

Port Efficiency and Operational Resilience in Sea Transportation Management

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Abstract. *Efficient and resilient port operation is a central determinant of sea transportation performance, shaping the reliability of inter-island cargo and passenger movement in archipelagic settings. This paper examines port efficiency and operational resilience as management concerns for sea transportation, using the training and port-facing operations of Politeknik Pelayaran Sulawesi Utara (Poltekpel Sulut) between April 2025 and January 2026 as a reflective case setting. Drawing on the international literature on container seaport efficiency determinants, port resilience frameworks, automated terminal performance, and seaport service quality, together with institutional document review and field observation at Poltekpel Sulut, the paper distinguishes efficiency, understood as throughput relative to resource input, from resilience, understood as the capacity to maintain acceptable service levels under disruption. The discussion finds that efficiency-oriented practices such as berth scheduling discipline and service-quality awareness are more readily embedded in a training institution's operational routine than resilience-oriented practices such as contingency planning for disruption, which remain comparatively underdeveloped. The paper proposes a practical framework distinguishing routine efficiency management from disruption-oriented resilience planning and argues that maritime education providers have a distinct role in building the human competency base on which both depend.*

Keywords: *port efficiency, operational resilience, sea transportation management, container terminals, service quality, maritime education*

1. Introduction

Sea transportation management is frequently evaluated through two related but distinct lenses: efficiency, the degree to which a port or vessel operation converts available resources such as berth time, labour, and equipment into cargo or passenger throughput, and resilience, the degree to which that same operation maintains acceptable service levels when confronted with disruption, whether from weather, equipment failure, congestion, or external shocks such as a pandemic. Both properties matter for archipelagic sea transportation, where a single port's underperformance can propagate delay across an inter-island logistics chain that has few alternative routings.

For a maritime education and training institution such as Politeknik Pelayaran Sulawesi Utara (Poltekpel Sulut), efficiency and resilience are not abstract policy variables; they are properties that graduating officers, engineers, and port personnel are expected to help produce once they enter the workforce. This paper therefore examines port efficiency and operational resilience as management concerns relevant to a maritime polytechnic's training mission, using Poltekpel Sulut's port-facing operations between April 2025 and January 2026 as a reflective case setting. The paper draws on the container seaport efficiency, port resilience, and terminal performance literature to interpret

institutional documentation and field observation from the stated period, with the aim of distinguishing what a training-oriented port operation can realistically achieve on efficiency grounds from what it can achieve on resilience grounds, and what this implies for curriculum emphasis.

2. Literature Review

2.1 Determinants of Port and Terminal Efficiency

Caldas et al. (2024) provide a systematic assessment of container seaport efficiency determinants, finding that efficiency is shaped less by any single infrastructural factor than by the interaction of berth allocation practice, equipment availability, and labour scheduling discipline; ports that manage these interacting factors coherently outperform ports with strong infrastructure but weak coordination. This finding is instructive for training institutions, because it implies that efficiency is substantially a management and scheduling competency rather than purely a capital investment outcome, meaning that a well-trained port workforce can materially improve efficiency even where infrastructure is modest.

Liao and Lee (2023), applying a directional distance function approach to port operational performance, similarly find that efficiency gains are often available through better utilization of existing capacity before new capacity is required, reinforcing the view that operational and scheduling discipline, the kind of competency built through hands-on cadet training, is a first-order lever for efficiency improvement. Kim et al. (2022), examining fully automated container terminals during the COVID-19 period, add a caveat: automation improved efficiency and reduced disruption sensitivity in the terminals studied, but only where the automated systems were supported by personnel capable of managing exception handling when automated processes failed, underscoring that even highly automated port systems remain dependent on skilled human oversight.

2.2 Port Resilience and Disruption Management

Kim et al. (2021) propose a framework for measuring port resilience in Korean ports that separates resilience into absorptive capacity, the ability to continue operating during a disruption, and recovery capacity, the speed with which normal operations resume afterward. Their findings indicate that ports scoring well on efficiency measures do not automatically score well on resilience measures, because resilience depends on redundancy, contingency planning, and organizational flexibility, properties that can be in tension with the lean, tightly scheduled operations that efficiency optimization tends to favour. This distinction is directly relevant to sea transportation management in

archipelagic contexts, where a port serving as a critical node for inter-island connectivity cannot rely solely on efficiency metrics to demonstrate readiness for disruption.

Caldeirinha et al. (2024), using a fuzzy-set qualitative comparative analysis of ports supporting floating offshore wind farm logistics, find that resilience and sustainability performance in ports is typically achieved through combinations of conditions, such as institutional coordination paired with adequate operational flexibility, rather than through any single necessary factor, which suggests that resilience-building at a training institution is more usefully approached as a set of complementary practices than as a single intervention.

2.3 Service Quality and Human Capital in Port Operations

Mwendapole and Jin (2021), evaluating seaport service quality in Tanzania, find that perceived service quality among port users is strongly associated with the responsiveness and competence of port personnel rather than solely with physical infrastructure, indicating that service-quality outcomes, much like efficiency outcomes, are substantially a function of workforce competency. Cahyadi et al. (2025), in their study of maritime vocational schools and leadership for sustainable port and shipping practices, argue that leadership commitment within training institutions is a meaningful determinant of whether graduates carry forward service-quality and operational-discipline habits into their subsequent maritime careers, linking the institutional training environment directly to the port-level efficiency and service outcomes described in the wider literature.

3. Methodology

This paper applies a qualitative, case-based management analysis to Poltekel Sulut's port-facing training operations over April 2025 to January 2026. Institutional scheduling documentation for cadet practical training, including berth-side and simulator-based exercises, was reviewed to identify the degree to which efficiency-related competencies, such as scheduling discipline and equipment handling, and resilience-related competencies, such as contingency and exception-handling training, are represented in the curriculum. Field observation during the stated period supplemented this document review with descriptive, non-statistical accounts of how these competencies were practiced during training activity. These institutional observations were then interpreted against the efficiency and resilience literature identified above, following the same three-part structure used in the literature review: efficiency determinants, resilience and disruption management, and service quality and human capital.

4. Results and Discussion

4.1 Efficiency-Oriented Training Practice

Cadet training documentation at Poltekpel Sulut during the observed period showed consistent emphasis on scheduling discipline, equipment familiarization, and procedural accuracy in simulated berth and cargo-handling exercises, which corresponds closely with the coordination-based efficiency determinants identified by Caldas et al. (2024). This suggests that the institution's training design already reflects, whether by deliberate design or by inheritance from established maritime curricula, an appreciation that efficiency is primarily a coordination and scheduling competency rather than an infrastructural one. Consistent with Liao and Lee (2023), training exercises that emphasized getting more out of existing simulated capacity, for example through more disciplined turnaround sequencing, appeared better retained by cadets than exercises framed purely around equipment operation.

Where automation-related content appeared in the curriculum, it was framed primarily around operating automated systems rather than around the exception-handling competency that Kim et al. (2022) identify as critical to sustaining efficiency when automated systems fail. This is a reasonable gap to flag for curriculum development, since Indonesian domestic ports are progressively adopting automation and cadets who understand how to intervene when automated processes break down will be more valuable to future employers than those trained only in routine operation.

4.2 Resilience and Disruption Planning: An Underdeveloped Area

Document review found comparatively limited formal coverage of disruption scenarios, weather-related contingency planning, or exception management of the kind emphasized by Kim et al. (2021) in their resilience framework. This is consistent with a broader pattern noted in the literature, in which resilience competencies tend to be less institutionalized than efficiency competencies because they are exercised less frequently and are harder to simulate realistically in a training environment. For a maritime polytechnic situated in a region exposed to weather-related disruption to inter-island shipping, this represents a meaningful opportunity: incorporating structured disruption scenarios, informed by the absorptive-versus-recovery capacity distinction proposed by Kim et al. (2021), into simulator-based training would directly address a documented gap.

The combination-based view of resilience proposed by Caldeirinha et al. (2024) is useful here: rather than treating resilience training as a single new course, Poltekpel Sulut could integrate resilience-oriented decision exercises into existing efficiency-focused

modules, pairing routine scheduling exercises with periodic disruption injects, so that cadets practice reallocating resources under pressure rather than only under normal operating conditions.

4.3 Service Quality as a Bridge Between Efficiency and Resilience

Consistent with Mwendapole and Jin (2021), field observation suggested that cadet interactions during practical training placed noticeable emphasis on responsiveness and procedural courtesy toward simulated port users, which is a service-quality competency independent of technical efficiency or resilience skill. Cahyadi et al. (2025) suggest that this kind of service orientation, when reinforced by institutional leadership, tends to persist into professional practice, implying that Poltekpel Sulut 's apparent strength in this area is likely to translate into workforce outcomes once cadets enter port and shipping operations. Service quality functions as a bridge between efficiency and resilience because a workforce accustomed to responsive, procedurally disciplined behaviour under normal conditions is better positioned to extend that discipline into disrupted conditions, even without formal resilience training, though formal training would still be expected to improve outcomes further.

5. Conclusion

Port efficiency and operational resilience are related but analytically distinct properties of sea transportation management, and the case of Politeknik Pelayaran Sulawesi Utara over April 2025 to January 2026 indicates that training institutions are currently better positioned to build efficiency-oriented competency, particularly scheduling discipline and service responsiveness, than resilience-oriented competency such as structured disruption management. Given the exposure of archipelagic sea transportation to weather and operational disruption, this paper recommends that maritime polytechnics deliberately integrate disruption-inject exercises into existing efficiency-focused training modules rather than treating resilience as a separate, lower-priority curriculum addition. Future applied research at Poltekpel Sulut could usefully track cadet performance in disruption-inject simulator exercises across cohorts to build a locally grounded evidence base on how training design affects resilience competency.

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