Optimising WMS Performance at Tanjung Emas Port

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ABSTRACT

Abstract : Port warehouse efficiency is critical for maintaining competitiveness in global maritime logistics networks. This study examines operational challenges in warehouse management at Tanjung Emas Port, Semarang, where traditional manual processes have resulted in prolonged dwell times, suboptimal space utilization, and increased logistics costs. Through a mixed-method approach combining operational data analysis, stakeholder interviews, and comparative benchmarking with international ports, this research identifies key management bottlenecks: inefficient cargo handling workflows, inadequate inventory visibility, poor coordination among stakeholders, and resistance to operational changes. The study develops a strategic framework for warehouse management optimization that integrates three pillars: operational process reengineering, stakeholder collaboration enhancement, and phased technology adoption. Findings from 12-month operational data (2024) reveal that container dwelling time averaged 4.8 days (vs. 2.1 days international standard), truck turnaround time reached 1.5 hours (vs. 45 minutes benchmark), and yard occupancy fluctuated at 72% with poor space allocation patterns. The proposed management framework emphasizes change leadership, performance management systems, and collaborative governance models alongside selective technology deployment. Cost-benefit analysis demonstrates potential annual savings of USD 3.2 million through operational improvements and revenue enhancement of USD 2.5 million from increased throughput capacity. The research contributes practical insights for port managers and logistics practitioners in emerging economies seeking to enhance warehouse performance through balanced management and technology strategies.

Keywords: Warehouse Management, Port Logistics, Operational Efficiency, Digital Transformation, Stakeholder Management, Tanjung Emas Port

1. INTRODUCTION

1.1 Background and Problem Statement

Tanjung Emas Port Semarang serves as the primary logistics hub for Central Java and faces competitive pressure to enhance warehouse operational efficiency. With container throughput reaching 300,000 TEUs annually and projected growth of 8-12% per year, unresolved warehouse management issues threaten port competitiveness and escalate total logistics costs for users.

Primary operational challenges identified include: (1) High container dwelling time averaging 4.8 days, significantly above the international standard of 2-3 days, causing

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container accumulation and operational bottlenecks; (2) Truck turnaround time of 1.5 hours resulting in prolonged queues and complaints from trucking companies; (3) Uneven yard occupancy with some areas reaching 95% while others remain at 50%, indicating poor space management; (4) Inventory accuracy of only 85%, indicating tracking and documentation issues; (5) Weak stakeholder coordination among terminal operators, customs, shipping lines, and trucking companies causing delays in document clearance and cargo release.

From a logistics management perspective, the root causes extend beyond technology limitations to encompass more complex dimensions: non-standardized business processes, change-resistant organizational culture, absence of performance management systems, inadequate training programs, and fragmented stakeholder relationships (Christopher, 2016).

1.2 Research Objectives and Significance

This research aims to: (1) Identify and analyze warehouse management phenomena at Tanjung Emas Port from the perspectives of operational efficiency, stakeholder management, and organizational readiness; (2) Develop a strategic framework for warehouse management optimization integrating process improvement, people development, and technology enablement; (3) Design realistic implementation roadmaps aligned with organizational capabilities and budget constraints; (4) Evaluate potential benefits and critical success factors. This research contributes practical guidance for port managers in developing economies facing similar challenges in transforming warehouse operations with limited resources.

1.3 Literature Review

Supply chain management focuses on flow optimization to maximize profitability (Chopra & Meindl, 2019), with warehouses serving as critical nodes linking sea and land transport (Bowersox et al., 2020) and (Christopher, 2016). Five key capabilities in logistics excellence include: strategic alignment, customer focus, operational flexibility, measurement proficiency, and relationship management (Bowersox et al., 2020). Port operations evolution from labor-intensive to information-intensive environments (Notteboom & Rodrigue, 2022) and (Notteboom et al., 2020) requires organizational transformation alongside technology adoption (Steenken et al., 2004).

Research demonstrates that successful ports invest equally in process redesign and people development (Mjøsund et al., 2024) and (Notteboom & Rodrigue, 2022). Change management excellence (Kotter, 2012) and (Mjøsund et al., 2024), stakeholder collaboration (Behdani et al., 2020) and (Satta et al., 2025), and comprehensive performance measurement (Kaplan & Norton, 2015) and (Karim et al., 2020) serve as critical success factors. Literature emphasizes that sustainable transformation requires a balanced approach: process standardization, people development, and selective technology adoption (Custodio & Machado, 2020), (Molavi et al., 2023), and (Verma et al., 2023).

2. METHODOLOGY

2.1 Research Design

This research employs a mixed-method approach combining:

Qualitative Methods: In-depth interviews with 15 key stakeholders (port management, customs officials, shipping line representatives, trucking company managers, warehouse operators); Focus Group Discussions (3 sessions) with operational staff to understand workflow challenges and gather improvement suggestions; Direct observation of warehouse operations over 2 months; Document analysis of SOPs, performance reports, and complaint records.

Quantitative Methods: Operational data analysis from 12-month period (January-December 2024) covering 300,000 TEUs; Time-motion studies measuring actual versus standard operating times; Statistical analysis for pattern identification; Benchmarking comparison with five regional ports (Jakarta, Surabaya, Port Klang, Laem Chabang, Singapore).

2.2 Data Collection and Analytical Framework

Primary Data: Interview transcripts and FGD notes, observation checklists, survey questionnaires to 120 warehouse staff regarding operational challenges and change readiness, time-motion study results for eight key processes.

Secondary Data: Container dwelling time records, truck arrival and departure logs, yard occupancy reports, customs clearance processing times, customer complaint records, financial data, and benchmarking data from published port statistics.

Analysis Methods: Value Stream Mapping, Root Cause Analysis (Fishbone Diagrams), Gap Analysis, Power-Interest Matrix for stakeholder mapping, Balanced Scorecard framework, and Benchmarking analysis against international standards.

2.3 Research Limitations

This research has limitations: (1) Data collection restricted to one port, requiring further validation for broader generalizability; (2) 2-month observation period may not capture seasonal variations; (3) Self-reported survey data may contain bias; (4) Benchmarking comparison limited to publicly available data.

3. RESEARCH FINDINGS AND DISCUSSION

3.1 Current State Analysis: Operational Challenges

3.1.1 Process Inefficiencies

Based on value stream mapping and time-motion studies, the total lead time from container discharge to gate-out includes: Container discharge & receiving (2-4 hours vs. standard 1-2 hours); Documentation processing (1-2 days vs. standard 4-8 hours) - MAJOR BOTTLENECK; Customs clearance (1-3 days vs. standard 24 hours); Storage & retrieval (2-6 hours vs. standard 1-2 hours); Gate-out processing (45-90 minutes vs. standard 15-30 minutes).

Root causes identified: Manual documentation processes with multiple handoffs; Non-standardized workflows; Lack of coordination in document exchange; Peak time congestion without demand management strategy; Inefficient equipment allocation.

3.1.2 Space Management Issues

Table 1.
Yard occupancy analysis

Area	Average Occupancy	Peak Occupancy	Utilization Issue
Area A (Import FCL)	85%	98%	Overcrowded - blocking issues
Area B (Export FCL)	68%	82%	Moderate – seasonal variation
Area C (Empty containers)	52%	65%	Underutilized
Area D (Reefer containers)	78%	95%	Insufficient power points
CFS Warehouse 1	72%	88%	Poor internal layout
CFS Warehouse 2	48%	60%	Significantly underutilized

Management challenges:
No dynamic slotting system; FIFO principles not enforced; Reefer container placement not adjacent to power sources; Reactive empty container management without structured leasing or reuse programs, as in table 1.

3.1.3 Stakeholder Coordination Gaps

From 15 stakeholder interviews, fragmented relationships were identified:

1. Port Operator and Customs:
   a. Information exchange via email and phone calls
   b. No shared system for document status tracking
   c. Frequent miscommunication about inspection schedules
   d. Average customs clearance: 1.8 days (could be reduced to 8 hours on better coordination)
2. Port Operator and Shipping Lines:
   a. Vessel schedule changes often communicated to short notice
   b. Document submission is not standardized (different formats)
   c. Dispute resolution mechanism informal dan time-consuming
   d. No service level agreements (SLAs) for performance expectations
3. Port Operator and Trucking Companies:
   a. No appointment system - trucks come randomly causing congestion
   b. Peak hours (08:00-11:00) absorb 60% daily volume
   c. Communication about container readiness inadequate
   d. Driver complaints about long waiting times not addressed systematically

Power-Interest Matrix analysis shows that Customs and major shipping lines have high power-high interest. However, engagement levels are still low to moderate, indicating missed opportunities for collaborative problem-solving.

3.2 Performance Gap Analysis

3.2.1 Benchmarking Results

Table 2.
Comparison international ports show significant performance gaps

KPI	Tanjung Emas (Current)	Regional Average	International Best Practice	Gap (%)
Container Dwelling Time	4.8 days	5.45days	2.1 days	+129%
Truck Turnaround Time	1.5 hours	0.9 hours	0.45 hours	+233%
Yard Occupancy (optimal)	72% (uneven)	75-80%	75-85%	-4% to +14%
Berth Productivity	22 moves/hour	28 moves/hour	35 moves/hour	-37%
Doc. Accuracy	85%	92%	98%	-13%
Gate Processing Time	25 minutes	12 minutes	5 minutes	+400%
Operating Cost per TEU	$125	$105	$85	+47%

Financial Impact:
Prolonged dwelling time: USD 2.5M annual lost revenue; Inefficient operations: USD 12M excess costs; Customer dissatisfaction: 15,000 TEUs yearly loss, as in table 2

3.2.2 Balanced Scorecard Analysis

The Balanced Scorecard framework (Kaplan & Norton, 2015) was employed to provide comprehensive assessment of warehouse performance across four perspectives, as in table 3.

Table 3. Balanced Scorecard Analysis of Warehouse Management Performance

Perspective	Current State	Issues
Financial	- Operating cost per TEU 47% above best practice - Revenue per TEU stagnan for 3 years	Infrastructure investment has been done (cranes, RTG)
Customer	- Customer satisfaction score: 6.2/10 (survey 2024) - Complaint volume increase 23% year-over-year - No formal customer feedback mechanism	Pricing competitive with regional ports

Perspective	Current State	Issues
Internal Process	- Process standardization low (assessed 45/100) - Quality issues (documentation errors 15%) - No continuous improvement program	Equipment availability 92% (acceptable but can be better)
Learning & Growth	- Training budget just 1.2% from payroll (industry standard 3-5%) - Staff turnover rate 18% annually (industry 12%) - No competency development program	Technology literacy staff low(35% comfortable with digital systems)

Source: Port Performance Assessment (2024)

Analizing BSC uncovering Systematic Underperformance with a Clear Causal Chain:

1. Financial underperformance (cost +47%, revenue stagnant).
2. Customer dissatisfaction (score 6.2/10, complaints +23%).
3. Internal Process weaknesses (standardization 45/100, error rate 15%)
4. Learning & Growth neglect (training budget 1.2% vs industry 3-5%, turnover 18% vs 12%)

3.3 Strategic Framework for Warehouse Management Optimization

Based on gap analysis, WMS conceptual foundation, and stakeholder input, this study proposes an integrated framework consisting of three mutually reinforcing Strategic Pillars.

This framework is designed with the principles: Process First, People Second, Technology Third ensuring organizational readiness before heavy technology investment, as in table 4.

Table 4. Three-Pillar Strategic Framework for Warehouse Optimization

Pillar	Objective	Key Initiatives	Expected Outcomes	Timeline
PILLAR 1 Operational Process Excellence	Standardize, streamline, dan optimize core warehouse processes	- Standard Operating Procedures (SOP) development - Workflow redesign & elimination of non-value activities - Dynamic space optimization with slotting rules - Truck appointment system for demand management	- Dwelling time: -27% - Truck turnaround: -40% - Yard utilization: +8% - Documentation accuracy: +10%	0-12 months

Pillar	Objective	Key Initiatives	Expected Outcomes	Timeline
PILLAR 2 Stakeholder Collaboration Enhancement	Build trust-based relationships & collaborative governance	- Service Level Agreements (SLAs) with stakeholders - Quarterly business review & joint problem-solving - Information sharing portal for real-time updates - Formal dispute resolution mechanism	- Customs clearance: -56% - Stakeholder satisfaction: 6.2→8.0 - Document resubmission: -65% - Complaint resolution: -60%	0-18 months
PILLAR 3 Selective Technology Enablement	Deploy ROI driven technology solutions	**Phase 1:** Basic WMS, barcode **Phase 2:** RFID, automated gates **Phase 3:** IoT, predictive analytics	- Inventory accuracy: 98%+ - Real-time visibility: 100% - Operating cost: -22% - Gate processing: -68%	0-30 months (phased)

Source: Research Framework Design

PILLAR 1: Operational Process Excellence focuses at standardization and workflow optimization through: (1) SOP development for 12 critical processes with clear ownership; (2) Workflow redesign to eliminate non-value activities and reduce handoff points from 8 to 4; (3) Dynamic space optimization rule-based slotting system and FIFO enforcement; (4) Demand management through truck appointment system dan peak-hour pricing implementation over 12 months, targeting dwelling time reduction 27% and truck turnaround improvement 40%.

PILLAR 2: Stakeholder Collaboration Enhancement acknowledges that port warehouse was multi-stakeholder ecosystem (Behdani et al., 2020) dan (Satta et al., 2025). Key initiatives: SLA establishment with penalty/incentive mechanisms, structured engagement programs (quarterly reviews, monthly coordination meetings), web-based information sharing platform to real-time status tracking, dan formal dispute resolution mechanism. Expected outcomes include customs clearance reduction from 1.8 days to 0.8 days dan stakeholder satisfaction improvement from 6.2 to 8.0/10.

PILLAR 3: Selective Technology Enablement adopts phased ROI-driven approach: Phase 1 (USD 150K) deploys basic WMS and barcode scanning to quick wins; Phase 2 (USD 800K) advances to RFID tracking and automated gates; Phase 3

(USD 1.5M) implements IoT sensors dan AI-based optimization. Technology serves as enabler, not driver, to each phase gated by demonstrated benefits dan organizational readiness assessment (Mjøsund et al., 2024) dan (Van Geest et al., 2021).

3.4 Change Management Strategy

Adopting an eight-step change management model (Kotter, 2012) with the context of Tanjung Emas, the implementation strategy includes:

1. Create Urgency (Month 0-2)
    a. Present competitive analysis show cargo diversion to competing ports
    b. Share financial impact from operational inefficiencies
    c. Customer testimonials about service dissatisfaction
    d. Leadership Action: Port Director announces transformation initiative as strategic priority
2. Build Guiding Coalition (Month 0-3)
    a. Form Transformation Steering Committee: Port Director (chair), Terminal Manager, Operations Manager, IT Manager, HR Manager, Customer Service Manager
    b. Establish cross-functional task forces to each pillar
    c. Engage external advisor to independent perspective
    d. Success Metric: Committee meets bi-weekly with >90% attendance
3. Form Strategic Vision (Month 2-3)
    a. Develop vision statement: "To be Central Java's most efficient and customer-centric port by 2027"
    b. Define 3-year targets for each KPI
    c. Communicate vision through town halls, posters, internal communications
    d. Success Metric: 80% staff get articulate the vision on surveys
4. Enlist Volunteer Army (Month 3-6)
    a. Recruit Change Champions from each department (15-20 individuals)
    b. Provide training about change management and improvement methodologies
    c. Empower champions to lead small improvement projects
    d. Success Metric: 20 champions trained, 10+ quick-win projects initiated
5. Enable Action by Removing Barriers (Month 3-12)
    a. Revise outdated SOPs inhibiting efficiency
    b. Provide training for new processes dan systems
    c. Allocate budget and resources to improvement initiatives
    d. Address staff concerns through open forums
    e. Success Metric: 90% staff trained, zero budget-related project delays
6. Generate Short-term Wins (Month 6-12)
    a. Implement quick wins: truck appointment system, basic WMS, SOP standardization
    b. Celebrate successes publicly with recognition awards
    c. Measure and communicate early results
    d. Success Metric: Achieve 10-15% improvement in the 3 KPIs within first year

7. Sustain Acceleration (Month 12-24)
   a. Scale successful pilots across all areas
   b. Deepen stakeholder collaboration practices
   c. Deploy Phase 2 technology solutions
   d. Refresh improvement initiatives based on lessons learned
   e. Success Metric: Continuous improvement projects ongoing in the all departments
8. Institute Change (Month 24-36)
   a. Embed new processes in the organizational routines
   b. Update performance management system for align with new KPIs
   c. Integrate transformation into onboarding for new employees
   d. Transition from project mode ke business-as-usual
   e. Success Metric: Transformation achievements sustained for 6+ months without special oversight

3.5 Implementation Roadmap & Resource Requirements

Table 5.

Phase	Timeline	Budget	Focus	Key Deliverables
1: Foundation	0-6M	$250K	Process & People	12 SOPs, 150 trained staff, truck appointment system, Quick-win improvements 10-15%
2: Scale & Integrate	7-18M	$1.2M	Stakeholder & Tech	5 SLAs operational, RFID tracking 80%, Gate time -50%, Mid-term improvements 25-35%
3: Optimization	19-30M	$1.8M	Analytics & CI	98% inventory accuracy, Target KPIs achieved, CI culture embedded

Total Investment: USD 3.25M over 30 months. Implementation follows phased approach stage gates to risk management dan resource optimization, as in table 5.

3.6 Cost-Benefit Analysis

Table 6.
Investment Breakdown:

Category	Amount (USD)	% of Total
Technology (Hardware/Software)	1,450,000	44.6%
Process Consulting & Design	450,000	13.8%
Training & Change Management	550,000	16.9%
Integration & Implementation Services	500,000	15.4%
Contingency (10%)	300,000	9.2%
TOTAL	**3,250,000**	**100%**

Table 7.
Annual Benefits (Steady State):

Benefit Category	Amount (USD/year)	Source
Operating Cost Reduction	3,200,000	Labor efficiency +20%, equipment utilization +15%, reduced rework
Revenue Enhancement	2,500,000	Increased throughput capacity (15,000 additional TEUs @ $160/TEU)
Penalty Avoidance	400,000	Reduced SLA violations, fewer customer compensations
Asset Optimization	350,000	Better space utilization reducing need for expansion
Risk Reduction	150,000	Fewer accidents, cargo damages, documentation errors
TOTAL ANNUAL BENEFITS	**6,600,000**	

Financial Metrics:

1. Payback Period**: 1.5 years (18 months)**
2. Net Present Value (NPV): **USD 18.2M (5-year horizon, 10% discount rate)**
3. Internal Rate of Return (IRR): **62%**
4. Return on Investment (ROI): **240% over 5 years**
5. Benefit-Cost Ratio: **10.2:1**

Sensitivity Analysis: Even in worst case scenario (+15% investment, -20% benefits), project remains attractive with NPV > USD 10M dan payback < 2.5 years, as in table 5 and table 6.

3.7 Critical Success Factors & Risk Mitigation

Critical Success Factors:

1. Strong Leadership Commitment: Port Director as visible champion
2. Stakeholder Buy-in: early continuous engagement
3. Change Management Excellence: comprehensive training and managing resistance proactively
4. Phased Implementation: start with process improvements before heavy technology
5. Performance Measurement: clear KPIs with regular monitoring.

Table 8.
Principal Risks & Mitigation Strategies:

Risk	Probability	Impact	Mitigation Strategy
Staff Resistance to Change	High	High	Extensive change management program, early involvement, clear communication

Risk	Probability	Impact	Mitigation Strategy
Budget Overruns	Medium	High	Phased investment dengan stage gates, 10% contingency, vendor selection dengan fixed-price contracts
Technology Implementation Delays	Medium	Medium	Select proven solutions, pilot testing
Stakeholder Non-cooperation	Medium	High	SLAs dengan incentives, executive-level engagement

Mitigation Priorities:
Highest priority at staff resistance & stakeholder cooperation (foundational); Medium priority at budget & technology delivery (manageable with good governance); Lower priority pada external factors (less controllable), as in table 8.

3.8 Expected Performance Outcomes

Table 9.
Projected KPI Improvements

KPI	Baseline (2024)	Year 1 Target	Year 2 Target	Year 3 Target	International Best Practice
Container Dwelling Time	4.8 days	4.0 days	3.0 days	2.3 days	2.1 days
Truck Turnaround Time	1.5 hours	1.1 hours	0.7 hours	0.5 hours	0.45 hours
Yard Occupancy (Optimized)	72%	75%	78%	80%	75-85%
Inventory Accuracy	85%	92%	96%	98%	98%+
Documentation Accuracy	85%	91%	95%	97%	98%+
Gate Processing Time	25 min	18 min	10 min	6 min	5 min
Operating Cost per TEU	$125	$115	$102	$92	$85
Customer Satisfaction	6.2/10	7.0/10	7.8/10	8.5/10	8.5+/10

Beyond primary KPIs, framework targets organizational capability improvements including process standardization (45% to 90%), employee engagement (58% to 78%), training hours (12 to 40 hours annually), SLA compliance (95% achievement), andinformation sharing maturity (dari email-based ke real-time portal), as in table 9.

4. CONCLUSION

4.1 Key Findings

This study identifies that warehouse management challenges at Tanjung Emas Port are multi dimensional, including process inefficiencies, stakeholder coordination gaps, organizational culture issues, and technology underutilization. Performance gap analysis shows that dwelling time is 129% higher and operational costs are 47% above international benchmarks.

The root cause analysis reveals that technology deficiency is not the primary bottleneck but the main problem lies in the lack of process standardization, weak stakeholder relationships, and limited change management capability. The framework developed addresses the root of this problem through a three-pillar approach with best practices from warehouse management (Custodio & Machado, 2020), (Karim et al., 2020), and (Verma et al., 2023), port digitalization (Heilig et al., 2024), (Molavi et al., 2023), and (Paraskevas et al., 2024), and stakeholder management literature (Behdani et al., 2020), (Moeremans & Dooms, 2025), and (Satta et al., 2025). The cost-benefit analysis demonstrates strong financial justification with a payback period of 1.5 years, an NPV of USD 18.2M, and an ROI of 240% in 5 years.

4.2 Practical Implications

For Port Management: Process before technology - Invest in process reengineering before massive technology deployment; People are central - allocate significant resources to change management and stakeholder engagement; Phased implementation - start with quick wins; Collaborative governance - transform adversarial relationships; Performance measurement - establish robust KPI systems.

For Industry Practitioners: Framework applicable to ports at emerging economies with similar contexts: limited budgets, traditional organizational cultures, multi-stakeholder complexity (Almeida & Okon, 2025), (Notteboom et al., 2021), and (Sari et al., 2024). Key lesson: sustainable transformation requires balanced attention to Process, People, and Technology.

For Policy Makers: Port digitalization policies should recognize that technology grants alone insufficient. Supporting policies needed: standardization of inter-agency data exchange protocols, training subsidies, incentives for collaborative initiatives, regulatory frameworks that enable digital document exchange.

4.3 Limitations and Future Research

Limitations: Study focused at one port; implementation not really fully executed; stakeholder input may contain bias; external factors tidak entirely predictable.

Future Research: Longitudinal study tracking actual implementation results; comparative analysis across multiple Indonesian ports; sustainability assessment examining environmental impacts (Bartolini et al., 2019) and (Sari et al., 2024); technology adoption patterns (Jin & Guo, 2025), (Shivam & Gupta, 2024), and (Tian et al., 2023); workforce transformation (Yoo, 2025); regional integration opportunities.

4.4 Recommendations

Immediate actions: Establish Transformation Steering Committee dengan Port Director leadership; Conduct comprehensive process mapping; Initiate stakeholder engagement program; Launch change champion recruitment; Develop detailed implementation plan dengan resource allocation.

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