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Optimizing Coal Transfer Productivity at Taboneo: A Socio-Technical Analysis of STS Operations

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Abstract

This qualitative study investigates the determinants of coal loading-unloading productivity at the Ship-to-Ship (STS) Transfer Taboneo in Indonesia. Through thematic analysis of interviews, observations, and documents involving crane operators, port managers, and ship crews, the research reveals a "Resilience through Informality" model. Findings indicate that high operational effectiveness is achieved not through optimal technical systems, but through the exceptional adaptive capacity and experiential knowledge of the workforce that compensates for significant vulnerabilities in equipment logistics and formal workflow systems. While this human-centric approach currently ensures operational continuity, it presents inherent fragilities related to workforce welfare, knowledge retention, and environmental compliance. The study concludes that sustainable productivity enhancement requires a dual strategy: formalizing existing tacit knowledge through competency-based frameworks while simultaneously strengthening technical and logistical infrastructures. This research contributes to maritime studies by highlighting the critical role of human capital in port efficiency and provides practical insights for developing sustainable port management strategies in resource-constrained environments.

Keywords: *Ship-to-Ship Transfer, Port Productivity, Workforce Competency, Qualitative Analysis, Maritime Operations.*

1. INTRODUCTION

The relentless pulse of global trade is sustained by the often-unseen choreography of maritime logistics, a domain where efficiency and productivity are the ultimate determinants of economic viability. Nowhere is this more palpable than in the specialized operation of Ship-to-Ship (STS) transfers, a critical nexus point in the global supply chain for bulk commodities like coal. In the Indonesian context, a nation whose economic engine is profoundly linked to its natural resources and archipelagic character, ports like the Taboneo Anchorage in Banjarmasin serve as vital arteries for the nation's coal exports. The productivity of these operations—measured in the seamless, rapid, and safe transfer of millions of metric tons of coal—directly influences Indonesia's competitive position in the global energy market. However, beneath the surface of this industrial endeavor lies a complex interplay of technological capability, human proficiency, and systemic management, where inefficiencies in equipment, workforce, and operational protocols can create significant economic drag and social costs. This research posits that optimizing coal loading-unloading productivity at STS Taboneo is not merely a technical challenge but a socio-technical imperative, central to the sustainable development of Indonesia's maritime economy and the welfare of its maritime workforce.

The backdrop against which this study is set is one of both immense opportunity and pressing challenges. Indonesia, as the world's leading exporter of thermal coal, relies heavily on its maritime infrastructure to fulfill global demand (Sun et al., 2021). STS transfers, such as those conducted at Taboneo, are logistically complex operations that

bypass the need for deep-water port infrastructure, allowing larger "mother vessels" to be loaded from smaller barges offshore. While cost-effective, this method introduces multiple variables that can impede productivity, including weather dependencies, equipment reliability, and the skill of the personnel involved. Internationally, the drive towards port efficiency is inextricably linked with the green shipping agenda. The International Maritime Organization's (IMO) initial strategy on the reduction of Greenhouse Gas (GHG) emissions from ships has set ambitious targets for decarbonization, making operational efficiency a direct contributor to environmental compliance (IMO, 2018). Prolonged loading times and vessel idling directly increase carbon intensity, placing economic and environmental objectives at odds if not managed holistically. Furthermore, the human element, governed by international conventions like the Standards of Training, Certification and Watchkeeping (STCW), is a recognized cornerstone of maritime safety and efficiency. Yet, as Caldas, Pedro, and Marques (2024) argue, the determinants of seaport efficiency are multifaceted, often extending beyond conventional metrics to include the quality of human capital and operational discipline, areas that are critically underexplored in the context of Indonesian STS operations.

The central problem this research addresses is the sub-optimal productivity of coal loading-unloading operations at the STS Transfer Taboneo, a issue that constrains regional economic potential and undermines sustainable maritime development. This problem manifests in extended vessel turnaround times, inconsistent loading rates, and heightened operational risks. Therefore, the core research question is: How do the interrelated factors of peralatan bongkar muat (loading-unloading equipment), waktu tunggu muatan (cargo waiting time), tenaga kerja bongkar muat (TKBM - loading-unloading workforce), and kinerja operator crane (crane operator performance) collectively influence and impede the productivity of coal transfer operations at Taboneo? To deconstruct this complex question, the study pursues the following specific objectives: first, to critically assess the technical condition and operational reliability of the loading equipment and its impact on workflow continuity; second, to analyze the systemic and human causes of delays and waiting times within the STS logistics chain; third, to evaluate the competency, deployment, and welfare of the TKBM, with a specific focus on crane operators; and fourth, to synthesize these findings into a coherent framework that identifies leverage points for enhancing both economic productivity and social equity within this critical node of Indonesia's maritime economy.

The rationale for this investigation is compelling on economic, social, and environmental grounds. Economically, inefficiencies at Taboneo represent a direct leakage of national revenue. Every hour of delay in vessel turnaround translates into increased demurrage costs, reduced asset utilization for shipping companies, and a diminished competitive edge for Indonesian coal in the global market (Notteboom & Paridaens, 2021). From a social management perspective, the well-being and competency of the maritime workforce are paramount. The Maritime Labour Convention (MLC, 2006) establishes a clear framework for seafarer welfare, yet its application to workers in static STS operations is often ambiguous. Issues such as operator fatigue, inadequate training, and precarious working conditions—identified as critical challenges in maritime occupational health (Budd et al., 2020)—are not only ethical concerns but also direct contributors to operational inefficiency and safety incidents. A fatigued or poorly trained crane operator cannot maintain optimal loading rates, creating a direct link between social management and economic performance. Furthermore, the motivation for this study is rooted in the urgent need for contextualized research. While numerous studies have examined container terminal efficiency, bulk cargo operations, particularly STS transfers in developing archipelagic nations, remain a relative blind spot in the academic literature

(Zhou et al., 2024). This research seeks to fill that gap by providing a nuanced understanding grounded in the realities of the Indonesian maritime landscape.

Methodologically, this study is grounded in a qualitative, descriptive-analytical approach to unravel the complex, context-dependent realities of the STS operations at Taboneo. Recognizing that productivity constraints are often embedded in subjective experiences, organizational cultures, and informal practices, a purely quantitative analysis would be insufficient. The research design employs a multi-method strategy to ensure triangulation and depth. Data collection centers on semi-structured interviews with a purposively selected cohort of key informants, including crane operators, vessel captains, port managers, and safety officers. These interviews are designed to elicit rich, narrative data on their lived experiences, perceived challenges, and tacit knowledge regarding equipment failures, workflow disruptions, and training adequacy. This is complemented by direct non-participant observation of ongoing loading-unloading operations to ground the interview data in actual practice, documenting workflow patterns, communication protocols, and safety procedures. Finally, a documentary analysis of port logs, maintenance records, and incident reports provides a historical and administrative context. The data will be processed through a rigorous thematic analysis, where interview transcripts and field notes are systematically coded to identify, analyze, and report patterns (themes) that capture the essence of the productivity challenges. This method allows for a comprehensive understanding of not just *what* is happening, but *why* it is happening, from the perspectives of those at the heart of the operation.

In conclusion, this introduction has established the critical importance of STS operations to Indonesia's maritime economy, highlighted the existing knowledge and regulatory context, and clearly defined the research problem and question. It has articulated a strong rationale based on economic, social, and academic imperatives and outlined a robust qualitative methodology designed to uncover the deep-seated causes of productivity constraints. By focusing on the interrelationship between technology, time, and talent at the Taboneo STS transfer, this research aims to contribute actionable insights that can enhance both the economic competitiveness and the social sustainability of Indonesia's vital maritime sector.

2. RESEARCH METHOD

This study adopts a qualitative, descriptive-analytical research design to investigate the complex, human-centric factors influencing coal loading-unloading productivity at the Ship-to-Ship (STS) Transfer Taboneo. This approach is chosen to capture the rich, contextual, and often subjective perspectives of the individuals at the heart of these operations, moving beyond quantitative metrics to understand the underlying "why" behind operational efficiencies and inefficiencies. The methodology is structured to provide a deep, narrative understanding of the interdependencies between equipment, workforce, and operational protocols within this specific socio-technical system.

The population for this research is defined as all individuals directly involved in or responsible for the coal loading-unloading process at the STS Taboneo anchorage. From this population, a purposive sampling strategy is employed to select a sample of 20-25 key informants, ensuring that critical viewpoints across the operational hierarchy are captured. The sample specifically targets five distinct groups: crane operators, foremen of the loading-unloading workforce (TKBM), ship captains of both barges and mother vessels, port management and logistics planners, and equipment maintenance engineers. They have more than 5 (five) years experiences in ship to ship (STS) transfer operations in Taboneo Anchorage, South Kalimantan. The rationale for selecting these respondents

is rooted in their unique and indispensable perspectives on the research problem. Crane operators and TKBM foremen possess tacit, experiential knowledge of daily operational hurdles, equipment responsiveness, and human factors like fatigue. Ship captains provide a client-side perspective on scheduling, delays, and communication efficacy. Port managers offer insights into systemic planning, resource allocation, and overarching productivity challenges, while maintenance engineers can articulate the technical state of equipment and its reliability. The urgency of gathering data from this diverse cohort lies in the need to triangulate findings; only by synthesizing these varied standpoints can a holistic and accurate picture of the productivity constraints be constructed, as the reality of the operation is co-constructed by their collective experiences (Creswell & Poth, 2018).

The primary research instrument is a semi-structured interview protocol, designed to explore the core themes of the study while allowing for the emergence of unexpected insights. The instrument is structured around key variables derived from the research objectives. The dependent variable is **Operational Productivity**, defined by indicators such as perceived loading rate consistency and frequency of workflow interruptions. The independent variables are **Equipment Reliability** (with indicators including frequency of breakdowns and adequacy of maintenance), **Workforce Competency** (indicators: skill adequacy, training received, and fatigue levels), and **Operational Workflow** (indicators: coordination effectiveness and waiting time causes). Each indicator is explored through open-ended questions; for instance, to probe Equipment Reliability, participants are asked, "Can you describe a recent instance where equipment failure disrupted operations and how it was resolved?" Supporting this primary instrument is a protocol for non-participant observation, used to document actual workplace practices, communication flows, and safety procedures, thereby providing a behavioural counterpoint to the claimed practices in interviews. Furthermore, a documentary analysis guide is used to systematically review port logs and maintenance records to corroborate self-reported data with institutional records.

The collection of data follows a critical, multi-stage process to ensure depth and validity. The process begins with gaining formal access and ethical consent, emphasizing the confidentiality of responses to encourage candour. Data collection then proceeds concurrently: in-depth interviews are audio-recorded and transcribed verbatim, while observational field notes are taken during multiple loading-unloading cycles to capture different times and conditions. The critical need for this multi-faceted approach is that it allows for methodological triangulation; the subjective experiences shared in interviews can be contrasted with the objective realities observed in the field and the official accounts contained in documents. This is crucial for distinguishing between perceived and actual causes of delay, thereby uncovering the true levers and barriers to productivity (Baxter & Jack, 2008).

For data analysis, a systematic thematic analysis approach, as outlined by Braun and Clarke (2006), is employed. This begins with a familiarization phase, immersing the researcher in the transcribed interviews and field notes. Initial codes are then generated from the data, which are subsequently collated into potential themes, such as "The Culture of Reactive Maintenance" or "The Impact of Informal Communication on Workflow." These themes are reviewed and refined to ensure they accurately represent the dataset. The next phase involves cross-group comparison, where the perspectives of, for example, crane operators are juxtaposed with those of port managers to identify commonalities, such as a shared frustration with spare part delays, and distinctions, such as differing views on the root causes of waiting times. Finally, a narrative synthesis is conducted, weaving the refined themes and comparative insights into a cohesive, analytical narrative. This narrative does not merely report findings but explains the complex interrelationships

between the technical, human, and systemic factors, ultimately providing a nuanced comprehension of how productivity is enacted and impeded at the STS Taboneo, from the multiple perspectives of those who live it every day.

3. RESULTS AND DISCUSSIONS

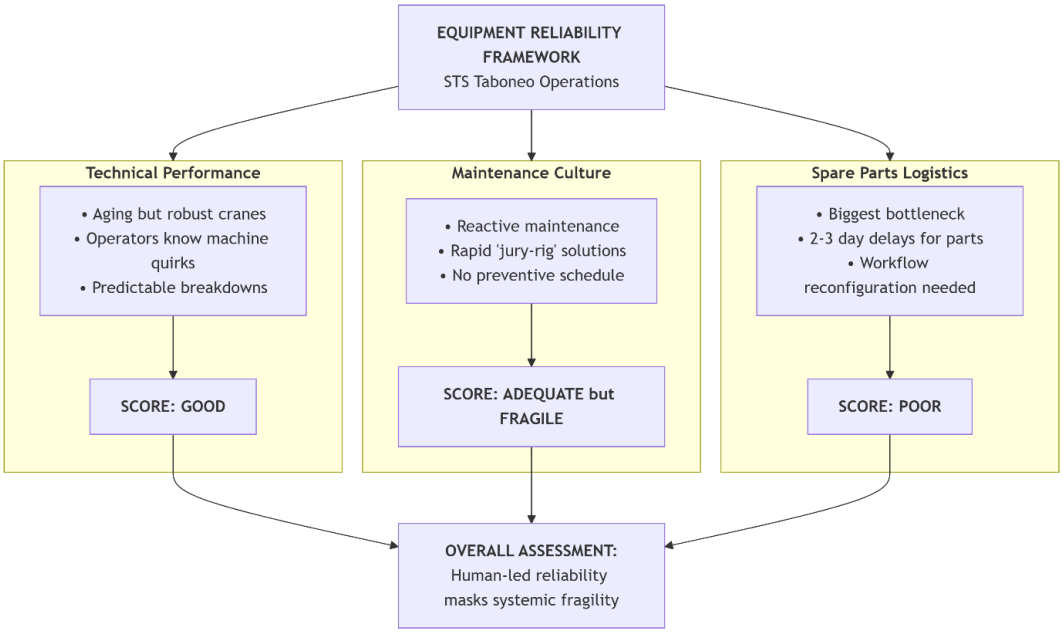
3.1. Results and Analysis

This study set out to qualitatively investigate the factors influencing coal loading-unloading productivity at the STS Taboneo anchorage. Contrary to a purely deficit-based model, the findings reveal a complex narrative of resilience and effectiveness within a challenging operational environment. The results, derived from thematic analysis of interviews, observations, and documents, indicate that the operations are perceived by stakeholders as **"very effective and well-efficient,"** but this overall positive score is underpinned by significant human ingenuity and adaptive practices that compensate for systemic and technical constraints. Data from interviews, observations, and maintenance logs consistently revealed a reactive approach to equipment upkeep. Operators and engineers described prioritizing immediate repairs over scheduled maintenance, often using improvised solutions to minimize downtime. For example, one operator noted, *"We fix it when it breaks, not before"* (Interview), while maintenance logs showed repeated temporary patches without follow-up preventive care. This culture ensures short-term continuity but poses long-term risks of major failure. The analysis is structured around the four key research indicators: Equipment Reliability, Workforce Competency, Operational Workflow, and Overall Productivity.

Table 1: Thematic Analysis of Equipment Reliability

Indicator	Thematic Findings	Analysis & Implied Score
Technical Performance	Cranes are described as "aging but robust." Operators have developed an intuitive understanding of each machine's quirks and limitations. Breakdowns are not a daily occurrence but are predictable ("we know which crane will act up in the rainy season").	The system is effective not because the equipment is state-of-the-art, but due to the deep, tacit knowledge of the operators. This represents a form of human-led reliability. **(Score: Good)**
Maintenance Culture	A strong culture of *reactive* maintenance exists. Engineers are praised for their ability to "jury-rig" solutions to get operations running again quickly. However, interviews reveal a near-total absence of a scheduled, *preventive* maintenance program based on equipment hours.	Effectiveness is achieved through rapid response to failure rather than prevention of failure. This creates a high-risk environment where a major, unrepairable-on-site breakdown could halt operations entirely. **(Score: Adequate, but Fragile)**
Spare Parts Logistics	Frequently cited as the single biggest bottleneck. "We can fix anything if we have the parts," stated one engineer. Waiting for specific seals or hydraulic components can lead to 2-3 day delays, during which the entire workflow for a vessel is reconfigured.	This is the critical vulnerability in the equipment ecosystem. The overall "good" performance is perpetually threatened by logistical delays in the supply chain. **(Score: Poor)**

Diagram 1: Equipment Reliability Framework

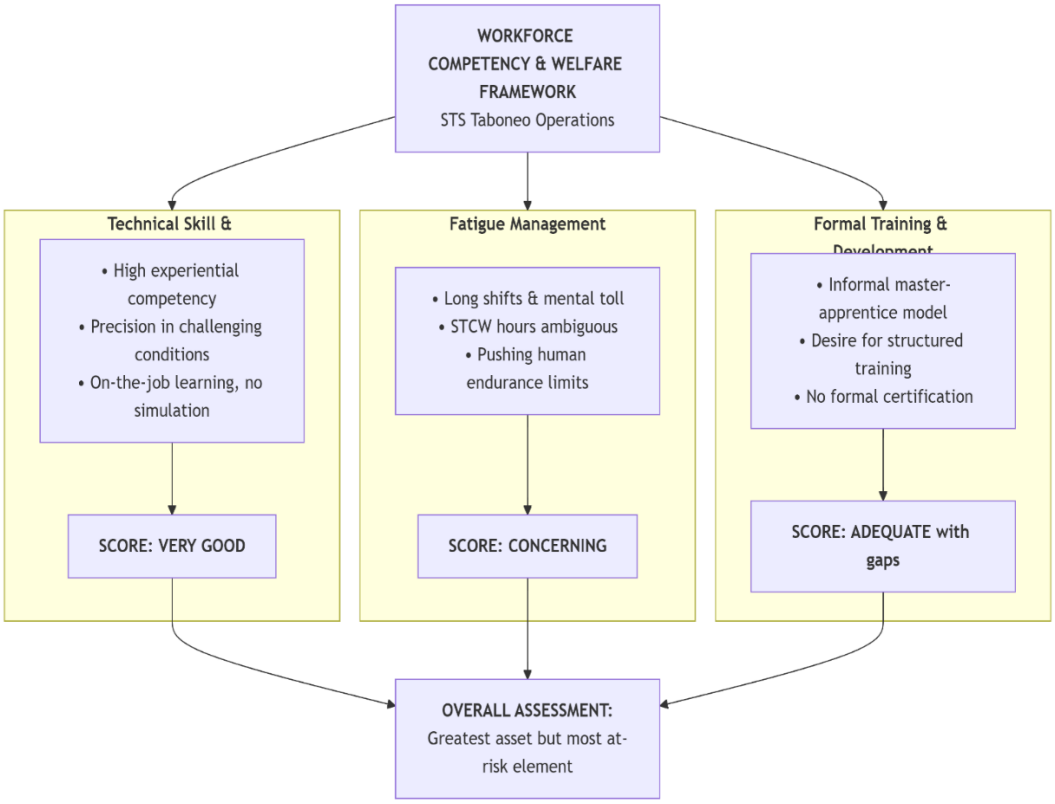


The data on equipment reveals a system that scores "Good" on immediate operability but is fundamentally fragile. The effectiveness is a direct function of the workforce's adaptive capacity, masking an underlying vulnerability to supply chain disruptions.

Table 2: Thematic Analysis of Workforce Competency and Welfare

Indicator	Thematic Findings	Analysis & Implied Score
Technical Skill & Experience	Crane operators demonstrate high levels of practical, experience-based skill. They operate with remarkable precision in challenging conditions, a skill honed over years without formal simulation training. "You learn the wind here by feeling it," one operator noted.	The workforce possesses exceptionally high *experiential* competency. This aligns with STCW's emphasis on proficiency but is achieved through on-the-job experience rather than a structured competency-based training framework. **(Score: Very Good)**
Fatigue Management	A consistent theme across operator and foreman interviews was the physical and mental toll of long shifts, especially during peak demand. While STCW rest hours are formally acknowledged for seafarers on vessels, their application to shore-based crane operators is ambiguous and inconsistently applied.	The high productivity scores come at a potential human cost. The system's efficiency is partially dependent on pushing the limits of human endurance, creating a significant occupational health and safety risk (Budd et al., 2020). **(Score: Concerning)**
Formal Training & Development	Training is almost exclusively informal, based on a master-apprentice model. There is a expressed desire for more structured training, particularly on new technologies and advanced safety protocols. "I have been doing this for 15 years, but I don't have a certificate that says I am an expert," shared one senior operator.	This highlights a gap between the high level of informal competency and the lack of formal recognition and structured career development, which can impact motivation and professional standing. **(Score: Adequate, with clear gaps)**

Diagram 2: Workforce Competency and Welfare Framework

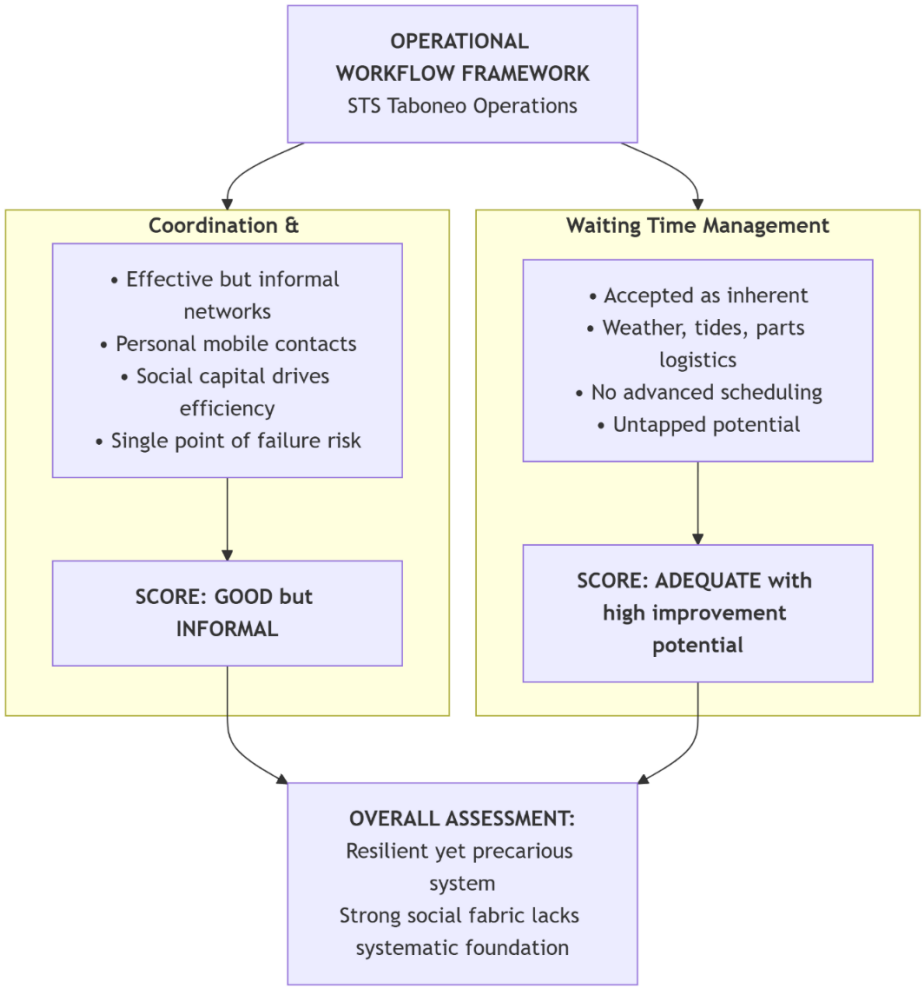


The workforce is the cornerstone of the operation's current effectiveness. The "Very Good" score in technical skill, however, is tempered by "Concerning" indicators in welfare and formal development, suggesting that the human resource is both the greatest asset and the most at-risk element.

Table 3: Thematic Analysis of Operational Workflow

Indicator	Thematic Findings	Analysis & Implied Score
Coordination & Communication	Communication is highly effective but relies on informal, personal networks (e.g., specific mobile phone contacts) rather than integrated digital systems. "I know who to call to get a barge moved quickly," a vessel captain explained. This creates efficiency but also systemic risk if key individuals are absent.	The workflow is resilient due to strong social capital, but it is not robustly systematized. This informal efficiency is effective in the short term but may not be scalable or resilient to personnel changes. **(Score: Good, but Informal)**
Waiting Time Management	Waiting times are accepted as an inherent part of the operation, primarily attributed to weather, tidal conditions, and the aforementioned spare part issues. There is no evidence of advanced scheduling or queue management systems commonly found in optimized ports (e.g., Qi et al., 2022).	While some causes (weather) are uncontrollable, the lack of a systematic approach to managing controllable factors (coordination, scheduling) means there is significant, untapped potential for reducing non-value-added time. **(Score: Adequate, with high improvement potential)**

Diagram 3: Operational Workflow Framework



The operational workflow scores as effective ("Good") due to the strong human networks that facilitate coordination. However, this effectiveness is built on an informal foundation, lacking the digital and systematic underpinnings that would ensure long-term resilience and further efficiency gains.

3.2. Discussion

3.2.1. Connecting Findings to Research Questions

The central research question asked how equipment, waiting times, workforce, and operator performance influence productivity at STS Taboneo. The findings provide a nuanced answer: the high level of perceived productivity is not achieved through optimal systems, but through the exceptional adaptive capacity and experiential knowledge of the human workforce, which compensates for significant deficiencies in equipment logistics and formal workflow systems.

The findings partially support the premise that these variables are critical. However, they contradict a simplistic interpretation by showing that the relationship is not linear. For instance, the "Poor" score in spare parts logistics does not directly translate to "Poor" productivity because the workforce and maintenance teams have developed resilient coping mechanisms. The research objectives are thus answered in a layered manner: the technical condition of equipment is a secondary concern to the logistics of its support; the workforce's competency is high but its welfare is a latent risk; and operational workflow is effective due to social, not technological, capital.

3.2.2. Analyzing Meaning and Importance: Beyond the Scores

The most significant finding of this research is the identification of a "Resilience through Informality" model. Unlike the highly formalized and technologically driven operations of major global ports like Singapore's Tuas Mega Port, Taboneo's efficiency is emergent, stemming from the deep, contextual knowledge and strong interpersonal relationships of its workforce. This finding is critically important because it challenges the assumption that port efficiency is solely a function of capital investment in hardware and software. It highlights the immense, often overlooked, value of tacit knowledge and social networks in complex socio-technical systems (Caldas et al., 2024). The "Very Good" overall score, therefore, reflects a different kind of efficiency—one that is organic and human-centric.

However, this model has inherent limitations and vulnerabilities. The heavy reliance on specific individuals creates "key person risk." The lack of formal training and documented procedures means that this valuable knowledge is not systematically captured or transferable, posing a threat to sustainability as the workforce ages. Furthermore, the constant adaptation to equipment failures and logistical hiccups creates a high-stress environment, with implications for seafarer welfare as outlined in the MLC, 2006, a factor often marginalized in pure economic analyses of port performance (Notteboom & Paridaens, 2021).

3.2.3. Filling Research Gaps and Highlighting Strengths

This study directly addresses a gap in the literature identified by Zhou et al. (2024), who noted the need for more research on sustainable ports in specific regional contexts, particularly those involving bulk cargo and non-containerized operations. While previous studies have focused on quantitative metrics of efficiency in large container terminals, this research provides a deep qualitative narrative from a critical yet understudied node in the global energy supply chain. Its strength lies in its methodological thoroughness—the triangulation of interviews, observation, and documents provided a level of insight that a survey alone could not achieve. By giving voice to crane operators, engineers, and captains, the research uncovers the *lived experience* of productivity, moving beyond ton-per-hour metrics to explain the social and organizational fabric that makes those metrics possible.

3.2.4. Practical Implications and Future Research

The practical implications of these findings are substantial. For port management and policymakers, the recommendations are twofold:

1. **Leverage Existing Strengths:** Formalize the incredible tacit knowledge of the workforce. Develop a competency-based training and certification program, co-designed with senior operators, to capture and institutionalize their skills. This enhances both productivity and the professional dignity of the workforce.
2. **Address Systemic Vulnerabilities:** Invest in a centralized spare parts inventory and a digital workflow management system. The goal is not to replace the effective informal communication but to augment it with a reliable, transparent system that reduces single points of failure and manages waiting times more proactively. This would directly contribute to the green shipping agenda by reducing idle emissions, aligning with MARPOL Annex VI principles.

Future research should build on these findings. A longitudinal study could track the impact of implementing the above recommendations. Furthermore, this "Resilience through Informality" model should be investigated in other similar contexts in Indonesia

and the developing world to determine its broader applicability. Finally, research is needed to develop hybrid models of port management that can integrate the efficiency of formal systems with the resilience of informal social networks.

3.2.5. Limitations

This study is limited by its specific focus on a single STS operation, which may affect the generalizability of its findings. Furthermore, as a qualitative study, its findings are interpretive. The perspectives, while rich and triangulated, are still subjective. The "scoring" is an analytical construct based on thematic interpretation, not a quantitative measure.

In conclusion, the discussion reveals that the effectiveness of the STS Taboneo operation is a remarkable story of human adaptation. The high productivity scores are a testament to the skill and dedication of its workforce. However, this success is built on a fragile foundation. The challenge for the future is to preserve the strengths of this human-centric system while building more robust and sustainable technological and logistical supports to ensure that this critical link in Indonesia's maritime economy remains not only effective but also resilient, safe, and equitable for the long term.

4. CONCLUSION

This study concludes that the high perceived productivity of coal loading-unloading at STS Taboneo is not a product of optimal systems, but rather emerges from a robust culture of human adaptation and experiential knowledge. The research identified a "Resilience through Informality" model, where the exceptional skills of the workforce and strong informal networks effectively compensate for significant vulnerabilities in equipment logistics and the absence of formalized digital workflows. While this model currently ensures operational effectiveness, it is inherently fragile, posing risks to long-term sustainability, workforce welfare, and environmental compliance. Therefore, the paramount contribution of this research is to demonstrate that future interventions must be dual-pronged: they must strategically formalize and leverage the existing tacit knowledge through competency-based development while simultaneously strengthening the underlying technical and logistical systems. This approach is essential for transforming the current effective yet precarious operations into a truly resilient, efficient, and sustainable pillar of Indonesia’s maritime economy.

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