port Authority Official observed, “We often have more ships

waiting than the four berths can handle. On average, vessels wait 30–40 hours before docking.” This lived reality translates directly into increased anchorage fees, higher bunker fuel consumption, and knock-on delays in yard stacking and gate processing. The consistency of this theme across stakeholders highlights that without additional berth capacity or more dynamic slot management, vessel congestion will continue to drive up demurrage charges and erode the terminal’s service reliability.

Closely tied to the queue issue is the theme of *Manual Scheduling Inefficiencies*, cited by 14 interviewees, which compounds capacity pressures even when physical space exists. As a Terminal Operator lamented, “Our berth planning is still manual. Without AI scheduling, we can’t optimize slot allocation, exacerbating delays.” Manual planning not only slows down reassignments when ships deviate from their estimated arrival times but also leads to uneven quay utilization some berths remain underused while others suffer long queues. This misalignment underlies the 78.4% average berth occupancy and suggests that digital scheduling tools could unlock latent throughput by reallocating vessel slots in real time.

Beyond these primary themes, respondents highlighted critical coordination gaps and projected the benefits of technological intervention. Poor communication between shipping lines and terminal planners often triggers last-minute berth swaps, further destabilizing schedules and increasing idle quay time. Conversely, a Terminal Manager estimated that implementing AI-driven berth-allocation could slash vessel waiting times by up to 20%, a figure supported by parallel studies in similar ports. Together, these insights point to a two-pronged solution: expand physical berth capacity where feasible and crucially adopt digital scheduling systems to ensure that existing quays are used as efficiently as possible.

5. Discussion:

The quantitative analysis revealed a robust relationship between berth occupancy and demurrage charges, with a Pearson correlation of r

= .68 and a standardized regression coefficient of $\beta = .34$ ($p < .001$), and the overall model explaining 58% of the variance in daily penalties. These magnitudes mirror Notteboom and Rodrigue's (2013) findings that ports operating near or above 80% quay utilization incur disproportionately higher vessel waiting costs, confirming that Dar es Salaam's mean occupancy of 78.4% places it on the brink of critical thresholds. Queuing theory further predicts that as utilization (ρ) approaches unity, expected waiting times (W_q) escalate non-linearly (Gupta, Verma, & Singh, 2017), a pattern borne out by the 36–40 hour average turnaround times observed. Collectively, these results underscore berth capacity as the foremost lever for mitigating demurrage liabilities.

Comparative evidence from other regional and global ports reinforces this conclusion. In major European and Asian terminals, Wilmsmeier, Sanchez, and Hoffmann (2014) reported that each 5% increase in berth occupancy adds approximately 2–3 hours of vessel waiting, inflating port-call costs by up to 10%. Similarly, Mombasa Port another key East African gateway experiences occupancy peaks above 85% during high seasons, prompting shipping alliances to skip calls or adjust rotations, with Moshi (2019) documenting a 15% reduction in wait times after introducing algorithmic scheduling tools. These parallels suggest that Dar es Salaam's congestion dynamics are not unique but reflect a broader phenomenon in high-growth ports where capacity expansion lags demand.

Qualitative insights illuminate the operational mechanisms by which berth constraints translate into cost penalties. Stakeholders consistently pointed to manual scheduling inefficiencies "Our berth planning is still manual. Without AI scheduling, we can't optimize slot allocation" (Terminal Operator) as a critical enabler of high occupancy even when physical space is underutilized. This finding aligns with Li and Panayides (2020), who demonstrated that ports leveraging real-time data and algorithmic berth allocation achieve 15–20% reductions in vessel

waiting times. Moreover, poor coordination between shipping lines and terminal planners exacerbates last-minute berth swaps, destabilizing schedules and contributing to the 78.4% average utilization rate.

Technological interventions thus emerge as high-impact remedies. Deploying a Port Community System (PCS) with AI-driven scheduling can dynamically balance quay assignments in response to ETA variations, vessel priority, and maintenance windows. In Mombasa, such systems yielded significant throughput gains and lower demurrage exposure (Moshi, 2019), while Cullinane and Wang (2021) argue that holistic digital platforms are essential for modern port operations, enabling seamless stakeholder collaboration and real-time resource optimization. These precedents indicate that Dar es Salaam could capture similar efficiencies by integrating AIS-fed berth-allocation algorithms, yard-occupation sensors, and truck-booking modules within a unified PCS framework.

The mixed-methods evidence underscores that capacity solutions must be multifaceted, coupling digital optimization with targeted infrastructure development and governance reforms. Incremental quay extensions guided by performance data can raise the physical ceiling for throughput, while public–private partnerships (PPPs) can mobilize the capital and expertise needed for both hard assets and IT systems (Mangan, Lalwani, & Gardner, 2016). Clear regulatory frameworks and performance-based concession agreements will ensure accountability and sustained service levels. By aligning digital scheduling, infrastructure expansion, and stakeholder governance, Dar es Salaam Container Terminal can systematically dismantle berth capacity constraints, drive down demurrage charges, and strengthen its role as East Africa's maritime gateway.

6. Conclusion:

This study has demonstrated that berth capacity constraints at the Dar es Salaam Container Terminal are a principal driver of elevated

shipping costs, with berth occupancy explaining over one-third of the variance in daily demurrage charges ($\beta = 0.34$) and showing a strong correlation ($r = 0.68$) with penalty fees. Stakeholder interviews revealed that manual planning and poor coordination exacerbate quay congestion, prolonging vessel wait times by 30–40 hours on average and cascading delays into yard and gate operations. By integrating quantitative evidence with thematic insights, the research highlights the critical need for AI-driven berth-allocation within a unified Port Community System, alongside phased quay expansions and public–private partnerships to fund both digital and physical upgrades. Together, these interventions offer a cohesive roadmap to unlock latent capacity, reduce demurrage liabilities, and enhance the terminal’s competitiveness as a regional maritime hub.

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